University of Agronomic Sciences
and Veterinary Medicine of Bucharest
Faculty of Land Reclamation
and Environmental Engineering

SCIENTIFIC PAPERS

Series E

LAND RECLAMATION, EARTH OBSERVATION & SURVEYING, ENVIRONMENTAL ENGINEERING

Volume XI

2022
BUCHAREST

SCIENTIFIC PAPERS

SERIES E

LAND RECLAMATION, EARTH OBSERVATION &
SURVEYING, ENVIRONMENTAL ENGINEERING

VOLUME XI

University of Agronomic Sciences
and Veterinary Medicine of Bucharest
Faculty of Land Reclamation
and Environmental Engineering

SCIENTIFIC PAPERS

Series E

LAND RECLAMATION, EARTH OBSERVATION & SURVEYING, ENVIRONMENTAL ENGINEERING

Volume XI

2022
Bucharest

PUBLISHERS:
University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania - Faculty of Land Reclamation and Environmetal Engineering
Address: 5 9 Marasti Blvd., District l, Zip code 011464 Bucharest, Romania
Phone: + 40 213 1830 75, E-mail: conference@fifim.ro, Webpage: www.fifim.ro

CERES Publishing House
Address: 29 Oastei Street, District 1, Bucharest, Romania
Phone: + 40 21 317 90 23, E-mail: edituraceres@yahoo.com, Webpage: www.editura-ceres.ro

To be cited: Scientific Papers. Series E. LAND RECLAMATION, EARTH OBSERVATION & SURVEYING, ENVIRONMENTAL ENGINEERING, Vol. XI, 2022

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

International Database Indexing:
Web of Science Core Collection (Emerging Sources Citation Index)
Index Copernicus; Ulrich's Periodical Directory (ProQuest); PNB (Polish Scholarly Bibliography);
Scientific Indexing Service; Cite Factor (Academic Scientific Journals) Scipio; OCLC; Research Bible

SCIENTIFIC & REVIEW COMMITTEE

SCIENTIFIC CHAIRMAN
Prof. univ. dr. Sorin Mihai CÎMPEANU

MEMBERS*

- Alexandru BADEA - University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
- Ioan BICA - Technical University of Civil Engineering of Bucharest, Romania
- Daniel BUCUR - "Ion Ionescu de la Brad" University University of Life Sciences of Iasi, Romania
- Stefano CASADEI - University of Perugia, Italy
- Fulvio CELICO - University of Molise, Italy
- Carmen CÎMPEANU - University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
- Sorin Mihai CÎMPEANU - University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
- Marcel DARJA - University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Romania
- Claudiu DRAGOMIR - University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
- Eric DUCLOS-GENDREU - Spot Image, GEO-Information Services, France
- Delia DUMITRIU - Manchester Metropolitan University, United Kingdom
- Ion GIURMA - "Gheorghe Asachi" Technical University of Iasi, Romania
- Jean-Luc HORNICK - Faculté de Médecine Vétérinaire, Université de Liège, Belgium
- Ilias KYRIAZAKIS - Newcastle University - United Kingdom
- Eugeniu LUCA - University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
- Carmen MAFTEI - Transilvania University - Brasov, Romania
- Raluca MANEA - University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
- Sevastel MIRCEA - University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
- Alina ORŢAN - University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
- Marius Ioan PISO - Romanian Space Agency, Romania
- Maria POPA - "1 Decembrie1918" University of Alba Iulia, Romania
- Dorin Dumitru PRUNARIU - Romanian Space Agency, Romania
- Ramiro SOFRONIE - University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
- Răzvan Ionuţ TEODORESCU - University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
- Augustina TRONAC - University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
- Ana VÎRSTA - University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania

**alphabetically ordered by family name*

CONTENTS

ENVIRONMENTAL SCIENCE AND ENGINEERING

SUSTAINABLE DEVELOPMENT OF RURAL AREA

DISASTER MANAGEMENT

WATER RESOURCES MANAGEMENT

POLLUTION CONTROL, LAND PLANING

TOPOGRAPHY AND CADASTRE

EARTH OBSERVATION AND GEOGRAPHIC INFORMATION SYSTEMS

MISCELLANEOUS

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE INFLUENCE OF PHARMACEUTICAL RESIDUES FROM SURFACE WATERS ON FISH OXIDATIVE STRESS: A REVIEW

Alina ANTACHE, Valentina CALMUC, Stefan-Mihai PETREA, Ira-Adeline SIMIONOV, Madalina CALMUC, Aurelia NICA, Dragos CRISTEA, Mihaela NECULITA

"Dunarea de Jos" University of Galati, 47 Domneasca Street, Galati, Romania

Corresponding author email: alina.antache@ugal.ro

Abstract

In the last time, pharmaceutical residues have been discovered in almost all environmental matrices in the world, especially in surface water (lakes, rivers, seawater). The consumption of medicinal products contributes to the emission of pharmaceutical residues into the environment mainly through human (hospital effluents) and farm animal excretions. Once pharmaceutical residues reach in surface water, they also become incorporated into aquatic organism having a toxic effect on them. The biochemical response is dependent by the level of concentration and by the exposure time which largely contributes to the appearance of oxidative stress due to changes in the levels of antioxidant enzymes. In fish, due to detoxification and biotransformation capacity, the liver is the most important metabolizing organ, thus, one of the main defences against pharmaceutical residues. Analysis of biochemical indicators includes superoxide dismutase (SOD), glutathione S-transferase (GST), reduced glutathione (GSH), glutathione peroxidase (GPx), glutathione reductase (GR), catalase (CAT) and malondialdehyde (MDA). In the near future, the development of "green" and eco-friendly pharmaceuticals with low persistence in water surface, bioaccumulation and toxicity could help minimize accumulation in the aquatic environment.

***Key words**: antioxidant enzymes, fish, pharmaceutical residues, oxidative stress, water surfaces.*

INTRODUCTION

The quality of aquatic environments is compromised by the entry of toxic substances mainly from the anthropogenic activities. Pharmaceuticals products are considered one of these toxic substances during the last two decades due to the presence, abundance, and possible effects of these products in aquatic ecosystems (Jijie et al., 2021; Strungaru et al., 2021).

Biologically active pharmaceutical compounds are produced and also used in a very high quantity where their use and diversity are increasing every year (Shreenidhi et al., 2021).

With over 600 pharmaceuticals detected in the surface waters, at the global level, those from the category of analgesics, antidepressants and antihypertensive drugs are preponderent (Furduson et al., 2019; Shuraiqi et al., 2021). Within these classes, diclofenac (DCF), fluoxetine (FLX) and propranolol (PROP) are among the most used and prescribed drugs, and therefore some of the most frequently detected compounds in the aquatic environment, at concentrations ranging from ng/L to µg/L (Bonnefille et al., 2018).

The residues of these drugs are discharged into the aquatic environment; therefore, they can be found in wastewater, treated wastewater, surface water, groundwater and drinking water, in concentrations generally low in ng/L or µg/L, but having effects due to their continuous discharge into the aquatic environment (Archer et al., 2017; Pedrazzani et al., 2019).

In the last years the monitoring of pharmaceuticals in the aquatic environment is becoming a priority for competent authorities. Concerning to the analytical determination, the mainly used techniques are based on chromatographic mechanisms (gas chromatographic and HPLC) coupled to specific mass spectrometry and spectrophotometric detectors (Rivoira et al., 2015) which permitted the determination of some environmental effects of pharmaceuticals and can be established in the µg/L and ng/L concentration ranges (Lindsey et al., 2001; Kanda et al., 2003; Daughton, 2004; Larrson, 2014). Through these techniques can be determined and quantified approximately 3000 biologically active compounds in the environment (Richardson, 2006; Richardson & Ternes, 2014).

For the wild fish population, the pollution with pharmaceutical products and residues can conduct to reduced species richness and even at the loss of stocks in habitats.

In the evaluation of the ecological status of aquatic environments are used fish because they are very sensitive to anthropogenic impacts and for this reason some of them can be chosen as bio-monitors.

Bioindicators serve as a measurable indicator of a biochemical, physiological, toxicological, or ecological process or function that has been correlated to effects on organisms, populations, or ecosystems (Burger, 2006). One of the most important used bioindicators in the aquatic ecosystem is represented by fish because they have an important ecological function at the level of trophic chain. Fishes can sensitively reflect the concentrations of contaminants in the environment in which they are found (Gallego et al., 2021) and making them a tool for detecting the effects of pharmaceuticals early generating an overview of the state of the aquatic ecosystem (Martínez-Morcillo et al., 2020).

Several studies have been carried out for the purpose of choice of the best biomarkers, where different responses have been tested in aquatic fish species to given pharmaceutical product (Recabarren-Villalon et al., 2019). Thus, the biomarkers were grouped into three categories: biomarkers of exposure, biomarkers of effect (which assess the biochemical, physiological or behavioural disturbances in an organism) and biomarkers of susceptibility (ability of organism to respond to exposure to a specific xenobiotic substance, including genetic factors) (Oost et al., 2003; Arango, 2012).

SOURCE OF THE PHARMACEUTICAL RESIDUES IN AQUATIC ENVIRONMENT

Large numbers of pharmaceutical compounds are found in the environment as the result of biological degradation by the organism present in ecosystems. These compounds have high biological activity even at low concentrations to the aquatic biota (Nunes et al., 2006)

The consumed pharmaceutical drug does not decompose completely in the body, a small amount of drug is excreted through the biological system (Winker et al., 2008). The involuntary (excretion through body or washing off topical medicine) and purposeful (disposal of unused or out of date medicine) action by humans are the primary reason for the discharge of pharmaceutical compounds into the environment (Daughton & Ruhoy, 2009). Discharge from various sources of pharmaceutical wastes are industries, hospitals, animal husbandry and many others, whereas the dominant source of pharmaceuticals in water is urban wastewater emission (Aus der Beek et al., 2016).

Once discharged into aquatic environments, pharmaceuticals and their metabolites can undergo biotic and abiotic transformation (degradation) and sorb to suspended particulate matter (SPM) and sediments, and in some cases accumulate in the tissues of aquatic organisms (Ramirez et al., 2009).

Sources of human pharmaceuticals in sewage include patient use in the community, discharges from hospitals and, in some cases, wastewater from pharmaceutical manufacturing (Gaw et al., 2014).

A range of veterinary medicines including antibiotics, also registered for human use, is used prophylactically and to control disease outbreaks in marine aquaculture. Up to 75% of the administered dietary dose of a veterinary medicine can be lost to the surrounding environment. The loss mechanisms include dispersal of non-ingested pellets, gill and renal excretion of the unprocessed drug, and renal and faecal excretion of drug metabolites (Grigorakis & Rigos, 2011).

Animal husbandry and horticulture along rivers and in coastal areas may also contribute to loadings of pharmaceuticals entering in coastal waterways (Kummerer, 2009a; Jia et al., 2011). Antibiotics are added to animal feeds and in some cases drinking water to treat disease particularly in feedlots housing large numbers of animals (Kemper, 2008). The use of low doses of antibiotics in feed as growth promoters still occurs in some regions of the world despite being banned in Europe (Du & Liu, 2012). Some countries permit the use of antibiotics including oxytetracycline and streptomycin on horticultural crops (Kummerer, 2009a).

Pharmaceutical compounds most often identified in the aquatic environment belong to several classes of human and veterinary antibiotics and human prescription and nonprescription drugs such as NSAIDs, β-blockers, blood lipid regulators, antiepileptics, analgesics, and antidepressants (Petrovic et al., 2014; Radovic et al., 2015; Patel et al., 2019).

Pharmaceuticals versus other contaminants

Pharmaceutical contaminants differ from most other contaminants according to these aspects (Zuccato et al., 2000; Kummerer, 2009b; Rivera-Utrilla et al., 2013):

- having a molecular mass < 500 Da, although larger for some compounds,
- containing chemically complex molecules with a large variety of structures, shapes, molecular masses, and functionalities,
- having more than one ionizable group,
- a degree of ionization that depends on the medium's pH,
- have lipophilic properties,
- persistence in nature, accumulate in life forms and remain biologically active (naproxen, sulfamethoxazole, and erythromycin can persist for almost one year and clofibric acid can persist for multiple years),
- tend to adsorb and be distributed in a living body, which from a metabolic point of view modifies their chemical structure.

OXIDATIVE STRESS IN FISH

A disturbance in the balance between the prooxidants and antioxidants leading to detrimental biochemical and physiological effects is known as oxidative stress. Indicators of oxidative stress include changes in antioxidant enzyme activity, damaged DNA bases, protein oxidation products, and lipid peroxidation products.

It has been found that pollutants present in the water surface can mediate their toxicity in fish by the appearance of oxidative stress resulting in changes in proteins, membrane lipids and DNA molecules (Bethanie, 2008). The result of such exposure leading to oxidative stress can impair cellular or biological function which can lead to the appearance of diseases.

Biomarkers of oxidative stress, such as changes in antioxidant enzyme activity or in degree of accumulation of damaged molecules, can offer an early warning sign for exposure to toxic substances.

For the reducing oxidative stress the activity of antioxidant enzymes as catalase (CAT) and superoxide dismutase (SOD) are involved in the detoxification of reactive oxygen species (ROS). On the other hand, glutathione-S-transferase (GST) is responsible for the metabolism of xenobiotic compounds such as pharmaceuticals. CAT is mainly located in the peroxisomes and is responsible for the reduction of H_2O_2 produced from the metabolism of long chain fatty acids in peroxisomes; GPx catalyzes the reduction of both H_2O_2 and lipid peroxide. The different responses of CAT and GPx indicate different mechanisms for ROS removal (Gao et al., 2018).

The most abundant and important molecular antioxidants in cellular cytoplasm is reduced glutathione (GSH). GSH is used as a conjugating molecule by GST to ease excretion of xenobiotics. GSH is also used for reduction of lipid peroxides by the action of glutathione peroxidase (GPx). Gluthatione reductase (GR) was proposed to use as biomarkers in fish oxidative stress (Stephensen et al., 2002).

The lipid peroxidation (MDA) process also affects biomolecules associated with the membrane, i.e., membrane bound proteins or cholesterol, and may be of importance in fish as their membranes contain a higher degree of PUFA than other vertebrates (Monserrat et al., 2007).

Huang et al. (2007) have measured contaminant-induced oxidative damage in *Cyprinus carpio* captured in the Yellow River, China, a river contaminated by phenols, oils, PAHs and ammonia. While SOD and GST were upregulated in all tissues investigated, CAT and GPx were decreased in both kidney and gut tissues, the same tissues which were also found to have higher levels of MDA, suggesting that a lack of antioxidant defences could result in oxidative damage.

Studies have shown that the exposure to iron sulphate of the *Carassius auratus* species has led to an increased levels of protein carbonylation and lipid peroxidation and decreases in CAT, GST and GR activities (Bagnyukova et al., 2006). On the other hand, goldfish exposed to arsenic had increased activities of SOD, CAT and GPx as well as increased levels of lipid peroxides and GSSG (Bagnyukova et al., 2007).

Three species of cichlid from a metal-contaminated river showed changes in SOD, CAT and GPx activities. All species showed increases in lipid peroxidation in the metal1contaminated river in both spring and autumn (Ruas et al., 2007).

EFFECT OF PHARMACEUTICAL RESIDUES ON FISH OXIDATIVE STRESS

Accumulation of pharmaceuticals in biological tissues is related to a small portion of un-ionized species, with a high affinity for lipophilic matter, remaining in the aqueous phase (Fabbri & Franzellitti, 2016). It is known that the response of antioxidant enzymes depends on the intensity of the oxidative pressure, and that an overload of the antioxidant defence system can occur in conditions of oxidative stress (Mauro et al., 2021).
The effect of different pharmaceutical products from watersurface on fish oxidative stress is presented in Table 1.

Antibiotics
A long period of exposure to antibiotics can cause a reduction in the activity of antioxidant defences (glutathione and catalase) (Almeida et al., 2019). This induces oxidative damage, probably due to the prolonged exposure to the drug and its resulting accumulation in the tissues, leading to a reduction of the enzymatic activity (Zhou et al., 2018).
The level of lipid degradation in terms of lipid peroxidation (MDA) was found to be significantly higher in liver tissue of *Pangasius* sp. exposed to norfloxacin 30 mg/L. MDA has been increased about 1.61-fold in norfloxacin treated fish than the control fish (Shreenidhi et al., 2021).

Antipsychotics and antiepileptics drugs
Sehonova et al. (2017) studied the effects of the tricyclic antidepressants amitriptyline, nortriptyline and clomipramine at concentrations of 10, 100 and 500 μg/L on early-life stages of common carp (*Cyprinus carpio*) for a period of 30 days. Long-term exposure resulted in a significant increase in mortality, developmental retardation, morphological anomalies, and pathological changes in brain, heart and kidney. In addition, changes in antioxidant enzyme activity as well as an increase in lipid peroxidation were observed, even at the lowest tested concentrations.
Studies by Li et al. (2010) showed that the inhibition of CAT activity in the *Oncorhynchus mykiss* after exposure to individual carbamazepine (2mg/L), due to the overwhelming production of hydrogen peroxide by SOD.

Analgesic/anti-inflammatory drugs
Literature studies show that pharmaceuticals (especially diclofenac) and their photolysis by products were, to some extent, able to cause moderate toxicity on zebrafish after seven days of exposure (Diniz et al., 2015).
Gao et al. (2018) showed obvious decrease of antioxidant enzymes activity in *Cyprinus carpio* groups exposed to analgesic drugs may be due to the impairment of the antioxidant system, responsible for the increasing lipid peroxidation and disequilibrium of GSH/GSSG.

Antihistaminic drugs
Teixeira et al. (2017) observed that 12 μg/L cetirizine inhibited the activity of glutathione S-transferases activity (GSTs) and the activity of SOD and CAT.

Table 1. Effect of different pharmaceutical products from watersurface on fish oxidative stress

Crt. no.	Type of drug	Drug	Environmental concentrations	Concentration/Time exposure	Fish species	Samples	Biochemical responses	References
1.	Antibiotics	Oxytetracycline	ng/L to µg/L	0, 0.1, 10, 10000 µg/L for two months	*Danio rerio*	Whole body	(-) Total Gluthatione; Glutathione S-Transferase; Catalase	Carvalho & Santos, 2016; Almeida et al., 2019
2.				0.005, 0.050, 0.500, 5 and 50 mg/L for 96 hour	*Oncorhynchus mykiss*	Gills, Liver	(+) Catalase in gills; Gluthatione Peroxidase in gills; Lipid peroxidation in liver (-) Catalase in liver; Gluthatione reductase; Lipid peroxidation in gills	Rodrigues et al., 2017
3.				0.3125, 0.625, 1.25, 2.5 and 5.0 µg/L for 28 days			(+) Catalase, Gluthatione Peroxidase in liver; Gluthatione Reductase; Lipide peroxidation in liver (-) Catalase, Gluthatione Peroxidase in gills;	
4.		Sulfamethoxazole Oxytetracycline	259.6 ng/L and 350 ng/L	260 ng/L and 420 ng/L for six Weeks	*Danio rerio*	Intestine, Liver, Muscle	(-) Superoxide Dismutase; Peroxidase; Reduced Glutathione	Zhou et al., 2018a
5.				100 and 80 mg/kg for six weeks			(+) Malondialdehyde (-) Peroxidase; Superoxide Dismutase; Reduced Glutathione.	Zhou et al., 2018b
6.		Amoxicillin Oxytetracycline	6 and 340 ng/L	0.1, 10, 25, 50, 100 mg/L for 96 h	*Danio rerio*	Head, Muscle, Liver, Gills	(-) Catalase; Glutathione S-Transferase;	Park & Choi, 2008; Oliveira et al., 2013
7.		Ivermectin	25 up to 60 ng/L	10, 20, 40, 60, 80, 100, 200 µg/L for 96 h	*Danio rerio*	Head, Muscle, Liver, Gills	(-) Glutathione S-Transferase	Montforts et al., 2004; Sanderson et al., 2007; Oliveira et al., 2016
8.						Head, Trunck	(-) Catalase; Glutathione S-Transferase	Domingues et al., 2016
9.		Norfloxacin	0.0001 mg/L	0.0001, 0.1, 1, 10 and 30 mg/L for 28 days	*Danie rerio*	Whole body	(+) Gluthatione reductase; Gluthatione S-Transferase; Gluthatione peroxidase; Catalase; Lipid peroxidation	Bartoskova et al., 2014
10.	Antiepileptics and Antipsychotics	Carbamazepine Clonazepam	0.002 to 11.5 µg/L respectively 145 ng/L	75 µg/L for 96 h	*Danio rerio*	Brain, Liver, Kidney	(-) Glutathione in Liver; Catalase (+) Glutathione in Brain; Glutathione S-Transferase in Brain and in liver	Cunha et al., 2017; Ekpeghere et al., 2018; Gomes et al., 2019

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

11.		Carbamazepine	0.002 to 11.5 µg/L	0, 10 or 10000 µg/l for 63 days	*Danio rerio*	Muscle, Head, Gills, Liver, Gut	(-) Catalase (+) Glutathione S-Transferase	Ekpeghere et al., 2018; Santos et al., 2018
12.				1, 10 and 100 µg/L for 45 Days	*Danio rerio*	Whole Body	(-) Glutathione S-Transferase; Superoxide Dismutase (+) Catalase	Jia et al., 2020
13.		Carbamazepine		60 µg/L / 35 days	*Tinca tinca*	Whole Body	(-) Gluthatione S-Transferase; Gluthatione peroxidase; Catalase; Lipid peroxidation	Stancova et al., 2017
14.	Analgesic, Antipyretic and Anti-Inflammatory Drugs	Diclofenac	0.02 mg/L	0.02, 5, 15, 30, and 60 mg/L for 28 Days	*Danio rerio*	Whole Body	(+) Lipid Peroxidation	Praskova et al., 2014
15.				3 mg/L and 2 µg/L of for 96 h	*Danio rerio*	Gills, Liver	(+) Glutathione S-Transferase; Lipid Peroxidation	De Carvalho Penha et al., 2021
16.		Ketoprofen, Diclofenac and their Photodegradation products	up to 1µg/L; 0.02 mg/L	1 mg/L for Ketoprofen, 7.5 and 60 min; for Diclofenac 1.5 and 5 min	*Danio rerio*	Whole Body	(+) Lipid Peroxidation (-) Catalase; Glutathione S-Transferase; Superoxid Dismutase	Cuklev et al., 2012; Praskova et al., 2014; Diniz et al., 2015
17.		Diclofenac, Naproxen, and Ibuprofen	-	Mix of diclofenac, naproxen, and ibuprofen, 0.1 µM / 96 h	*Cyprinus carpio*	Liver	(+) Lipid peroxidation (-) Superoxide dismutase; catalase; glutathione Peroxidase; GSH/GSSG	Gao et al., 2018
18.		Diclofenac, Ibuprofen, Carbamazepine	-	mixturesmof pharmaceuticals at nominal concentrations of 0.02, 0.2, 2, 20, and 60 µg/l of each pharmaceutical / 35 days	*Tinca tinca*	Whole Body	(+) Gluthatione reductase; Gluthatione S-Transferase (-) Gluthatione peroxidase	Stancova et al., 2017
19.		Diclofenac,	-	60 µg/L / 35 days	*Tinca tinca*	Whole Body	(+) Gluthatione reductase; Gluthatione S-Transferase; Gluthatione peroxidase; Catalase (-) Lipid peroxidation	Stancova et al., 2017
20.		Ibuprofen	-	60 µg/L / 35 days	*Tinca tinca*	Whole Body	(-) Gluthatione reductase; Gluthatione S-Transferase; Gluthatione peroxidase; Catalase; Lipid peroxidation	Stancova et al., 2017
21.	Anesthetics	Phenol	-	21 mg/L / 2 days	*Pangasius* sp.	Liver	(+) Lipid peroxidation (-) Total antioxidant capacity	Vijaya Geetha et al., 2021
22.	Antilipidemic	Clofibrate	-	1000 mg/L/ 7days	*Pangasius* sp.	Liver	(+) Lipid peroxidation; Total antioxidant capacity	
23.	Effluent A and B from two pharmaceutical industries in Lagos, Nigeria			LC50 after 14 and 28 days	*Oreochromis Niloticus*	Gills, Liver	(-) Reduced gluthatione; Superoxid dismutase; Catalase (+) Lipid peroxidation	Lan et al., 2021

Note: (+) – increase; (-) - decrease

POLICY INSTRUMENTS TO CONTROL PHARMACEUTICALS IN THE ENVIRONMENT

The use of best practices, a good international cooperation, awareness of the dangers of these substances in the aquatic environment and an improvement of understanding of risks should be used to reduce pharmaceuticals products in surface water.

The development of "green" and eco-friendly pharmaceuticals with low environmental persistence, no bioaccumulation, and reduced toxicity could help minimize accumulation in the environment. The Stockholm County Council of Sweden developed a classification system for the environmental impact of pharmaceuticals called the PBT index (Patel et al., 2019). This is defined as the sum of the values for persistence, bioaccumulation, and toxicity. Pharmaceuticals are classified on a 0-3 scale in this index for persistence, bioaccumulation, and toxicity. A value of 0 corresponds to the most environmentally friendly while 3 is the worst for the environment. Physicians should discourage using pharmaceuticals with high PBT index values and encourage development of more eco-friendly pharmaceuticals (Patel et al., 2019). Some important recommendations are listed below:

- advanced methods for accurate and continuous detection of pharmaceuticals in environmental systems should be developed and applied,
- strict regulations for effluent release from industrial and hospital point sources must be implemented,
- greener technologies should be implemented for pharmaceutical development, manufacture, and use,
- continuous research is required to how chronic exposure to micropollutants effects aquatic environment,
- implementation a standard to limit micropollutants in wastewaters and environmental water systems,
- choosing an effective technology and equipment for pharmaceutical remediation and implementation of these on a large scale and at a low cost.

CONCLUSIONS

In conclusion, for the future studies is necessary to test the same concentrations of various drugs for the same time intervals on the same fish species. This is required in order to make comparisons and to prove the hypothesis on the effect of a certain drug on fish oxidative stress. Also, there are insufficient data on the potential for impacts on higher trophic levels, either through trophic transfer of pharmaceuticals or indirect effects due to impacts on lower trophic levels including algae.

At the same time, it is necessary to implement a pharmaceutical return program for unwanted and expired drugs which will help control the volume of pharmaceuticals released that are present in household wastes and domestic effluents.

In the near future, the development of an eco-friendly pharmaceuticals with low persistence in water surface, bioaccumulation and toxicity could help minimize accumulation in the aquatic environment.

ACKNOWLEDGEMENTS

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CNCS/CCCDI – UEFISCDI, project PN-III-P2-2.1-PTE-2019-0697, within PNCDI III.

REFERENCES

Almeida, A.R., Tacão, M., Machado, A.L., Golovko, O., Zlabek, V., Domingues, I., Henriques, I. (2019). Long-Term Effects of Oxytetracy1cline Exposure in Zebrafish: A Multi-Level Perspective. *Chemosphere*, 222, 333–344.

Arango V, S.S. (2012). Biomarcadores para la evaluacion ´ de riesgo en la salud humana. *Rev. Fac. Nac. Salud Pública* 30, 75–82. https://doi.org/10.1007/978-1-4939-0986- 5_19.

Archer, E., Petrie, B., Kasprzyk-Hordern, B., Wolfaardt, G.M. (2017). The fate of pharmaceuticals and personal care products (PPCPs), endocrine disrupting contaminants (EDCs), metabolites and illicit drugs in a WWTW and environmental waters. *Chemosphere* 174, 437–446. https://doi.org/10.1016/j.chemosphere.2017.01.101.

Aus der Beek, T., Weber, F.A., Bergmann, A., Hickmann, S., Ebert, I., Hein, A., Küster, A. (2016). Pharmaceuticals in the environment-Global occurrences and perspectives. *Environmental*

Toxicology and Chemistry 35(4):823–835, https://doi.org/10.1002/etc.3339.

Bagnyukova, T. V., Chahrak, O. I., Lushchak, V. I. (2006). Coordinated response of goldfish antioxidant defenses to environmental stress. *Aquatic Toxicology*, 78, 325.

Bagnyukova, T. V., Luzhna, L. I., Pogribny, I. P. and Lushchak, V. I. (2007). Oxidative stress and antioxidant defenses in goldfish liver in response to short-term exposure to arsenite. *Environmental and Molecular Mutagenesis*, 48, 658-665.

Bartoskova, M., Dobsikova, R., Stancova, V., Pana, O., Zivna, D., Plhalova, L., Blahova, J., Marsalek, P. (2014). Norfloxacin-Toxicity for Zebrafish (*Danio rerio*) Focused on Oxidative Stress Parameters. *Hindawi Publishing Corporation BioMed Research International*, 1-6, ID 560235, http://dx.doi.org/10.1155/2014/560235

Bethanie Carney Almroth (2008). Oxidative damage in fish used as biomarkers in field and laboratory studies. *Department of Zoology/Zoophysiology, University of Gothenburg, Box* 463, 405 30 Göteborg, Sweden.

Bonnefille, B., Gomez, E., Courant, F., Escande, A., Fenet, H. (2018). Diclofenac in the marine environment: a review of its occurrence and effects. *Mar. Pollut. Bull.* https://doi.org/10.1016/j.marpolbul.2018.04.053.

Burger, J. (2006). Bioindicators: types, development, and use in ecological assessment and research. *Environ. Bioindic.* 1, 22–39. https://doi.org/10.1080/15555270590966483.

Carvalho, I.T., Santos, L. (2016). Antibiotics in the Aquatic Environments: A Review of the European Scenario. *Environ. Int.* 94, 736–757.

Cuklev, F., Fick, J., Cvijovic, M., Kristiansson, E., Förlin, L., Larsson, D.G.J. (2012). Does Ketoprofen or Diclofenac Pose the Lowest Risk to Fish? J. *Hazard. Mater.* 229–230, 100–106.

Daughton, C.G., Ruhoy, I.S. (2009). Environmental footprint of pharmaceuticals: the significance of factors beyond direct excretion to sewers. *Environ. Toxicol. Chem*., 28(12):2495, https://doi.org/10.1897/08-382.1.

Daughton, C. G. (2004). Non-Regulated Water Contaminants: Emerging Research. *Environ. Impact Assess. Rev.,* 24, 711−732.

De Carvalho Penha, L.C.C., Rola, R.C., Martinez, C.B.D.R., de Martins, C.M.G. (2021). Effects of Anti-Inflammatory Diclofenac Assessed by Toxicity Tests and Biomarkers in Adults and Larvae of *Danio Rerio*. *Comp. Biochem. Physiol. C Toxicol. Pharmacol.*, 242, 108955.

Diniz, M. S. et al. (2015). Ecotoxicity of ketoprofen, diclofenac, atenolol and their photolysis byproducts in zebrafsh (*Danio rerio*). *Sci. Total Environ*. 505, 282–289.

Domingues, I., Oliveira, R., Soares, A.M.V.M., Amorim, M.J.B. (2016). Effects of Ivermectin on Danio Rerio: A Multiple Endpoint Approach: Behaviour, Weight and Subcellular Markers. *Ecotoxicology*, 25, 491–499.

Du, L., Liu, W. (2012). Occurrence, fate, and ecotoxicity of antibiotics in agro-ecosystems. A review. *Agron. Sustain. Dev.* 32, 309– 327. (doi:10.1007/s13593-011-0062-9)

Fabbri, E., Franzellitti, S. (2016). Human pharmaceuticals in the marine environment:focus on exposure and biological effects in animal species. *Environmental Toxicology and Chemistry*, 35(4): 799–812. DOI: 10.1002/etc.3131

Fursdon, J.B., Martin, J.M., Bertram, M.G., Lehtonen, T.K., Wong, B.B. (2019). The pharmaceutical pollutant fluoxetine alters reproductive behaviour in a fish independent of predation risk. *Sci. Total Environ*. 650, 642-652.

Gallego, R, S.E., Penuela, G.A., Martínez-Lopez, E. (2021). Enzymatic activity changes in striped cat fi sh Pseudoplatystoma magdaleniatum, induced by exposure to different concentrations of ibuprofen and triclosan. *Chemosphere* 271, 1–13. https://doi.org/10.1016/j.chemosphere.2020.129399.

Gao, X., Geng, J., Du, Y., Li, S., Wu, G., Fu, Y., Ren, H. (2018). Comparative study of the toxicity between three non-steroidal anti1infammatory drugs and their UV/ $Na_2S_2O_8$ degradation products on *Cyprinus carpio*. *Scientific Reports*, 8:13512, 1-11. DOI:10.1038/s41598-018-29524-1.

Gaw, S., Thomas, K.V., Hutchinson, T.H. (2014). Sources, impacts and trends of pharmaceuticals in the marine and coastal environment. *Phil. Trans. R. Soc. B* 369:20130572. http://dx.doi.org/10.1098/rstb.2013.0572

Gomes, T.B., Fernandes Sales Junior, S., Saint'Pierre, T.D., Correia, F.V., Hauser-Davis, R.A., Saggioro, E.M. (2019). Sublethal Psychotropic Pharmaceutical Effects on the Model Organism *Danio rerio*: Oxidative Stress and Metal Dishomeostasis. *Ecotoxicol. Environ. Saf.*, 171, 781–789.

Grigorakis, K., Rigos, G. (2011). Aquaculture effects on environmental and public welfare—the case of Mediterranean mariculture. *Chemosphere* 85, 899–919. (doi:10.1016/j.chemosphere.2011.07.015)

Huang, D.J., Zhang, Y.M., Song, G., Long, J., Liu, J. H., Ji, W. H. (2007). Contaminants-Induced Oxidative Damage on the Carp *Cyprinus carpio* Collected from the Upper Yellow River, China. *Environmental Monitoring and Assessment*. 128, 483-488.

Jia, A., Hu, J., Wu, X., Peng, H., Wu, S., Dong, Z. (2011). Occurrence and source apportionment of sulfonamides and their metabolites in Liaodong Bay and the adjacent Liao River Basin, North China. *Environ. Toxicol. Chem*. 30, 1252 – 1260. (doi:10. 1002/etc.508)

Jia, D., Li, X., Du, S., Xu, N., Zhang, W., Yang, R., Zhang, Y., He, Y., Zhang, Y. (2020). Single and Combined Effects of Carbamazepine and Copper on Nervous and Antioxidant Systems of Zebrafish (*Danio rerio*). *Environ. Toxicol*., 35, 1091–1099.

Jijie, R., Mihalache, G., Balmus, I.M., Strungaru, S.A., Baltag, E.S., Ciobica, A., Nicoara, M., Faggio, C. (2021). Review zebrafish as a screening model to study the single and joint effects of antibiotics. *Pharmaceuticals* 14, 1–26. https://doi.org/10.3390/ph14060578.

Kanda, R., Griffin, P., James, H. A., Fothergill, J. (2003). Pharmaceutical and Personal Care Products in Sewage Treatment Works. *J. Environ. Monit*., 5, 823−830.

Kemper, N. (2008). Veterinary antibiotics in the aquatic and terrestrial environment. *Ecol. Indicators* 8, 1 – 13. (doi:10.1016/j.ecolind.2007.06.002)

Kummerer, K. (2009a). Antibiotics in the aquatic environment: a review. I. *Chemosphere* 75, 417– 434. (doi:10.1016/j.chemosphere.2008.11.086)

Kuummerer, K. (2009b). The Presence of Pharmaceuticals in the Environment Due to Human Use−Present Knowledge and Future Challenges. *J. Environ. Manage.*, 90, 2354−2366.

Lan, S.M., Briggs, T.-M.D., Obanya, H.E., Amaeze, N.H. and Otitoloju, A.A. (2021). Toxicity Evaluation of Pharmaceutical Wastewater to the Nile Tilapia (Oreochromis niloticus). *Journal of Environmental Protection,* 12, 296-309. https://doi.org/10.4236/jep.2021.124019

Larsson, D. J. (2014). Pollution from Drug Manufacturing: Review and Perspectives. *Philos. Trans. R. Soc., B*, 369, 20130571.

Li, Z.-H. et al. (2010). Modulation of antioxidant defence system in brain of rainbow trout (*Oncorhynchus mykiss*) after chronic carbamazepine treatment. Comp. Biochem. Physiol. C: Pharmacol. Toxicol. 151, 137–141.

Lindsey, M. E., Meyer, M., Thurman, E. M. (2001). Analysis of Trace Levels of Sulfonamide and Tetracycline Antimicrobials in Ground1water and Surface Water Using Solid-Phase Extraction and Liquid Chromatography/Mass Spectrometry. *Anal. Chem.*, 73, 4640 − 4646.

Martínez-Morcillo, S., Rodríguez-Gil, J.L., Fernandez-Rubio, J., Rodríguez-Mozaz, S., Míguez-Santiyan, M.P., Valdes, M.E., Barcelo, D., Valcarcel, Y. (2020). Presence of pharmaceutical compounds, levels of biochemical biomarkers in seafood tissues and risk assessment for human health: results from a case study in North-Western Spain. *Int. J. Hyg. Environ. Health* 223, 10–21. https://doi.org/10.1016/j.ijheh.2019.10.011.

Mauro, M., Lazzara, V., Arizza, V., Luparello, C., Ferrantelli, V., Cammilleri, G., Inguglia, L., Vazzana, M. (2021). Human Drug Pollution in the Aquatic System: The Biochemical Responses of *Danio rerio* Adults. *Biology*, 10, 1064. https://doi.org/10.3390/biology10101064

Monserrat, J. M., Martinez, P. E., Geracitano, L. A., Lund Amado, L., Martinez Gaspar Martins, C., Lopes Leaes Pinho, G., Soares Chaves, I., Ferreira-Cravo, M., Ventura-Lima, J. and Bianchini, A. (2007). Pollution biomarkers in estuarine animals: Critical review and new perspectives. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology*. 146, 221-234.

Montforts, M.H.M.M., van Rijswick, H.F.M.W., de Haes, H.A.U. (2004). Legal Constraints in EU Product Labelling to Mitigate the Environmental Risk of Veterinary Medicines at Use. *Regul. Toxicol. Pharmacol*., 40, 327–335.

Nunes, B., Carvalho, F., Guilhermino,L. (2006). Effects of widely used pharmaceuticals and a detergent on oxidative stress biomarkers of the crustacean Artemia parthenogenetica, *Chemosphere*, 62(4):581–594.

Oliveira, R., Grisolia, C.K., Monteiro, M.S., Soares, A.M.V.M., Domingues, I. (2016). Multilevel Assessment of Ivermectin Effects Using Different Zebrafish Life Stages. *Comp. Biochem. Physiol. C Toxicol. Pharmacol.*, 187, 50–61.

Oliveira, R., McDonough, S., Ladewig, J.C.L., Soares, A.M.V.M., Nogueira, A.J.A., Domingues, I. (2013). (Effects of Oxytetracycline and Amoxicillin on Development and Biomarkers Activities of Zebrafish (*Danio rerio*). *Environ. Toxicol. Pharmacol*., 36, 903–912.

Oost, D., Beyer, J., Vermeulen, N.P.E. (2003). Fish bioaccumulation and biomarkers in environmental risk assessment: a review. *Environ. Toxicol. Pharmacol.* 13, 57–149. https://doi.org/10.1016/S1382-6689(02)00126-6.

Park, S., Choi, K. (2008). Hazard Assessment of Commonly Used Agricultural Antibiotics on Aquatic Ecosystems. Ecotoxicology, 17, 526–538.

Patel, M., Kumar, R., Kishor, K., Mlsna, T., Pittman, C.U., Modan, D. (2019). Pharmaceuticals of Emerging Concern in Aquatic Systems: Chemistry, Occurrence, Effects, and Removal Methods. *Chemical Reviews*, 119, 3510–3673. DOI: 10.1021/acs.chemrev.8b00299

Pedrazzani, R., Bertanza, G., Brnardic, I., Cetecioglu, Z., Dries, J., Dvarioniene, J., García-Fernandez, A.J., Langenhoff, A., Libralato, G., Lofrano, G., Skrbic, B., Martínez-Lopez, E., Meriç, S., Pavlovic, D.M., Papa, M., Schroder, P., Tsagarakis, K. P., Vogelsang, C. (2019). Opinion paper about organic trace pollutants in wastewater: Toxicity assessment in a European perspective. *Sci. Total Environ*. 651, 3202–3221. https://doi.org/10.1016/j.scitotenv.2018.10.027.

Petrovic, M., Škrbic, B., Živancev, J., Ferrando-Climent, L., Barcelo, D. (2014). Determination of 81 Pharmaceutical Drugs by High Performance Liquid Chromatography Coupled to Mass Spectrometry with Hybrid Triple Quadrupole–Linear Ion Trap in Different Types of Water in Serbia. *Sci. Total Environ*., 468–469, 415–428.

Praskova, E., Plhalova, L., Chromcova, L., Stepanova, S., Bedanova, I., Blahova, J., Hostovsky, M., Skoric, M., Maršálek, P., Voslarova, E. (2014). Effects of Subchronic Exposure of Diclofenac on Growth, Histopathological Changes, and Oxidative Stress in Zebrafish (*Danio rerio*). *Sci. World J*., 2014, 645737.

Radovic, T., Grujic, S., Petkovic, A., Dimkic, M., Laušević, M. (2015). Determination of Pharmaceuticals and Pesticides in River Sediments and Corresponding Surface and Ground Water in the Danube River and Tributaries in Serbia. *Environ. Monit. Assess.*, 187, 4092.

Ramirez, A.J. et al. (2009). Occurrence of pharmaceuticals and personal care products in fish: results of a national pilot study in the United States. *Environ. Toxicol. Chem*. 28, 2587 – 2597. (doi:10.1897/08-561.1).

Recabarren-Villalon, T., Ronda, A.C., Arias, A.H., (2019). Uso de biomarcadores en la evaluacion ´ ambiental de ecosistemas marinos en Am´erica. *JAINA Costas y Mares ante el Cambio Climatico* 1, 1–18. https://doi.org/10.26359/52462.0719.

Richardson, S. D. (2006). Environmental Mass Spectrometry: Emerging Contaminants and Current Issues. Anal. Chem., 78, 4021−4046.

Richardson, S. D., Ternes, T. A. (2014). Water Analysis: Emerging Contaminants and Current Issues. *Anal. Chem*., 86, 2813−2848.

Rivera-Utrilla, J., Sanchez-Polo, M., Ferro-García, M. A., PradosJoya, G,; Ocampo-Perez, R. (2013). Pharmaceuticals as Emerging Contaminants and Their Removal from Water. A Review. *Chemosphere*, 93, 1268−1287.

Rivoira, L., de Carlo, R.M., Cavalli, S., Bruzzoniti, M.C. (2015). Simple SPE-HPLC determina1tion of some common drugs and herbicides of environmental concern by pulsed amperometry. *Talanta* 131, 205–212.

Rodrigues, S., Antunes, S.C., Correia, A.T., Nunes, B. (2017). Rainbow trout (*Oncorhynchus mykiss*) pro-oxidant and genotoxic responses following acute and chronic exposure to the antibiotic oxytetracycline. *Ecotoxicology* 26:104–117. DOI 10.1007/s10646-016-1746-3

Ruas, C. B. G., Carvalho, C. d. S., de Araujo, H. S. S., Espindola, E. L. G., Fernandes, M. N. (2007). Oxidative stress biomarkers of exposure in the blood of cichlid species from a metal-contaminated river. *Ecotoxicology and Environmental Safety*. doi:10.1016/j.ecoenv.2007.08.018.

Sanderson, H., Laird, B., Pope, L., Brain, R., Wilson, C., Johnson, D., Bryning, G., Peregrine, A.S., Boxall, A., Solomon, K. (2007). Assessment of the Environmental Fate and Effects of Ivermectin in Aquatic Mesocosms. *Aquat. Toxicol*. 2007, 85, 229–240.

Santos Da Silva, N., Oliveira, R., Lisboa, C.A., Mona E Pinto, J., Sousa-Moura, D., Camargo, N.S., Perillo, V., Oliveira, M., Grisolia, C.K., Domingues, I. (2018). Chronic Effects of Carbamazepine on Zebrafish: Behavioral, Reproductive and *Biochemical Endpoints. Ecotoxicol. Environ. Saf*., 164, 297–304.

Sehonova, P., Plhalova, L., Blahova, J., Doubkova, V., Marsalek, P., Prokes, M., Tichy, F., Skladana, M., Fiorino, E., Mikula, P., Vecerek, V., Faggio, C., Svobodovs, Z. (2017). Effects of selected tricyclic antidepressants on early-life stages of common carp (*Cyprinus carpio*). *Chemosphere* 185, 1072–1080.

Shreenidhi, K.S., Priyavadhana, P., Purnima, N., Rashminiza, A., Sneha, S., Vijaya Geetha, B. (2021). Study on the toxic effects of pharmaceutical drugs – Norfloxacin using *Pangasius Sp*. fish model and its mitigation using *Artemisia pallens*. *Acta Ecologica Sinica*, https://doi.org/10.1016/j.chnaes.2021.08.014 (In Press).

Shuraiqi, A.Al., Al-Habsi, A., Barry, M.J. (2021). Time, dose and transgenerational effects of fluoxetine on the behavioural responses of zebrafish to a conspecific alarm substance. *Environmental Pollution* 270, 116164. doi.org/10.1016/j.envpol.2020.116164

Stephensen, E., Sturve, J. and Forlin, L. (2002). Effects of redox cycling compounds on glutathione content and activity of glutathione-related enzymes in rainbow trout liver. *Comparative Biochemistry and Physiology Part C*. 133, 435-442.

Strungaru, S.A., Pohontiu, C.M., Nicoara, M., Teodosiu, C., Baltag, E.S., Jijie, R., Plavan, G., Pacioglu, O., Faggio, C. (2021). Response of aquatic macroinvertebrates communities to multiple anthropogenic stressors in a lowland tributary river. *Environ. Toxicol. Pharmacol*. 87, 103687. doi.org/10.1016/j. etap.2021.103687.

Teixeira, M., Almeida, Â., Calisto, V., Esteves, V.I., Schneider, R.J., Wrona, F.J., Soares, A.M., Figueira, E., Freitas, R. (2017). Toxic effects of the antihistamine cetirizine in mussel *Mytilus galloprovincialis*. *Water Res*. 114, 316–326.

Vijaya Geetha, B., Shreenidhi, K.S., Sundararaman, T.R.A. (2021). Study on the Oxidative Stress Status of *Pangasius sp*. Exposed to Phenol and Clofibrate. *Zeichen Journal*, 7(1):23-32.

Winker, M., Tettenborn, F., Faika, D., Gulyas, H., Otterpohl, R. (2008). Comparison of analytical and theoretical pharmaceutical concentrations in human urine in Germany, Water Res. 42(14):3633–3640, https://doi.org/10.1016/j. watres.2008.06.002.

Zhou, L., Limbu, S.M., Qiao, F., Du, Z.-Y., Zhang, M. (2018). Influence of Long-Term Feeding Antibiotics on the Gut Health of Zebrafish. *Zebrafish*, 15, 340–348.

Zhou, L., Limbu, S.M., Shen, M., Zhai, W., Qiao, F., He, A., Du, Z.-Y., Zhang, M. (2018b). Environmental Concentrations of Antibiotics Impair Zebrafish Gut Health. *Environ. Pollut.*, 235, 245–254.

Zuccato, E., Calamari, D., Natangelo, M., Fanelli, R. (2000). Presence of Therapeutic Drugs in the Environment. *Lancet*, 355, 1789− 1790.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

BIOACCUMULATION AND DISTRIBUTION OF HEAVY METALS, MACRO- AND MICROELEMENTS IN *ODONTARRHENA CHALCIDICA* FROM BULGARIAN SERPENTINE SOILS

Violina ANGELOVA

Agricultural University of Plovdiv, 12 Mendeleev Blvd, 4000, Plovdiv, Bulgaria

Corresponding author email: vileriz@abv.bg

Abstract

Comparative research has been carried out to determine the accumulation of heavy metals, macro, and microelements in the vegetative organs of Odontarrhena chalcidica, collected from serpentine soils from the Eastern and South Rhodopes Mountains (Bulgaria). The content of metals in the plant varies depending on the sampling location and, above all, on the content of their mobile forms in the soil. In Odontarrhena chalcidica plants, the maximum concentrations of Ni were up to 873.1 mg/kg in roots, 924.9 mg/kg in shoots, 8317 mg/kg in leaves, and 6693 mg/kg in flowers. Ca/Mg ratio in plant tissues were up to 6.2 (roots), 7.4 (stems), 10.2 (leaves), and 7.4 (flowers). There is a distinct pattern in the accumulation of heavy metals in the vegetative organs of Odontarrhena chalcidica. Most of the Ni, Ca and Mg accumulate in the leaves and flowers, K and P in the flowers. There is no clear trend for Pb, Zn, Cu Fe, Mn, Cr and Co. This study shows that Odontarrhena chalcidica from serpentine soils of Bulgaria appears as a strong Ni hyperaccumulator and can be used for phytoextraction purposes.

Key words*: serpentine soils, nickel hyperaccumulator, heavy metals, Odontarrhena chalcidica, Bulgaria.*

INTRODUCTION

Serpentine soils are widespread in various parts of the world (Cuba, New Caledonia, Australia, Turkey, Brazil, China, etc.) (Brooks, 1987). In Europe, they are found mainly in the Balkans (Bani et al., 2010). They exist as large blocks or as small outcrops separated by other geological formations in central Bosnia and western and central Serbia, central and south-eastern parts of Albania, the regions of Epirus and Thessaly in Greece.

Small amounts of serpentine rocks are typical in the southwestern, southern, and central parts of Bulgaria, mainly in the Central and East parts of the Rhodope Mountains (Pavlova, 2001a; 2001b). Serpentine soils originate from serpentine rocks, which are usually shallow, and have specific physical and chemical properties, such as low nutrient status, cation imbalance, moisture stress, soil instability, high surface temperature and high metal concentrations. Fe, Mg, Si, Ni, Cr, and Co are present in large amounts, while N, P, Ca, K, and B are generally deficient (Shallari et al., 1998). Mn content may also be higher compared to other soil types. The Mg/Ca ratio is high because soils are rich in Mg and poor in Ca (Proctor, 1999). Plants growing on serpentine soils have elevated Ni and Co contents compared to the same plants on other soil types. Extremely high concentrations of Ni (known as Ni hyperaccumulators) have been found in the aerial parts of some plants growing on serpentine soils. The species Alyssum (family Brassicaceae) is endemic to serpentine soils in the Mediterranean and can uptake Ni >1000 mg/kg in its tissues without showing symptoms of toxicity (Van der Ent et al., 2013). Significant variability in the Ni content of plants has been found (Reeves and Adgüzel 2008), with the highest values found in A. murale (7-34690 mg/kg) and A. heldreichii (1440-32040 mg/kg) (Bani et al., 2010). The Ni-enriched biomass can be considered raw material for Ni production, and the whole process is called phytomining (Sheoran et al., 2009; Van der Ent et al., 2015). With phytomining technologies, Ni-contaminated soils can be cleaned, and high purity Ni metal can be recovered (Chaney et al., 1999; Li et al., 2003a; Li et al., 2003b; Nkrumah et al., 2016).

The present work aims to conduct a comparative study that will allow us to determine the uptake of heavy metals, macro, and microelements in the vegetative organs of

Odontarrhena chalcidica collected from serpentine soils and establish the potential for Ni phytoextraction.

MATERIALS AND METHODS

Plant and soil samples were collected for analysis in May and June of 2020 and 2021 from 9 locations in Eastern and South Rhodopes Mountains (Bulgaria). Table 1 shows the coordinates and sampling sites.

Five plants were collected from each site. Simultaneously, three soil samples were collected at 0-20 cm depth from each site.

The soils were air-dried and ground. *Odontarrhena chalcidica* plants were washed with water, separated into their parts (roots, stems, leaves and flowers), and dried at 45oC. The contents of heavy metals and micro and macroelements in the plant material (roots, stems, leaves and flowers) were determined by microwave mineralization. The total content of heavy metals in soils was determined in accordance with ISO 11466. The mobilizable heavy metals contents in soils, considered a "potentially bioavailable metal fraction", were extracted by a solution of DTPA (ISO 14870). The quantitative measurements were carried out with inductively coupled plasma emission spectrometry (ICP) (Jobin Yvon Emission - JY 38 S, France).

Table 1. Sampling sites

Sampling sites	Site code	Geographical coordinates	
		Latitude (N)	Longitude (E)
Eastern Rhodopes Mt			
Avren	Av	41°20'616"	25°41'8.1"
Goljamo Kamenjane	GK	41°24'1.4"	25°42'58.1"
Chernichevo	Ch	41°20'42.5"	25°45'45.8"
Kazak	K	41°24' 42.7"	25°53'2.0"
Kardzali	Kd	41°33'15.0"	25°33'24.5"
Dobromirzi	D	41°23'2.3"	25°12'28.6"
Djuliza	Dju	42°22'35.8"	25°19'23.3"
Central Rhodopes Mt			
Parvenetz	Pz	42°3'55.9"	24°39'28.3"
Gornoslav	G	41°54'38.5"	24°57'20.1"

RESULTS AND DISCUSSIONS

Soil characteristics

The contents of heavy metals and macro and microelements in the studied serpentine soils are presented in Table 2. The soils had a neutral to slightly alkaline reaction (pH 6.4 to 7.6) and a medium to high organic matter content.

Serpentine soils from all locations are characterized by elevated metals Ni, Cr, Co, and Mn levels, which is typical of such soils (Table 2). The total Ni content in the study areas ranged from 1269.9 to 2281 mg/kg, while DTPA extracted Ni ranged from 6.1 mg/kg to 99.4 mg/kg. All concentrations were much higher than those considered toxic to normal plants by Allen et al. (1974) and Kabata-Pendias (2011). In serpentine soils, Ni and Cr concentrations are known to reach several g/kg typically and reach more than 10 g/kg (Proctor, 1999; Nkrumah et al., 2016). The obtained values are similar to Bani et al. (2010) results for serpentine soils from Bulgaria, Greece and Albania, with values exceeding 3.0 g/kg Ni in some soils from Albania.

The Cr content of the soils ranged from 327.9 to 1876.8 mg/kg. All exceed the upper limit given for normal soils by Allen et al. (1974) and Brooks (1987) (500 mg/kg) except for the soils from Dobromirzi. The values we obtained are similar to those found by Karataglis et al. (1982) for northern Greece and Bani et al. (2010) for Albania.

Cobalt in soils ranged from 200.4 to 314.4 mg/kg and was within the normal range for serpentines. Cobalt's relatively easy interaction with all metals geochemically or biochemically associated with Fe significantly influences its behaviour in soils and its phytoavailability (Kabata Pendias, 2011).

The Fe content in serpentine soils is high and ranges from 40704 to 72964 mg/kg, typical for the Balkan Peninsula's serpentine soils (Salihaj and Bani, 2018, Pavlova 2001b).

Mn content ranges from 787 to 2019 mg/kg and is characteristic of serpentine soils from Albania, Greece and Bulgaria (Bani et al., 2010).

The Fe content of the studied soils shows typical values for serpentine soils and ranges from 4.1% to 7.3%, which is in agreement with published data by other authors (2.43-6.28%, Bani et al., 2010). The high pH of soils (6.4-7.6) causes poorly soluble oxides of Fe, Mn, and Cr, resulting in these metals being unavailable to plants (Babalonas et al., 1984).

The Cu content ranged from 4 to 120.6 mg/kg, while Zn ranged from 42.6 to 392 mg/kg.

These values fall within limits for normal soils (Allen et al., 1974; Kabata-Pendias, 2011).

Serpentine soils are rich in Mg but low in Ca. The Mg content ranges from 3.9 to 23.7% and Ca from 0.14 to 0.52%. All soils are characterized by an extremely low Ca/Mg ratio (0.02-0.04), which can lead to Ca deficiency stress for plants.

The P content ranged from 76.2 to 442 mg/kg, while the K content ranged from 142 to 1849 mg/kg. Most of the soil samples are characterized by low nutrient (P and K) levels, a common characteristic of serpentine soils (Brooks, 1987).

The low available phosphorus in serpentine soils is related to the high affinity of soluble phosphates for serpentines (Brooks, 1987). The content of available macronutrients such as Ca and K is also very low and ranges from 94 to 1317.2 mg/kg for Ca and 13 to 50.2 mg/kg for K, which is also characteristic of serpentine soils.

The chemical composition of serpentine soils from the Eastern and Central Rhodopes is similar to serpentine soils from the Balkan Peninsula (Brooks, 1987; Bani et al., 2010), with high metals such as Ni and Cr relatively low Ca/Mg ratios. The Ca and Mg levels found in these Bulgarian serpentine soils are typical of such soils from other areas (Brooks, 1987). The total Ni content of the soils is similar to that of Italian (Vergnan Gambi et al., 1982), Greek (Babalonas et al., 1984) and Albanian (Shallari et al., 1998; Bani et al., 2010) serpentine zones.

Chemical composition of plant material

The contents of heavy metals, and macro and nicroelements in different parts of *Odontarrhena chalcidica* are presented in Tables 3, 4, 5 and 6.

In all *Odontarrhena chalcidica* plants tested from serpentine soils, the highest Ni values were recorded in the leaves, up to ten times higher than in the stems. The Ni content ranged from 108.8 to 924.9 mg/kg in stems, 1444 to 8285 mg/kg in leaves, and 870 to 6084 mg/kg in flowers.

Leaves and flowers are the main Ni storage organs. From the roots and the conducting system, Ni moves and accumulates in the leaves and flowers. The results confirm the findings of Broadhurst et al. (2004a; 2004b, 2009) that leaves contain the most Ni of all Ni hyperaccumulator organs, and Ni is highly concentrated in vacuoles of epidermal cells and epidermal villi (trichomes). The values found for Ni are significantly lower than the data published by Bani et al. (2014), who found more than 20,000 mg/kg Ni in plant leaves from serpentine soils in Albania and Greece. According to Bani et al. (2010), the highest Ni concentrations in leaves collected from serpentine soils in Bulgaria (Rhodope Massif) range from 5,000 mg/kg (Kardzali) to 15,100 mg/kg (Kazak), while in Serbia the Ni content in leaves ranges from 700 to 13,000 mg/kg (Tumi et al., 2012). No correlation between soil pH and Ni uptake in *Odontarrhena chalcidica* has been found from serpentines in the Balkans (Bani et al., 2010). According to the authors, the Ni content of this species strongly depends on the site of sample collection (Bani et al. 2010, 2013, 2015a, 2015b). No relationship between Ni levels in plant leaves and those in soil was found. This is probably due to the wide variability of the sites from which the plants were collected, and differences in their physical and chemical properties, climate and altitude.

Despite the high Cr content of the soil, the amounts of Cr taken up by *Odontarrhena chalcidica* reach up to 0.5 mg/kg in the stems, 11.5 mg/kg in the leaves and 6.0 mg/kg in the flowers. According to Brooks (1987), plants from serpentine soils typically contain <15 mg/kg Cr.

It is known that the Co content rarely reaches 10 mg kg in plants from both normal soils and serpentine soils. The values we obtained confirm that this level is not exceeded, except in plants from Kardjali (11.4 mg/kg). In their study, Bani et al. (2010) found unusually high Co values in Ni hyperaccumulators (15-100 mg/kg).

Ca content ranged from 11652 to 34822 mg/kg in leaves and 10744 to 36199 mg/kg in flowers. It is noteworthy that the Ca uptake by *Odontarrhena chalcidica* is significant, although the Ca content of serpentine soils is low. According to Proctor (1971), Ca is one of the elements influencing lowering the toxicity of heavy metals. Probably *Odontarrhena chalcidica* growing on serpentine soils absorb more Ca to compensate for the toxic action of

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

various toxic metals. Karataglis et al. (1982) suggested that the plants have a mechanism to assimilate significant amounts of Ca. Bani et al. (2010) found that Ca and Ni can be antagonists. The higher Ca and the lower Ni concentrations can explain the content in the leaves of *Odontarrhena chalcidica*. In all *Odontarrhena chalcidica* plants tested, the Ni: Ca ratio was lower than unity (0.07-0.4), while the Ni: Mg ratio was higher than unity (2.4-19.0). Broadhurst and Chaney (2016) reported the exceptional Ca uptake in the leaves of hyperaccumulator species (and the genus Alyssum). This is probably an adaptive ability of this genus (Odontarrhenae) to Ca deficiency in serpentine soils. The reason for the high leaf Ca content is the density of trichomes and the nodules of $CaCO_3$ covering the trichome surface (Broadhurst and Chaney, 2016)

The Ca content in the leaves of species of the genus Alyssum is very high, despite the low Ca values in the soil. This property of species of the genus Alyssum from serpentine soils has also been noted by other authors (Reeves & Adigüzel, 2008). High Ca concentrations have been recorded for A. murale from the Thessaloniki region (3.98%), and up to 4.3% in Albania. No correlation was found between Ca and Ni values in leaves of *Odontarrhena chalcidica*. Still, there was a significant negative correlation between Ni in leaves of *Odontarrhena chalcidica*, and the total Ca content of the soil. Extremely high Ca uptake is essential for Ni-hyperaccumulator physiology (Broadhurst et al., 2004; Chaney et al., 2008). Walker et al. (1955) suggested that serpentine plants survive because they uptake greater Ca than Mg.

However, the hydrometallurgical method must consider the significant amounts of Ca in the leaves and flowers when phytoextracting Ni from the plant.

Although the Mg content of soils is high, Mg is accumulated to a significantly lesser extent by *Odontarrhena chalcidica* compared to Ni and Ca. The highest Mg content was in leaves and flowers, where it ranged from 1147 to 8317 mg/kg (leaves) and from 1452 to 6693 mg/kg (flowers). The Mg content is significantly lower in stems and roots. According to Bani et al. (2010), the average Mg content for Alyssum species is 0.43-0.83%.

Brooks and Yang (1984) found a negative correlation between Mg content and the content of other nutrients such as Fe, Co, and Mn. The results suggest that Mg uptake leads to less uptake of other nutrients. Brooks and Young (1984) suggested that elevated Mg levels in serpentine soils and antagonism with other elements may be the most critical factor in plant survival in serpentine soils.

There are conflicting opinions on the relationship between Ni and Mg uptake in Alyssum species (Kazakou et al., 2008). According to Robinson et al. (1999), it is possible that Mg also limits Ni accumulation by the plant and that there is a negative correlation between Ni and Fe. It was found that an antagonistic relationship may exist between Ni and Mg, similar to the relationship between Mg and Fe.

The Ca/Mg ratio in all plant samples was > 1. *Odontarrhena chalcidica* from serpentine soils can maintain a ratio greater than one despite minimal Ca levels in the soils. It is suggested that plants have very efficient uptake systems or the ability to exclude Mg despite high soil contents.

P and K contents are highest in flowers and range from1273 to 4361 mg/kg for P and from 2928 to 11460 mg/kg for K. K is a crucial plant nutrient whose most important role in the maintenance of plant water balance (osmore-gulation). Although K in serpentine soils is low, K accumulates in leaves and flowers.

No trends in Fe accumulation were found in the plants tested. In plants from the Kazak, Dulitsa and Parvenetz areas, Fe accumulated in the leaves, whereas in plants from Avren, Chernichevo, Kardzali, Gornoslav and Golyamo Kamenyane, it accumulated in the roots. Fe is also essential for many plant functions as it is a constituent of some enzymes and proteins and plays a role in energy transfer in the plant. Similar values for the Fe content in the aboveground mass of *O. Chalcidica* have also been found by other authors (Bani et al., 2014; Broadhurst and Chaney, 2016; Xhaferri et al., 2018). According to Bani et al. (2010), the Fe content is usually below 1000 mg/kg, confirmed by results from this study. Higher values indicate contamination of foliar samples by serpentine soil or dust, which is difficult to remove by washing samples before analysis.

No trends in Mn accumulation were detected either. Most of the Mn accumulated in the leaves in plants from Avren, Chernichevo, Kazak, Kardzali and Parvenetz, in the roots (Golyamo Kamenene and Dulitsa), and plants from Dobromirtsi, no significant difference in concentration was found between roots, stems, leaves and flowers. According to Broadhurst et al. (2004b, 2009), Alyssum accumulates a significant Mn in the same vacuole cavities. That contains Ni. Ni hyperaccumulators accumulate less Mn and Co than other transition metals such as Fe, Cr, or Cu (Broadhurst and Cheeney, 2016). According to Broadhurst et al. (2009) and Ghaderian et al. (2015), there is a specific relationship between Mn accumulation and Ni hyperaccumulation rather than Mn uptake and storage associated with enhanced Ca uptake in trichomes (McNear and Kupper, 2013).

Similar results were obtained for Cu, Zn, Pb and Co.

Zn uptake is similar to that observed in normal soils. This is not surprising as Zn concentrations in serpentine soils are not unusual.

The bioaccumulation coefficients (ratio of metal concentrations in the aboveground mass and soil) and the translocation factor (ratio of metal concentrations in the aboveground mass and roots) were used to estimate plant uptake of Ni. In hyperaccumulators, the values of both factors are usually above 1 (Baker and Whiting, 2002).

The translocation factor (TF) provides information on the ability of plants to uptake heavy metals through the roots and move them to the aboveground mass (leaves). Hyperaccumulators usually contain fewer heavy metals in the roots than the aboveground mass. (Baker et al., 1994). TF in hyperaccumulators can reach values > 1, indicating that the heavy metal content in the aboveground mass is higher than that in the below-ground parts (roots). The obtained values ranged from 5.7 to 40 (Figure1).

The bioconcentration factor also determines the efficiency of phytoextraction. It measures the plant's ability to absorb and move metals to the aboveground mass that can be readily harvested. In hyperaccumulators, the bioconcentration factor is higher than one and, in some cases, can reach 50-100. The results indicate that Ni in the aboveground mass of *O. chalcidica* is 1 to 10 times higher than in soil. Values were lower in Gornoslav, Parvenetz and Dulitsa (slightly above 1), intermediate in Kazak, Golyamo Kamenyane and Dobromirtsi (2.8-5.3), and highest in Avren, Kardzali and Chernichevo (above 9). The tested plant *Odontarrhena chalcidica* is a hyperaccumulator and can be used for Ni phytoextraction.

There is a distinct pattern in the accumulation of heavy metals and micro and macro elements in the vegetative organs of *Odontarrhena chalcidica*. Most of the Ni, Ca and Mg accumulate in the leaves and flowers, K and P in the flowers. There is no clear trend for Pb, Zn, Cu Fe, Mn, Cr and Co.

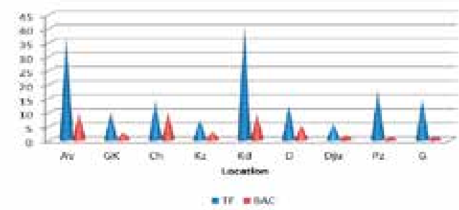


Figure 1. Translocation |TF|
and bioconcentration (BAC) factors

Table 2. Content of heavy metals, micro and macroelements (mg/kg) in serpentine soils

	Pb	Zn	Cu	Fe	Mn	P	Cr	**Ni**	Ca	Mg	K	Co
Av	2.8	45.1	5.3	59175.3	1075	149.2	1335	1439	1372	38676	895.6	200.4
GK	6.7	43.5	37.0	67230.3	1295	179.5	1630	2123	2821	40729	968.9	233.7
Ch	11.1	48.3	120.6	72963.5	1702	442	672.9	1270	4529	66630	1357	228.3
Kz	19.9	67.5	8.0	67442.8	2019	266.3	1877	1481	2768	63513	999.5	314.4
Kd	71.1	130.8	10.9	64373.5	1419	209.5	1456	1709	5171	139254	1849	222.2
D	439.2	392	55.8	56187.4	1187	215.5	327.9	1276	3363	52935	1117	239.3
Dju	81.7	73.6	4.0	63847.2	1239	209	1610	1678	1775	85769	931.2	250.0
Pz	17.7	48.4	16.8	40704.2	787	76.2	562	2281	2159	236569	142.6	226.6
G	9.7	42.6	22.2	49919.1	1473	88.2	1069	2228	1419	216708	550.5	308.4

Table 3. Content of heavy metals, micro and macroelements (mg/kg) in roots of *Odontarrhena chalcidica*

	Pb	Zn	Cu	Fe	Mn	P	Cr	**Ni**	Ca	Mg	K	Co
Av	0.83	21.9	2.3	1413	112.4	341.1	9.2	352.8	1464	3732	879.8	12.6
GK	2.7	48.5	4.8	4684	92.5	566.8	37.8	589.2	3893	4657	967.4	22.2
Ch	1.1	65.4	3.4	1443	42.97	1077	13.2	873.7	4109	1821	7750	7.5
Kz	0.14	116	2.3	239.1	12.1	1608	3.7	603.2	2879	654	7600	1.8
Kd	0.2	80.3	2.2	232.5	26.7	840.3	1.5	327.1	1516	421.7	2381	1.5
D	2.8	56.5	11.2	2817	54.9	660.2	22.9	556.2	4003	1856	1411	3.6
Dju	92.6	169.7	4.2	599.2	27.8	1476	2.5	512.8	3479	1683	6182	32.9
Pz	0.63	56.3	0.89	39.5	6.7	112.4	0.09	133.1	1989	235	884.5	0.54
G	50.9	168.7	7.1	1174	36.3	349.6	6.1	216.2	3792	2132	914.6	4.9

Table 4. Content of heavy metals, micro and macroelements (mg/kg) in stems of *Odontarrhena chalcidica*

	Pb	Zn	Cu	Fe	Mn	P	Cr	Ni	Ca	Mg	K	Co
Av	0.03	10.3	0.91	20,3	8,1	326	0.01	328.6	2958	399.8	3254	0.44
GK	0.49	20.2	1.7	102.7	11.4	321.5	0.34	387.7	5237	433.2	1396	1.4
Ch	0.64	25	2.5	41.8	10.3	630.2	0.01	924.9	7272	1571	6871	0.85
Kz	0.52	11.2	1.1	22.9	6.8	776.7	0.03	304.8	3036	451.9	5493	0.30
Kd	0.04	26.4	1.8	115.3	18.8	2070	0.54	441.6	2152	906.9	10320	0.79
D	0.24	24.6	2.1	69.7	10.2	730.6	0.23	336.5	3832	702.0	5347	1.49
Dju	7.1	52.2	1.7	32	3.3	433.6	0.01	152.7	2244	290.4	5032	0.29
Pz	1.3	11.3	0.84	44.2	9.6	278.2	0.1	108.8	3629	627.2	2370	0.54
G	2.1	51.7	1.6	82.9	5.1	583.1	0.53	159.4	3567	526.0	5693	0.62

Table 5. Content of heavy metals, micro and macroelements (mg/kg) in leaves of *Odontarrhena chalcidica*

	Pb	Zn	Cu	Fe	Mn	P	Cr	**Ni**	Ca	Mg	K	Co
Av	3.2	37.3	4.2	1079	137.5	1102	3.6	6952	21868	5866	8604	29.9
GK	0.61	19.3	2.5	567.9	46.3	1021	3.1	2922	25519	1549	4634	12.4
Ch	4.2	34.9	4.7	341.6	67.7	904	2.8	5184	34822	3372	9727	15.1
Kz	0.33	10.1	0.86	78.8	21.4	536	0.73	2421	11652	1147	3679	6.4
Kd	1.5	35.7	4.4	1405	221.5	2181	11.5	8285	20241	8317	11460	41.4
D	2.4	24.6	3.9	382.5	47.2	1474	3.2	3526	21143	2332	9323	18.7
Dju	4.8	87.8	1.7	869.3	14.5	462	0.52	1444	12876	1712	2928	5.9
Pz	2.0	28.7	2.3	316.2	73.6	1455	1.7	1553	22047	4981	10641	42.4
G	3.6	29.8	1.4	178.6	26.4	552	0.76	1779	27100	1427	3182	6.5

Table 6. Content of heavy metals, micro and macroelements (mg/kg) in flowers of *Odontarrhena chalcidica*

	Pb	Zn	Cu	Fe	Mn	P	Cr	Ni	Ca	Mg	K	Co
Av	0.82	29.9	3.8	196.4	95.0	4361	0.29	5808	19960	4502	19777	8.7
GK	0.28	22.1	2.5	110.2	34.8	1832	0.94	2475	22782	1612	9057	4.8
Ch	0.67	36.4	7.1	138.4	85.1	3548	0.01	6068	36199	4187	14957	8.2
Kz	0.49	27.7	2.0	99.1	33.5	1947	0.02	1744	19748	1452	9166	2.1
Kd	1.33	31.1	7.1	868.4	165.3	4266	6.0	4558	14596	6693	18060	11.4
D	0.68	25.9	4.7	249.6	44.6	3968	2.1	2945	19959	3664	14776	9.6
Dju	0.92	48.5	1.8	160.3	13.1	1644	0.05	1322	13110	2180	8731	2.1
Pz	0.5	18.95	1.6	67.5	29.0	1778	0.01	870.1	10744	3484	9877	5.6
G	1.8	36.1	2.1	89.8	29.6	1273	0.04	1210	20273	1548	9402	2.2

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

CONCLUSIONS

Based on the results obtained, the following conclusions can be drawn:

1. The chemical composition of serpentine soils from the Eastern and Southern Rhodopes is similar to serpentine soils from the Balkan Peninsula, and is characterized by high contents of Ni (1270-2281 mg/kg), Cr (32.7-1877 mg/kg), and Mg (38676-236569 mg/kg).
2. The content of metals in *Odontarrhena chalcidica* varies depending on the sampling location and, above all, on the content of their mobile forms in the soil.
3. There is a distinct pattern in the accumulation of heavy metals and micro and macro elements in the vegetative organs of *Odontarrhena chalcidica*. Most of the Ni, Ca and Mg accumulate in the leaves and flowers, K and P in the flowers. There is no clear trend for Pb, Zn, Cu, Fe, Mn, Cr and Co.
4. The tested hyperaccumulator plant *Odontarrhena chalcidica* can be used for Ni phytomining.

ACKNOWLEDGEMENTS

This research work was carried out with the support of Bulgarian National Science Fund and also was financed from Project KP-6-Austria/7.

REFERENCES

Alan, J., Baker, M., & Whiting, St.N. (2002). In search of the Holy Grail – a further step in understanding metal hyperaccumulation? *New Phytologist*, 155, 1–7

Allen, S.E., Grimshaw, H.M., Parkinson, J.A., & Quarmby, C. (1974). Chemical Analysis of Ecological Materials. Blackwell Scientifi c Publications, Oxford, UK.

Babalonas, D., Karataglis, S., & Kabassakalis, V. (1984). The ecology of plant populations growing on serpentine soils. III. Some plant species from North Greece in relation to the serpentine problem. *Phyton* (Austria), 24, 225-238.

Baker, A.J.M., & Brooks, R.R. (1989). Terrestrial higher plants which hyperaccumulate chemical elements – a review of their distribution, ecology and phytochemistry. *Biorecovery,* 1, 81–126.

Baker, A.J.M., & Whiting, S.N. (2002). In search of the Holy Grail—a further step in understanding metal hyperaccumulation? *New Phytol*. 155, 1–7.

Bani, A., Echevarria, G., Sulce, S., & Morel, J.L. (2015a). Improving the agronomy of Alyssum murale for extensive phytomining: a five-year field study. *Int J Phytoremediation*, 17, 117–127

Bani, A., Echevarria, G., Zhang, X., Benizri, E., Laubie, B., & Morel, J.L. (2015b). The effect of plant density in nickel—phytomining field experiments with Alyssum murale in Albania. *Aust J Bot*, 63,72–77.

Bani, A., Imeri, A., Echevarria, G., Pavlova, D., Reeves, R.D., Morel, J.L., & Sulce, S. (2013). Nickel hyperaccumulation in the serpentine flora of Albania. *Fresenius Environ Bull*. 22, 1792–1801.

Bani, A., Echevarria, G., Montarges-Pelletier, E., Gjoka, F., Sulce, S., & Morel J.L. (2014). Pedogenesis and nickel biogeochemistry in a typical Albanian ultramafic toposequence. *Environ. Monit. Assess*, 186, 4431-4442.

Bani, A., Pavlova, D., Echevarria, G., Mullaj, A., Reeves, R. D., Jean Louis Morel, J.L., & Sulce, S. (2010). Nickel hyperaccumulation by the species of Alyssum and Thlaspi (Brassicaceae) from the ultramafic soils of the Balkans, *Botanica Serbia*, 34(1), 3-14.

Broadhurst, C.L., & Chaney, R.L. (2016). Growth and Metal Accumulation of an Alyssum murale Nickel Hyperaccumulator Ecotype Co-cropped with Alyssum montanum and Perennial Ryegrass in Serpentine Soil. *Front. Plant Sci*., 7, 451.

Broadhurst, C.L., Chaney, R.L., Angle, J.S., Maugel, T.K., Erbe, E.F., & Murphy, C.A. (2004). Simultaneous hyperaccumulation of nickel, manganese and calcium in Alyssum leaf trichomes. *Environ. Sci. Technol*., 38, 5797–5802.

Broadhurst, C.L., Chaney, R. L., Angle, J.A., Erbe, E. F., & Maugel, T.K. (2004a). Nickel localization and response to increasing Ni soil levels in leaves of the Ni hyperaccumulator Alyssum murale. *Plant Soil,* 265, 225–242.

Broadhurst, C.L., Chaney, R.L., Angle, J.A., Maugel, T.K., Erbe, E.F., & Murphy, C.A. (2004b). Simultaneous hyperaccumulation of nickel, manganese and calcium in Alyssum leaf trichomes. *Environ. Sci. Technol*., 38, 5797–5802.

Broadhurst, C.L., Tappero, R.V., Maugel, T.K., Erbe, E.F., Sparks, D.L., & Chaney, R.L. (2009). Interaction of nickel and manganese in accumulation and localization in leaves of the Ni hyperaccumulators Alyssum murale and Alyssum corsicum. *Plant Soil,* 314, 35–48.

Brooks, R.R. (1987). Serpentine and its Vegetation. A Multidisciplinary Approach. 1, 407, Dioscorides Press, Portland, Oregon, USA.

Brooks, R.R., & Yang, X.H. (1984). Elemental levels and relationships in the endemic serpentine flora of the Great Dyke, Zimbabwe and their significance as controlling factors for this flora. *Taxon,* 33, 392– 399.

Chaney, R.L., Angle, J.S., Baker, A.J.M., & Li, Y.M. (1999). Method for Phytomining of Nickel, Cobalt and Other Metals from Soil. US Patent No. 5,944,872 issued Aug. 31, 1999. (Continuation-in-Part of US Patent 5,711,784 issued Jan. 27, 1998).

Chaney, R.L., Chen, K.Y., Li, Y.M., Angle, J.S., & Baker, A.J.M. (2008). Effects of calcium on nickel tolerance and accumulation in Alyssum species and cabbage grown in nutrient solution. *Plant and Soil*, 311,131–140.

Ghaderian, S.M., Ghasemi, R., & Hajihashemi, F. (2015). Interaction of nickel and manganese in uptake, translocation and accumulation by the nickelhyperaccumulator plant, Alyssum bracteatum (Brassicaceae). *Aust. J. Bot*., 63, 47–55.

ISO 11466. (1955). Soil quality - Extraction of trace elements soluble in aqua regia

ISO 14870. (2001). Soil quality -- Extraction of trace elements by buffered DTPA solution

Kabata-Pendias, A. (2011). Trace elements in soils and plants. 4th ed. – CRC Press.Taylor & Francis Group, Boca Raton. London, New York. 2011, 369–385.

Karataglis S, Babalonas D & Kabasakalis B. (1982). The ecology of plant populations growing on serpentine soils. II Ca/Mg Ratio and the Cr, Fe, Ni, Co concentrations as development factors of Buxus sempervirens L. *Phyton* (Austria) 22, 317-327.

Kazakou, E., Dimitrakopoulos. P.G., Baker, A.J.M., Reeves, R.D., & Troumbis, A.Y. (2008). Hypotheses, mechanisms and trade-off s of tolerance and adaptation to serpentine soils: from species to ecosystem level. *Biol. Rev*, 83, 495-508.

Li, Y.M., Chaney, R.L., Brewer, E., Angle, J.S., & Nelkin, J. (2003a). Phytoextraction of nickel and cobalt by hyperaccumulator Alyssum species grown on nickel-contaminated soils. *Environ. Sci. Technol*., 37, 1463–1468.

Li, Y.M., Chaney, R., Brewer, E., Rosenberg, R., Angle, J. S., Baker, A., & Reeves, R. (2003b). Development of a technology for commercial phytoextraction of nickel: economic and technical considerations. *Plant Soil*, 249, 107–115.

McNear, D.H., & Kupper, J.V. (2013). Mechanisms of trichome-specific Mn accumulation and toxicity in the Ni hyperaccumulator Alyssum murale. *Planta,* 227, 1363–1375.

Nkrumah, P.N., Baker, A.J.M., Chaney, R L., Erskine, P. D., Guillame, E., & Morel, J.L. (2016). Current status and challenges in developing nickel phytomining: an agronomic perspective. Environ. Pollut., 406, 55–69.

Pavlova, D. (2001a). Mountain vegetation on serpentine areas in the Bulgarian Eastern and Central Rhodopes Mts. – ecology and conservation. In: Radoglou K (ed.), Proceedings of International Conference: Forest Research: a challenge for an integrated European approach, August 2001, Thessaloniki, 1, 227-232.

Pavlova, D. (2001b). Concentration of heavy metals in plants growing on serpentine soils in the Rhodopes Mts. (Bulgaria). In: Ozhatay N (ed.). Plants of the Balkan Peninsula: into the next Millennium. Proceedings of the Second Balkan Botanical Congress. 1, 425–428.

Proctor, J. (1999). Toxins, nutrient shortages and droughts: the serpentine challenge. *Trends Ecol. Evol*., 14, 334-335.

Proctor, J. (1971). The plant ecology of serpentine. III. The influence of a high magnesium/calcium ratio and high nickel and chromium levels in some British and Swedish serpentine soils. *Journal of Ecology,* 59, 827–842.

Reeves, R.D. & Adıgüzel, N. (2008). The nickel hyperaccumulating plants of the serpentines of Turkey and adjacent areas: a review with new data. *Turk. J Biol*., 32, 143–153.

Robinson, B.H., Brooks, R.R., & Clothier, B.E. (1999). Soil amendments affecting nickel and cobalt uptake by Berkheya coddii: Potential use for phytomining and phytoremediation, *Ann. Bot,* 84, 689 – 694.

Salihaj, M., & Bani, A. (2018). Chemical Properties of Serpentine Soils from Kosovo. *Albanian J. Agric. Sci*., 17 (1), 78-83.

Shallari, S, Schwartz, C, Hasko, A. & Morel, J.L (1998). Heavy metal in soils and plants of serpentine and industrial sites of Albania. *Sci. Tot. Environ*., 209, 133–142.

Sheoran, V., Sheoran, A.S., & Poonia, P. (2009). Phytomining: a review. *Miner Eng*,, 22,1007–1019.

Tumi, A., Mihailovic, N., Gajic, B., Niketic, M., & Tomovic, G. (2012). Comparative study of hyperaccumulation of nickel by Alyssum murale s.l. populations from the ultramafics of Serbia. *Pol. J. Environ Stud*, 21,1855–1866.

van der Ent, A., Baker, A.J.M., Reeves, R.D., & Chaney, R.L. (2015). Agromining: farming for metals in the future? *Environ Sci Technol*, 49, 4773–4780.

Van der Ent, A., Baker, A.J.M., Reeves, R.D., Pollard, A.J., & Schat, H. (2013). Hyperaccumulators of metal and metalloid trace elements: facts and fiction. *Plant Soil*, 362, 319–334.

Vergnano Gambi, O. (1992). The distribution and ecology of the vegetation of ultramafic soils in Italy. In: Roberts, B.A., Proctor, J. (Eds.), The Ecology of Areas with Serpentinized Rocks: A World View. Kluwer, Dordrecht, 271–313

Walker H.M., & Ashworth P.R. (1955). Calcium-Magnesium nutrition with special reference to serpentine soils. *Plant Physiol*., 30, 214—221.

Xhaferri, B., Miho, L., Bani, A., Shallari, S., Echevarria, G., Gjeta, E., Pavlova, D., & Shahu, E. (2018). Which populations of Alyssum murale from southeastern Albania are more efficient in biomass production. European Academic Research, VI (8), 4087-4100.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

HEAVY METAL ACCUMULATION AND CHEMICAL COMPOSITION OF ESSENTIAL OIL OF *JUNIPERUS OXYCEDRUS* L. (CUPRESSACEAE) GROWN ON SERPENTINE SOILS IN BULGARIA

Violina ANGELOVA

Agricultural University Plovdiv, 4000, Plovdiv, Bulgaria

Corresponding author email: vileriz@abv.bg

Abstract

This study investigated the heavy metal concentrations and chemical compositions of the essential oils of Juniperus oxycedrus L. (Cupressaceae), growing on serpentine soils in the Eastern Rhodopes Mountains, Bulgaria. Elevated Ni content in soils does not affect the development of Juniperus oxycedrus L. and the quality and quantity of oil obtained from it. Sixty components representing 98.10-98.92% of the total oil were identified. The major compounds were determined limonene (12.10-13-84%), γ-himachalene (7.47-12.58%), manoyl oxide (6.60-12.80%), α-pinene (6.41-8.78%), dibutyl phthalate (1.48-8.14%), δ-cadinene (2.93-6.33%), γ-cadinene (3.64-5.00%), β-bisabolene (2.98-4.29%) in needles oil. The Juniperus oxycedrus L. can be considered as "excluder plant," containing relatively low metal concentrations in the needles even in cases of high elemental concentrations in the soils. Metal concentrations for toxic elements in plants and oils were below the permissible limits for pharmaceutical purposes. Therefore, Juniperus oxycedrus L. found on serpentine soils is recommended to be collected for pharmaceutical purposes.

Key words*: serpentine soils, essential oil composition, heavy metals, Juniperus oxycedrus L.*

INTRODUCTION

Juniperus oxycedrus (red juniper, prickly juniper), a member of the cypress family (Cupressaceae), is an evergreen, shrubby plant or small tree forming red galbules (Franco, 2002). The species belongs to the genus Juniperus and is widely distributed in the Mediterranean region (Adams, 2008; Farjon, 2013, Semerdjieva et al., 2019). The distribution of the species on rocky, stony slopes in poor skeletal soils is of practical importance as it prevents erosion and regulates soil water content (Franco, 2002; Gussev, 2015).

All plant parts, including the galbules, contain aromatic essential oil (Semerdjieva et al., 2019). *Juniperus oxycedrus* essential oil is produced by steam distillation of young twigs and stem bark. The oil is resinous with a very dark brown colour, and has a characteristic tarry odour. *J. oxycedrus* oil is used in the food industry and has antimicrobial and antifungal biological properties (Cavaleiro et al., 2006).

The content and composition of juniper oil are influenced by (1) origin (location), (2) sex, (3) stage of phenological development, (4) plant part, and (5) method and duration of oil extraction (Cantrell et al., 2013; Zhelyazkov et al., 2013).

Figueiredo et al. (2006) reported that environmental conditions, geographical variations and genetic factors could affect the oil content of plants. Furthermore, some heavy metals are reported to affect the yield of essential oils from aromatic medicinal plants (Zhelyazkov et al., 2008). Yeritsyan & Economakis (2002) found that high Fe concentration in juniper reduced essential oil yield. The main components in the oil are α-pinene, α-felandrene, sabinene, myrcene and others (Adams et al., 2005; Medini et al., 2009; Derwich & Chabir, 2011). The composition of oil varies widely, which affects biological activity.

The present work aims to conduct a comparative study that will allow us to determine the amounts of heavy metals, macro and trace elements in serpentine soils, the needles of *Juniperus oxycedrus* and the quality of oil from juniper growing on serpentine soils.

MATERIALS AND METHODS

The plant material used in this study was randomly selected plants and needles from *J. oxycedrus* growing on serpentine soils in the

Eastern Rhodopes. The serpentine soils are collected near the village of Kazak, the village of Golyamo Kamenyane, and the village of Avren,

All samples were collected in late June and early July and air-dried. Oils were extracted from each needle sample with a Clevenger apparatus by steam distillation for 2 hours. At the end of each distillation, the oil was separated from the water, collected in glass vials, and stored until gas chromatographic analyses were performed. The oils were analyzed for heavy metals, and their chemical composition determined. Determination of the chemical constituents of the oil was performed on a 7890A gas chromatograph (Agilent Technologies) and a 5975C mass spectral detector (Agilent Technologies). Compounds were identified by comparing retention times and Kovacs relative indices (RI) with those of standard substances and mass spectral data from the NIST'08 library (National Institute of Standards and Technology, USA).

Soil samples were prepared for analysis by treatment with aqua regia (ISO 11466). The plant and oil samples were treated by the method of microwave mineralization. To determine the content of heavy metal, macro and microelement of in the plant and soil samples, an inductively coupled emission spectrometer (Jobin Yvon Horiba "ULTIMA 2", France) was used.

RESULTS AND DISCUSSIONS

The contents of heavy metals, macro and microelements in the studied serpentine soils are presented in Table 1. The soils were neutral to slightly alkaline and had medium to high organic matter content (data are no shown) = Ultramafic (serpentine) soils are considered unfavourable habitats for plants due to low nutrient content, calcium deficiency, magnesium toxicity and high concentrations of potentially toxic elements such as chromium, nickel, and cobalt.

High concentrations of Mg relative to Ca and elevated concentrations of Ni are considered important factors affecting plant growth and survival on serpentine soils.

Eastern Rhodope soils are characterized by elevated Fe, Ni, Cr, Co and Mn levels, which is typical of serpentine soils (Table 1). The Ni content ranges from 1365.1 to 2397.2 mg/kg and is considered typical (500-5000 mg/kg) for serpentine and Mg- and Fe-rich soils. Nickel is known to be toxic in soils at levels above 500 mg/kg (Allen et al., 1974), although toxicity is dependent on Ni bioavailability.

The total Cr content of soils ranges from 493.7 to 2233 mg/kg) and exceeds the upper limit given for soils by Allen et al. (1974) and Brooks (1987) (500 mg/kg).

While the Cu content at all sites was within normal limits (Kabata-Pendias and Pendias, 1984), the Pb content was significantly higher and reached a maximum level of 31.7 mg/kg, which is in agreement with the data reported by Babalonas et al. (1984) from serpentine soils in northern Greece.

The Zn content falls within the range of normal soils, and ranges from 43.5-90.3 mg/kg.

The Cd content of the soils is below the limits given by Allen et al. (1974). Mn concentrations in soils ranged between 1294.7 and 2733 mg/kg.

Total Ca concentrations in serpentine soil samples ranged from 2653.8 mg/kg to 5599.5 mg/kg. The Mg content is higher than Ca and ranges from 29182.6 to 63512.8 mg/kg, and the Ca/Mg ratio is less than 1.

The Fe content of serpentine soils is high and ranges from 69.9 to 457.0 mg/kg, typical for the Balkan Peninsula's serpentine soils (Salihaj & Bani, 2008; Pavlova, 2001).

The element composition of serpentine soils from the Eastern Rhodopes is similar to serpentine soils from the Balkan Peninsula (Brooks 1987), with high concentrations of metals such as Ni and Cr and relatively low Ca/Mg ratios. Ca/Mg ratios range from 0.088 to 0.091. The Ca and Mg levels found in these Bulgarian serpentine soils are typical of such soils from other areas (Brooks, 1987). The total Ni content of the soil is similar to that of Italian (Vergnan Gambi et al., 1982), Greek (Babalonas et al., 1984) and Albanian (Shallari et al., 1998) serpentine zones.

Table 2 presents the results obtained for the heavy metal, macro and microelement contents in the needles of *Juniperus oxycedrus* growing on serpentine soils in the Eastern Rhodopes.

Table 1. Content of heavy metals, micro and macro elements (mg/kg) in serpentine soils from Eastern Rhodopes, Bulgaria

Element	Min	Max	Average
Pb	0.56	1.87	1.13
Cd	0.26	0.38	0.32
Zn	6.1	29.2	12.8
Cu	2.9	4.45	3.8
Fe	69.9	457.0	178.2
Mn	26.2	85.7	43.0
P	270.9	676.4	490.0
Cr	0.26	2.38	0.96
Ni	2.44	46.7	16.4
Ca	5374.2	14295.1	8878.1
Mg	814.1	1984.3	1516.0
K	1278.5	2900.1	2209.5
Co	0.59	2.68	1.097

Table 2. Contents of heavy metals, macro and microelements (mg/kg) in *Juniperus oxycedrus* needles

Element	Min	Max	Average
Pb	0.56	1.87	1.13
Cd	0.26	0.38	0.32
Zn	6.1	29.2	12.8
Cu	2.9	4.45	3.8
Fe	69.9	457.0	178.2
Mn	26.2	85.7	43.0
P	270.9	676.4	490.0
Cr	0.26	2.38	0.96
Ni	2.44	46.7	16.4
Ca	5374.2	14295.1	8878.1
Mg	814.1	1984.3	1516.0
K	1278.5	2900.1	2209.5
Co	0.59	2.68	1.097

The Ni content of juniper needles ranged from 2.44 mg/kg to 46.7 mg/kg, while the Cr content ranged from 0.26 to 2.38 mg/kg.

Despite the high Ni and Cr contents in the soil, the amounts of Ni and Cr assimilated by the plants were small and did not exceed the limits suggested by Kabata-Pendias and Pendias (1984).

The elevated levels of Pb in soils found in the Kazak area are likely due to traffic on the roadway but not due to the soil-forming rocks. The Pb and Cd content of juniper needles is within normal ranges. Mn concentrations in soils ranged from 1294.7 to 2733 mg/kg and from 26.2 to 85.7 mg/kg in juniper needles. The high Mn levels in the soils of the Kazak area are atypical and are likely due to the soil-forming rocks, topography, vegetation, and high limiting soil matter content. Plant Mn values are within the ranges given by Kabata-Pendias and Pendias (1984).

The Fe content in juniper needles was lower than the limit of 500 ppm suggested by Allen et al. (1974).

It is noteworthy that the amount of Ca taken up by the plants is significant (ranging from 5374.2 to 14295.1 mg/kg), although the amount of Ca in serpentine soils is low. According to Proctor (1971), Ca is one of the elements influencing the reduction of heavy metal toxicity. Probably plants growing on serpentine soils absorb more Ca to compensate for the toxic action of various toxic metals. Karataglis et al. (1982) suggested that plants have a mechanism that allows them to take up significant amounts of Ca

The high Mg content of serpentine soils determines the high Mg content of plant tissues (mean range 1516.0 mg/kg). The Ca/Mg ratio in all plant samples was > 1. Plants from serpentine soils can maintain a ratio greater than 1 despite the minimum Ca levels found in the soils. They either have very efficient uptake systems or the ability to exclude Mg despite high soil concentrations.

The heavy metal content of juniper essential oil has also been determined (data not shown). The results indicate that most of the heavy metals in red juniper needles do not pass into the oil during needle processing. Therefore their content in the oil is significantly lower. The results show that the essential oils' heavy metal content is lower than the aboveground part of juniper, and the amounts of Pb, Zn and Cd in juniper oil are lower than the accepted maximum permissible values the oil meets the criteria for an environmentally friendly product.

Juniperus oxycedrus can be classified as an exclusion plant, containing relatively low concentrations of metals in the aboveground parts, despite high concentrations of the elements in the soil.

The results of the chromatographic analysis of essential oils obtained by processing *Juniperus oxycedrus* needles growing on serpentine soils in the Eastern Rhodopes are presented in Table 3.

Table 3. Chemical composition (%) of *Juniperus oxycedrus* oil

№	Component		Min	Max	Average
1	α-Pinene	933	6.41	8.78	7.67
2	Sabinene	969	0.45	1.21	0.79
3	β-Pinene	974	0.51	0.70	0.61
4	β-Myrcene	991	1.06	1.45	1.27
5	δ-2-Carene	1001	0.13	0.18	0.15
6	α-Phellandrene	1006	0.27	0.37	0.32
7	δ-3-Carene	1018	0.06	0.09	0.07
8	p-Cymene	1025	1.17	1.60	1.40
9	**Limonene**	1029	**12.10**	**13.84**	**13.18**
10	β-Phellandrene	1030	0.11	0.16	0.14
11	α-Terpinolene	1087	0.20	0.27	0.24
12	p-Cymenene	1089	0.17	0.23	0.20
13	β-Linalool	1096	0.56	0.77	0.67
14	n-Nonanal	1110	0.28	0.38	0.33
15	trans-Pinene hydrate	1119	0.10	0.14	0.12
16	α-Campholenal	1122	0.27	0.36	0.32
17	cis-Limonene oxide	1132	0.38	0.52	0.45
18	trans-Pinocarveol	1135	0.47	0.64	0.56
19	cis-Verbenol	1138	0.35	0.48	0.42
20	Pinocarvone	1160	0.13	0.18	0.16
21	Terpinen-4-ol	1174	0.18	0.25	0.22
22	p-Cymen-8-ol	1177	0.22	0.30	0.27
23	Cryptone	1183	0.89	1.22	1.07
24	α-Terpineol	1187	1.35	1.84	1.61
25	Myrtenal	1195	0.26	0.36	0.31
26	Verbenone	1204	1.01	1.39	1.21
27	trans-Carveol	1215	0.98	1.34	1.17
28	Phellandral	1275	0.21	0.29	0.26
29	Bornyl acetate	1285	0.31	0.42	0.37
30	α-Copaene	1374	0.70	0.96	0.84
31	β-Bourbonene	1386	0.39	0.53	0.47
32	7-epi-Sesquithujene	1390	0.29	0.39	0.34
33	α-Cedrene	1410	0.20	0.27	0.24
34	β-Caryophyllene	1417	0.73	0.99	0.87
35	β-Cedrene	1419	0.48	0.66	0.58
36	trans-Geranylacetone	1452	0.24	0.33	0.28
37	(Z)-β-Farnesene	1454	0.50	0.69	0.60
38	α-Caryophyllene	1456	0.62	0.84	0.74
39	γ-Muurolene	1476	0.30	0.42	0.36
40	α-Curcumene	1480	0.22	0.30	0.26
41	**γ-Himachalene**	**1482**	**7.47**	**1.58**	**10.63**
42	Germacrene D	1484	0.36	0.49	0.43
43	α-Muurolene	1499	0.72	0.98	0.86
44	**β-Bisabolene**	**1505**	**3.13**	**4.29**	**3.74**
45	**γ-Cadinene**	**1513**	**3.64**	**5.00**	**4.36**
46	δ-Cadinene	1524	2.93	6,33	4.93
47	α-Calacorene	1545	1.45	1,98	1.73
48	±-trans-Nerolidol	1556	0.34	0.68	0.44
49	β-Calacorene	1564	0.38	0.54	0.46
50	(-)-Spathulenol	1577	2.66	3.55	3.12
51	Caryophyllene oxide	1582	1.26	3.43	1.76
52	α-Cedrol	1596	1.87	2.56	2.24
53	tau.-Cadinol	1619	1.21	1.95	1.50
54	tau.-Muurolol	1638	1.40	2.24	1.89
55	Cadalene	1675	1.09	2.23	1.43
56	10-nor-Calamenen-10one	1702	0.35	0.84	0.46
57	(Z.Z)-Farnesyl acetone	1860	0.27	0.37	0.33
58	n-Nonadecane	1901	2.03	2.78	2.43
59	Dibutyl phthalate	1919	**1.48**	**8.14**	4.94
60	Manoyl oxide	1992	**6.60**	**12.80**	9.77

Sixty components were identified in Juniperus oxycedrus needles oils. The oil composition was dominated by limonene (12.10-13-84%), γ-himachalene (7.47-12.58%), manoyl oxide (6.60-12.80%), α-pinene (6.41-8.78%), dibutyl phthalate (1.48-8.14%), δ-cadinene (2.93-6.33%), γ-cadinene (3.64-5.00%), β-bisabolene (2.98-4.29%).

The content of monoterpenes in Juniperus oxycedrus oil ranged from 29.81 to 38.69%. Semerdjieva et al. (2019) found that the predominant component in the oil of monoterpenes is α-pinene (9.4-24.5%), followed by limonene (1.8-15.2%) and caryophyllene oxide (0.73-13.1%). However, the results obtained showed that the oil was dominated by limonene (12.10-13-84%,)) followed by α-Pyrene (6.41-8.78%), p-Cymene (1.17-1.60%) and β-Myrcene (1.06 -1.45%).

Studies have shown that α-pinene in the oil of needles of J. oxycedrus varies over an extensive range, from 40% to 57% in Spain, 20.7-85.6% in Italy, 6.3-70.7% in Portugal, Croatia and Greece, 27.4-58.0% in Tunisia, 22.5%-27.1% in the Republic of North Macedonia and 17.8-29.0% in Bulgaria (Adams, 1998, 1999; Angioni et al., 2003; Medini et al., 2010; Salido et al., 2002; Sela et al., 2013; Semerdjieva et al., 2019). Differences in plant genetics explain differences in the amount of α-pinene (at subspecies and cultivar levels) and seasonal variations in oil composition (Medini et al., 2010). According to Adams et al. (2005) limonene is present in higher concentrations in oil, including in Bulgarian samples. Samples with higher limonene content were characterized by large amounts of Manoyl oxide or β-Caryophyllene. The limonene content of needles varies considerably; in the Republic of North Macedonia it is between 2.8% and 18.1%, in Algeria it is 5.8%, in Corsica it is 1.2-1.3%, in Italy it is about 30%, in Greece it ranges from 17.1% to 27.7%, and in Bulgaria it is between 5.8% and 13.6% (Adams et al., 1999; Valentini et al., 2003; Boti et al., 2006; Sela et al., 2013; Semerdjieva et al., 2019).

The oil's sesquiterpenes ranged from 34.5% to 56.12%. The amount of sesquiterpene hydrocarbons varied from 22.31 to 37.71%. The major components of this group are γ-Himachalene (7.47-12.59%), δ-Cadinene (2.93-6.33%), γ-Cadinene (3.64-5.00%), β-Bisabolene (3.13-4.29%), α-Calacorene (1.45-1.98%). The oxygen-containing sesquiterpenes vary from 10.82 to 18.41% of the total oil composition. The oil contains (-)-Spathulenol (2.66-3.53%), α-Cedrol (1.87-2.56%), tau.-Muurolol (1.40-2.24%), Caryophyllene oxide (1.26-3.43%), tau.-Cadinol (1.21-1.95%), Cadalene (1.09-2.23%).

Four chemotypes (a-pinene type, limonene type, sabinene type and trans-pinocarveol type) of J. oxycedrus were identified by Dob et al. (2006). The oils we studied belong to the limonene type chemotype. Limonene is considered to be specific to the oil of J. oxycedrus from the Balkan Peninsula, including Bulgaria (Adams et al., 2005; Adams and Tashev, 2012).

Figure 2 presents the classification of the identified compounds based on functional groups. The highest content of sesquiterpene hydrocarbons was found in juniper leaf essential oil (24.13-37.71%), followed by monoterpene hydrocarbons (22.64-28.87%), oxygen-containing sesquiterpenes (10.82-18.41%), diterpenes (6.60-12.80%), oxygen-containing monoterpenes (7.17-9.82%) and other classes of organic compounds (4.54-12.33%) (Figure1).

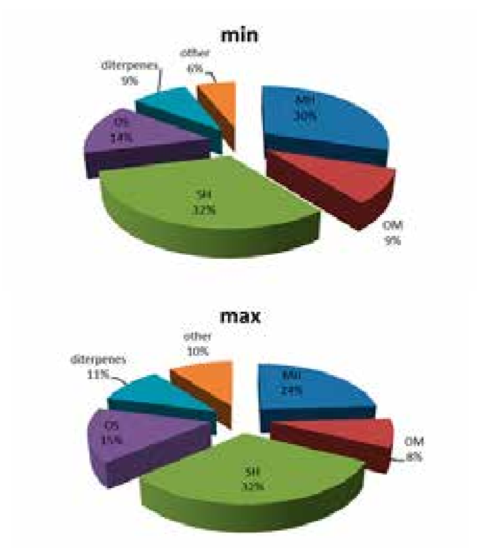


Figure 1. Classification of identified compounds based on functional groups in juniper needles oils

CONCLUSIONS

Based on the results obtained, the following conclusions can be drawn:

1. The chemical composition of serpentine soils from the Eastern Rhodopes is similar to serpentine soils from the Balkan Peninsula and is characterized by a high content of Ni (1365.1-2397.2 mg/kg), Cr (493.7-2233 mg/kg), and Mg (29182.6-63512.8 mg/kg).
2. The unfavourable soil characteristics do not affect the development of red juniper, nor the quality and quantity of the oil obtained.
3. *Juniperus oxycedrus* is an exclusionary plant containing relatively low concentrations of metals in aboveground parts despite high concentrations of elements in the soil.
4. The highest content of sesquiterpene hydrocarbons in juniper needles essential oil (24.13-37.71%), followed by monoterpene hydrocarbons (22.64-28.87%), oxygen-containing sesquiterpenes (10.82-18.41%), diterpenes (6.60-12.80%), oxygen-containing monoterpenes (7.17-9.82%), and other classes of organic compounds (4.54-12.33%).

ACKNOWLEDGEMENTS

This research work was carried out with the support of Bulgarian National Science Fund and also was financed from Project KP-6-Austria/7.

REFERENCES

Adams, R. (2008). *Juniperus* of Canada and the United States: taxonomy, key and dis tribution. *Phytologia,* 90 (3), 255–314.

Adams, R., Morris, J.A., Pandey, R., & Schwarzbach, A. (2005). Cryptic speciation between Juniperus deltoides and *Juniperus oxycedrus* (cupressaceae) in the mediterranean. *Biochem. Syst. Ecol*,, 33 (8), 771–787.

Adams, R.P. (1998). The leaf essential oils and chemotaxonomy of Juniperus sect. Juniperus. *Biochem, Syst. Ecol*, 26, 637–645.

Adams, R.P., & Tashev, A.N. (2012). Geographic variation in leaf oils of *Juniperus deltoides* from Bulgaria, Greece, Italy and Turkey. Phytologia, 94 (3), 310–318.

Adams, R.P., Altarejos, J., Fernandez, C., & Camacho, A. (1999). The leaf essential oils and taxonomy of *Juniperus oxycedrus* L. subsp. *oxycedrus*, subsp. *badia* (H.Gay) Debeaux, and subsp. *macrocarpa* (Sibth. & Sm.). *Ball. J. Essent. Oil Res*. 11, 167–172.

Allen, S., Grimshaw, H., Parkinson, J. & Quarmby, C. (1974). Chemical Analysis of Ecological Materials. Blackwell Scientific Publications, Oxford, London, Edinburgh, Melbourne.

Angioni, A., Barra, A., Russo, M.T., Coroneo, V., Dessiä, S., & Cabras, P. (2003). Chemical composition of the essential oils of Juniperus from ripe and unripe berries and leaves and their antimicrobial activity. *J. Agric. Food Chem*, 51 (10), 3073–3078.

Babalonas, D., Karataglis, S., & Kabassakalis, V. (1984). The ecology of plant populations growing on serpentine soils. III. Some plant species from North Greece in relation to the serpentine problem. *Phyton*, 24, 225–238.

Boti, J.B., Bighelli, A., Cavaleiro, C., Salgueiro, L., & Casanova, J. (2006). Chemical varia bility of *Juniperus oxycedrus* ssp. *oxycedrus* berry and leaf oils from Corsica, analysed by combination of GC, GC–MS and 13C-NMR. *Flavour Fragrance J*, 21, 268–273.

Brooks, R. R. (1987). Serpentine and its Vegetation. A Multidisciplinary Approach. 1, Dioscorides Press, Portland, Oregon, USA, p. 407.

Cantrell, C.L., Zheljazkov, V.D., Osbrink, W.L.A., Castro, A., Maddox, V., Craker, L.E., & Astatkie, T. (2013). Podophyllotoxin and essential oil profile of *Juniperus* and related species. *Ind. Crops Prod*. 43, 668–676.

Cavaleiro, C., Pinto, E., Goncalves, M.J., & Salgueiro, L. (2006). Antifungal activity of *Juniperus* essential oils against dermatophyte, *Aspergillus* and *Candida* strains. *J. Appl. Microbiol*, 100, 1333–1338.

Derwich, E., & Chabir, R.A. (2011). Identification of the volatile constituents of the essential oil of *Juniperus oxycedrus* L. (Cupressaceae) from the north centre region of Morocco. Asian J. Pharmaceut. Clin. Res, 4 (1), 50–54.

Dob, T., Dahmane, D., & Chelghoum, D. (2006). Essential oil composition of *Juniperus oxycedrus* growing in Algeria. *Pharm. Biol*, 44 (1), 1–6.

Farjon, A. (2013). *Juniperus oxycedrus*. The IUCN Red List of Threatened Species 2013, e.T42243A2965838.

Figueiredo, A.C., Barroso, J.G., Pedro, L.G., & Scheffer, J.J.C. (2006), Factors affecting secondary metabolite production in plants: volatile components and essential oils, *Flavor and Fragrance Journal*, 23, 213–226.

Franco, J. do A. (2002). *Juniperus* L. In: second ed. In: Tutin, T.G., Heywood, V.H., Burges,

Gussev, Ch, (2015). Red book of the republic Bulgaria. In: Biserkov, V. (Ed.), 3 Natural habitats. BAS & MOSV, Sofia. /in Bulgarian.

ISO 11466. (1995). Soil Quality-Extraction of Trace Elements Soluble in Aqua Regia

Kabata-Pendias, A., & Pendias, H. (1984). Trace elements in soils and plants. CRC Press, Boca Raton, FL.

Karataglis, S., Babalonas, D., & Kabasakalis, B. (1982). The Ecology of plant populations growing on serpentine soils. II. Ca/Mg Ratio and the Cr, Fe, Ni, Co concentrations as development factors of Buxus sempervirens L. Phyton (Austria), 22,317–327.

Medini, H., Elaissia, A., Khoujab, M.L., & Chraief, I. (2010). Leaf essential oil of Juniperus oxycedrus L. (Cupressaceae) harvested in Northern Tunisia: composition and intra specific variability. *Chem. Biodivers*. 7, 1254–1266.

Medini, N., Marzouki, H., Chemli, R., Khouja, M.L., Marongiu, B., Piras, A., Porcedda, A., & Tuveri, E. (2009). Comparison of the antimicrobial activity and the essential oil composition of *Juniperus oxycedrus* subsp. *macrocarpa* and *J. oxycedrus* subsp. *rufescens* obtained by hydrodestilation and supercritical carbon dioxide extraction methods. *Chem. Nat. Compd*, 45 (5), 739–741.

Pavlova, D. (2001). Mountain vegetation on serpentine areas in the Bulgarian Eastern and Central Rhodopes Mts. - ecology and conservation, in: Radoglou, K.: Proceedings of International Conference: Forest Research: a challenge for an integrated European approach. Aug. 27–Sept. 1, Thessaloniki, 1, 227–232.

Proctor, J. (1971). The plant ecology of serpentine. III. The influence of a high magnesium/calcium ratio and high nickel and chromium levels in some British and Swedish serpentine soils. *J Ecol*, 59, 827-842.

Salido, S., Altarejos, J., Nogueras, M., Sanchez, A., Pannecouque, C., Witvrouw, M., & De Clercq, E. (2002). Chemical studies Essential oils of Juniperus oxycedrus of essential oils of *Juniperus oxycedrus* ssp. *badia*. *J. Ethnopharmacol*, 81, 129–134.

Salihaj, M., & Bani, A. (2018). Chemical Properties of Serpentine Soils from Kosovo. *Albanian j. agric. sci*. 2018;17 (1): 78-83

Sela, F., Karapandzova, M., Stefkov, G., Cvetkovikj, I., Trajkovska-Dokikj, E., Kaftandzieva, A., & Kulevanova, S. (2013). Chemical composition and antimicrobial activity of berry essential oil of *Juniperus oxycedrus* L. (Cupressaceae) grown wild in Republic of Macedonia. Maced. *Pharm. Bull*, 59 (1, 2), 41–48.

Semerdjieva, I., Zheljazkov, V.D., Radoukovac, T., Radanovic, D., Markovic, T., Dincheva, I., Stoyanova, A., Astatkie, T., & Kacaniovah, M. (2019). Essential oil yield, composition, bioactivity and leaf morphology of *Juniperus oxycedrus* L. from Bulgaria and Serbia. *Biochemical Systematics and Ecology*, 84, 55–63.

Shallari, S., Schwartza, C., Haskob, A., & Morelat, A. (1998). Heavy metals in soils and plants of serpentine and industrial sites of Albania. *The Science of the Total Environment*, 209, 133-142.

Valentini, G., Bellomaria, B., Maggi, F., & Manzi, A. (2003). The Leaf and Female Cone Oils of *Juniperus oxycedrus* L. ssp. *oxycedrus* and *J. oxycedrus* ssp. *macrocarpa* (Sibth. et Sm.) Ball. from Abruzzo. *J. Essent. Oil Res,* 15 (6), 418–421.

Vergnano Gambi, O. (1992). The distribution and ecology of the vegetation of ultramafic soils in Italy. In: Roberts, B.A., Proctor, J. (Eds.), The Ecology of Areas with Serpentinized Rocks: A World View. Kluwer, Dordrecht, 271–313.

Walters, S.M., Webb, D.A. (Eds.), Flora Europaea, vol. 1. Cambridge University Press,

Yeritsyan, N., & Economakis, C. (2002). Effect of nutrient solution's irons concentration on growth and essential oil content of oregano plants grown in solution culture. International Conference on Medicinal and Aromatic Plants, Possibilities and Limitations of Medicinal and Aromatic Plant Production in the 21st Century, vol.1, Budapest Hungary.

Zheljazkov V.D., Craker L.E., Baoshan X., Nielsen N.E., Wilcox A., (2008), Aromatic plant production on metal contaminated soils, Science of the *Total Environment,* 395, 51-62.

Zheljazkov, V., Astatkie, T., & Jeliazkova, E. (2013). Year-round variations in essential oil content and composition of male and female juniper. *Hortscience*, 48 (7), 883–886.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

3D FINITE ELEMENT ANALYSIS MODEL TO ACCESS THE SETTLEMENT OF SOFT SOIL TREATED WITH NANO-MgO

Ahmed AL-RUBAYE, Anton CHIRICA, Ioan BOTI

Technical University of Civil Engineering Bucharest, 124 Lacul Tei Blvd, District 2, Bucharest, Romania

Corresponding author email: ahmadalrobai@yahoo.com

Abstract

In this study, a numerical model was developed to assess the settlement and the damaging mechanism of an old masonry church Adormirea Maicii Domnului located in Perisoru village, Romania by using finite element software Plaxis 3D. The main aim of this research was to simulate the ground problems and the structural failures observed. The rectangular foundation is placed on yellowish silty clay-loess, which was modelled and analysed in the present paper. Mohr-Coulomb soil model was used for the soil and the linear elastic model was used for the foundation. After computing the settlements, it was resulted the need of improving the soil. The soil was improved with cement, but some nano materials were considered as well, as an alternative. The results showed that the value of the settlements reduced with an increase in the amount (0.5%, 0.75%, 1%, 2%) of the Nano-MgO. The results have been compared with the soil treated with 2 % cement.

***Key words**: historic structures, Nano-MgO, Plaxis 3D, settlement, soft soil.*

INTRODUCTION

In this study, a numerical model of geotechnical and structural problems was developed using finite element software, Plaxis 3D to assess the foundation settlements, that had been observed and recorded at a masonry historical Church Adormirea Maicii Domnului, located in Romania, Perisoru, 120 km east of Bucharest with coordinate (44°26'12.29"N, 27°32'43.76"E), which was built with area 200m^2 between (1937-1944) AD. The Church form Perisoru village (Calarasi County) has a cross shape and is distinguished by a special architectural beauty. The general dimensions in the plan are 27.40 x 15.50 m with a main opening of 8.75 m.

The height at the cornice is 7.65 m, at the dome of the main tower 20.85 m, and the maximum height with the cross is 23.34 m (elevations compared to the finished elevation of the interior floor +0.00 m, 72 cm higher than the elevation of the landscaped land). The walls are made of 75 cm thick brick masonry (27 x 13 x 6 cm bricks), connected with lime mortar. The roof is a wooden frame with sheet metal roofing. The structure of the towers is also made of brick masonry (alternating solid brick pressed with brick with vertical holes) with lime mortar, supported on a brick masonry pedestal that includes reinforced concrete. In masonry, bricks occupy 85% of the total volume while mortar represents 15%. The total amount of primary energy required to achieve a cubic meter of masonry was obtained from the sum of 85% of the embedded energy in bricks with the 15% of mortar energy (Dragomir et al., 2014).

The physical condition of the church is precarious: fractures, cracks, and fissures have been identified in the masonry, caused by uneven settlements. These settlements which are exceeding 30-40cm are mainly caused by the increase of groundwater table level in time. The roof sheet is corroded, and the water collection and drainage system are damaged. The vertical systematization of the land is improperly made, unfinished and damaged.

The rectangular foundation is placed on saturated yellowish silty clay, soft consistency (wetted loess) at 1.5 m depth from the ground surface. We had considered and applied an effective pressure of 200 kPa. The foundation is that part of a structure that transmits loads directly to the soil, a process known as soil-structure interaction. The foundation must be designed to have sufficient capacity or resistance to support the applied load and to

avoid any large deformation under these loads, which might damage the structure (Abdullah, 2022).
For many years the settlements did not cause any structural problems. One may consider that the consolidation process took place, and no problems were recorded. After heavy irrigation in the area, an increase of groundwater table level had been recorded; the additional water wetted the loess layer and caused additional settlements to many buildings in the area, including the church. After that, a monitoring report showed settlements larger than 30 cm and, most important, showed no decrease in the settlement's incremental evolution. This put in danger the use of the church safely. For this reason, we had studied the option to improve the soil under foundations.

History of the church

In 1927, a monk priest named Galaction Negulescu was sent from Gheorghe Lazăr commune, Ialomiţa. In less than a year, he managed to set up a religious committee with which he raised funds and initially bought a 318 kg bell. In December 1929, he was ordained and appointed the first ordained priest Dojan G. Nicolae. He reorganized the old church committee and began raising funds to build a new church. 250,000 bricks were made; an estimate and a plan for a church with three cross-shaped towers were drawn up by the engineer Napoleon Constantin essay, according to the type of the Holy Archbishopric of Bucharest (Figure 1).
In 1936, the foundation stone of today's monumental church with an interior area of 200 square meters was laid. In 1937, the plan of the church was redone by the diplomat architect from Paris, Pândele Șerbănescu, and the construction works were completed in 1944. The church was consecrated on 11 of November 1946 (http://www.biserici.org).

Figure 1. Front and side view of the church (photocopy after Church plans, 1927)

MATERIALS AND METHODS

In order to characterize the soil stratification were performed geotechnical boreholes at 20m, the boreholes were located in the area of the church. Based on the field investigation, the following overall stratification is noted:
Layer 1 - Topsoil soil: this layer has a thickness of about 0.5 m;
Layer 2 - Cohesive complex, this layer is made of yellowish silty clay, soft (wetted loess), and has a thickness of about 9.0 m;
Layer 3 - Non-cohesive complex, this layer is made of fine to medium dense sand and has a thickness of more than 10.0 m. The groundwater level was found at -3.0 m from the natural ground level.
In order to establish the depth of the

foundation, a test pit was dug at the foundation of the church, according to that found the depth of the foundation was equal to 1.2 m, the foundation was made from concrete and does not show any degradation, the foundation is placed on soft silty clay (wet loess).
The area is known for the presence of loessoid deposits which are water sensitive. Their thickness may easily exceed 10 m, in Perișoru area. The main reason for problems of the structural failure element (Figure 2) is the rising in the groundwater level, in addition, most of the existing buildings were built during this period when seismic action was not considered in the design, so they were built from the beginning by traditional methods and designed only for rapacious actions (Hemeda, 2019).
Some geotechnical laboratory investigations were done in this research on the soil samples that were obtained from the study area.
In order to establish the optimal foundation solution, an essential geotechnical property is the compressibility of the foundation soil (Olinic et al., 2021). A set of laboratory tests were done on the soil samples to get the numerical model of the soil (Al-Rubaye Ahmed, 2021). The tests were performed on not treated soil and on treated soil with various percentages of nano MgO. Results are shown in Tables 1 and 2.

Figure 2. Deformations and cracks on the Brick Walls of Church Adormirea Maicii Domnului, Perisoru

Figure 3. Deformation and Cracks in the Different Structure inside the Church Adormirea Maicii Domnului, Perisoru

Table 1. Oedometer modulus Eoed (kPa) of the soil samples

Type and percent of additive	Non treated soil	0.5% nano-MgO	0.75% nano-MgO	1% nano-MgO	2% nano-MgO	2% cement
Oedometer modulus E_{oed}, (kPa)	4080	5900	6490	7870	9660	11000

Table 2. Results of direct shear tests for soil samples treated with a different percentage of nano-MgO

Type and percent of the additive	Internal friction angle (Φ’)	Cohesion (c’), kPa
Non-treated soil	16°	15
0.5% Nano-MgO	16°	15
0.75% Nano-MgO	19°	14
1% Nano-MgO	20°	20
2% Nano-MgO	22°	28

RESULTS AND DISCUSSIONS

In this study, Plaxis 3D software was used to determine the behaviour of the wetted yellowish silty clay and the old masonry structure of the church

Numerical modelling for the rectangular foundation by using FEM 3D software was done. The applied load from the superstructure was added to 200 kPa on the foundation, the water is located -3.0 m deep. This study aims to assess the total settlement of the soil by stimulating the rectangular foundation of the church in six cases.

In the current situation (when the foundation is placed on natural soil), the results of the numerical analysis of the church show that some of the surface settlement occurs during the construction period, and because of the rising water ground-level, the displacement in and surrounding the soil and foundation developed and increase above the maximum value of about 27.14 cm (Figure 6.a.). Each soil acts differently depending on its mineralogical and granulometric composition: for this reason, there is no 'recipe' for the improvement of difficult soils (Ivasuc et al., 2015).

In order to see the importance of soil improvements technologies by mixing, simulations were performed when foundation soil differs. The settlement (Table 3, Figure 6) was calculated when the foundation soil was improved (when the compressibility parameters differ - Table 1).

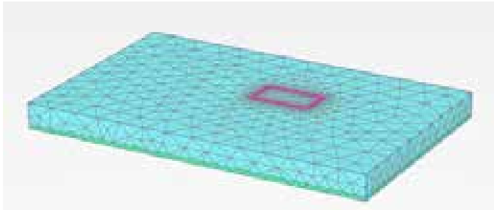


Figure 4. Typical Finite Element mesh adopted for numerical analysis

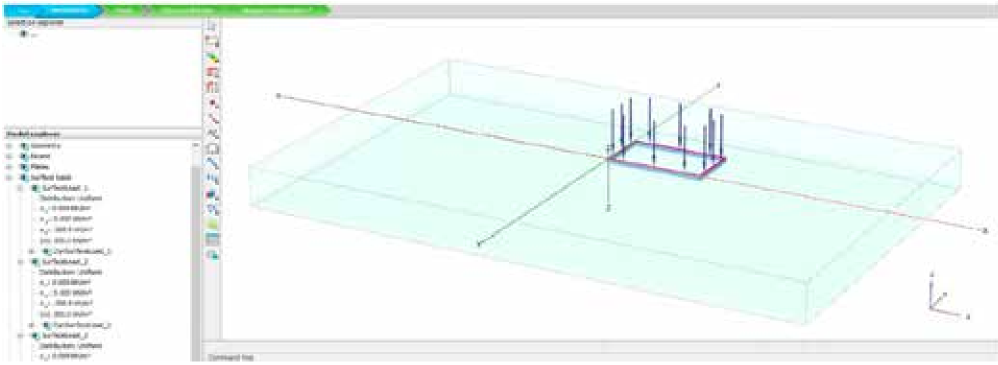
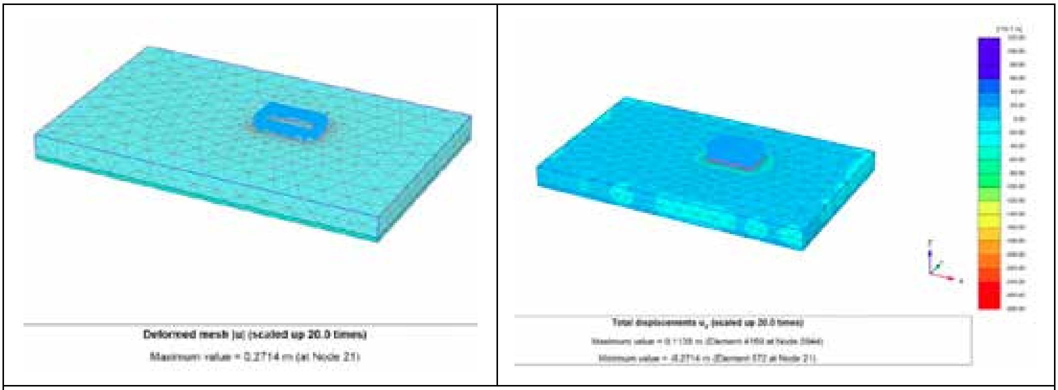


Figure 5. The applied distribution load of 200 kPa from the structure on the soil

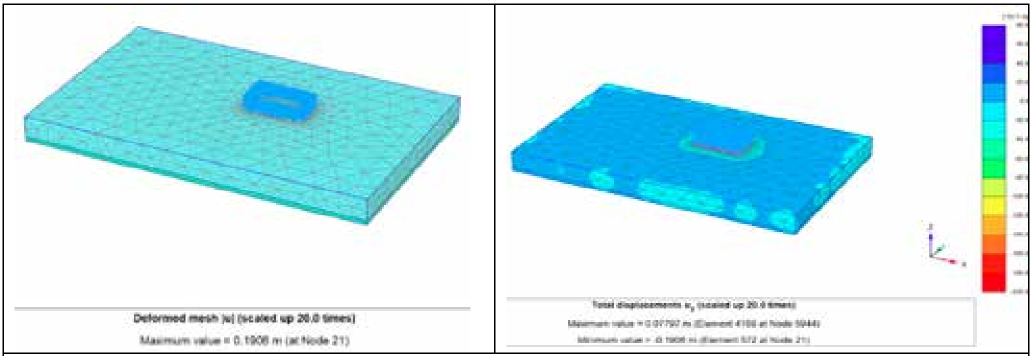
Table 3. The value of the settlement for soil samples treated with a different percentage of nano-MgO

Type and percent of additive	Non treated soil (cm)	0.5% nano-MgO (cm)	0.75% nano-MgO (cm)	1% nano-MgO (cm)	2% nano-MgO (cm)	2% cement (cm)
Settlement	27.2	19.1	15.8	10.6	8.0	6.0

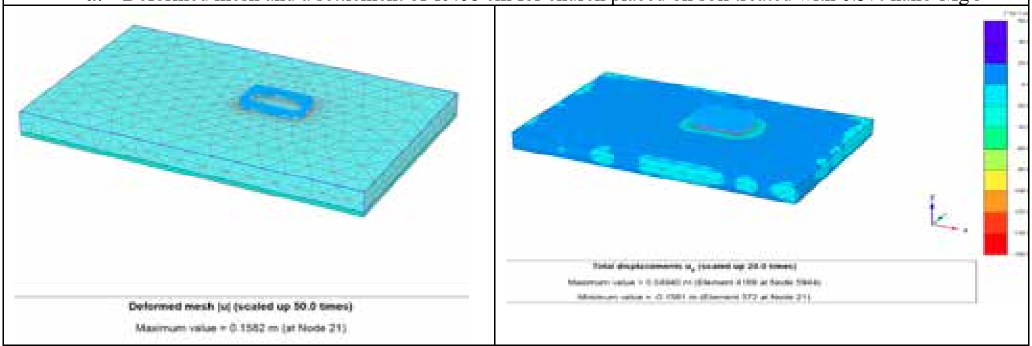


Deformed mesh and a settlement of 27.14 cm for church placed on natural soil

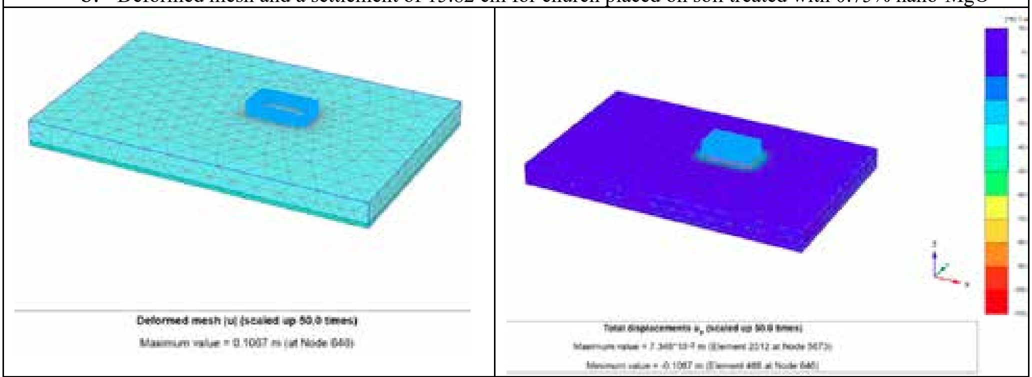
Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064



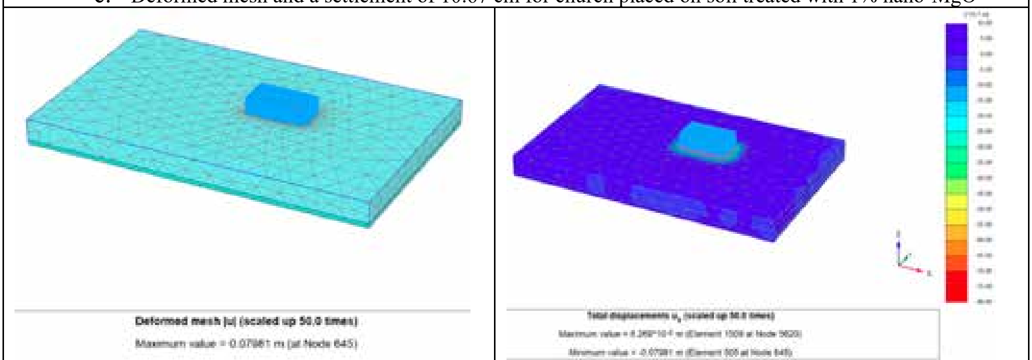
a. Deformed mesh and a settlement of 19.06 cm for church placed on soil treated with 0.5% nano-MgO



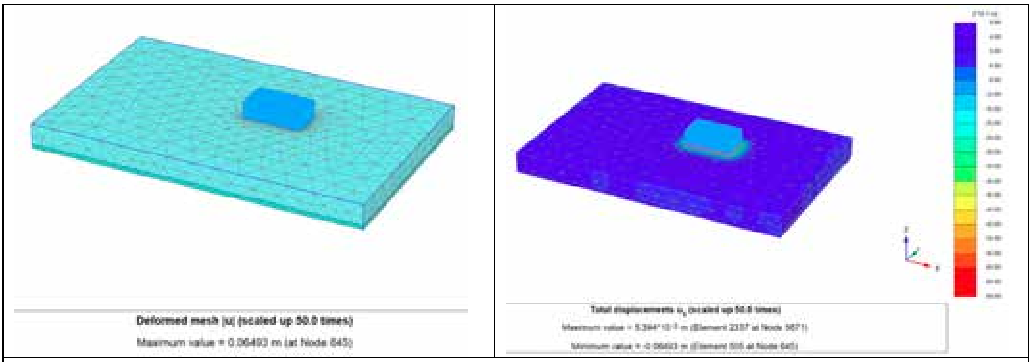
b. Deformed mesh and a settlement of 15.82 cm for church placed on soil treated with 0.75% nano-MgO



c. Deformed mesh and a settlement of 10.67 cm for church placed on soil treated with 1% nano-MgO



d. Deformed mesh and a settlement of 7.98 cm for church placed on soil treated with 2% nano-MgO



e. Deformed mesh and a settlement of 6.49 cm for church placed on soil treated with 2% cement

Figure 6. The settlement of the foundation soil

CONCLUSIONS

This study was conducted to assess the efficiency of the soil improvement meant to stabilize the settlements for the church Adormirea Maicii Domnului, Perisoru village, Romania. A series of laboratory tests and three-dimensional FEM analyses were used to perform this task. The soil parameters, required for the numerical analysis were obtained from laboratory and field tests. The results of the numerical analysis showed that the total vertical displacement of the soil was 27.2 cm. The main reason for this high value of the settlement and the damages in the structures are due to the rising groundwater level in the region. Different percentages of nano-MgO have been used to improve and modify the soil properties. All the results have been compared with 2% soil mixtures with cement. The value of the settlement decreases with an increase in the percentage (0.5%, 0.75%, 1%, 2%) of the nano-MgO (19.0, 15.8, 10.7, 8.0) cm, respectively, and 6.5cm when using 2% cement. It can be observed that the value of the settlement when using nano-MgO is still larger than the value of the settlement when using 2% cement.

In conclusion, the use of cement is more suitable from a technical point of view, in addition to the high-cost difference between cement and nanomaterials, in general.

REFERENCES

Abdullah., G. M. (2022). Using Plaxis 2D finite element modeling to assess bearing capacity of Sultana's soil in Najran Region, Kingdom of Saudi Arabia. *Materials Today: Proceedings*, 49, 2679-2687.

AL-Rubaye Ahmed, C. A. (2021). Soft soil improvement using Nanomaterial Nano-MgO. *Proceedings of XIV National Conference on Soil Mechanics and Foundation Engineering*, Bucharest, Romania, ISBN 978-606-23-1250-3.

Dragomir C. S., Codita A., Tronac A. S. (2014) Energetic and dynamic analysis of modern and original masonry buildings. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, Vol. III*, Print ISSN 2285-6072, 45-50.

Hemeda, S. (2019). Geotechnical and geophysical investigation techniques in Ben Ezra Synagogue in Old Cairo area, Egypt. *Heritage Science 7*(1), 1-15.

Ivasuc T., Olinic E. (2015). The effect of clay desensitization with granular materials on slope stability analysis. *Agriculture and Agricultural Science Procedia 6*, 459-466

Olinic T., Olinic E. (2021) Foundation solutions for an industrial platform built on contaminated soft soil. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, Vol. X*, Print ISSN 2285-6064, 64-69.

http://www.biserici.org. (n.d.).

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

A REVIEW OF IMPROVEMENT GEOTECHNICAL CHARACTERISTICS BY NANO ADDITIVES

Ahmed AL-RUBAYE, Anton CHIRICA, Ioan BOTI

Technical University of Civil Engineering Bucharest, 122-124 Lacul Tei Blvd, District 2, Bucharest, Romania

Corresponding author email: ahmadalrobai@yahoo.com

Abstract

This paper reviews and discussed soil stabilization by using the nanomaterials as additives; analysed their effect on soil. With the urban development and the rapid increase in population, including projects to expand cities, the need has become urgent to implement various types of projects such as buildings, dams, highways, and others. The foundation soil on some sites is weak and do not have the necessary and required engineering properties. Because of that, the soil properties should be improved from "bad" soil to a better foundation soil, increasing the shear strength parameters, reducing soil compressibility and reducing soil permeability. Therefore, soil improvement is an essential solution to enhance it characteristics. Nanomaterials can be described as materials with particles of at least one dimension between 1-100 nm. In recent years, nanotechnology has been used for improving the geotechnical properties of soils, and it has given a significant advantage in this field. The objective of this review article is to analyse some of the publications using nanomaterials as additives to the soil.

Key words: *nanoparticle, soil stabilization, nano-MgO cement, nano-clay.*

INTRODUCTION

Soil is natural mineral particles that can be separated into relatively small pieces which have been formed by breaking down the rocks, as a result of weathering processes such as water, air, or organic materials (formed by the decomposition of plants). In another hand, it is considered the oldest and the cheapest material used as a construction material. There is an increasing need to use the marginalized sites for construction and the implementation of new projects, which include projects to expand cities and infrastructure projects and others. Some of those sites contain weak soils which don't have the necessary and required engineering properties. For this reason, the soil properties should be improved and stabilized, in order to reach the level of acceptance in the engineering community and transform from weak soil into a good foundation soil.
The necessity of foundation soils improvement and stabilization was admitted since the beginning of the constructions, the solutions and technologies advancing in time (Ivasuc et al., 2014). Soil stabilization is defined as the method used to change the soil's texture and improve its geotechnical properties such as increase the shear strength, reduce the permeability and compressibility, and thus increase the bearing capacity of the soil. Two stabilizations type have been observed, called, mechanical and chemical stabilization (Patel, 2019).
Mechanical stabilization is the physical process of improving the ground by changing its gradation, including soil compaction by using rollers, vibration techniques, and rammers, or by incorporating other physical properties like barriers and nailing (Afrin, 2017).
Chemical stabilization is a process of mixing chemical additives (binder materials) to the soils to improve it engineering properties. This method can be achieved in the site or in the laboratory, and it is divided into two parts, traditional and non-traditional additives (Zahri et al., 2019).
Physical stabilization is done by the modification of the grain size distribution of a soil by mixing it with another soil; chemical stabilization is done by altering the soil structure by mixing it with some chemicals (Olinic et al., 2015). Examples of conventional additives are cement, lime, and fly ash. When

they exposed to water, a chemical change occurs, which leads to improved soil properties, reducing swelling, improving shear strength, and avoiding the harmful effects of wetting and drying. Cement is one of the oldest materials are added to the soil to improve its properties due to its high efficiency. It's suitable for a wide range of soils because its reaction doesn't depend on the soil type but appears when in contact with water. Also, the use of cement has many limitations. For example, the content of the organic material must not exceed 2% for the soil wanted to mix it with cement, contain a small amount of clay, and be without salts such as sulphate salts that affect the formation time of the cement soil (Ikeagwuani et al., 2019).

Non-traditional soil stabilization additives like nanomaterials consist of a wide range of chemical agents that differ in their composition and the mode they react with the soil. Nanotechnology is the term is given to managing matter at a very small scale between (1-100) nano-meter scales. Also, it is the branch of science, engineering, and technology conducted in at least one dimension is in the nano-meter scale. Nanotechnology is involved in many domains, including industrial, engineering, medicinal, and energy uses. Recently, it used several nanomaterials in the civil engineering sciences, to enhance their performance such as steel, concrete, glass, wood, coating, and structural monitoring which made significant and rapid progress in the last years. Nanotechnology in geotechnical engineering can be seen in two ways: the soil's structure at the nanoscale, secondly at the atomic or molecular level through the addition of nanoparticles as an external factor to the soil (Majeed et al., 2013). Nanomaterials can be described as materials with particles of at least one dimension between 1-100 nm. Nanomaterials can occur naturally, be created as products of combustion reactions, or be produced purposefully through engineering to perform a specialized function. Nanomaterials can have different physical and chemical properties than their bulk-form counterparts. They can exist in single, aggregated, or agglomerated forms with spherical, tubular, and irregular shapes. The idea of using nanomaterial to improve soil properties comes from the inter-particles concept. Because of their small dimensions and the high specific surface area, they are more active and affect the soil matrix. The difference in the particle size contributes to inter-particle filling or interlayer filling, which reduces the void ratio, which will make the soil more resistant to the applied load.

The idea of modifying the engineering properties of the soils is not new. Some of the principles of soil improvement like dewatering, densification, and the use of admixtures have excited thousands of years. In Mesopotamia the area between the Tigris and Euphrates rivers, now Iraq, they use in the ancient time the wood and straw inclusion mixed with mud for “Adobe” (Nicholson, 2014).

Also, from the Chinese civilizations, the written works describe the use of the column and timber inclusions. An early report on soil improvement in 1978 was that of the ASCE Committee on placement and improvement of soils which it was noted: “Soil, nature’s most abundant construction material, has been used by man for his engineering works since prior to the beginnings of recorded history” (ASCE, 1978). In the nineteenth century 19th during the great industrial revolution and the development of the machinery and equipment has a greater effect on increasing the efficiency of the ground improvement techniques and decrease of its problems. In Europe, in the twentieth century 20th, and to our present days many ground modification techniques have been developed by contractors during their implementation of projects as well as geological institutions.

MATERIALS AND METHODS

This paper reviews and discussed soil stabilization by using the nanomaterials as additives and analysed their effect on soil. A series of bibliographic references, which are reported below, were analyzed.

Jarrahzadeand Bajestan (2010), studied the change of clay structure by nanotechnology due to soil stabilization in both urban and rural roads. They have suggested a new and cheaper method to improve soil properties than usual methods. Their studies are based on changing clay structure by nanotechnology. It will change to be hydrophobic after it is hydrophilic. They used several sheets made of silica and alumina. The water is strongly bound to the surface of the clay particles and cannot be removed by sunlight drying or using ovens. Still, it can be removed easily by using chemicals called con-aid, which causes an ion exchange and takes place on the surface of the clay. On the other hand, the adsorbed water will displace or remove to make the clay in a hydrophobic state. Their results show that nanocomposites of clays can reduce the thickness of the asphalt from 27 cm to 5 cm.

Majeed et al., 2012, studied the effect of nanomaterial treatment on the geotechnical properties of Penang soft soil. A different nanomaterial, nano-MgO, nano-clay, and nano-Cu, with proportions ranging from 0.05% to 1%, and added to soft soil samples from the State of Penang to investigate and study their effect on geotechnical properties. Atterberg limits, linear shrinkage, dry unit weight, moisture content, and shear strength of the soil were determined, and it is decreased with increasing the percentage of nanomaterials. On the other hand, the increase of nanomaterials due to an increase in the maximum dry density generally indicates soil improvement. Also, the optimum moisture content increased, and the results showed that the compressive strength of the soil increased with nanomaterials.

In 2014, Majeed et al. studied how to modify and stabilize soft soil by using nanomaterials. Three types with less than 1% are used in this research: nano-magnesium, nano-copper, and nano-clay. Nanomaterials were added to the soft samples collected from two different sites in Malaysia. The results show that nanomaterials' addition decreases the linear shrinkage, liquid limits, plastic limit, and plasticity index. On the other hand, the dry maximum density and the compressive strength of the soil increase with increasing the amount of nanomaterial and decreasing the optimum water content.

Babu and Joseph, 2016, presented an experimental work. They studied the effect of adding different nanomaterials nano Fly ash and nano Titanium Dioxide (TiO_2) with a proportion (0.5%, 1%, 1.5%, 2%) on the samples of soft soil collected from the Nedumudi region of Kuttanadu. Their results showed that the increasing amount of nano fly ash and TiO_2 decrease the liquid limit and plastic limit by around 60%. Optimum moisture content decreased by 5.2%, the maximum dry density increased by 2.94%, and the shear strength increased to twice the original value. Also, they noticed that the nano fly ash is better than TiO_2 for reduction settlement at the optimum percentage of nano fly ash and Titanium Dioxide (67%, 60%), respectively.

Priyadharshini and Arumairaj, 2015, investigated the effect of adding three types of nanomaterials, nano-Al_2O_3 and nano-MgO and nano-clay, with a different percentage to soft clay samples, consistency between (0.25-0.5) and UCS between (25 to 50) kN/m^2 experimentally. Their model studied the conducted in a steel tank of (30 x 30 x 30) cm with (6 x 6) cm square footing to determine the load-carrying capacity of the footing for soft clay with nanomaterials. The results showed that the increasing amount of nano-Al_2O_3 and nano-MgO decreased Atterberg's limits and the increase in nano clay amount increase the Atterberg's limits. The optimum moisture content increases when the amount of nano-Al_2O_3 and nano clay increases, and vice versa for nano-MgO. Also, increasing the amount of nano-Al_2O_3 and nano clay leads to a decrease in the maximum dry density, and an increase in the amount of nano-MgO leads to an increase in the maximum dry density. The unconfined compressive strength increases up to 43% for 0.75% of nano-Al_2O_3 and 41% for 0.3% nano-MgO and 48% for 1% nano-clay. Their study also found that nano-MgO reduces the settlement better than the nano clay and nano-Al_2O_3.

Subramani and Sridevi, 2016, studied the effect of nanomaterials nano-cement and nano-clay, with the various percentages ranging from (0.5% to 2%) on the soft soil (peat). Consistency limits, compaction characteristics, and compressive strength are determined in their investigation. The results showed that the increase of nanomaterials increases the maximum dry density, indicating improvement in geotechnical properties. The unconfined compressive strength increases when one increases the number of nanomaterials and the plasticity index decrease with an increase in the number of nanomaterials. Also, they found that when combined, addition (1% nano-clay and

1% nano-cement) gave maximum strength compared with 2% nano-cement and 2% nano-clay.

Mostafa et al. (2016) investigated the stabilization of subgrade pavement using nanomaterials (nano-silica and silica fume) with various amounts. They used 1, 2 and 3% for nano-silica 5, 10 and 15% for silica fume while used 2, 4, 6 and 8% for lime. Their study was to estimate the physical and mechanical properties using the Atterberg limits test, direct shear test, free swelling, modified proctor test, unconfined compressive strength, and California bearing ratio. They did unconfined compressive strength and free swelling test after two curing periods, 7 and 28 days. The results showed that the maximum dry density decreased, and the optimum moisture content increased for all user activities, the unconfined compressive strength increased; also, they noticed that the maximum drop in free swelling was when used a combination of (8% lime + 15% silica fume) and (8% lime +3%nano silica).

Majeed et al., 2016, analysed and studied the geotechnical properties of the soft soil after mixing it with a different percent of nanomaterials (nano-MgO, nano-Al_2O_3, and nano-Cu_2O). They determined the compressive strength, dry unit weight, and moisture content. They found that the soft soil's compressive strength and dry density increased with increasing the number of nanomaterials; at the same time, the moisture content decreased.

Naval et al., 2017, studied the effect of different percent of nanomaterials, 0.5%, 1.0%, 1.5%, and 2.0%, from nano-Al_2O_3 and nano-MgO on the properties of expansive soils. They found out that the swelling potential of the soil decreased when the number of nanomaterials increased from 0 to 2%. This decrease is due to a decrease in the values of liquid limit, plastic limits, and plasticity index of the soil. This may be a structural unit of kaolinite mineral composed of silica and gibbsite sheets. When water enters, it causes swelling, in the other hand, the additional nanomaterials led to fill the tiny pores, and therefore reduce the amount of water into these units of the structure, thus decreasing the swelling of the minerals. Also, the maximum dry density increases with increasing the number of nanomaterials.

Rajendiran's and Vadivel's, 2016, study was made on a neat cementitious grout with a w/c ratio 1.20 incorporated with different percent (0%, 0.10%, 0.50%, 1.0%, 1.50%) of nano-silica (SiO_2). They found that the bleeding potential decreased with an increase in the amount of nano-silica. On the other hand, they found that the neat cement grout had unstable high bleed ability. Also, the specimen that was treated with nano cementitious grouted was found more impermeable to water, and compressive strength increased 1.6 times that treatment with neat cement grouted. The nano-silica (SiO_2) added cementitious grout shows improvement of engineering properties as well as the fresh mixed grout properties.

Taha and Ashraf, 2018, studied the effect of Carbon Nanomaterials (carbon nanotube was compared to carbon nanofiber) on sandy clay soil improvement. The maximum percentage of nanomaterials was used in their study was 0.2%. They found that the pH, the specific gravity, and the maximum dry density of the mixture soil-nanomaterials increase with the addition of nanomaterials. The results of the hydraulic conductivity test showed that nanomaterials reduce the value coefficient of permeability, and the sample of the soil treatment with carbon nanofiber (CNF) appears a higher reduction of hydraulic conductivity when compared with the use of carbon nanotube (CNT).

Table 1. Summary of the experimental studies on improving soils with nanomaterials

Author	year	Nanomaterial type	Soil type	Results
Jarrahzade et al.	2010	silica and alumina	Clay	Nanocomposites of clays have the ability to reduce the thickness of the asphalt from 27 cm to 5 cm
Majeed and Taha	2012	MgO, nano-clay, Cu	Soft soil	increase in the maximum dry density and compressive strength of the soil increased
Majeed and Taha	2014	nano-magnesium, nano-copper, and nano-clay	Soft soil	decreases the linear shrinkage, liquid limits, plastic limit, and plasticity index
Babu and Joseph	2016	Fly ash and nano Titanium Dioxide (TiO_2)	Soft soil	decrease the liquid limit and plastic limit by around 60%. optimum moisture content decreased by 5.2%, the maximum dry density increased by 2.94%, and the shear strength increases to twice the original value
Priyadharshini et al.	2015	Al_2O_3, MgO, nano-clay	Soft clay	the increasing amount of nano Al_2O_3 and nano MgO decrease in Atterberg's limits and increase in nano clay amount increase the Atterberg's limits. The optimum moisture content increase when increasing the amount of nano Al_2O_3 and nano clay, and vice versa for nano MgO. The unconfined compressive strength increases up to 43% for 0.75% of nano Al_2O_3 and 41% for 0.3% nano MgO and 48% for 1% nano clay
Subramani et al.	2016	Nano-cement and nano- clay	Soft soil-peat	increases the maximum dry density, the unconfined compressive strength increases, and the plasticity index decrease
Mostafa et al.	2016	nano-silica and silica fume	Subgrade pavement	the maximum dry density decreased, the optimum moisture content increased, and the unconfined compressive strength increased
Majed and Taha	2016	MgO, Al_2O_3, Cu (2)O	Soft soil	the compressive strength and the dry density of the soft soil increased, and the moisture content decreased
Naval et al.	2017	Al_2O_3, MgO	expansive soils	the swelling potential of the soil decreased, decrease in the values of liquid limit, plastic limits, and plasticity index of the soil, and the maximum dry density increases
Vadivel and Stalin	2016	Nano-silica (SiO_2).		compressive strength increases 1.6 times
Taha and Ashraf	2018	Carbon Nanomaterials	Sandy clay	the PH, the specific gravity, and the maximum dry density of the mixture of soil-nanomaterials increase and reductions in the value coefficient of permeability

RESULTS AND DISCUSSIONS

SEM SCANNING ELECTRON MICROSCOPY AND TEM TRANSMISSION ELECTRON MICROSCOPY

Understanding the nature and the structure of materials has always been significant. Scanning electron microscopy and transmission electron microscopy is a high-resolution electron microscope used for the measurement of nanoparticles, which can observe the specimen surface and resolve down to 10 nm. And it's considered a direct method to provide information about the particles at the nanoscale level like the shape, the dimension, and the morphology of the particles (Figures 1 and 2).
By this technology, we can observe if there is a change in the soil matrix and/or the formation of the bonds between the particles (Goldstein, Joseph, 2017).

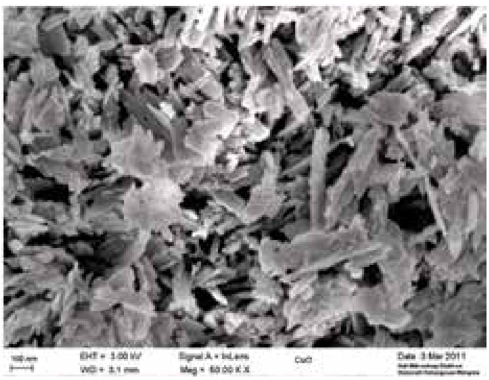
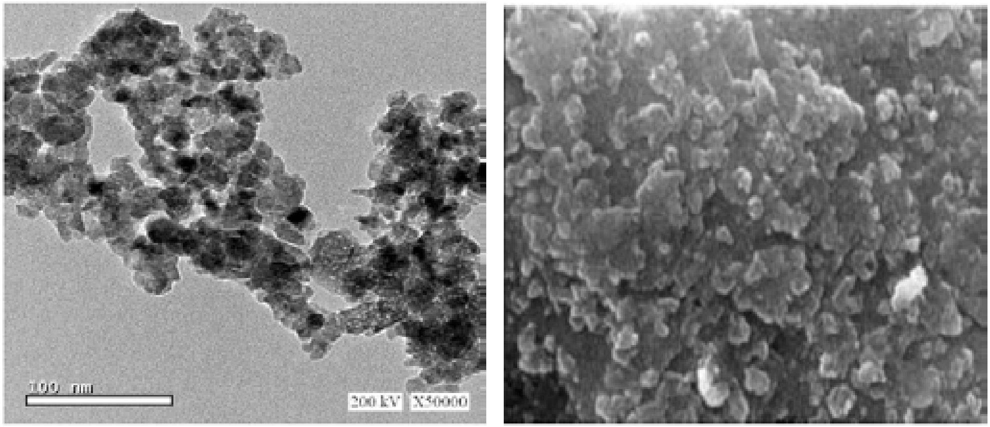


Figure 1. Nano-CuO particles under SEM (Majeed and Taha, 2016)

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064



a. b.

Figure 2. a) SEM of CuO nanoparticles b) SEM of CuO nanoparticles (Barbara et al, 2015)

X-RAY DIFFRACTION

X-ray Diffraction is a rapid analytical technique mainly used for phase identification of a crystalline structure also can give information about the cell dimension. It is considered one of the most important tests when studying stabilized soil to find out the changes in the phase mineralogical reaction. By x-ray diffraction, it can be seen if there is an effect of the materials additives on the soil samples (Figure 3) (Alfaryjat et al., 2015).

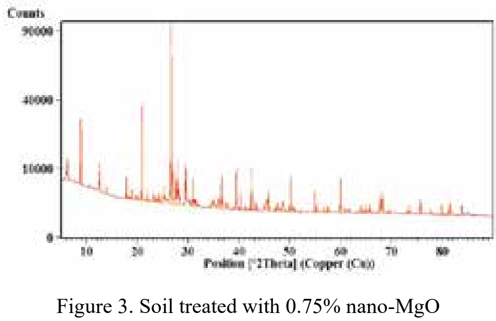


Figure 3. Soil treated with 0.75% nano-MgO (Al-Rubaye et al., 2021)

NANOPOWDER/CEMENT DESCRIPTION AND APPLICATIONS

Aluminum Oxide (Al_2O_3) is a white powder consisting of alpha phase aluminium oxide. It is used in many applications such as oxide ceramic, nanocomposites materials, biomaterials, catalyst support, and wear resistance additives also has been used in recent years in various engineering projects, as well as in improving the properties of soft soils and making them suitable for many engineering requirements (Table 2, Figure 4). The SEM microscopy measurement for nano-Al_2O_3 can by observed in Figure 7.

Table 2. Properties of nano- Al_2O_3

Parameter	Value / comment
Formula	Al2O3
Colour	White
Purity	99.9 %
density	3.95 g/cm^3
D50	10-50 nm
Specific surface area (SSA)	≤ 50 m^2/g

Figure 4. Nanoparticle of Al_2O_3

Magnesium oxide (MgO) is a fine white powder made up primarily of magnesium oxide particles ranging from (10 to 30) nm in diameter (Table 3). It is used for refractory materials, electric insulation, dehydration, fuel additive, and fire retardant, in addition to its multiple uses in construction. The SEM microscopy measurement for nano-MgO can by observed in Figures 5 and 8.

Table 3. Properties of nano- MgO

Formula	MgO
Colour	White
Purity	99.9%
Bulk density	0.1 g/cm^3
D50	10-30 nm
Specific surface area (SSA)	>50 m^2/g
Melting point	2.852°C
Boiling point	3.600°C at 1.013 hPa
Density	0.13-0.16 g/cm^3
Water solubility	Insoluble

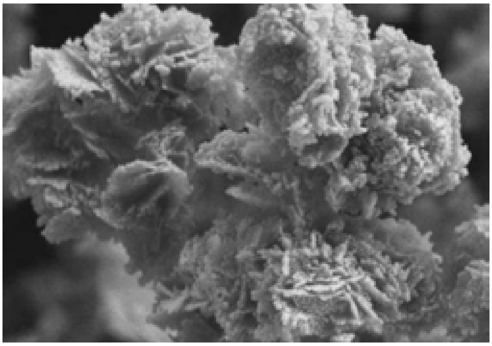


Figure 5. SEM measurement
for nano- MgO (Majeed, 2013)

Zirconium Oxide (ZrO_2) is a white powder with purity reached 99.9% and a density of 5.6 g/cm^3 with particle shape nearly spherical.

It was used in many applications, such as improving the characteristics of cement mortars, pigments and glazes, ceramic, artificial jewellery, fire retardant, abrasives, electronics, pyro-optics, insulation, energy storage, and high-stress (Figure 6).

The SEM microscopy measurement for nano-Al_2O_3 can by observed in Figure 9.

Figure 6. Nanoparticles of ZrO_2

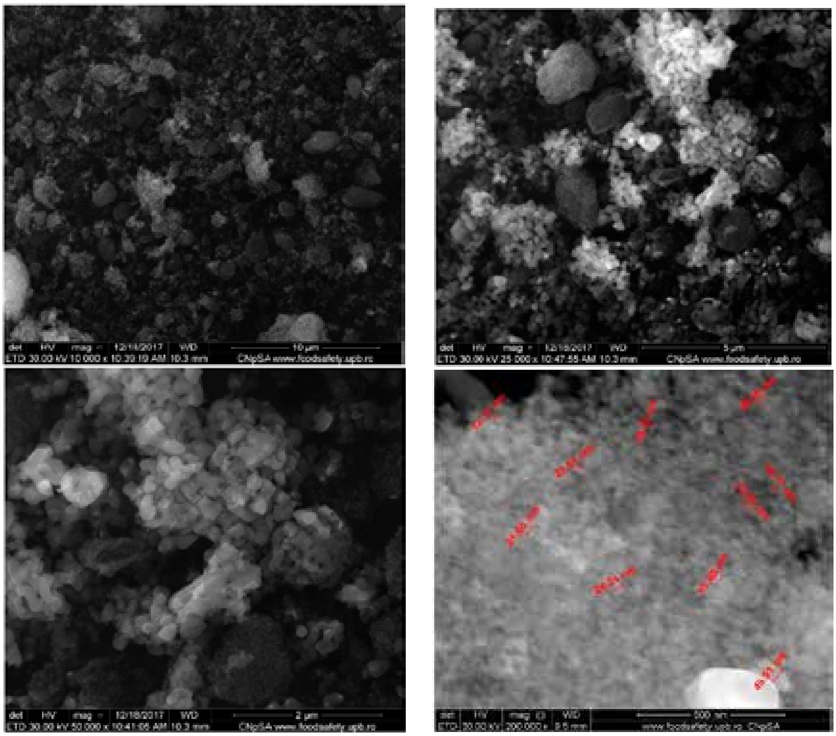


Figure 7. SEM measurement of nano-Al_2O_3 (Alfaryat et al., 2019)

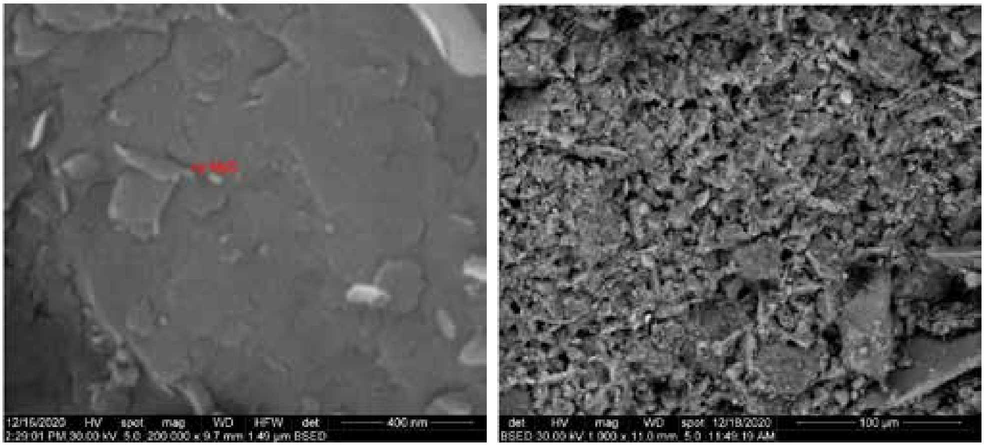


Figure 8. SEM microscopy measurement on soil samples treated with nano-MgO (Al-Rubaye et al., 2021)

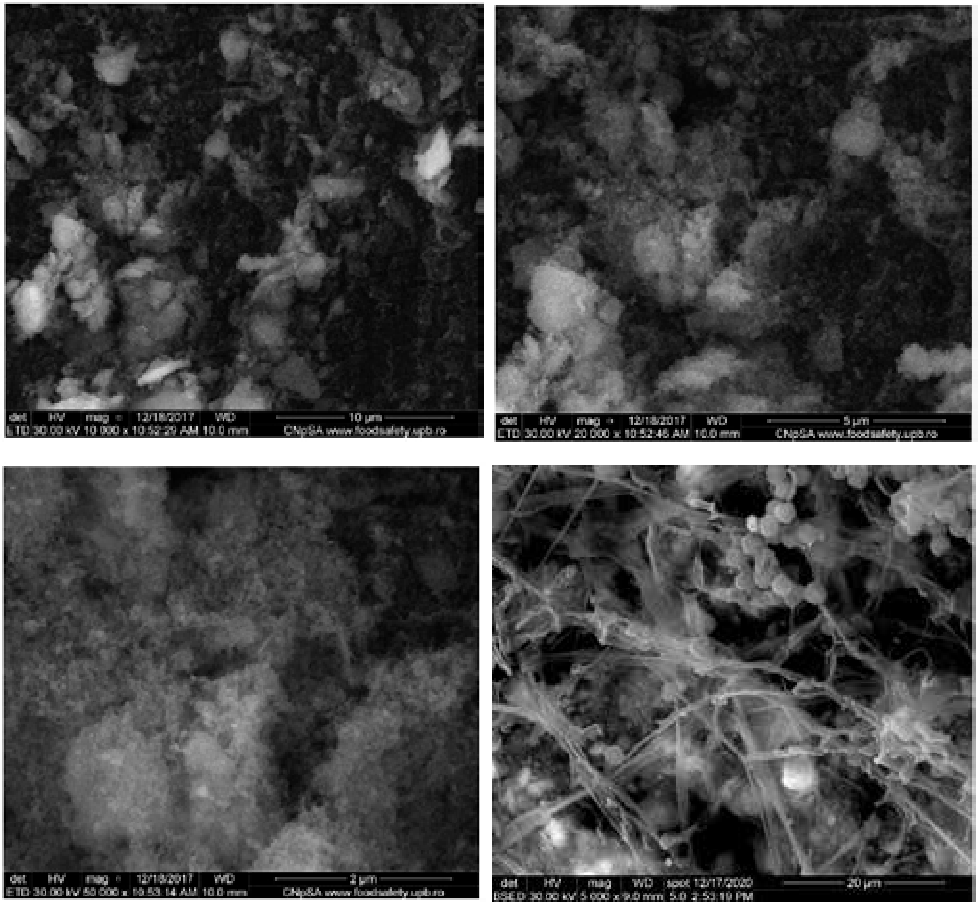


Figure 5. SEM measurement of nano-ZrO_2 (Alfaryat et al., 2019)

The Titanium Dioxide Nanoparticles' (TiO_2) size ranges from (10-30) nm, and they are transparent, chemically stable, and weather resistant. It has several uses in the field of construction, especially when added to the concrete to improve its properties or adding it to the paints and windows for sterilization purpose, as well as adding it to the surfaces of the external building to reduce and prevent damage to it, thus reduce the maintenance times and costs. Also, in the field of geotechnical engineering, it has been used to improve the engineering properties of the soil.

Cement is one of the oldest binding materials since the invention of soil stabilization technology, which is added to the soil to improve its properties. The reaction of the cement does not depend on the mineral of the soil, and it appears in any soil with water. It is, in general, an adhesive material that substance in the form of a powder when mixed with water, a hard mass is formed due to the presence of the chemical mixtures of cement compounds with water which results in a gel-like substance with a high surface area, often called cement. There are many applications on the soil-cement like roads, airports, shoulders, storage areas, and subbases for rigid pavement. The SEM microscopy measurement on soil samples treated with cement can by observed in Figure 10.

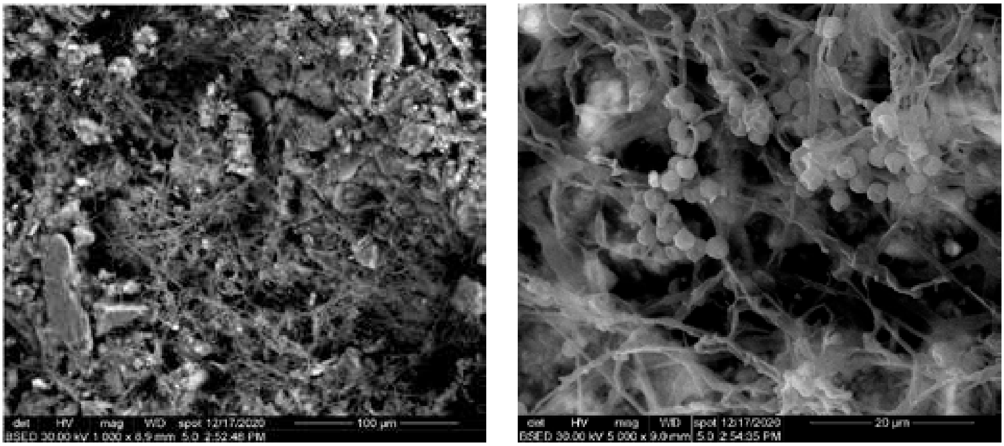


Figure10. SEM microscopy measurement on soil samples treated with cement (Al-Rubaye et al., 2021)

CONCLUSIONS

This paper reviews the nanotechnology and nanomaterials as additives to the soil and discusses the effects and results on the treated soils' physical, mechanical, and chemical properties.

Many types and different percentages of nanomaterials were used in the research, such as nano-clay, nano-Al_2O_3, nano- MgO, Nano Titanium Dioxide (TiO_2), nano-silica (SiO_2). SEM, FEM and XRD were used to study the soil nanostructure. Because of the small particle size and a higher cation exchange capacity can be active and react on the soil matrix. This state-of-the-art study found that soil improvement using nanomaterials depends on the type and the amount of these materials. The addition of nanoparticles to the soil improves its physical and chemical properties.

REFERENCES

https://ssnano.com/nanopowders-micron-powders. (n.d.).

Afrin, H. (2017). A review on different types soil stabilization techniques. *International Journal of Transportation Engineering and Technology*, 3(2), vol. 3, pp. 19-24.

Alfaryjat, Altayyeb, Mariana Florentina Stefanescu, Alexandru Dobrovicescu (2019). Experimental investigation for the thermo-physical properties and stability of CeO2, ZrO2, and Al2O3 mixed with ethylene glycol and distilled water. *REVISTA DE CHIMIE*, 3908-3912.

Al-Rubaye Ahmed, Chirica Anton, Boti Ioan, Olinic Ernest, Olinic Tatiana (2021). Soft soil improvement using Nanomaterial Nano-MgO. *National Conference on Soil Mechanics and Foundation Engineering*.

ASCE (1978). Soil Improvement: History, Capabilities and Outlook. (R. b. Engineering, Ed.) Report by the Committee on Placement and Improvement of Soils of the Geotechnical Engineering Division of the American Society of Civil Engineering, p. 326.

Babu, Sanusha, Joseph Sh., (2016). Effect of nano materials on properties of soft soil. *Int J Sci Res*, 5.8, 634-7.

Bajestan, F. Jarrahzade, M.S. (2010). Changing clay structure by nanotechnology due to soil. *Int. Congr. Nanosci. Nanotechnol*., pp. 1–2.

Barbara, L. Dutrow, M.C. Christine (2015). X-Ray Powder Diffraction (XRD). https://serc. carleton. edu/research _ education/geochemsheets/techniques/XRD. html.

Goldstein, Joseph I. (2017). Scanning electron microscopy and X-ray microanalysis. Springer.

Ikeagwuani, C.C., & Nwonu, D.C. (2019). Emerging trends in expansive soil stabilisation: A review. *Journal of Rock Mechanics and Geotechnical Engineering*, 11(2), 423-440.

Ivasuc, T., Olinic, E., & Siminea, I. (2014). Remarks on main methods of expansive soils improvement. *International Multidisciplinary Scientific GeoConference: SGEM*, vol. 2, 769.

Majeed, Z.H., & Taha, M.R. (2013). A review of stabilization of soils by using nanomaterials. *Australian Journal of Basic and Applied Sciences*, 7(2), 576-581.

Majeed, Zaid Hameed, Mohd Raihan Taha (2012). Effect of nanomaterial treatment on geotechnical properties of a Penang soft soil. *Journal of Asian Scientific Research*, 2.11, 587-592.

Majeed, Zaid Hameed, Mohd Raihan Taha (2016). The effects of using nanomaterials to improvement soft soils. *Saudi J Eng Technol*, 1.3, 58-63.

Majeed, Zaid Hameed, Mohd Raihan Taha, Ibtehaj Taha Jawad, (2014). Stabilization of soft soil using nanomaterials. *Research Journal of Applied Sciences, Engineering and Technology*, 8.4, 503-509.

Mostafa, A., Mohamed S. Ouf, M. Elgendy (2016). Stabilization of subgrade pavement layer using silica fume and nano silica. International *Journal of Scientific & Engineering Research*, 573-81.

Naval, Sanjeev, Kanav Chandan, Diksha Sharma (2017). Stabilization of expansive soil using nanomaterials. Proceedings of the International Interdisciplinary Conference on Science Technology Engineering Management Pharmacy and Humanities, Singapore.

Nicholson, P.G. (2014). Soil improvement and ground modification methods. Butterworth-Heinemann.

Olinic, E., Ivasuc, T., & Manea, S. (2015). Improvement of difficult soils by mixing with mineral materials and inorganic waste. Experimental projects and case studies from Romania. Conference Proceedings - ICE Virtual Library. Geotechnical Engineering for Infrastructure and Development.

Patel (2019). Geotechnical investigations and improvement of ground conditions. Woodhead Publishing.

Priyadharshini, Arumairaj (2015). Improvement of bearing capacity of soft clay using nanomaterials. *Int J Sci Res*, 4.6, 218-21.

Rajendiran, Vadivel (2016). Effect of nano silica on the performance of cementitious grout for ground modification. *Japanese Geotechnical Society Special Publication*, 2.63, 2138-2143.

Subramani, V.; Sridevi S. (2016). Soil stabilization using nano materials. *Int J Res Appl Sci Eng Techno*, 4, 641-645.

Taha, Mohd Raihan, Jamal M. A. Alsharef (2018). Performance of soil stabilized with carbon nanomaterials. *Chemical Engineering Transactions*, 757-762.

Zahri, A. M., Zainorabidin, A.Zahri, A. M., & Zainorabidin, A. (2019). An overview of traditional and non-traditional stabilizer for soft soil. IOP Conference Series: Materials Science and Engineering, 527, p. 012015.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

SEASONAL HETEROGENEITY OF SOIL MICROCLIMATE IN *FAGUS SYLVATICA* FOREST IN RELATION WITH STAND AGE

Cosmin BRAGA[1], Lucian DINCA[1], Gheorghe SPARCHEZ[2], Vlad CRISAN[1]

[1]National Institute for Research and Development in Forestry "Marin Dracea", Closca Street, Brasov, Romania
[2]Transilvania University, Ludwig van Beethoven Street, Brasov, Romania

Corresponding author email: braga_cosmin@yahoo.com

Abstract

The heterogeneity of soil temperature (Tsoil) and soil moisture (Usoil) is recognized as bearing an influence on plant communities, due to the variability of vegetation-specific resource requirements. We tested the temporal differences of heterogeneity of the soil microclimate in an even aged beech forest with four different stand age (10, 30, 80, 120 years) located in the southern part of Romania. The bimonthly measurements of Tsoil and Usoil, made over almost a year (April-December) aimed to investigate the interaction between the age of the trees and these climatic variables in the soil. Both climatic parameters were calculated for each experimental plot for each season and for the entire measurement period. The one-way analysis of variance (ANOVA) was used to test the differences between the plots with trees of different ages for the temporal variability of the soil microclimate. The temporal patterns of soil microclimate differ significantly between tree ages, being more sensitive to Usoil compared to Tsoil. The analysis of our data showed a decrease in Tsoil with the age of the tree in the spring and similar trends in the rest of the measurement periods. On the other hand, the Usoil model showed less seasonality compared to the Tsoil, probably being more receptive to the characteristics of local conditions, such as the slope of the land, the thickness of the litter layer, the porosity of the soil or the degree of closure of the forest canopy. These results can conclude that, the ability of forest at small stand ages will increase seasonal the soil microclimatic parameters (Tsoil and Usoil) at highest levels.

Key words: *forest, heterogeneity, soil temperature, soil moisture, stand age.*

INTRODUCTION

The climate is one of the most crucial environmental factors affecting the forest ecosystem architecture and function (Zheng et al., 2000; Vlad et al., 2019; Ducci et al., 2021; Kutnar et al., 2021). While the effects of macroclimate influence at large scales, the microclimate directly dominates the ecological and biogeochemical processes of ecosystem at local scale (i.e., forest stand, tree species). Likewise, the microclimate is highly interactive with other ecosystem components (i.e., vegetation cover, soils features or topography of terrain) and demand an assessment of the ecosystem behavior (Zheng et al., 2000; Nurudin and Tokiman, 2005).
The dynamic behavior of the forest is being changed by interactions between cover, biotic and abiotic characteristics and especially climatic and microclimatic conditions (Kovacs et al., 2016).
It is well known that, in general, the vegetation cover and in particular, the forest canopy can regulate the climatic conditions and achieve a specific microclimate, by influencing soil temperature regime and the hydrological process (Latif & Blackburn, 2010; Lozano-Parra et al., 2018; Ni et al., 2019; Dinca et al., 2020; Ilek et al., 2021). This local microclimate depends on the climate itself and the physical attributes, with implications in the design (structure and nature) of vegetation cover (Figure 1). In addition, microclimatic variables (i.e., soil temperature and soil moisture) can act as drivers for simulating the plant water status and photosynthesis (Zheng et al., 2000; Ozcelik and Sengonul, 2021).

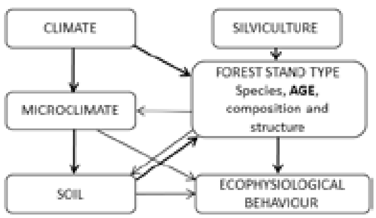


Figure 1. Interactions between climate and forest stand (Adapted by Gilbert Aussenac, 1999)

Other factors such as elevation and exposition can alter soil microclimate fundamentally (especially soil moisture) with potential impact in development of forest (Pichler et al., 2009; Dinca et al., 2020). One the other hand, lower levels effects on soil microclimate (i.e., temperature and moisture) can be influenced by soil features and stand characteristics, such as humus content, the amount of litter layer, species composition, age and vertical structure of stand, cover and distribution of vascular plants, etc. (Kovacs et al 2016, Fekete et al., 2019). Both tree age and heterogeneity together with silvicultural interventions are the variables that explain the most variability of species composition from the local to regional scale (Aude & Lawesson, 1998; Dinca and Achim, 2019). Therefore, solar radiation modulated by phenology is a considerable environmental parameter for competition, restraining vegetation survival and plant growth (De Frenne et al., 2013). Indeed, phenological behaviour can differ greatly when taking in consideration trees of different development stages, specific each of forest age stand (Gressler et al., 2015).

Forest structure (e.g., vertical complexity) can directly control the amount and variability of light (De Frenne et al., 2013), while the amount of litter can alter bellow-canopy microclimate culminating in reduced soil water evaporation or change albedo (Fekete et al., 2019). In addition, it has been shown that the forest canopy is an important driver in controlling stand climate. Besides, age stand can influence thermodynamic efficiency, absorb and dissipates incoming solar energy more efficiently (Kovacs et al., 2016; Dinca et al., 2019).

However, while many studies have focused on the relationship between age stand, forest structure and vegetation dynamics (Murariu et al., 2021), relatively little attention has been given to understanding the link between age forest and soil microclimatic conditions throughout all seasons. The aim of this study is to explore the dynamics of soil microclimate in even age deciduous forest, in particular the effect that stand age poses on soil temperature and soil moisture.

The specific objectives of our study were as follows:

(1) to determine soil microclimate variability per each season (Spring, Summer, Fall and Winter);

(2) to highlight the link between soil microclimate components (temperature and moisture) and gradient of stand age.

In order to achieve the objectives, we conducted a study on even age beech forest, in four age classes (10 years-old, 30-years-old, 80-years-old, 120-years old). The analysis of influence of stand age on seasonal soil microclimate was carried out over unreplicated age classes.

MATERIALS AND METHODS

Study area, experimental design and soil microclimate measurements

Field investigations were conducted in the Experimental Forest District Mihaești (Argeș county) managed by the National Institute for Research and Development in Forestry "Marin Drăcea", throughout the southern part of Romania (Figure 2).

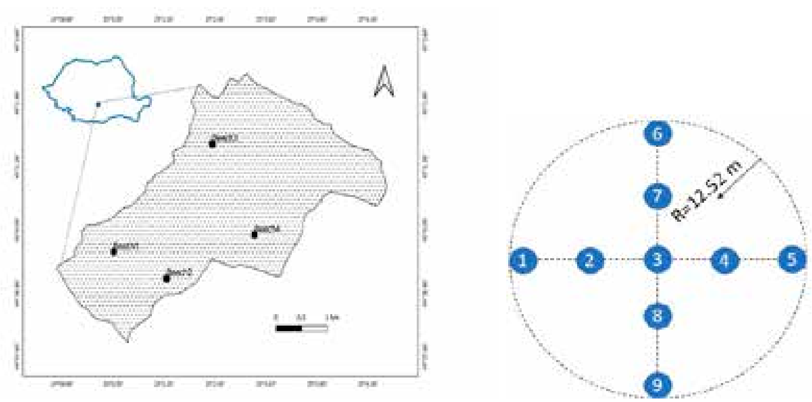


Figure 2. The location of soil microclimatic sites and sampling design (filled blue circles) within a 0.05 ha plot

According to Köppen and Geiger, the climate for all experimental sites is characterized by temperate continental, classified as *cfb*, with a mean annual temperature of 9.5°C and mean annual precipitations of 867 mm, respectively. July is the hottest month with an average temperature of 20.1°C and January is the coldest month with -1.7°C. The rainiest month is June (117 mm) and the driest month is February (44 mm) (estimates calculated using climate-data.org) (Figure 3).

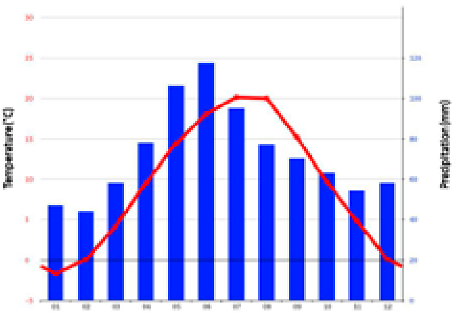


Figure 3. Climate-diagram of air temperature (red line) and precipitations (blue column) of Mihaești region (climate-data.org)

The mean elevation is 525 m, ranging from 509 to 541 m above sea level (Table 1), with small modification of topography, with the most common landscape elements being hills. According to the FAO World References Base (Târziu and Spârchez, 2013), the most frequent soil type is Eutric Cambosols (clay loam), covered with mull type, developed on a sandstone with marls parental material (Braga and Spârchez, 2014; Heres et al., 2021). The forest cover of the studied region is highly heterogeneous, both tree species composition and stand structure vary among the stands. The dominant tree species in the region is beech (*Fagus sylvatica* L.), although other tree species may also be present: sessile oak (*Quercus petraea* Matt. (Liebl) and peduculate oak (*Quercus robur* L.), hornbeam (*Carpinus betulus* L.), sweet cherry (*Prunus avium* L.) or sycamore (*Acer pseudoplatanus* L.). The European beech trees within the study stand differ by site, from younger (main age at 10 years) to adult (main age at 120 years), which allows to consider it as an even aged forest stand by each site, with the oldest stand being mature for harvest. All the stands in the present study, within a 1 km radius, had reached canopy closure and were characterized by a nearly heterogeneous herbaceous vegetation. The age of beech stand was provide by the forest administration (Management Plan of Experimental forest district Mihaești). According to the general protocol (Braga and Sparchez, 2014) forest structure around each soil microclimate measurements (500 m^2 area) were inventoried: the diameter of breast height (DBH, cm) and total height of the tree, (H, m). After that, we determined the tree density (N, stem ha^{-1}), the basal area (BA, m^{2}ha^{-1}) and the volume (V, m^{3}ha^{-1}) within a 12.52 m radius (R) based on the stem mapping database of the all 4 stands age (Table 1, formula 1 and 2).

$$BA = \frac{\sum_i^n\left(\left(\frac{1}{2}\right) \times DBH_i\right)}{R^2} \qquad (1)$$

$$\log V = a_0 + a_1 \log DBH + a_2 log^2 DBH + a_3 \log H + a_4 log^2 H \qquad (2)$$

where: a_0, a_1, a_2, a_3, a_4 represent the regression coefficients for each tree species (Giurgiu et al., 2004).

Soil microclimate measurements (temperature and moisture) were carried out in two perpendicular transects within a 12.62 m radius (500 m^2) of each stand age. Within 500m^2 plots, a series of nine points at 6.26 m were permanently marked per stand for soil microclimate measurements (Figure 2).

Table 1. The main characteristics of each site (Geographic coordinates, A - stand age, DBH - diameter of breast height, N - number of trees per ha, BA - basal area, V - volume of trees per ha.). The stand age was provided by the forest administration and the rest of date was determined

Site	Latitude (N)	Longitude (E)	Altitude (m)	A (years)	DBH (cm)	N (N/ha)	BA (m^2/ha)	V (m^3/ha)
Beech1	44.9930	25.0002	509	10	3.2	4438	9.2	23.1
Beech2	44.9846	25.0209	517	30	8.6	1237	18.3	77.6
Beech3	45.0271	25.0389	553	80	32.5	532	27.3	456.5
Beech4	44.9984	25.0554	541	120	44.8	323	33.2	346.8

The soil temperature (Tsoil) was measured to a depth of 10 cm in all 9 measurement points per each plot, using a specific device (CEM DT 131, UE). Simultaneously to the Tsoil measurements, the soil moisture (Usoil) was measured to a depth of 20 cm at the same positions, using the time domain reflectometry technique with *a FieldScout TDR 300 (Spectrum Technologies Inc., USA).* All soil microclimate measurements were done, in general, bimonthly throughout all unfrozen season (from April to December).

Statistical analysis

In order to test the hypothesis that mean values of the dependent factors (soil temperature and soil moisture) differ for each type of forest site (stand age), one-way analysis of variance (ANOVA) was used. Assumptions were examined by Levene's test for homogeneity of variances (Snedecor and Cochran, 1980). The analysis was run independently for every sampling period (Spring, Summer, Fall and Winter) for all variables. When groups were significantly different, ANOVA were followed by Tukey's HSD test. When p value < 0.05, examined values were expressed to be significantly different. All statistical analyses were performed using Statistica 7.1. (Statsoft, Inc., 2005).

RESULTS AND DISCUSSION

Seasonal variability of soil temperature (Tsoil) and soil moisture (Usoil)

As we expected, both soil microclimatic dependent variables (i.e., Tsoil and Usoil) followed a different pattern during the study period (Table 2, Figure 4).

On the one hand, Tsoil accomplished large seasonal changes, culminated during the summer embracing its minimum during the winter (Table 2, Figure 4A).

Furthermore, values of soil moisture accomplished less seasonality, reaching a minimum during summer, but being more stable and similar for the rest of the year (Table 2, Figure 4B).

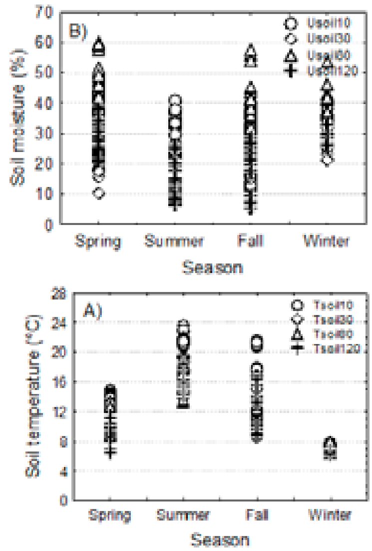


Figure 4. Seasonal (i.e. spring, summer, fall and winter) pattern of A) soil temperature and B) soil moisture for 10, 30, 80 and 120 old stand

Relationship between soil microclimate variables (Tsoil and Usoil) and stand age

In spring, the lowest value of soil temperature at 10 cm depth was recorded at the 120-year-old stand and the highest value was recorded in the youngest stand (Table 2). Besides, the highest value along all period of measurements, was recorded in summer (20.41±1.91˚C), in the rest of site being recorded relatively similar values.

Moreover, the same trend was reported during the fall. As expected, the lowest soil temperature, was recorded in the winter season, and the value between plots was relatively similar.

Soil moisture determined in the first 20 cm of the soil profiles experienced less seasonality, with the lowest value recorded in summer 3.21±3.37%, 30-year-old stand) and the highest value recorded in spring time (46.10±6.07%, 80-year-old stand). However, throughout all periods of measurements, the 30-year-old stand averaged soil moisture significantly lower in comparison with the rest of the stands (Table 2).

Table 2. Mean and standard deviation values of soil microclimate (soil temperature and soil moisture) for ich season in each site (n = sampling dates in which an average of 9 points per site were sampled)

Season	n	Soil temperature (°C)				Soil moisture (%)			
		10-year old	30-year old	80-year old	120-year old	10-year old	30-year old	80-year old	120-year old
Spring	3	13.47±1.16	11.80±1.54	10.57±1.33	9.26±1.78	31.22±5.75	27.05±6.36	46.10±6.07	27.66±4.12
Summer	6	20.41±1.91	16.45±1.88	16.79±2.16	16.33±1.57	21.02±7.13	13.21±3.37	32.18±8.17	13.60±4.63
Fall	5	15.17±4.13	12.71±2.97	12.90±3.15	12.69±3.12	20.86±6.23	14.68±5.71	33.70±9.62	16.59±7.61
Winter	1	7.28±0.33	7.27±0.29	7.27±0.53	6.56±0.23	30.69±3.80	27.60±4.89	42.58±4.94	28.71±2.18
Annual	15	16.21±4.57	13.55±3.35	13.42±3.75	12.81±3.87	24.12±7.88	18.03±8.00	36.78±9.93	18.99±8.24

Note. The above-mentioned statistics have been calculated both at the seasonal level (i.e., spring, summer, autumn and winter) and over the four seasons combined (i.e., annual).

Soil temperature (Tsoil) and soil moisture (Usoil) measured at each site were compared with the one obtained at their references sites by mean one-way repeated-measures ANOVA.

In spring time, when performing soil microclimate measurements, throughout all plots, we found significant differences in mean soil temperature, between the 10-year-old stand and the rest of the plots ($p < 0.05$, Figure 5A). Not the same thing happened in the rest of the year, where only the 10-year-old plot recorded differences between the others plots in summer and fall seasons (Figure 5B and 5C). In addition, in the winter season, only the 120-year-old plot recorded significant differences on soil temperature from the rest of plots ($p < 0.05$, Figure 5D).

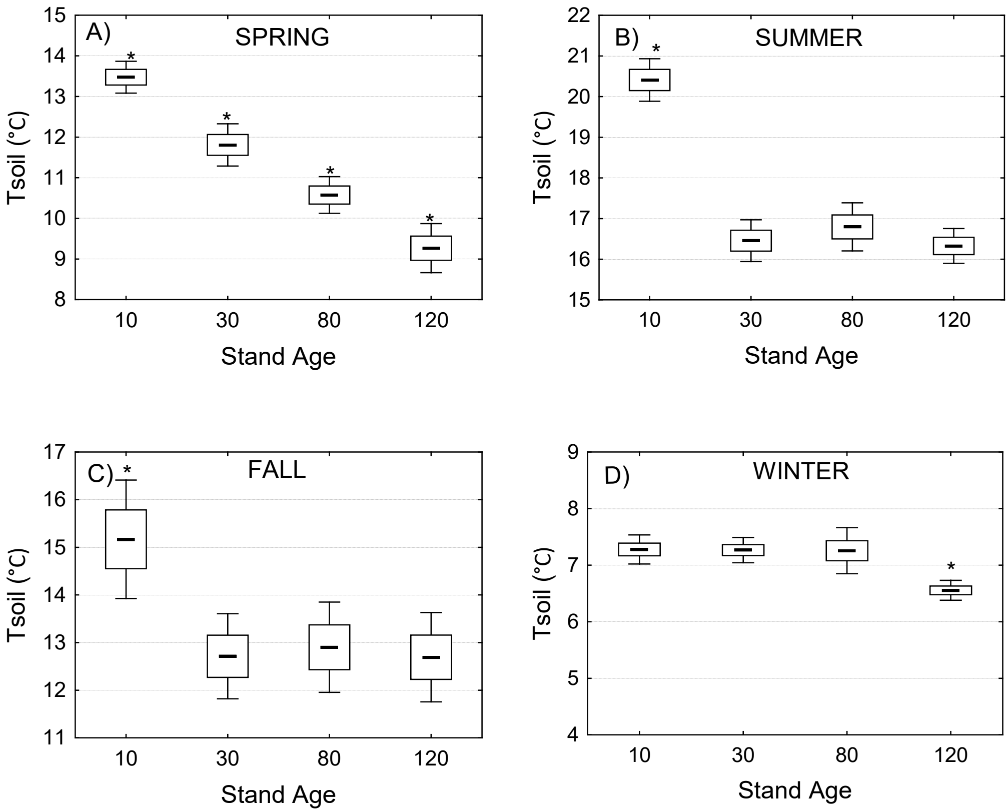


Figure 5. Seasonal variation of soil temperature in the different stand ages. Box-plots represent the mean value and error bars are standard errors of the means. Asterisk (*) symbol denote significant correlations at the $p < 0.05$.

On the other hand, we found a similar trend by significant differences ($p < 0.05$) of the soil moisture pattern for Spring, Summer and Fall season (Figure 6A, B, C), where the 10-year-old and the 80-year-old recorded significant differences compared with the other plots ($p < 0.05$), the 30-year-old and the 120-year-old. In winter (December), the seasonality of Usoil followed a pattern similar with the rest of the seasons (year), but the mean value of Usoil recorded a significant value only for the 80-year-old stand ($p < 0.05$, Figure 6D).

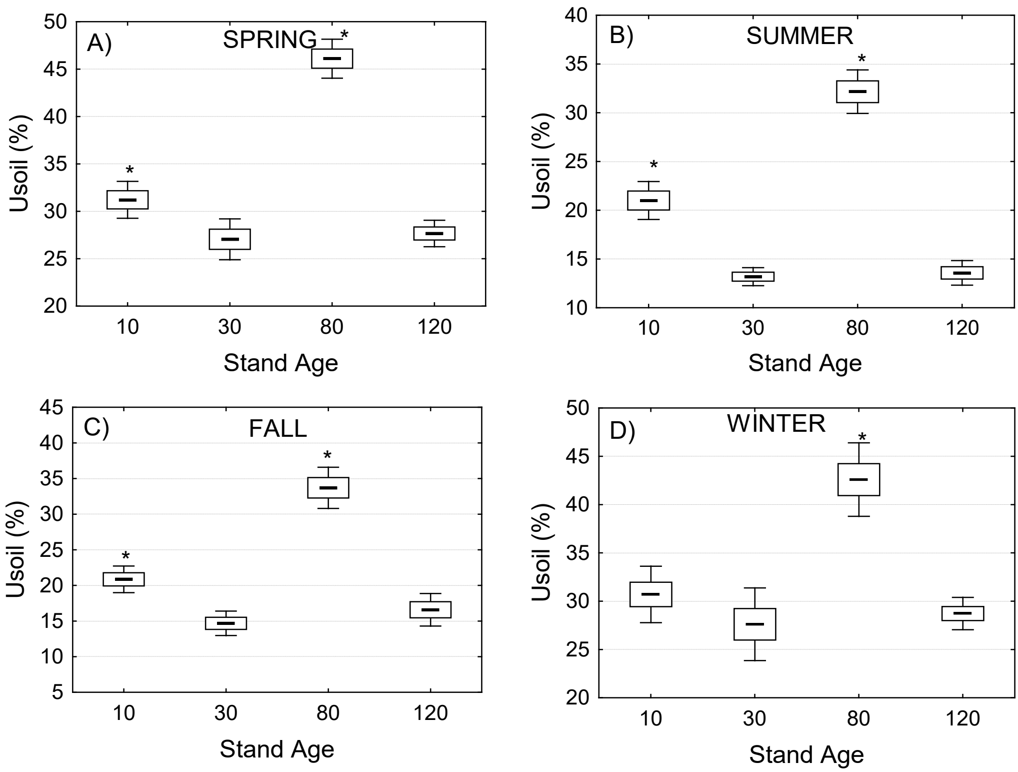


Figure 6. Seasonal variation of soil moisture in the different stand ages. Box-plots represent the mean value and error bars are standard errors of the means. Asterisk (*) symbol denote significant correlations at the $p < 0.05$

As we expected, seasonal variation (April to December) of soil microclimate in beech forest developed a similar trend for all sites (Figure 4) and was much larger in soil moisture heterogeneity than in soil temperature variability, between stands age (Table 2, Figure 5, Figure 6). Our results demonstrate the influence of stand characteristic (i.e., age stand), but they also suggest that the importance of tree age is lower than we had expected. The limitation may be attributed to the variability of other soil characteristics, such as soil porosity, local topography, thickness of litter, forest structure (Kovacs et al., 2016; Ni et al., 2019; Onet et al., 2019). The analysis of the experimental plots (different age stands) showed a decrease of soil temperature with stand age in the spring season and a similar decreasing trend in the summer and the fall period (Figure 3). A possible explanation for the fluctuation of soil temperature between the studied sites can be done by the amount of the litter layer, which is larger in older stands (Braga & Sparchez, 2014). The soil temperature under the youngest stand (10-year-old) recorded the highest value for the vegetation season (Spring, Summer and Fall) and insignificant differences between sites in December. Indeed, the annual litterfall quantity can act as a buffer zone which regulates the particularity of the soil temperature regime (Fekete el al., 2019). As we expected, in colder periods of measurements (i.e., December period), the influence of age stand on soil temperature was insignificant, with the exception of the 120-year-old stand where the mean value determined was much lower (Table 2, Figure 6). An explanation for the frozen period (cold December) can be given by the low activity of the trees due to a very weak metabolism of the fine roots. Indeed, the soil temperature reduction could limit the growth vegetation (Alvaria Uria & Korner, 2008). Furthermore, the roots expansion of most plants could stop at temperature below 5°C (Vapaavuori et al., 1992; Ni et al., 2019), even if in our study the soil temperature values recorded in December was much higher than this threshold (Table 2). Moreover, the thickness of the litter layer can have an isolating response on the soil temperature regime (MacKinney, 1929) by delaying freezing in temperate zone (Sayer, 2006). On the other hand, the soil temperature regime can be influenced by a soil biochemical process. Through the decomposition of organic matter and soil biota activities, a significant amount of heat can be released, with substantial repercussions on the soil microclimate regime (Holst et al., 2004; Fekete et al., 2016; Onet et al., 2019). As more sunlight reaches the ground, the range of soil surface temperatures increases and moisture balance are altered (Zheng et al., 2000), with implications in regulating the hydrological process (Ni et al., 2019). The 80-year old stand was the most significant driver in the maintenance of soil moisture microclimates, while the 10-year-old stand was the most significant driver in the maintenance of the soil drought. One cause can also be attributed to the presence and thickness of the litter layer, one of the factors that highlight the extent of the canopy, especially mature trees that have similarities in maintaining certain climatic conditions. On the other hand, the 80-year-old stand was not affected by natural perturbation (windbreaks or insect attacks) or anthropic interventions (silvicultural practice) in the last decade, confirmed by the forest management plan. In this case (i.e., Beech80 site), characterized by high-density trees with a big crown, the forest canopy intercepted all the water content from precipitation events at low intensity (< 10 mm), but allowed infiltration during larger rainfall (James et al., 2003). At the same time, for younger trees (Beech10 and Beech30 sites) the balance between interception and evaporation of water at soil surface from precipitation events was more or less different, with implications in the hydrological process (Figure 5). Furthermore, the litter horizon (e.g. dead leaves, bark, twigs) allows more or less the infiltration of water to high depths in the soil profile and reduces the evaporation from the mineral horizon of soil while absorbing a fraction of the rainfall. These facts strongly suggest that the soil water regime acts as a bridge between deficits in precipitation and failures of plant growth (Shinoda & Nandintsetseg, 2011).

Although the maximum value of the trees volume (Beech80 site) linked to the close canopy, recorded throughout all growth vegetation, the highest value of Usoil compared with others sites. However, there is a level of canopy density, which is probably correlated to site specific soil water availability. One the other hand, the canopy density was much lower in early spring and only reached high values after leaves were fully developed, with repercussions on the soil climatic regime (Georg von Arx et al., 2013).

The local conditions (Mihaești region) confirm the variability of the phenology during a year, namely the beginning and the end of the beech phenology (when the leaf begins to develop until the moment it falls at the end of autumn). There is a difference in phenology in terms of the stand age. Spring young trees start the foliage sooner compared to old trees. The end of the phenology shows the opposite situation, when leaf fall in old trees takes place later than in young trees (young tree leaf sooner and lose the leaf faster while the old trees' leaf later on and lose the leaf later) (Sidor, 2014). Further, the onset of phenological phases in the first part of the year is generally controlled by the total value (sum) of effective air temperatures preceding the phase (Bednarova &Merklova, 2007) even if the start of the phenophase can substantially differed by approximately half a month among individual trees, under different density canopy (Schieber, 2006). Additionally,

the phenological pattern of Fagus sylvatica can be different among trees, especially if they possess a different age. Indeed, the seedlings leafed out almost a month earlier than the adult tree, and an ontogenic effect might be responsible for this discrepancy (Gressler et al., 2015). Furthermore, the photoperiod duration, the temperature intensity and the amount of precipitation are the most climatic variables which control the phenological process of each individual trees (Schieber, 2006).
However, even though the soil temperature variable is controlled by the full verticality of the vegetation cover (Aussena, 2000), the effects of forest characteristics (i.e. structure, age) on soil moisture may be difficult to determine, as reduction in canopy cover may lead to more evaporation from the soil surface, but less transpiration loss (Abd Latif, Z., & Blackburn, G. A., 2010; Sparchez et al., 2017). Shifting balances between soil temperature and soil moisture along all seasons suggest potential changes in soil features and the complexity of terrain, with interaction with plants activities and the architecture of forest cover, particularly by amplitude of leaf area index in forest (Bequet et al., 2012). Besides, young trees situated below the main canopy, increase humidity by stronger shading and by reducing wind speed, filling the trunk space with variously dense foliage, thus creating a more moderate microclimate (in Kovacs et al., 2017).

CONCLUSIONS

The present study evaluated the implications of age stand on soil microclimatic conditions in an even aged beech forest. Due to the fact that the determination period was relatively short, only about one year, we consider that it was not possible to evaluate very well these forest-climate responses in the soil, compared to an analysis situation over a multi-year period. According to our results, the stand age influences the variability of the soil microclimate. On the one hand, the canopy of the forest, as an expression of the crown biomass, can regulate the dynamics of the soil climate. On the other hand, the soil activity and soil characteristics can influence the spatiotemporal variability of soil climatic parameters. A long-term assessment will be useful to investigate the particularities of forest ecosystems, such as the influence of the stand age on the variability of soil climate regimes.

ACKNOWLEDGEMENTS

This research was funded by the Romanian Ministry of Research Innovation and Digitalization, from the Nucleu National Programme, Project – PN - 19070506,*„Modelling the action of some extreme climatic factors upon forest ecosistems”*.

REFERENCES

Abd Latif, Z., & Blackburn, G. A., (2010). The effects of gap size on some microclimate variables during late summer and autumn in a temperate broadleaved deciduous forest. *International Journal of Biometeorology*, *54*(2), 119-129.

Alvarez-Uria, P., & Körner, C., (2007). Low temperature limits of root growth in deciduous and evergreen temperate tree species. *Functional ecology*, *21*(2), 211-218.

Aussenac, G., (2000). Interactions between forest stands and microclimate: ecophysiological aspects and consequences for silviculture. *Annals of forest science*, *57*(3), 287-301.

Bednárová, E., & Merklová, L., (2007). Results of monitoring the vegetative phenological phases of European beech (Fagus sylvatica L.) in 1991-2006. *Folia oecologica*, *34*(2), 77.

Bequet, R., Campioli, M., Kint, V., Vansteenkiste, D., Muys, B., & Ceulemans, R., (2011). Leaf area index development in temperate oak and beech forests is driven by stand characteristics and weather conditions. *Trees*, *25*(5), 935-946.

Braga, C., & Spârchez, G., (2014). The influence of forest management on the amount of litter organic carbon, in beech forests. *Bulletin of the Transilvania University of Brasov. Forestry, Wood Industry, Agricultural Food Engineering. Series II*, *8*(1), 1.

De Frenne, P., Rodríguez-Sánchez, F., Coomes, D.A., Baeten, L., Verstraeten, G., Vellend, M., & Verheyen, K., (2013). Microclimate moderates plant responses to macroclimate warming. *Proceedings of the National Academy of Sciences*, *110*(46), 18561-18565.

Dincă, L., & Achim, F., (2019). The management of forests situated on fields susceptible to landslides and erosion from the Southern Carpathians. *Scientific papers series Management, Economic Engineering in Agriculture and Rural Development*, *19*(3).

Dinca, L., Badea, O., Guiman, G., Braga, C., Crisan, V., Greavu, V., & Georgescu, L., (2018). Monitoring of soil moisture in long-term ecological research

(LTER) sites of Romanian Carpathians. *Annals of Forest Research*, *61*(2), 171-188.

Dinca, L., Murariu, G., Enescu, C.M., Achim, F., Georgescu, L., Murariu, A. & Holonec, L., (2020). Productivity differences between southern and northern slopes of Southern Carpathians (Romania) for Norway spruce, silver fir, birch and black alder. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *48*(2), 1070-1084.

Dincă, L., Murariu, G., Iticescu, C., Budeanu, M., & Murariu, A., (2019). Norway spruce (Picea abies (L.) Karst.) smart forests from the southern Carpathians. *International Journal of Conservation Science*, *10*(4), 781-790.

Dincă, L., Timiș-Gânsac, V., & Breabăn, I.G., (2020). Forest stands from accumulation and natural lakes slopes from the Southern Carpathians. *Present Environment and Sustainable Development*, (1), 212-218.

Ducci, F., De Rogatis, A., Proietti, R., Curtu, A.L., Marchi, M., & Belletti, P., (2021). Establishing a baseline to monitor future climate-change-effects on peripheral populations of Abies alba in central Apennines. *Annals of Forest Research*, *64*(2), 33-66.

Fekete, I., Varga, C., Biró, B., Tóth, J. A., Várbíró, G., Lajtha, K., & Kotroczó, Z., (2016). The effects of litter production and litter depth on soil microclimate in a central european deciduous forest. *Plant and soil*, *398*(1), 291-300.

Giurgiu V., Decei, I., Drăghiciu D., (2004). Metode şi tabele dendrometrice. Editura Ceres, p.51-54

Godefroid, S., Rucquoij, S., & Koedam, N., (2006). Spatial variability of summer microclimates and plant species response along transects within clearcuts in a beech forest. *Plant Ecology*, *185*(1), 107-121.

Gressler, E., Jochner, S., Capdevielle-Vargas, R.M., Morellato, L.P.C., & Menzel, A., (2015). Vertical variation in autumn leaf phenology of Fagus sylvatica L. in southern Germany. *Agricultural and Forest Meteorology*, *201*, 176-186.

Hereș, A.M., Bragă, C., Petritan, A.M., Petritan, I.C., & Curiel Yuste, J., (2021). Spatial variability of soil respiration (Rs) and its controls are subjected to strong seasonality in an even-aged European beech (Fagus sylvatica L.) stand. *European Journal of Soil Science*, *72*(5), 1988-2005.

Hohnwald, S., Indreica, A., Walentowski, H., & Leuschner, C., (2020). Microclimatic Tipping Points at the Beech–Oak Ecotone in the Western Romanian Carpathians. *Forests*, *11*(9), 919.

Holst, T., Mayer, H., & Schindler, D., (2004). Microclimate within beech stands—part II: thermal conditions. *European Journal of Forest Research*, *123*(1), 13-28.

Ilek, A., Nowak, M., & Błonska, E., (2021). Seasonal changes in water absorbability of some litterfall components in Scots pine stands differing in age. *Annals of Forest Research*, *64*(2), 149-164.

James, S. E., Pärtel, M., Wilson, S. D., & Peltzer, D. A. (2003). Temporal heterogeneity of soil moisture in grassland and forest. *Journal of Ecology*, 234-239.

Kovács, B., Tinya, F., & Ódor, P., (2017). Stand structural drivers of microclimate in mature temperate mixed forests. *Agricultural and Forest Meteorology*, *234*, 11-21.

Kutnar, L., Kermavnar, J., & Pintar, A.M., (2021). Climate change and disturbances will shape future temperate forests in the transition zone between Central and SE Europe. *Annals of Forest Research*, *64*(2), 67-86.

Lozano-Parra, J., Pulido, M., Lozano-Fondón, C., & Schnabel, S., (2018). How do soil moisture and vegetation covers influence soil temperature in drylands of Mediterranean regions? *Water*, *10*(12), 1747.

MacKinney, A.L., (1929). Effects of forest litter on soil temperature and soil freezing in autumn and winter. *Ecology*, *10* (3), 312-321.

Morecroft, M.D., Taylor, M.E., & Oliver, H.R., (1998). Air and soil microclimates of deciduous woodland compared to an open site. *Agricultural and Forest Meteorology*, *90*(1-2), 141-156.

Murariu, G., Dinca, L., Tudose, N., Crisan, V., Georgescu, L., Munteanu, D., & Mocanu, G.D., (2021). Structural Characteristics of the Main Resinous Stands from Southern Carpathians, Romania. *Forests*, *12*(8), 1029.

Ni, J., Cheng, Y., Wang, Q., Ng, C.W.W., & Garg, A., (2019). Effects of vegetation on soil temperature and water content: Field monitoring and numerical modelling. *Journal of Hydrology*, *571*, 494-502.

Norris, C., Hobson, P., & Ibisch, P.L., (2012). Microclimate and vegetation function as indicators of forest thermodynamic efficiency. *Journal of Applied Ecology*, *49*(3), 562-570.

Oneț, A., Dincă, L., Teușdea, A., Crișan, V., Bragă, C., Enescu, R., & Oneț, C., (2019). The influence of fires on the biological activity of forest soils in Vrancea, Romania. *Environmental Engineering & Management Journal (EEMJ)*, *18*(12).

Peters-Lidard, C.D., Blackburn, E., Liang, X., & Wood, E.F., (1998). The effect of soil thermal conductivity parameterization on surface energy fluxes and temperatures. *Journal of the Atmospheric Sciences*, *55*(7), 1209-1224.

Pichler, V., Ďurkovič, J., Capuliak, J., & Pichlerova, M., (2009). Altitudinal variability of the soil water content in natural and managed beech (Fagus sylvatica L.) forests. *Polish Journal of Ecology*, *57*(2), 313-319.

Sayer, E.J., (2006). Using experimental manipulation to assess the roles of leaf litter in the functioning of forest ecosystems. *Biological reviews*, *81*(1), 1-31.

Schieber, B., (2006). Spring phenology of European beech (Fagus sylvatica L.) in a submountain beech stand with different stocking in 1995–2004. Journal of Forest Science, 52(5), 208-216.

Shinoda, M., & Nandintsetseg, B., (2011). Soil moisture and vegetation memories in a cold, arid climate. *Global and Planetary Change*, *79*(1-2), 110-117.

Sidor, C.G., (2015). Phenological observations at 6 species of trees in the growing of season 2014. *Revista Pădurilor*, *130*(3/4), 13-18.

Snedecor, G.W., & Cochran, W.G., (1980). Statistical methods., 7th edn (Iowa State University Press: Ames, IA).

Spârchez, G., Dincă, L.C., Marin, G., Dincă, M., & Enescu, R.E., (2017). Variation of eutric cambisol'chemical properties based on altitudinal and geomorphologic zoning. *Environmental Engineering & Management Journal (EEMJ)*, *16*(12).

Târziu R.D., Spârchez G., (2013). Soluri şi staţiuni forestiere. Editura Universităţi din Braşov, p.104-105

Teuling, A.J., & Troch, P.A., (2005). Improved understanding of soil moisture variability dynamics. *Geophysical Research Letters*, *32*(5).

Vapaavuori, E.M., Rikala, R., & Ryyppö, A.J.T.P., (1992). Effects of root temperature on growth and photosynthesis in conifer seedlings during shoot elongation. *Tree physiology*, *10*(3), 217-230.

Vlad, R., Constandache, C., Dinca, L., Tudose, N.C., Sidor, C.G., Popovici, L., & Ispravnic, A., (2019). Influence of climatic, site and stand characteristics on some structural parameters of scots pine (Pinus sylvestris) forests situated on degraded lands from east Romania. *Range Management and Agroforestry*, *40*(1), 40-48.

Zheng, D., Chen, J., Song, B., Xu, M., Sneed, P., & Jensen, R., (2000). Effects of silvicultural treatments on summer forest microclimate in southeastern Missouri Ozarks. *Climate Research*, *15*(1), 45-59.

***, 2014. Management plan. Experimental Forest District Mihăeşti, pp. 62-65.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE LOGGING IMPACT ON THE SEEDLINGS FROM LOGGING SITES IN SOUTHWESTERN ROMANIA

Ilie-Cosmin CÂNTAR, Cătălin-Ionel CIONTU

National Institute for Research and Development in Forestry "Marin Dracea",
8 Padurea Verde Street, Timisoara, Romania

Corresponding author email: ilie.cantar@icas.ro

Abstract

From thinning to regeneration works, stand management works, can only be applied through logging, which become a vector of maintaining biodiversity through forest regeneration, but also a vector of reducing it, through the damage it causes to forest ecosystem and to seedlings. This paper analyzes the impact of logging works on the seedlings and its biodiversity in 96 sample plots located in 24 wood harvesting sites in southwestern Romania (8 logging sites for each relief form). The impact of logging works on the seedlings was studied by analyzing the evolution of seedlings damages and the impact of these damages on their further development, but also by analyzing the composition of the installed seedlings and comparing it with the composition of the exploited tree. The highest degree of seedling damage was recorded at final cuttings. The most accelerated seedling healing pattern was recorded for barkings. We have observed a maintaining diversity of species after logging that can lead, to a stable diversity of the species from the stand. The obtained results were discussed and compared with other researches in the field, highlighting the most important aspects observed.

***Key words**: logging works; logging technology; damages; regeneration areas.*

INTRODUCTION

The prejudice in forest exploitation is a change in the natural state of the soil, seedlings, and trees caused by logging that adversely affects the further development of forest ecosystems. It follows that not all negative influence in the process of logging on trees, soil or seedlings when it is to be promoted is prejudice.

Due to the damages brought to the natural seedlings in the forest exploitation process, the success of the natural regenerations can be reduced by 20-70% (Giurgiu, 1995). However, the impact of logging on the seedlings can also be indirect by impoverishing and destroying the soil and excessive compaction, especially on collection routes, that can hinder or prevent seed germination. Direct damage to the seedling is also common near the collection routes, especially in specimens with a height of 30-80 cm (Dămăceanu, 1976).

The tolerability threshold of the seedlings in the forestry works is clearly established in Order no. 1540/2011 for the approval of the instructions regarding the terms, modalities and periods of collection, removal and transport of the wood material (art. 15, paragraph 1). "In the case of treatments that promote natural regeneration, it is not a prejudice, the destruction or damage of the seedlings as a result of the normal development of the logging process within the maximum limit of 8% of the area with seedlings, provided in the minutes of handing over the logging site, in the case of cuttings for developing or enlarging regeneration areas, and not more than 12% in the case of final cuts or connection cuts (Ord. nr. 1540/2011). From all technological processes of the entire logging process, most of seedling's damages are produced in technological process of wood harvesting (Chisăliţă et al., 2018).

The negative effects of logging on the seedlings can be minimized in areas with optimal climatic and vegetation conditions. Thus, experiments which consisted in well-watered conditions of beach seedlings from south-western Romania, resulted in higher plant height and higher leaf number, suggesting higher plant growth potential (Cocozza et al., 2016). Similar studies indicate a high drought sensitivity for beech seedlings populations from south-western Romania (Bolte et al., 2016).

The hypothesis of this study is that the damage caused to the seedlings through logging only affects in the short term their further development and does not negatively influence the diversity of species in the future stand. In addition to the field observations that preceded and support the assumption, this hypothesis it is also supported by data from the literature, showing that total seedlings alongside the collection routes were surveyed (Badraghi et al., 2015).

The purpose of the paper is to analyze the impact of logging on seedlings in logging sites in southwestern Romania. This goal has been achieved by meeting the following objectives:

- Analysis of the damages brought to the seedling by studying the injury indexes;
- Analysis of the dynamics of seedlings damages;
- Analysis of the diversity of species from seedlings by comparing it with the diversity of the species from the logged stand.

MATERIALS AND METHODS

This paper analyzes the impact of logging on seedlings in 24 logging sites from southwest Romania, Caraş-Severin County with 8 replicates for each relief form, and 6 replicates for different regeneration works, constitutes on variants as follow:

V1 - logging sites with thinning works with two replicates on each relief form;

V2 - logging sites with works for opening regeneration areas - cutting I of progressive treatment and gardening cutting – with two replicates on each relief form;

V3 - logging sites with works for enlarging regeneration areas - cutting II and III of progressive treatment - with two replicates on each relief form;

V4 - logging sites with works for connecting regeneration areas - last cutting from progressive treatment - with two replicates on each relief form.

Field works have been realized in forest departments from Caraş-Severin forest directorate as Băile Herculane, Bocşa Montană, Bocşa Română, Moldova Nouă, Văliug, and in Caransebeş experimental base administrated by National Institute for Research and Development in Forestry "Marin Drăcea".

In each logging site, seedlings have been investigated in 4 circular sample plots of 5 m^2 each, located on each cardinal direction, at 10 m distance from a fix point from the middle logging site. Having into consideration all 24 logging sites, seedlings have been investigated in 96 sample plots, totalizing 480 m^2.

We have evaluated species diversity in the analyzed plots by evaluating the seedling population and species diversity compared with the composition of the exploited stand.

Seedling damages have been evaluated at a distance of two vegetation seasons, in 2019 and 2021.

Damages identified at seedlings level have been classified using a classification adapted from literature (Knežević et al., 2018; Ciubotaru, 1998) as follow: galling (damages without affecting cambium), barking (bark removing up to the wood), splintering (removing a part of the bark and the wood), breaking (branches or trunk), uprooting (total or partial).

For each seedling sample area, we noted the position of the center of the circular sample area evaluated (using FieldMap system or polar coordinates), the maximum seedling height (measured with measuring tape), the type of regeneration, the number of samples below 0.5 m in height, the number of samples between 0.5 and 1.3 m tall, the number of samples over 1.3 m tall, the percentage of usable seedlings, the species represented among the damaged seedlings identified, the percent-age of damaged seedlings by species, and the types of damage by species.

The evaluation of the injuries and damage done to seedlings through logging was performed by determining damage indexes. Damage indexes for seedlings involve correlating the number of damaged samples by damage type and version to the total number of samples from the sample area. We have evaluated seedling injuries and damage by creating seedling damage indexes that report the correlation between the number of damaged samples and the seed-ling coverage degree of the sample surfaces (expressed in percentages), using the following formula 1:

$$i = \frac{N_V}{A_S} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where: i - seedling damage index;

N_V - number of damaged seedlings from the sample surfaces;

A_S - seedling coverage in the sample surfaces, expressed in percentages.

The indexes presented and used to interpret the results were calculated as weighted averages based on the number of injuries of each type.

For seedlings, the damage dynamic was analyzed as a relationship between the number of samples that were healed, in the process of healing, dead, or without evident change (obtained during the reevaluation) and the initial number obtained from surfaces with seedlings.

RESULTS AND DISCUSSIONS

The damage indexes represent a quantification of the number of damaged specimens from the seedling in relation to the total seedlings cover, allowing the assessment of the seedling surfaces from the point of view of the damage caused to the seedling and the comparison from this point of view of the studied variants.

Important seedling injuries were caused progressively by wood mass exploitation works (Table 1).

Thus, the damage index increases as the work done over the stand's life increases.

The lowest values were found in thinning, where the purpose of the works was not to obtain usable seedlings.

The stand's damage index increases with the surfaces occupied by seedlings when different treatments are applied.

The highest values were thus obtained in final cuttings (Table 1).

Table 1. Seedling damage indexes on damage types in the studied versions

Version	Relief form	Damage index				
		General damage index	galling	barking	splintering	breaking
V1 - Thinning	plain	0	0	0	0	0
	hill	0	0	0	0	0
	mountain	0,145	0	0,055	0,036	0,055
Total V1		0,048	0	0,018	0,012	0,018
V2 - Progressive I or Transformation towards gardening	plain	0,29	0	0,14	0	0,14
	hill	1,33	0	0,67	0	0,67
	mountain	0,033	0,011	0,022	0	0,000
Total V2		0,551	0,004	0,277	0	0,270
V3 - Progressive 2 or 3	plain	1,29	0	0,57	0	0,71
	hill	1	0	0,43	0	0,57
	mountain	0,015	0	0,015	0	0
Total V3		0,768	0	0,338	0	0,427
V4 - Final cutting	plain	0,86	0	0,86	0	0
	hill	2,89	0,11	1,22	0	1,56
	mountain	0,311	0,089	0,178	0	0,044
Total V4		1,354	0,066	0,753	0	0,535
TOTAL		2,722	0,070	1,387	0,012	1,250

According to the calculated damage indexes, the highest damage degree is found in V4-Final cutting. The same indexes show us that seedling damage is higher in hills than in plains, especially when compared with mountains (Figure 1).

It was also observed that many samples have healed while the majority of those that are still damaged are healing.

These mending samples present bark growth at the level of the barked area and sprouts on broken samples.

All gallings and splintered samples have completely healed, as well as 73% of the barked ones and 42% of the broken ones.

The most accelerated seedling healing pattern was recorded for barkings with a slope value of -30 in the plot representing the healing dynamic (Figure 2). A sustained healing pattern was also observed for breakages, where the majority presented sprouts. Thus, the negative impact of forest exploitation work on seedlings weakens over time, and most samples recover in a short period.

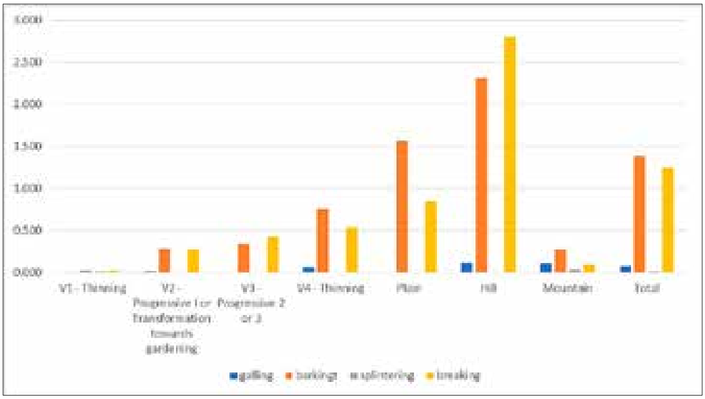


Figure 1. Seedling damage indexes from the analyzed versions

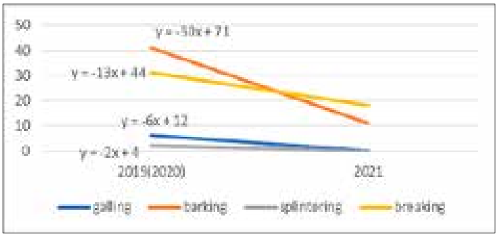


Figure 2. Dynamic of seedling damages on their type

In thinnings (Figure 3a), although the work is not intended to regenerate the stand, seedlings were identified and the composition was more varied than that of the existing stand. Species such as maple, elm, field maple, or ash are found in significant percentages among the seedling species, although these represented a very low percentage of the exploited stand in the DT category.
In opening eyes works from V2 (Progressive I or gardening transformations) (Figure 3b), only field maple and ash appear in significant percentages in the seedling species composition that were not part of the exploited stand.
Pine, sorb, and hawthorn were found in significant percentages among the species that diversify the seedling composition in stands where enlargement works for regeneration loci were performed (Progressive II or III from version V3) (Figure 3c).
For final cuttings (version V4) (Figure 3d), the seedling composition has diversified through the appearance of high percentages of elm, goat willow, field maple, and oak.

In the surfaces from the analyzed versions, the majority of injuries that were observed initially are now healed or healing. These results are supported by other studies concerning seedling recovery that have shown that seedlings damaged during logging for species such as Douglas fir could recover in 3 years (Tesch et al., 1990). However, studies have shown that seed-lings have grown 40% slower on tractor roads than in regeneration gaps (Howlett et al., 2003).
The lack of a negative influence of forest exploitation on biodiversity at the tree level is best demonstrated by seedlings. If we consider the increased number of species represented among seedlings, as shown above, we can predict a future increase of biodiversity at the tree level in the future stand. Some studies show that where forest species are represented by advanced and abundant regeneration, impact logging alone could be sufficient to sustain biodiversity areas. This applies as long as exploitation intensities are moderate and cutting cycles are long (Putz et al., 2008).

The same authors affirm that forest area biodiversity can decline if the techniques used are not silviculturally appropriate and where substantial crown openings are necessary, including soil perturbation. Sometimes, environmentalists and even ecologists wrongly equate only the forest structure before cutting with good management, failing to consider the newly obtained structure (Putz et al., 2008).

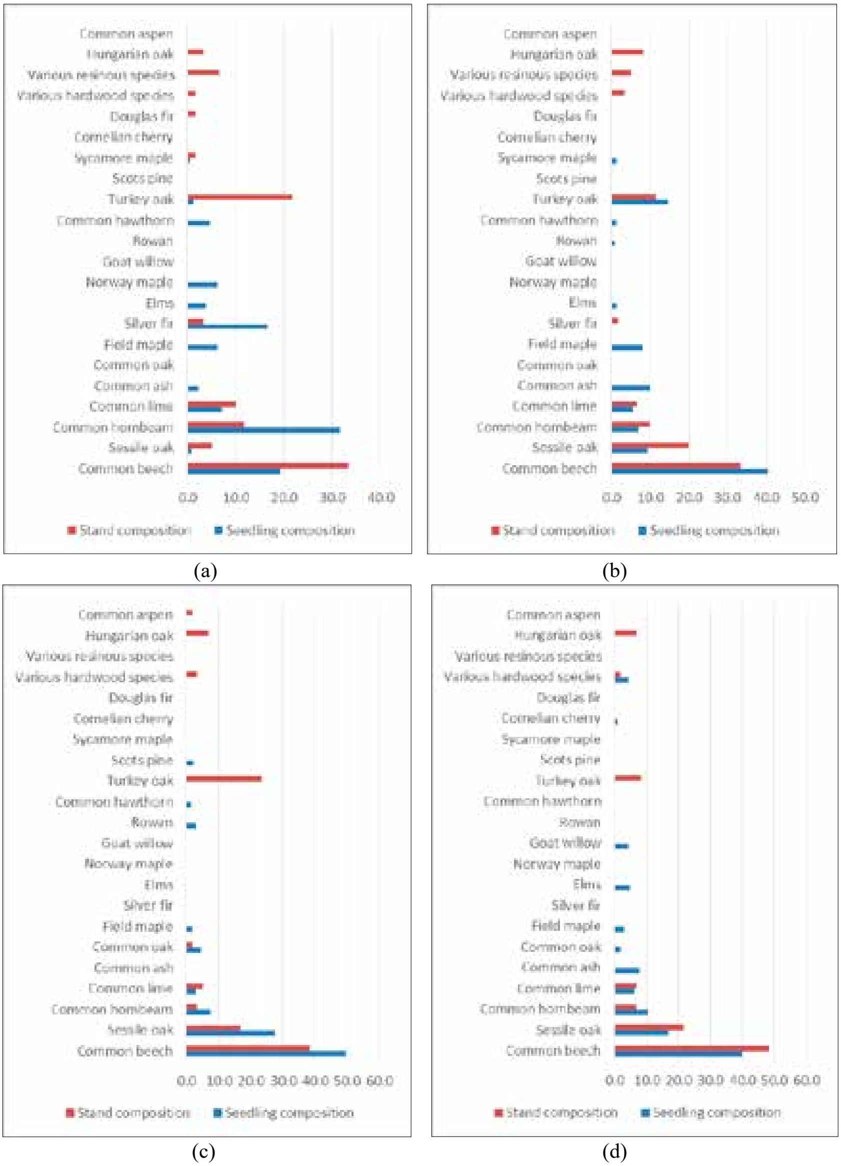


Figure 3. Species and seedling participation percentage in stand composition (a - V1 Thinning; b - V2 Progressive 1 and Gardening transformations c - V3 Progressive 2 or 3; d - V4 Final cutting)

The results of analyzing species diversity of seedling and composition compared with the composition of the exploited stand show that the species present in the exploited stand were also found in the new seedlings in most versions. Similar results show that selective forest exploitation represents a low threat for tree diversity as most of the species found in primary forests seem to be able to persist in exploited forests (Wilcove et al. 2013). However, other studies have shown that natural and anthropic disturbances, such as logging, decrease species richness and diversity. In this case, the exploited stands were not able to recover their diversity even after 150 years. This is correlated only with the presence of invasive species, which is not the case for our study (Brown and Gurevitch, 2004). An increase of species richness (pioneer trees, liana, and shrubs) 10 years post-logging is also mentioned by other authors among the biodiversity benefits of forest exploitation, together with increasing sub-stand density and in-creasing moss diversity. However, moss diversity decreases up to 40 years after logging (Putz et al., 2000).

CONCLUSIONS

In seedlings, all galling and splintered samples have healed completely, as well as 73% of the barked ones and 42% of the broken ones. This demonstrates the diminishing negative effect of logging on seedlings in a short period, as many samples are capable of a full recovery.

If we compare seedling and stand composition, we can observe a maintaining diversity of species after logging. If this diversification remains as the future stand grows, the new seedling composition can lead to a stable diversity of the species from the stand.

The results obtained by analyzing the impact of exploitation work on seedlings in this study, discussed and compared with results from other similar studies, show that forest exploitation can be considered a vector of maintaining biodiversity through forest regeneration. This situation applies as long as works are executed by respecting certain measures for protecting the forest ecosystem as well as by the applied silvicultural works.

ACKNOWLEDGEMENTS

This paper was carried out with the support of the Ministry of Research, Innovation and Digitization (MCID), through the "Nucleu" program - project no. 19070507 and through "Programul 1 - Dezvoltarea sistemului naţional de cercetare - dezvoltare, Subprogram 1.2 - Performanţă instituţională - Proiecte de finanţare a excelenţei în CDI" - project "Creșterea capacității și performanței instituționale a INCDS „MarinDrăcea") în activitatea de CDI - CresPerfInst" (Contract no. 34PFE./30.12.2021).

REFERENCES

Badraghi, N., Erler, J., Hosseini, S.A.O. (2015). Residual damage in different ground logging methods alongside skid trails and winching strips. *Journal of Forest Science, 61*(12), 526-534.

Bolte, A., Czajkowski, T., Cocozza, C., Tognetti, R., De Miguel, M., Pšidová, E., Dimitrová, L., Dincă, L., Delzon, S., Cochard, H., Ræbild, A., De Luis M., Cvjetkovic B., Heiri C., Müller, J. (2016). Desiccation and mortality dynamics in seedlings of different European beech (*Fagus sylvatica* L.) populations under extreme drought conditions. *Frontiers in plant science, 7*, 751.

Brown, K.A., Gurevitch, J. (2004). Long-term impacts of logging on forest diversity in Madagascar. *Proceedings of the National Academy of Sciences, U.S.A, 101*(16), 6045-6049.

Chisăliţă, I., Ciontu, C., Cântar, I. C. (2018). Seedlings damage evaluation on logging yards-case study from Experimental Basis Caransebeş. *Journal of Horticulture, Forestry and Biotechnology, 22*(2), 76-80.

Ciubotaru, A. (1998). *Exploatarea pădurilor.* Brașov, RO: Lux Libris Publishing House.

Cocozza, C., De Miguel, M., Pšidová, E., Marino, S., Maiuro, L., Alvino, A., Czajkowski, T., Bolte, A., Tognetti, R. (2016). Variation in ecophysiological traits and drought tolerance of beech (*Fagus sylvatica* L.) seedlings from different populations. *Frontiers in plant science, 7*, 886.

Dămăceanu, C. (1976). *Tehnologii noi de exploatare și influența lor asupra solului și regenerării naturale în diverse tipuri de pădure*, Manuscris I.C.A.S.

Giurgiu, V. (1995). *Protejarea şi dezvoltarea durabilă a pădurilor României*. Bucharest, RO: Arta Grafică Publishing House.

Howlett, B.E., Davidson, D.W. (2003). Effects of seed availability, site conditions, and herbivory on pioneer recruitment after logging in Sabah, Malaysia. *Forest Ecology and Management, 184*(1-3), 369-383.

Knežević, J., Gurda, S., Musić, J., Halilović, V., Soković, D., Bajrić, M. (2018). The Impact of Animal Logging on Residual Trees in Mixed Fir and Spruce Stands. *South-east European forestry: SEEFOR, 2018, 9*(2), 107-114.

Putz, F.E., Redford, K.H., Robinson, J.G., Fimbel, R., Blate, G.M. (2000). *Biodiversity conservation in the context of tropical forest management*. Washington D.C., USA: The International Bank for reconstruction and Development / The World Bank Publishing House.

Putz, F.E., Sist, P., Fredericksen, T., Dykstra, D. (2008). Reduced-impact logging: challenges and opportunities. *Forest Ecology and Management, 256*(7), 1427-1433.

Tesch, S.D., Crawford, M.S., Baker-Katz, K., Mann, J.W. (1990). Recovery of Douglas-fir seedlings from logging damage in southwestern Oregon: Preliminary evidence. *Northwest science, 64*(3), 131-139.

Wilcove, D.S., Giam, X., Edwards, D.P., Fisher, B., Koh, L.P. (2013). Navjot's nightmare revisited: logging, agriculture, and biodiversity in Southeast Asia. *Trends in ecology & evolution, 28*(9), 531-540.

***, Order no. 1540/2011 *for the approval of instructions on timing, modalities and periods for the collection, removal and transport of timber (art. 15, align. 1)*. Bucharest, RO: published in Official Romanian Monitor no. 430/2011.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

TOXICITY OF COPPER ON THE *SINAPIS ALBA* AND *TRITICUM AESTIVUM* PLANTS

Paula COJOCARU, Gabriela BIALI

"Gheorghe Asachi" Technical University of Iasi, 63-65 Dimitrie Mangeron Blvd, Iasi, Romania

Corresponding author email: paula.cojocaru@academic.tuiasi.ro

Abstract

In this paper, we studied the effects of soil pollution with copper on the biomass production, the fractal surface of leaves and the elongation of the roots of white mustard (Sinapis alba) and wheat (Triticum aestivum) plants. The soil used in our experiments was polluted with $CuSO_4{\cdot}5H_2O$ solutions in concentrations ranging from 200 mg/kg to 1200 mg/kg. Wheat was the most affected by soil pollution with copper. At the maximum concentration of pollutant in the soil, i.e., 1200 mg/kg, it did not germinate. Compared to white mustard, wheat had a lower plant biomass, i.e., between 28% and 34%, depending on the concentration of soil pollutant. Regarding the length of the roots of the two plants, there is a 50.82% difference between them at the maximum pollutant concentration applied, i.e., (1200 mg/kg), compared to the control sample. The measured fractal surface of the white mustard leaves decreased, as well as the length of the roots, as the copper concentration in the soil increased.

Key words: *toxicity, concentration, biomass, root elongation.*

INTRODUCTION

The presence of copper in the environment is essential for the life and development of many organisms because it is present in many physiological processes, including their respiration or photosynthesis (Hansch and Mendel, 2009).
For the human body, copper is important for the function of many enzymes, in regulating metabolism, heart function, connective tissue and also acts as an antioxidant in regulating immunity (Crandell L. and Mohler N., 2021; Collins J., 2021).
Its existence in high concentrations in the soil can be a consequence of industrial pollution, but it can also result from prolonged intensive fertilisation (Nicholson et al., 2003). Soil pollution with this metal leads to a degradation of the structure and water stability of structural aggregates, which favours soil erosion and compaction (Izydorczyk G. et al., 2021; Cui S. et al., 2021).
High concentrations of copper in plants can restrict their growth, thus having a negative effect on yield and quality (Manivasagaperumal et al., 2011) and can cause disease in humans and animals (Gaetke et al., 2014; Gujre et al., 2021). It is therefore important to maintain optimal copper concentrations in the soil and to limit the absorption thereof by plants if its level in the soil rises excessively (Wyszkowski M., 2017; Żołnowski A. et al., 2013).
A series of hyperaccumulating plants have been used to decontaminate soil contaminated with copper: *Typha orientalis*, *Iris ensata* and *Scirpus radicans* Schk (Usman et al., 2012), *Seriphidium terrae-albae* (Cui S. et al., 2021), *Pinus massoniana* and *P. yunnanensis* (Wang et al., 2019), *Brassica napus and Salix nigra* (Massenet et al., 2021).
Wheat is the most important cereal and the plant that occupies the largest areas in the world. It also represents one of the most important agricultural crops in Romania, with approximately 2 million hectares cultivated every year. It has high biomass yield and develops a strong and rich root system, essential conditions for plants used in soil phytoremediation. It was for this reason that wheat was chosen for this study, to observe from what concentration of copper in the soil these conditions are affected.
White mustard belongs to the same family as rape (*Brassica napus*), the cruciferous family. Rape is one of the plants studied by other researchers and recognised as a hyperaccumulator that can be used in the phytoremediation of soils.

The purpose of this study is to determine the toxicity of copper on germination, root elongation and the morphological development of white mustard (*Sinapis alba*) and wheat plants (*Triticum aestivum*).

MATERIALS AND METHODS

The soil used in the experiments was contaminated with a solution of $CuSO_4 \cdot 5H_2O$ in concentrations from 0 mg/kg to 1200 mg/kg.
The physicochemical characteristics of the soil used in the experiments are shown in Table 1.
Each experimental variant was performed in four repetitions. For each experimental variant, 65 g of soil and 6 seeds of plants were used. The plants used in the experiments were of white mustard and wheat. The plant seeds were purchased from the Bank of Plant Genetic Resources Suceava, Romania.
Pictures of the seeds used in the experiments can be seen in Figures 1-2.

Figure 1. Seeds of *Sinapis alba*

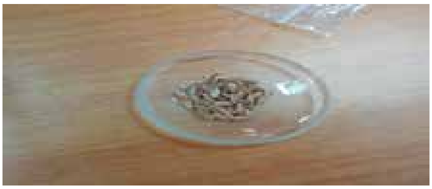


Figure 2. Seeds of *Triticum aestivum*

All experimental variants benefited from the same temperature and humidity conditions, being irrigated every 3 days. The plants sprouted three days after sowing and were harvested after 2 weeks in the case of white mustard and 1 month in the case of wheat.
After harvesting, the plants were separated into morphological parts (roots, stems, leaves) and the following were determined: biomass production, fractal dimension of mustard leaves and length of roots and stems for each experimental variant.

The amount of biomass obtained was determined by weighing the analytical balance of harvested morphological parts.
The fractal dimension is a number that quantifies the degree of irregularity and fragmentation of a geometric structure or object in nature (Zmeskal et al., 2003).
The box-counting method was used to determine the fractal dimension of the mustard leaves. The fractal dimension of binary digital images, i.e., D_b, determined by the box-counting method, measures complex dimensions in the $1 \leq D_b \leq 2$ range by calculating the ratio between the increase in detail and the increase in scale. This is calculated by placing a series of squares with decreasing size s over an image and by measuring, for each square, the number of pixel objects N(s) (Zmeskal et al., 2001). ImageJ1.38 software was used to calculate the fractal dimension.
Root elongation was measured using the Image Tool 3.0 software and the percentage of root elongation inhibition (RI) for each studied plant was calculated with Eq.1 (Oleszczuk, 2008):

$$RI = \frac{A-B}{A} \cdot 100 \qquad (1)$$

where: A is the average root length in the control sample; B is the average length of roots under the influence of copper.

RESULTS AND DISCUSSIONS

3 days after sowing, the white mustard and wheat plants sprouted. They can be seen in the Figures 3, 4, 5 and 6.

Figure 3. Emergence of *Sinapis alba* plants under the influence of soil pollution with Cu from the concentration of 0 mg/kg to 1200 mg/kg

Figure 4. Sprouting of *Triticum aestivum* plant under the influence of soil pollution with Cu from the concentration of 0 mg/kg to 1200 mg/kg

At the end of the growing period, 2 weeks in the case of white mustard and one month in the case of wheat, the 2 types of plants were harvested.

Figure 5. White mustard before harvesting

Figure 6. Wheat before harvesting

Sinapis alba and *Triticum aestivum* plants harvested and separated by morphological parts can be seen in Figures 7 and 8 and the amount of biomass obtained is shown in the Table 2.

0 mg/kg

1200 mg/kg

Figure 7. Separation of harvested white mustard by roots, stems and leaves

As it can be seen, first of all visually, the differences in obtained biomass, at the maximum concentration of soil pollutant, for both white mustard and wheat, are very large compared to the control sample.
At the maximum concentration of the soil pollutant, i.e., 1200 mg/kg, wheat seeds did not germinate.

0 mg/kg

1000 mg/kg

Figure 8. Separation of harvested wheat by roots, stems and leaves

Regarding the amount of biomass harvested, it can be seen that the highest amounts were obtained in the case of white mustard. Wheat was much more affected by the concentration of copper in the soil. To determine the average fractal surface of the white mustard leaves, 30 leaves were measured for each experimental variant.
The fractal surface measured in the ImageJ software for the control sample and the sample with the maximum copper concentration in the soil can be seen in Figure 9.
Results obtained for each experimental variant are presented in Table 3.

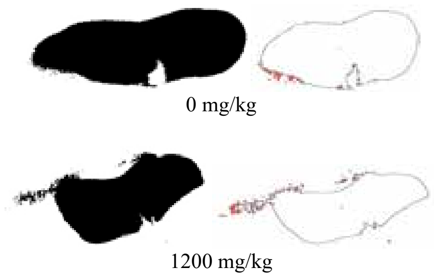


Figure 9. Measured fractal surface

Table 1. Physicochemical properties of the investigated soil

Characteristic parameter	Method of analysis	Analysed soil sample
pH	SR ISO 10390/1999	6.84
Humidity (%)	SR EN 12880/2000	10.13
Granulometry (%)	SR ISO 11465/1997	- sand: 23.60 - dust: 61.40 - clay: 15.00
Total organic carbon (mg/kg dw)	SR ISO 14235/2000 (Walkley-Black Method)	6740
Humus (mg/kg dw)	STAS 7107-1/1976	11793
Total phosphorus (mg/kg dw)	STAS 7184-14/1979	303.5
Total potassium (mg/kg dw)	STAS 7184-18/1980	70
Total nitrogen (mg/kg dw)	SR ISO 11261/2000 (Kjeldahl Method)	594
Nitrate (mg/kg dw)	STAS 7184-7/1987	13.49
Nitrite (mg/kg dw)	STAS 7184-7/1987	0.73
Sulphate (mg/kg dw)	STAS 7184-7/1987	1208
Chloride (mg/kg dw)	STAS 7184-7/1987	39.77

Table 2. Amount of harvested biomass

Name of the plant	Concentration of soil pollutant (mg/kg)	Components			Total biomass (g)
		Roots (g)	Stems (g)	Leaves (g)	
Sinapis alba	0	0.609	1.333	1.152	3.094
	200	0.583	1.218	0.952	2.753
	400	0.570	1.197	0.898	2.665
	600	0.565	1.178	0.852	2.595
	800	0.541	1.104	0.822	2.467
	1000	0.536	0.970	0.796	2.302
	1200	0.528	0.790	0.700	2.018
Triticum aestivum	0	0.634	0.733	1.086	2.453
	200	0.635	0.326	0.855	1.816
	400	0.620	0.422	0.763	1.805
	600	0.577	0.571	0.654	1.775
	800	0.546	0.564	0.634	1.771
	1000	0.533	0.527	0.551	1.611
	1200	0	0	0	0

Table 3. The fractal surface of the white mustard leaves

Name of the plant	Concentration of soil pollutant (mg/kg)	Measured fractal surface (m^2)
Sinapis alba	0	0.00187
	200	0.00186
	400	0.00108
	600	0.000925
	800	0.000825
	1000	0.000792
	1200	0.000757

Sinapis alba

0 mg/kg 800 mg/kg 1200 mg/kg

Triticum aestivum

0 mg/kg 800 mg/kg 1000 mg/kg

Figure 10. Harvesting white mustard plants

As shown in Table 1, the soil used in the experiments is a degraded soil, due to the relatively low pH value, high sand and dust content, as well as a low concentration of humus and nutrients.

It is acknowledged that soil characteristics are important for both plant growth and soil metal mobility.

Changing only the agrochemical properties of the soil (soil reaction, humus content, base saturation, granulometric composition) may reduce or increase the heavy metal content of plants several times.

Also, heavy metals are often found in the soil in forms which are less bioavailable to be extracted by the plant's roots. To overcome these shortcomings, various techniques are used that can increase the tolerance of plants to the toxicity of heavy metal ions and can change the conditions in the rhizosphere to favour the extraction of heavy metals, their transport to the roots and subsequent translocation to the aerial parts of the plant (Gavrilescu M., 2022).

For each studied plant, the average root length was determined (Figure 10).

The results obtained can be seen in Figure 11.

The root elongation of studied plants decreased with the increase of the copper concentration in the soil. Thus, the root length decreased in the case of *Triticum aestivum* from 148.30 mm

(0 mg/kg) to 18.70 mm (concentration of 1000 mg/kg) and from 63.70 mm (0 mg/kg) to 40.4 mm (concentration of 1200 mg/kg) in the case of *Sinapis alba.*

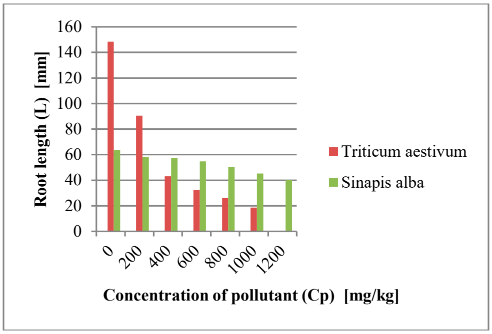


Figure 11. Elongation of wheat and white mustard roots

The correlation between the concentration of pollutant and the inhibition of plant roots under its influence can be seen in the Figures 12 and 13.

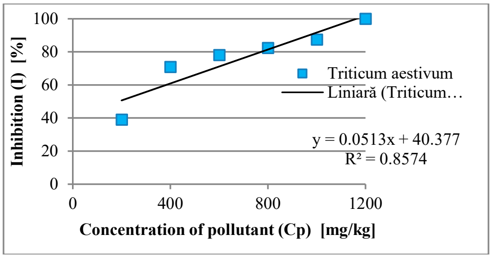


Figure 12. Correlation between the concentration of pollutant (Cp) and inhibition (I) of wheat seeds under the influence of soil pollution with Cu

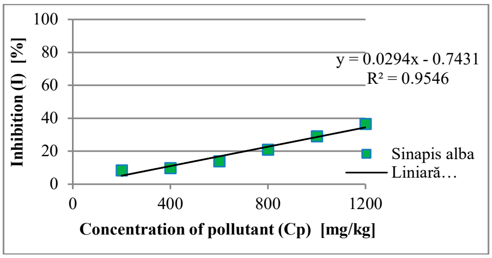


Figure 13. Correlation between the concentration of pollutant (Cp) and inhibition (I) of white mustard seeds under the influence of soil pollution with Cu

CONCLUSIONS

The research conducted and presented in this paper led to the following conclusions:

➢ The plant which was most affected by copper soil pollution was wheat.
➢ There is a biomass difference ranging from 28% to 34%between the two studied plants.
➢ The concentration of copper in the soil also affected the development of white mustard leaves. Their fractal surface area decreased by 59.51% in the case of soil contaminated at a maximum concentration of 1200 mg/kg compared to the unpolluted control sample (0 mg/kg).
➢ The germination of wheat seeds was much lower, decreasing as the applied pollutant concentration was higher. Thus, at a concentration of 1000 mg/kg, only one seed of the 6 seeds used germinated, while at the maximum concentration of 1200 mg/kg, none germinated.
➢ In terms of root length, at the maximum copper concentration in the soil, it decreased by 87.39% in the case of *Triticum aestivum* and by 36.57% in the case of *Sinapis alba* compared to the control sample.

We aim to ascertain in future research whether the two studied plants extracted the metal from the soil and can be used in phytoremediation of copper-polluted soils; also, we wish to determine which of the properties of the soil can contribute to increasing the metal mobility in the soil.

REFERENCES

Collins, J.F. (2021). Chapter Nine - Copper nutrition and biochemistry and human (patho)physiology. *Advances in Food and Nutrition Research*, 96, 311-364.
Crandell, L., Mohler, N. (2021). A Literature Review of the Effects of Copper Intrauterine Devices on Blood Copper Levels in Humans.*Nursing for Women's Health*, 25 (1), 71-81.
Cui, S., Zhou, K., Ding, R., Wang, J., Cheng, Y., Jiang, G. (2021). Monitoring the soil copper pollution degree based on the reflectance spectrum of an arid desert plant.*SpectrochimicaActa Part A: Molecular and Biomolecular Spectroscopy,* 263, 120186.
Gaetke, L.M., Chow-Johnson, H.S., Chow C.K. (2014). Copper: toxicological relevance and mechanisms. *Arch. Toxicol.* 88 (11), 1929-1937.
Gavrilescu M. (2022). Enhancing phytoremediation of soils polluted with heavy metals. *Current Opinion in Biotechnology,* 74, 1-11.
Gujre, N., Rangan, L., Mitra, S. (2021). Occurrence, geochemical fraction, ecological and health risk assessment of cadmium, copper and nickel in soils

contaminated with municipal solid wastes. *Chemosphere*, 271, 129573.

Hansch, R., Mendel, R.R. (2009). Physiological functions of mineral micronutrients (Cu, Zn, Mn, Fe, Ni, Mo, B, Cl). *Curr.Opin. Plant Biol.,* 12, 259-267.

Izydorczyk, G., Mikula, K., Skrzypczak, D., Moustakas, K., Witek-Krowiak, A., Chojnacka, K. (2021). Potential environmental pollution from copper metallurgy and methods of management. *Environmental Research*, 197, 111050.

Manivasagaperumal, R., Vijayarengan, P., Balamurugan, S., Thiyagarajan, G. (2011). Effect of copper on growth, dry matter yield and nutrient content of *Vigna radiata* (L.).*Wilczek. J. Phytol.* 3 (3), 53-63.

Massenet, A., Bonet, A., Laur, J., Labrecque, M. (2021). Co-planting *Brassica napus* and *Salix nigra* as a phytomanagement alternative for copper contaminated soil. *Chemosphere*, 279, 130517.

Nicholson, F.A., Smith, S.R., Alloway, B.J., Carlton-Smith, C., Chambers, B.J. (2003). An inventory of heavy metals inputs to agricultural soils in England and Wales. *Sci. Total Environ.,* 311(1-3), 205-213.

Oleszczuk, P. (2008). The toxicity of composts from sewage sludges evaluated by the direct contact tests phytotoxkit and ostracodtoxkit. *Waste Management*, 28(9), 1645-1653.

Usman, A.R.A., SooLee, S., Awad, Y.M., JaeLim, K., Yang, J.E., SikOk, Y. (2012). Soil pollution assessment and identification of hyperaccumulating plants in chromated copper arsenate (CCA) contaminated sites, Korea. *Chemosphere*, 87(8), 872-878.

Zmeskal, O., Vesely, M., Nezadal, M., Buchnicek, M. (2001). Fractal Analysis of Image Structures, HarFA-Harmonic and Fractal Image Analysis. *HarFA e-journal 3–5*. http://www.fch.vutbr.cz/lectures/imagesci/harfa.htm

Zmeskal, O., Nezadal, M., Buchnicek, M. (2003). Fractal-Cantorian geometry, Hausdorff dimension and the fundamental laws of physics. *Chaos, Solitons Fractals,* 17, 113–119.

Żołnowski, A., Busse, M., Zając, P. (2013). Response of maize (*Zea mays* L.) to soil contamination with copper depending on applied contamination neutralising substances. *J. Elem.* 18(3), 507-517.

Wang, Z., Liu, X., Qin, H. (2019). Bioconcentration and translocation of heavy metals in the soil-plants system in Machangqing copper mine, Yunnan Province, China. *Journal of Geochemical Exploration*, 200, 159-166.

Wyszkowski, M. (2017). Effect of contamination with copper and mineral or organic amendments on the content of trace elements in soil. *Environ. Prot. Eng.* 43(4), 165-173.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ECOLOGICAL RECONSTRUCTION OF THE STANDS AFFECTED BY DROUGHT FROM MEADOWS OF INLAND RIVERS

Cristinel CONSTANDACHE[1], Ciprian TUDOR[1], Laurenţiu POPOVICI[1], Lucian DINCĂ[2]

[1]National Institute for Research and Development in Forestry "Marin Dracea", 7 Republicii Street, Focsani, Romania
[2]National Institute for Research and Development in Forestry "Marin Dracea", 13 Closca Street, Brasov, Romania

Corresponding author email: cipriantudor95@yahoo.com

Abstract

The surface of the stands affected by drying, located in the meadows of the inland rivers is in continuous growing due to the modification of the hydrological parameters under abiotic, biotic and anthropogenic factors. The forest species frequently used in the past (1970-1990) for afforestation were the hybrid black poplars or the selected willows. Currently, they are less used, due to the change of environmental conditions but also by including them in protected areas, for the detriment of native species. In the paper, are presented data regarding on the characteristics of the stands affected by drying located in research plots from Buzău and Lower Siret meadows. The results bring the environmental potential of the lands by restoration of the affected stands from forest-steppe areas using adequate species adapted to resist on different types of soils, being able to face the new ecotope conditions. The ecological reconstruction of these stands is an urgent need and is the only way to maintain the ecological balance, biodiversity and, at the same time, to capitalize on these categories of land unsuitable for other destinations.

Key words*: ecological reconstruction, meadow, restoration, riverside coppice, riparian forests.*

INTRODUCTION

The deregulators of forest ecosystems along rivers are those that can alter the water supply conditions of the forest by: channeling the course to limit floods with the risk of raising the minor riverbed and lowering the groundwater; groundwater pumping; road crossings; extraction of sand and stone from the course bed; dams built along the water; pollution with household waste and construction materials (Constandache et al., 2018).

Some forestry works are likely to alter the dendrological richness and structure of the stands, especially by: large area cuts that cause difficulties in regeneration; monospecific plantations or with few species without ensuring dendrological diversity (Untaru et al., 2012; Untaru et al., 2013). In Romania, year 2005, there were registered abundant precipitations that favored the accumulation of rainwater and therefore the flooding of the land, as well as the prolonged stagnation of the water, causing partial or even total drying of the stands (Dănescu et al., 2011).

In some areas, there has been fragmentation of forest massifs and various structures have been implanted (treatment of water plants, stone and sand mining quarries, pumping stations), necessary for local development. However, in all cases, the riparian forests are a landscape and functional element that structures the mountain, hilly or plain valleys and are particularly and mostly important for environmental protection. The vegetation corridors of inland rivers, regardless of their type of property or their role of production or protection, must be the subject of a rational management (Constandache et al., 2018; Fedorca et al., 2020, Fedorca et al., 2021).

Biodiversity of species or the soil coverage degree decrease the intensity of rainfall and the specific erosion of the soil, emphasizing their hydrological and anti-erosion efficiency (Constandache et al., 2018; Vlad et al., 2019). The health state and stability of meadow forests riparian to inland rivers is threatened by various abiotic (climate change), biotic and anthropogenic factors. In general, lately, we are facing a decrease in the groundwater level and the number and duration of flood periods, which has led to major seasonal changes in inland river meadows. To this is added the massive deforestation of riparian forests in the area of plains and low hills where the land was given for agricultural use (cereals crops, pastures, hayfields, rarely orchards).

In the large river meadows, in which was kept the forestry use, have been installed monocultures of poplars and willows with shorter cycles, highly productive (Filat et al., 2009), but which no longer corresponding to the requirements of maintaining and stabilizing protected natural areas wihich were located mainly in such areas.

The area of stands affected by drought, located in the inland river meadows, is constantly growing due to climate change but also to the worsening of the seasonal conditions of the meadows through the modification of the hydrological parameters under anthropogenic action.

Climatic factors were analyzed for the plain areas in Romania (Banat, Bărăgan, Oltenia) which accentuated the drying phenomena (drought) of the last 2 decades (Angearu et al., 2020).

The factors that caused the expansion of arid areas were: destruction and abandonment of irrigation systems; deforestation; excessive land fragmentation; inappropriate agricultural practices (Constandache et al., 2006).

In the Bărăgan Plain, the extreme drought affected significant areas of agricultural land. For example: 22.4%, in 2002 (June), respectively, 35.7%, in 2007 (July). The results indicate a high drought vulnerability of the Bărăgan Plain, due to the increased intensity and frequency of climatic characteristics recorded in this region.

In the context of climate change, the increase of the average annual temperatures by more than 1-2ºC will have as a first consequence, the aridization of the southern and plain areas, but also of the hilly areas, causing major changes in seasonal conditions and the emergence of limits for forest vegetation, according to the "Climate Change Adaptation Guidelines" (https://www.meteoromania.ro/anm/images/clima/SSCGhidASC.pdf).

In the future, we need to look for resilient forms of species from riverside coppice or even other species that respond to the new complex challenges, respectively environmentally efficient methods of managing destabilizing factors (Onet et al., 2019; Ducci et al., 2021; Kutnar et al., 2021). To eliminate the excess water, drainage works or hydrophilic forest plantations are frequently applied, which aim at the efficient use of excess moisture from the soil. Poplar and willow are most often planted. The banks of rivers exposed to lateral erosion are fixed by plantations of willow, alder and sea buckthorn species, after which, at an interval of 3-5 years, are planted the species that make up the permanent stands (poplar, oak, ash and so on), resulting in finally a compact orchard wall that runs parallel to the watercourse (Bojariu et al., 2021). As species from *Populus* Genus, white poplar (*Populus alba*) was used for the afforestation of torrential alluvial situations or in the alluvial cones from the downstream torrents (Constandache et al., 2020).

On lands with additional moisture input (valley bottoms, micro-depressions with "mosaic structure") and with at least moderately deep and humid soil, starting from the forest-steppe area to the forest area, it is recommended to plant seedlings of species such as walnut, cherry and hazelnut (Constandache et al., 2006).

Ecological reconstruction consists in replacing the current Poplar or another forest plantations installed to water meadows and which in the current conditions of modification of the original stations especially, by decreasing soil trophicity, do not have the capacity of maintaining and further develop viable stands and finding the compositions and technologies of suitable regeneration (Roșu & Dănescu 2013; Davidescu et al., 2020).

For this reason, it is recommended to extend the biomonitoring of air quality and nutritional status of the main natural species and initiating riparian forest research projects (Gavrilescu & Bolea, 2014; Dinca et al., 2018). The effects of meadow forest crops consist in the improvement, stabilization and capitalization of lands, inefficient for other uses (Constandache et al., 2010) but also in mitigating the effects of global warming through the high storage capacity of atmospheric CO_2 (Dincă et al, 2015), stopping land degradation due to the ability to fix and improve soils (Nicolescu et

al., 2018), reducing anthropogenic pressure on natural forest ecosystems and using them as an alternative to fossil fuel replacement (Spîrchez & Lunguleasa, 2016).
The restoration of riparian forest may be a valuable strategy having the potential for fast carbon sequestration, are vectors of biodiversity and provide precious ecosystem services (Dybala et al., 2019; Murariu et al., 2021; Tiwary et al., 2020; Tudor et al., 2020; Vechiu et al., 2021).
In the Northern China, Poplar plantations, due the fast growing which means high productivity, have an extended potential in carbon sequestration. To maintain their high growth rate, they require more water (Zhou et al., 2013). In Israel, the ecological restoration include mainly the improvement of vegetation coverage and reducing the desertification by accessing projects addressed to the management of water resources, enhancing the downstream water supply from main rivers (Yao et al., 2021). Benefits from restoration depending of the nature of the intervention, several of them may provide a rapid benefit, an example being the establishment of riparian forests (Smith et al., 2014).
The studies carried out in the current stage were case studies aimed at applying the results of previous research conducted under "Marin Drăcea" National Institute for Research and Development in Silviculture in 2018-2019 regarding on *"Revision of the systematic of the forest sites used in the meadow areas of the inland rivers, in order to adapt the management measures of the stands at the modification of the environmental conditions"* (National Project Report, code PN 19070503).

MATERIALS AND METHODS

The researches were carried out in 10 research areas, located in representative situations of lands placed in the lower meadows of the rivers Buzău and Siret with stands or forest crops affected by drought.
The current state of the stands in different environmental conditions were analyzed and highlighted. In order to highlight the limiting factors for forest species, the pedo-stationary conditions were analyzed, starting from the fact that the physical environment of the terrestrial ecosystems is the ecotope, and the soil is one of its most important components (Untaru, 1976). For the characterization of the soil from the researched lands, the depth, the groundwater level, the thickness of the humus horizon (A), the depth at which horizon C appears, the texture and the $CaCO_3$ content in the horizons above the horizon C that limit the installation and development of forest species were taken into account (Dănescu et al., 2010).
The type of soil was determined by field work (description of soils on standard sheets) and with the help of laboratory analyzes of samples collected on diagnostic horizons from soil profiles.
In order to characterize the soils, main soil profiles and secondary profiles for control were carried out at distances of approximately 20-30 m, in order to ascertain the modification of the soil profile, being delimited the surfaces related to the main profile.
From the main profiles, soil samples were collected on diagnostic horizons. The soil samples collected were analyzed in the I.N.C.D.S "Marin Drăcea" laboratory, being determined the chemical properties (pH, humus content, carbonates, salts etc.) and physical (granulometry).
Territorially, the research was carried out in the lower meadows of the rivers Buzau and Siret. All the analyzed areas are located in the southeastern part of Romania, respectively in the south of the Moldavian Plateau (Lower Siret Meadow) and the North Bărăgan Plain (Lower Buzău Meadow). From the point of view of the bioclimatic zonality, the studied surfaces are framed in the forest-steppe zone (Ss).
The research consisted of collecting field data, processing and interpreting them. The processing of field data was done in a computer system by using specific statistical programs in forestry.
All the analyzed areas are located in the southeastern part of Romania, respectively in the south of the Moldavian Plateau (Lower Siret Meadow) and the North Bărăgan Plain (Lower Buzău Meadow). From the point of view of the bioclimatic zonality, the studied surfaces are framed in the forest-steppe zone (S_s).

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

RESULTS AND DISCUSSIONS

A. Pedo-stationary characteristics of lands with stands affected by drought in Buzău Meadow (Ianca Forest District)

Five situations of stands with white poplar and elm trees affected by drying were analyzed (Figure 1, Table 1), divided into three production units (U.P.).

Figure 1. White poplar stands affected by drying, Ianca Forest District

The analyzed soils were classified as *Aluviosol* soil type. They consist of fluvial parent material at least 50 centimeters thick, with a very high content of fine sand, for which reason they have been classified mainly in *the psamic subtype*, except in one case (u.a 16D, U.P III), where the subtype it is *molic* and *mesohyposaline*.

Table 1. Situation of areas with stands affected by drying (Ianca F.D.)

U.P	Total surface [hectares]	Surface affected by drying [hectares]	Affected stands [%]
II	460.47	27.50	6
III	538.61	8.21	2
V	1075.96	54.69	5

The texture of the soils is from coarse to medium between sand-loam to medium clay, except in u.a 16D, where the texture is fine, falling into the clay-clay class (Table 2).

There is an increase in the clay content per profile to the detriment of the percentage of sand, only in the case mentioned above.

The soils are weak to moderately humiferous in the first horizon between 15-25 centimeters, weak in the middle supplied with nitrogen, phosphorus and mobile potassium, they contained from weak to moderately carbonates and weak of salts with one exception (u.a 16D) where the number of salts increases, but below the threshold and at depths of more than 50 centimeters.

Table 2. The results of the physical analyzes of the soil in Lunca Buzaului (Ianca F.D)

Identification		Colloidal clay [%gr*]	Coarse sand [%gr*]	Fine sand [%gr*]	Silt [%gr*]
Profile	Depth [centimeters]				
P1	0-35	15.03	1.86	65.87	17.24
	35-60	15.33	0.38	52.42	31.87
	60-75	16.90	0.32	70.10	12.68
P2	0-35	29.6	0.46	45.94	24.54
	35-50	5.26	0.03	82.22	12.49
	50-90	16.63	0.01	48.08	35.28
P3	0-20	12.35	0.06	73.57	14.02
	20-47	7.07	0.17	81.56	11.20
	47-70	23.32	0.41	49.00	27.27
P4	0-25	34.88	1.33	35.44	28.35
	25-50	38.20	0.16	25.96	35.68
	50-75	32.71	0.39	34.65	32.25
P5	0-20	26.17	0.13	61.83	11.87
	20-40	17.31	0.10	59.00	23.59

Note: *) colloidal clay<0.002 milimeters; coarse sand=2.0-2 milimeters; fine sand=0.2-0.063 milimeters; silt=0.063-0.002 milimeters.

As limiting factors for the cultivation of forest species, we mention:

- lowering of groundwater levels to levels inaccessible to meadow-specific species: *Populus nigra* (Pl.n), *Populus alba* (Pl), *Salix* sp. (Sa);
- increasing the percentage of carbonates and salts per profile that limits the maintenance and development of certain forest species: *Robinia pseudacacia* (Sc), *Gleditsia triacanthos* (Gl), *Acer platanoides* (Pa), *Prunus avium* (Ci) (Enescu & Dănescu, 2015);
- low to very low amounts of mobile humus, nitrogen and potassium, concomitant with increasing alkalinity per profile;
- the increase in temperature and the sharp decrease in soil moisture per profile during the summer;

- infections with the Asian fungus *Ophiostoma novo-ulmi* which causes the mass drying of field elm (*Ulmus minor*).

As favorable factors, we mention:

- high clay content per profile, to the detriment of low amounts of fine and coarse sand, which makes it easier to catch, maintain and develop especially xerophytic oaks: *Quercus pedunculiflora* (St.b), *Quercus cerris* (Ce), to which are added the ashes: *Fraxinus excelsior* (Fr), *Fraxinus angustifolia* (Fr.î), *Fraxinus pennsylvanica* (Fr.b) and elms: *Ulmus pumila* (Ul.t), *Ulmus minor* (Ul.c);
- high percentages of nitrogen, phosphorus and mobile potassium in certain parts of the land, favorable to physiological processes for any species.

From the secondary surveys carried out, on certain parts of the land surface, especially near the course of the minor riverbed of the Buzău river, there is a load of soluble salts and carbonates, even from the upper horizons, which limits the development of forest species. Adaptable to these microstationary conditions are only the following forest species: *Eleagnus angustifolia* (Sl), *Pyrus piraster* (Pă), Acer tataricum (Ar), Prunus cerasifera (Cd), *Ulmus pumilla* (Ul.t). The total area is approximately 0.5 ha.

B. Lower Siret Meadow (Focșani Forest District)

In this area were analyzed five situations in which, the plantations with greyish oak (*Quercus pedunculiflora* K. Koch) carried out in the period 2017-2020, on agricultural lands, did not give results on certain portions of land, registering successive losses (over 50-60%). The plantations were made with greyish oak mixed with deciduous xerophytes species (20-30%), in prepared soil on the whole surface (ploughing, discing). The general pedo-stationary characteristics of the analyzed lands and soils are favorable to the greyish oak. However, insular, there are areas between 0.1-0.3 hectares, where the situation changes due to the great diversity of soil subtypes that are interspersed as a mosaic due to the existence of alluvial layers brought by the successive floods of the Siret River. The main parameters that most decisively change the fertility and favorability of these soils are the following: the varied content of clay, sand and dust on the profile, the contents of carbonates and salts and the process of stagnation or not of water from precipitation in the upper horizons and in the lower ones through ascent from the groundwater.

Therefore, the textural specificity presented in the description of each soil profile analyzed, differently influences the permeability and aeration regime of soils, stagnation and water retention mainly from precipitation (because floods are rare and at long intervals due to the damming of the area) with major impact r on the maintenance and development of forest seedlings.

Table 3. The results of physical analysis of the soil in the Lower Siret Meadow (Focșani Forest District)

Identification		Colloidal clay [%g*]	Coarse sand [%g*]	Fine sand [%g*]	Silt [%g*]
Profile	Depth [centimeters]				
P1	0-40	35.39	0.45	18.22	45.94
	41-60	50.02	0.34	1.23	48.41
	61-80	40.48	0.98	13.71	44.83
	81-110	54.89	2.10	36.45	6.56
P2	0-30	31.18	0.96	52.16	15.70
	31-60	23.39	11.15	60.26	5.20
	61-100	10.03	6.82	75.17	7.98
P3	0-18	35.48	0.20	33.41	30.91
	18-48	35.75	0.17	27.42	36.66
	48-68	40.30	0.02	16.84	42.85
	68-98	19.32	0.01	59.36	21.31
P4	0-30	24.21	0.12	43.61	32.06
	31-55	36.64	0.08	22.70	40.58
	56-90	41.62	0.08	26.20	32.10
	91-110	32.41	0.07	48.61	18.91
P5	0-17	44.84	1.87	26.95	26.34
	17-50	45.62	0.33	16.62	37.43
	50-80	35.03	0.12	23.05	41.80
	81-115	23.87	0.04	35.69	40.40

Analyzed in the order of decreasing clay content and changing texture from fine to coarse (Table 3), the analyzed soils are divided as follows:

- *soils with above average clay content (35-50%), in the first 60-70 centimeters.* Even if it has a high water storage capacity, the other physical and hydrophysical properties except for the aeration porosity which has very low values overall, become unfavorable: wilting coefficient - high, bulk density - high, total porosity - low, especially in the horizons where a maximum clay content is recorded, sometimes even from the surface. The low porosity of aeration can be explained by the long stagnation of water from rainfall, but also by the intensive grazing and pastures

fertilisation practiced previously, more in this area;
- *in the case of soil with medium texture (P2),* due to the maximum average clay content, the soil still has a high water retention capacity (useful water capacity has high values) and the wilting coefficient has medium to low values. The other physical and hydrophysical properties are generally favorable: bulk density - low, total porosity - large, aeration porosity - medium, but decrease with depth when they reach the sand layer (>50%).

The necessity for ecological reconstruction is to replace Poplar stands or forest crops from inland river meadows that do not have the capacity to maintain and develop viable stands under actual conditions of changing environmental conditions, especially by lowering groundwater levels and soil trophicity. In some places, the rise of carbonates and salts levels limit the development of species such as locust.

For lands in the Buzău meadow where the soil has a high sand content, the recommended species that can withstand the mentioned conditions are: honey locust, locust, mulberry, oleaster, cherry-plum. If the percentage of carbonates increases, the participation of locust decreases.

The technology of ecological reconstruction consists in the partial preparation of the soil in hearths, plantations in normal pits of 30x30x30 centimeters, with seedlings with bare roots, manually and maintenances for 5 years.

For soils with a higher percentage of clay, the soil preparation consists in removing stumps, scarifying, plowing and discing, and the maintenance's will be staggered over a period of 6-7 years (in the case of compositions with oak species).

In Siret meadow, the favorability of ecological factors and determinants for the main forest species in the area, recommends an optim of vegetation for the basic species: greyish oak, common oak, Turkey oak, pubescent oak and mixed species: Norway maple, European sweet cherry, European white lime, field maple, field elm, honey locus and oleaster.

It is recommended to introduce the following resistant forest species with a higher capacity to adapt to environmental conditions:

-in areas of land where the soil is clayey from the surface and which due to its high compactness in the summer season becomes a limitative factor for the main forest species, it is recommended to introduce the Turkey oak (*Quercus cerris*) from the oak family, assuming the risk that it may be dry if at very long intervals are produced floods followed by stagnant water exceeding 6 months;

-in the parts of the land where the soil has a medium texture, but in depth it becomes compact due to the higher content of migrated clay it is recommended the common oak (*Quercus robur*), which resist relatively good at compaction, but much better at stagnant waters or other biotic or abiotic factors with harmful effects on forest crops;

-in areas of land where the soil has a transitional texture in profile from medium to coarse, honey locust (*Gladitsia triacanthos*) is recommended, with ambivalent resistance both to clayey soils with compactness and water stagnation to sandy soils with low humidity and high temperatures, especially in the summer season.

Honey locust also led to good results on alluvial protisols, withstanding short-term floods well (Constandache et al., 2012).

-as a suitable oak species, pubescent oak (*Quercus pubescens*) or *Quercus virgiliana* is recommended, both of which being native species. The strong change of edapho-climatic factors determines the choice of alternative solutions regarding the structure of the stands from the inland river meadows using species, mostly exotic and the adoption of more extensive maintenance systems for viable forest crops.

CONCLUSIONS

The results of the study consisted in the analysis of the pedo-stationary conditions of the meadow lands with stands or forest crops affected by drying and the scientific substantiation of their restoration compositions.

The stability of riverside coppice (meadow forests, riparian inland rivers) is threatened by various abiotic factors (climate change), anthropogenic (qualitative and quantitative changes in surface water and groundwater) and biotic (oomycetes, fungi and invasive plants, with great power destabilization of stands.

In order to highlight the limiting factors for forest species, the pedo-stationary conditions were analyzed, starting from the fact that the physical environment of the terrestrial ecosystems is the station (ecotope) and the soil is one of its most important components.

As limiting factors for forest species culture, the following have been identified:

-decreasing the groundwater level to levels inaccessible to species specific to riverside coppice of meadow: *Populus nigra* (Pl.n), *Populus alba* (Pl), *Salix* sp. (Sa);

-increasing the percentage of carbonates and salts per profile that limits the maintenance and development of certain forest species: *Robinia pseudacacia* (Sc), *Gleditsia triacanthos* (Gl),

-increase in temperature and high decrease in soil moisture per profile during the summer season;

-infections with the Asian fungus *Ophiostoma novo-ulmi* which causes the mass drying of the field elm (*Ulmus minor*).

As favorable factors, identified in certain situations are mentioned:

-increasing the clay content per profile, to the detriment of the fine and coarse sand, which facilitates the catching, maintenance and development especially of xerophytic oaks: *Quercus pedunculiflora* (St.b), *Quercus cerris* (Ce), to which are added the ashes: *Fraxinus excelsior* (Fr), *Fraxinus angustifolia* (Fr.î), *Fraxinus pennsylvanica* (Fr.b) and elms: *Ulmus pumila* (Ul.t), *Ulmus minor* (Ul.c);

-high content of nitrogen, phosphorus and mobile potassium in certain parts of the lands, favorable to physiological processes for any species. The research carried out allowed the appropriate environmental classification of the lands with stands affected by drying and the scientific substantiation of the solutions for ecological reconstruction of the affected stands by identifying the species corresponding to the identified environmental conditions.

The strong change of edapho-climatic factors determines the choice of alternative solutions regarding the regeneration composition of the stands of the inland river meadows using species, often exotic and the adoption of more extensive maintenance systems for the realization of viable forest crops.

Having the significant existing areas at national level with the stands affected by drought in the meadow areas, as well as the need for their improvement and sustainable use, ecological reconstruction by afforestation of these lands contributes, in addition to generating essential ecosystem services (soil and water protection) in areas exposed to desertification and to the realization of additional incomes from the capitalization of the resulting wood or non-wood products.

ACKNOWLEDGEMENTS

This research work was carried out with the support of RNP-Romsilva, within the studies required for the ecological reconstruction of the stands affected by the drying from meadows and the establishment of optimal and feasible afforestation solutions, by respecting the norms and forest regulations in force from the production sector and of protected areas.

This paper is funded by the project: “Increasing the institutional capacity and performance of National Institute of Research and Development in Forestry "Marin Drăcea" in the activity of Research, Development and Innovation- CresPerfInst” (Contract no. 34PFE./30.12.2021) financed by the Ministry of Research, Innovation and Digitization through Program 1 - Development of the national research - development system, Subprogramme 1.2 - Institutional performance - Projects to finance excellence in Research, Development and Innovation.

REFERENCES

Angearu, C.V., Ontel, I., Boldeanu, G., Mihailescu, D., Craciunescu, V., Catana, S., & Irimescu, A. (2020). Multi-temporal analysis and trends of the drought based on MODIS data in agricultural areas, Romania. *Remote Sensing*, 12(23), 3940.

Bojariu, R., Nedealcov, M., Boincean, B., Bejan, I., Rurac, M., Pîntea, M., & Zaharia, N. (2021). Ghid de bune practici întru adaptarea la schimbările climatice și implementarea măsurilor de atenuare a schimbărilor climatice în sectorul agricol, 120p.

Constandache, C., Nistor, S., & Ivan, V. (2006). Afforestation of the degraded lands unsuitable for agriculture in the southeast of the country. *Analele ICAS*, 49, 187-204.

Constandache, C., Păcurar, V., Ivan, V., Nistor, S., & Munteanu, F. (2010). The functional efficiency of forestry plantations for protection and of amelioration works on degraded lands. *Revista Pădurilor*, 125(1), 26-31.

Constandache, C., Dincă, L., & Tudor, C. (2020). The bioproductive potential of fast-growing forest species on degraded lands, *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering,* Vol. 9, 87-93.

Constandache, C., Nistor, S., & Untaru, E. (2012). Cercetări privind comportarea unor specii de arbori şi arbuşti utilizate în compoziţia perdelelor forestiere de protecţie din sud-estul României. *Revista de Silvicultură şi Cinegetică*, 30, 35-47.

Constandache, C., Dinca, L., Tudose, N.C., & Panaitescu C. (2018). Protecting surface water resources through silvicultural methods. *SIMI 2018, Proceedings Book, section pollution assessment & management systems*, 276-284.

Davidescu, S., Murariu, G., Dinca, L., Vasile, D., Crisan, V., Cretu, R., Georgescu, L. & Deca, S. (2020). Growth potential of hybrid black poplar (*Populus x Canadensis* Moench) in Romania's East Plain. *International Journal of Conservation Science*, 11(3): 807-818.

Dănescu, F., Costăchescu, C., & Mihăilă, E. (2010). *Sistematica stațiunilor forestiere.* Editura Silvică, București, 253p.

Dănescu, F., Costăchescu, C., Mihăilă, E., & Drăgan, D. (2011). *Măsuri de gospodărire a suprafețelor forestiere cu risc de inundare și stagnare a apei din regiunea de câmpie.* Editura Silvică, București, 426p.

Dincă, L., Dincă, M., Vasile, D., Spârchez, G., & Holonec L. (2015). Calculating Organic Carbon Stock from Forest Soils, *Notulae Botanicae Horti Agrobotanici* Cluj-Napoca, 43(2), 568-575.

Dinca, L., Badea, O., Guiman, G., Braga, C., Crisan, V., Greavu, V., Murariu, G. & Georgescu, L. (2018). *Monitoring of soil moisture in Long-Term Ecological Research (LTER) sites of Romanian Carpathians*. Annals of Forest Research, 61(2): 171-188.

Dybala, K. E., Matzek, V., Gardali, T., & Seavy, N. E. (2019). Carbon sequestration in riparian forests: A global synthesis and meta-analysis. *Global Change Biology*, 25(1), 57-67.

Ducci, F., De Rogatis, A., Proietti, R., Curtu, L.A., Marchi, M. & Belletti, P. (2021). *Establishing a baseline to monitor future climate-change-effects on peripheral populations of Abies alba in central Apennines.* Ann For Res 64(2): 33-66.

Enescu, C.M., & Dănescu A. (2015). Black locust (Robinia pseudoacacia L.) - an invasive neophyte in the conventional land reclamation flora in Romania. *Bulletin of the Transilvania University of Braşov Series II: Forestry • Wood Industry • Agricultural Food Engineering*, 6 (55) No. 2, 23-30.

Fedorca, A., Popa, M., Jurj, R., Ionescu, G., Ionescu, O. & Fedorca, M. (2020). Assessing the regional landscape connectivity for multispecies to coordinate on-the-ground needs for mitigating linear infrastructure impact in Brasov – Prahova region. *Journal for Nature Conservation*. Volume 58, 125903.

Fedorca, A., Fedorca, M., Ionescu, O., Jurj, R., Ionescu, G. & Popa, M. (2021). *Sustainable landscape planning to mitigate wildlife-vehicle collisions*. Land 10(7), 737.

Filat, M., Benea, V. I., & Nicolae, C. (2009). *Poplars, willows and other forest species cultivation in floodable Danube*. Forestry Publishing House, 63-82.

Gavrilescu, G., & BOLEA, V. (2014). Ghidul inginerului silvic în contextul schimbărilor climatice. *Revista de Silvicultură și Cinegetică*, 7-17.

Kutnar, L., Kermavnar, L. & Pintar, A.M. (2021). *Climate change and disturbances will shape future temperate forests in the transition zone between Central and SE Europe.* Ann For Res 64(2): 67-86.

Murariu, G., Dinca, L., Tudose, N., Crisan, V., Georgescu, L., Munteanu, D., Dragu, M.D., Rosu, B. & Mocanu, G.D. (2021). *Structural Characteristics of the Main Resinous Stands from Southern Carpathians, Romania.* Forests, 12(8), 1029.

Nicolescu, V.N., Hernea, C., Bakti, B., Keser, Z., Antal, B., & Rédei, K. (2018). Black locust (Robinia pseudoacacia L.) as a multi-purpose tree species in Hungary and Romania: a review, *Journal of Forestry Research*, 29 (6), 1449-1463.

Onet, A., Dincă, L.C., Grenni, P., Laslo, V., Teusdea, A.C., Vasile, D.L., Enescu, R.E., & Crisan V.R. (2019). Biological indicators for evaluating soil quality improvement in a soil degraded by erosion processes. *Journal of Soils and Sediments*, 19(5), 2393-2404.

Roșu, C., Dănescu, F., (2013). Probleme privind stațiunile forestiere și reconstrucția ecologică a pădurilor în contextul schimbării condițiilor de mediu (regionale și locale) în România, *Revista Pădurilor* nr. 4-5, 11-16

Smith, B., Clifford, N. J., & Mant, J. (2014). The changing nature of river restoration. *Wiley Interdisciplinary Reviews: Water*, 1(3), 249-261.

Spîrchez, Gh.C., & Lunguleasa, A. (2016). Biomasa lemnoasă, o sursă importantă de energie regenerabilă, *Buletinul AGIR,* 1, 40-42.

Tiwary, A., Vilhar, U., Zhiyanski, M., Stojanovski, V. & Dinca, L. (2020). Management of nature-based goods and services provisioning from the urban common: a pan-European perspective. *Urban Ecosystems*, 23(3), 645-657

Tudor, C., Constandache, C. & Dincă, L. (2020**).** The social and economic contribution of the main categories of non-wood forest products from Buzau County, Romania. *Scientific Papers. Series A. Agronomy*, 63(2), 319-323

Untaru, E. (1976). Reforestation a means of reclaiming degraded soils in the Vrancea area [Romania]. *Buletinul-Academiei-de-Stiinte-Agricole-si-Silvice (Romania)*, 4, 43-52.

Untaru, E., Constandache, C., & Nistor, S. (2012 and 2013). Starea actuală şi proiecţii pentru viitor în privinţa reconstrucţiei ecologice prin împăduriri a terenurilor degradate din România (I şi II). *Revista Pădurilor*, 6/2012, 28-34 ; 1/2013, 16-26.

Yao, Y., Fu, B., Liu, Y., Wang, Y., & Song, S. (2021). The contribution of ecosystem restoration to sustainable development goals in Asian drylands: A literature review. *Land Degradation & Development*, 32(16), 4472-4483.

Vechiu, E., Dinca, L. & Breabăn, I. G. (2021). *Old Forests from Dobrogea's Plateau.* Present Environment and Sustainable Development, 15(1): 171-178

Vlad, R., Constandache, C., Dincă, L., Tudose N.C., Sidor, C.G., Popovici, L. & Ispravnic, A. (2019). *Influence of climatic, site and stand characteristics on some structural parameters of scots pine (Pinus sylvestris) forests situated on degraded lands from east Romania*. Range Management and Agroforestry, 40 (1): 40-48.

Zhou, J., Zhang, Z., Sun, G., Fang, X., Zha, T., McNulty, S., ... & Noormets, A. (2013). Response of ecosystem carbon fluxes to drought events in a poplar plantation in Northern China. *Forest Ecology and Management*, 300, 33-42.

***INCDS "Marin Dracea", 2021. *Studiu pedostaţional în vederea stabilirii compoziţiilor de regenerare în arborete afectate de uscare în masă datorită secetei (13,16 ha), situate pe raza OS Ianca.*

***INCDS "Marin Dracea". *Parcul memoriei naţionale - RoMandria Marasesti, judeţul Vrancea,* Memoriu tehnic (2017) si Addendum la studiu de fezabilitate (2021).

***INCDS "Marin Dracea", 2019. *Revizuirea sistematicii staţiunilor forestiere utilizată în zonele de luncă ale râurilor interioare, în vederea adaptării măsurilor de gospodărire a arboretelor la modificarea condiţiilor staţionale.* National Project Report, code PN 19070503.

https://www.meteoromania.ro/anm/images/clima/SSCGhidASC.pdf

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE VARIATION ON TYPES OF MICROHABITATS ON TREES IN A NATURAL FOREST - "IZVOARELE NEREI" NATURAL RESERVE - CASE STUDY

Cătălin-Ionel CIONTU[1, 2], Ilie-Cosmin CÂNTAR[1], Daniel-Ond TURCU[1], Gheorghe Florian BORLEA[2]

[1]National Institute for Research and Development in Forestry "Marin Dracea", 8 Padurea Verde Alley, Timisoara, Romania
[2]Banat Univeristy of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, 119 Calea Aradului, Timisoara, Romania

Corresponding author email: ciontu_catalin@yahoo.com

Abstract

The aim of the paper is to highlight the variation of the frequency and types of microhabitats on trees, in a natural beech forest, depending on different stand characteristics and site condition. The research was carried out in the "Izvoarele Nerei" Nature Reserve from Caras-Severin County, Romania, the previously announced aim being achieved by fulfilling objectives such as: identifying the types of microhabitats on trees (according classification from specialty literature) on altitudinal levels, establishing the influence of altitude on the frequency of microhabitats, identification of other stand characteristics and site conditions having an influence on the frequency of microhabitats on trees. The research was carried out on four altitudinal levels (800, 1000, 1200 and 1350 m), trees characteristics determination and microhabitats identification being carried out in sample areas of 2500 m^2, two on each altitudinal level. The most frequent microhabitats were: branch rot hole (length >= 5 cm), cracks and scars (length >= 100 cm), root buttress cavities (length >= 5 cm), epiphytic lichens (coverage > 25 %), root buttress cavities (length >= 10 cm), branch rot hole (length >= 10 cm).

***Key words**: biodiversity, beech forest, rot hole, buttress cavities.*

INTRODUCTION

The importance of research in virgin forests has been highlighted countless times by the possibility of applying the results obtained in the management of cultivated forests. Studying the correlations between the structure and dynamics of virgin forests, but also the links between species and environmental factors can lead to finding new solutions to improve regeneration techniques and the composition of forest stands. Research into virgin forests should be seen as a tool for understanding the processes and interactions between different species. This method can be used to obtain information that can be used in forestry close to nature. (Schuck et al., 1994).
The first research on ecosystems began in the second half of the 19th century. The favourite research topics at the time were freshwater biocenoses. Research on forest ecology began later, thanks to Russian forester Morosow. (Schuck et al., 1994)
Research in the natural forests of central and south-eastern Europe has been strongly influenced by Leibundgut. According to him, the problems and aims of research in virgin forests should focus on the following issues:
• processes and dynamics of different forest communities;
• the stability of forest stands in different stages of development against environmental factors;
• the influence of regeneration on the development and aging processes of the forest stand;
• the appearance and causes of the successions. (Schuck et al., 1994).
A rather little researched aspect in Europe, but especially in Romania, is that of tree-related microhabitats (hereafter TreMs), (Bütler et al., 2013) - these having a special importance in forest habitats, recent studies highlighting their use as a proxy for local taxonomic diversity (Larrieu et al., 2014b; Kraus et al., 2016; Larrieu et al., 2018).

Current research at European level in the field imposes a new paradigm: maintaining and improving the biodiversity of forest ecosystems, not only by creating reserves, but also by increasing the biodiversity of managed forests.

Tree microhabitats are important for the complexity of forest habitats, whose structural diversity enriches them, thus creating conditions for increasing biodiversity. In general, for the existence of most of the microhabitats identified so far, large trees (especially large diameters) are needed, but also an adequate density of these large trees. (Larrieu et al., 2014a).

This study should be considered as one of the first to provide quantitative data on microhabitat densities for Romania, along with other studies (Tomescu et al., 2004; Tomescu et al., 2008; Turcu, 2012). The research is complementary to that of other studies already published for other forests, types and biogeographical regions in France and Europe (Bouget et al., 2013; 2014; Larrieu et al., 2014b; Winter et al., 2015).

In the literature there is a very varied terminology regarding the definition of forests with a high degree of naturalness, without this terminology always being used in a unitary way. Thus, based on the literature, the most frequently used terms that define the forests mentioned above were searched. These terms are: ancient forest, natural forest, old-growth forest, primary forest, primeval forest, relict forest, untouched forest, virgin forest. Based on the definitions published in various scientific papers, they have been translated and explained.

Since there is already a long tradition in the study of natural forests (Tomescu et al., 2004; Tomescu et al., 2008; Turcu, 2012), this study proposes to complete this research with aspects on TreMs.

The hypothesis of the research that was the basis of this study is that the types of microhabitats in the “Izvoarele Nerei” Nature Reserve vary with the characteristics of the forest stands (plot description) and with the specific forest site.

The aim of the paper is to highlight the differences regarding the frequency of microhabitats by their types in “Izvoarele Nerei” Nature Reserve and the influence of tree characteristics and the conditions of the forest site on microhabitats. The goal was achieved by fulfilling the following objectives:

1. Identifying the types of TreMs on altitudinal levels;
2. Establishing a link between altitude and the frequency of some TreMs;
3. Identify other characteristics of the forest stand and the forest site on the frequency and types of TreMs.

MATERIALS AND METHODS

The research is located in the “Izvoarele Nerei” Nature Reserve, in the southwest of Romania, on the territory of Caraş-Severin County, within the Nera Forest District and from the point of view of the local administration within the Prigor commune. The location of the Reserve at the Romanian level is shown in Figure 1a.

Currently, the Reserve is included in the Semenic - Cheile Caraşului National Park, occupying its southeastern part and also constituting one of the wildest areas of the Park (Figure 1b).

The “Izvoarele Nerei” reservate is located from a geographical point of view between the coordinates 45°5′ - 45°10′ north latitude and 22°2′30″ - 22°6′40″ east longitude; Regarding the forest management, the reserve is located within the Nera Forest District, managed by the Caras-Severin Forestry Department and belongs to the production units II Nergana and III Nergăniţa.

The reservate occupies a total area of 5028.0 ha, included in the upper basins of the rivers Nergana (Bănieş) and Nergăniţa. According to OM 552/2003, GEO 57/2007 regarding the regime of protected natural areas, conservation of natural habitats, of wild flora and fauna, approved with modifications and completions by Law no. 49/2011, the strictly protected areas, included in the type of functional category T1 -excluding any kind of forestry interventions, are found in the following development units:

• U.P. II Nergana: parcells 19, 20, 24, 25, 28, 29, 31-33, 52-14, total 2930.0 ha
• U.P. III Nergăniţa: parcells 6-63, total 1956.0 ha

It was installed 8 plots in the natural forest ("Izvoarele Nerei" Nature Reserve), with an area of 0.25 hectares (2500 m^2) each, distributed respectively 2 on 4 altitude levels: 800, 1000, 1200 and 1350 m (Figure 1).

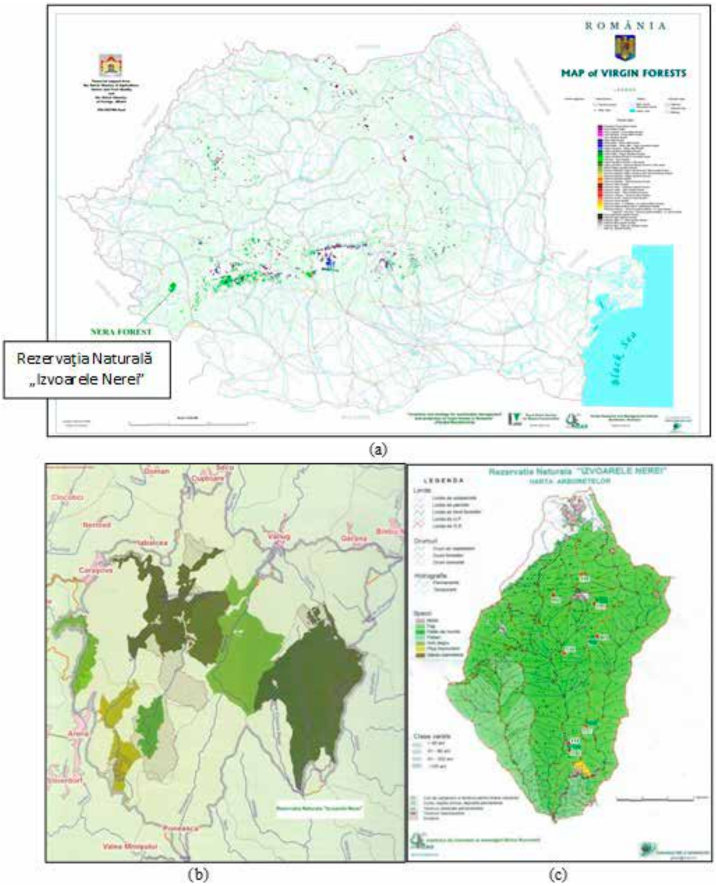
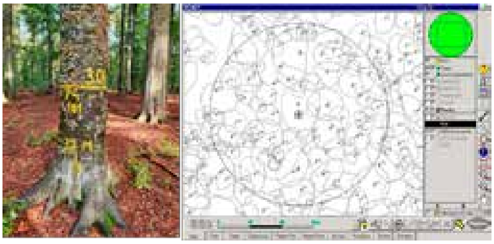


Figure 1. The location of the “Izvoarele Nerei” Nature Reserve and the location of the test areas;
a - map of Romania - Distribution of virgin forests in Romania (after Veen and Biriş, 2004), b - Location of the “Izvoarele Nerei” Nature Reserve within the Semenic National Park - Cheile Caraşului (dark green) (after Bădescu and Vlaicu 2011); c - Map of “Izvoarele Nerei” Nature Reserve and the location of the 8 permanent sample plots of 0.25 ha each (based on Tomescu et al. 2004-2006)

The assessment of the frequency and qualitative characteristics of the TreMs in the natural forest was done in the test areas, the trees were identified and their position was taken with the help of FildMap equipment, the diameters were measured using a forest calliper, the heights of the trees were measured with the help of Vertex III equipment.
Regarding the presence and frequency of microhabitats, the classification proposed by the European Forestry Institute (EFI) through the Integrate + project (www.integrateplus.org) and materialized in the Catalogue of tree microhabitats (Kraus et al., 2016).
For the correct inventory and characterization of the microhabitats encountered on each tree, a specific terrain sheet was elaborated. Although the inventory and description of the microhabitats was carried out on individual trees, the characterization of the presence, respectively the frequency/abundance, was made at the level of the forest stand (and, for an easier use of the results, by reduction per hectare). A relationship was made between the

presence/frequency of microhabitats and the presence of thick trees, both in the natural forest, to establish possible correlations.

The research was done in 8 plots with an area of 0.25 hectares (2500 m2) each, distributed respectively 2 by 4 altitudinal levels: 800 m (plots 114 and 116), 1000 m (plots 110 and 112), 1200 m (101 and 102) and 1350 m (plots 118 and 119). These were materialized in the field with the device FieldMap (www.field-map.com) (Figure 2 a, b).



(a) (b)

Figure 2. a - Field materialization of the plot;
b - Graphic representation of plot no. 112 measured with FieldMap

The 10 most common types of TreMs at altitude levels were presented. With the help of the t-student statistical test, the hypothesis was tested according to which is a statistical link between groups of certain types of TreMs and altitude. Using the Pearson correlation coefficient, the correlation between the number of TreMs in the groups with the most common microhabitat types and the altitudinal levels at which they were observed was studied. For groups of microhabitats that have the highest correlation between the number of microhabitats and exposition (expressed in sexagesimal degrees to the north) and the slope (expressed in degrees), models of linear statistical links were developed.

RESULTS AND DISCUSSIONS

Types of TreMs in the "Izvoarele Nerei" Nature Reserve

The types of TreMs inventoried in the 8 plots in which the research was conducted are listed in Table 1, being in accordance with the latest classification in the literature, as previously specified in the chapter material and method (Kraus et al., 2016).

Table 1. TreMs frequency. The list refers to the TreMs frequencies within all 8 plots.
The record "Other" refers to 32 TreMs types that present individual frequencies lower than 10

TreMs Code	TreMs type	Frequency of TreMs	Frequency (%)
CV31	Branch hole ø ≥ 5 cm	635	14.96
IN32	Cracks and scars Length ≥ 100 cm; width > 1 cm; depth > 10 cm	377	8.88
GR11	Root buttress cavities ø ≥ 5 cm	359	8.46
EP32	Epiphytic foliose and fruticose lichens, coverage > 25 %	247	5.82
GR12	Root buttress cavities ø ≥ 10 cm	229	5.39
CV32	Branch hole ø ≥ 10 cm	199	4.69
GR31	Cancerous growth, ø > 20 cm	170	4.01
BA11	Bark shelter, width > 1 cm; depth > 10 cm; height > 10 cm	148	3.49
BA12	Bark pocket, width > 1 cm; depth > 10 cm; height > 10 cm	132	3.11
CV33	Hollow branch, ø ≥ 10 cm	111	2.61
CV44	Dendrotelms and water-filled holes ø ≥ 15 cm/crown	93	2.19
DE13	Dead branches and limbs ø 10–20 cm, not sun-exposed	92	2.17
CV12	Woodpecker cavities ø = 5–6 cm	89	2.10
BA21	Coarse bark	81	1.91
EP12	Perennial polypores, ø > 10 cm	80	1.88
CV23	Trunk and mould cavities ø ≥ 10 cm	71	1.67
DE11	Dead branches and limbs ø 10–20 cm, sun-exposed	66	1.55
IN31	Cracks and scars Length ≥ 30 cm; width > 1 cm; depth > 10 cm	61	1.44
IN11	Bark loss 25- 600 cm^2, decay stage < 3	53	1.25
CV14	Woodpecker cavities ø ≥ 10 cm feeding hole)	46	1.08

CV24	Trunk and mould cavities ø ≥ 30 cm	46	1.08
CV15	Woodpecker "flute " / cavity string	44	1.04
EP13	Woodpecker cavities ø ≥ 10 cm feeding hole)	44	1.04
IN12	Bark loss > 600 cm^2, decay stage < 3	30	0.71
DE12	Dead branches and limbs ø > 20 cm, sun exposed	25	0.59
EP31	Epiphytic bryophyte coverage > 25 %	25	0.59
GR13	Trunk cleavage length ≥ 30 cm	21	0.49
GR22	Water sprout	21	0.49
OT11	Sap flow > 50 cm	19	0.45
CV13	Woodpecker cavities ø > 10 cm	11	0.26
IN14	Bark loss > 600 cm^2, decay stage = 3	11	0.26
EP11	Annual polypores, ø > 5cm	10	0.24
Others	Other TreMs	599	14.11

Based on the graphs presented below, the main four microhabitats for each altitudinal level were selected (Figure 3). The first four most numerous microhabitats identified on each altitudinal level were also tracked within the other altitudinal levels.

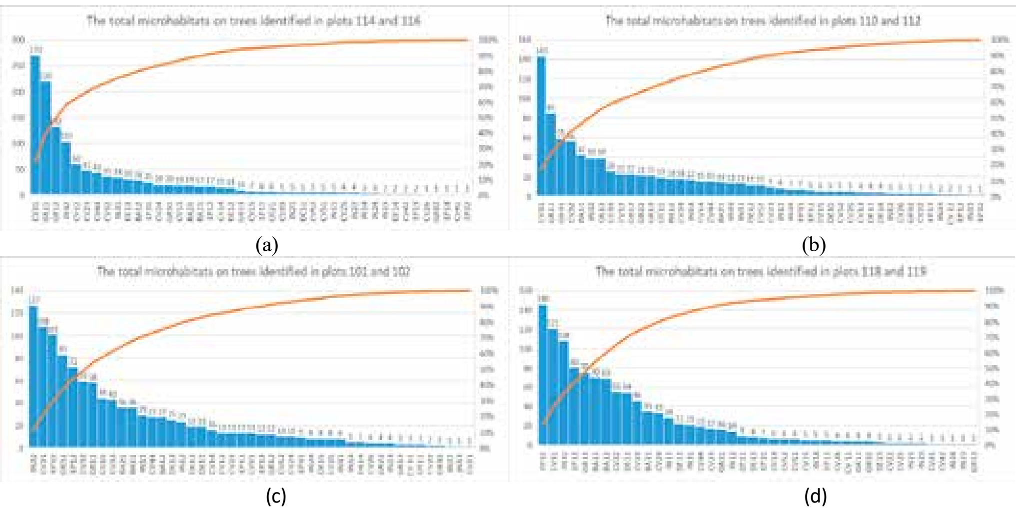


Figure 3. Total number of microhabitats by their types in the plots (a - 800 m altitude level; b - 1000 m altitude level; c - 1200 m altitude level; d - 1350 altitude level)

Thus, the most common microhabitat in the studied sample areas was CV31, with an almost double number of microhabitats compared to those of type IN32 and GR11. The following microhabitats encountered, presented in descending order of number are: EP32, GR 12, CV 32, GR 31, EP12 (Table 2).

Table 2. The most popular microhabitats that appear on the 4 altitudinal levels

Altitude	CV31	IN32	GR11	EP32	GR12	CV32	GR31	EP12
800	270	103	220	1	132	35	20	17
1000	143	39	85	1	22	56	59	2
1200	108	127	58	101	12	59	83	72
1350	121	108	4	146	75	55	16	80
TOTAL	642	377	367	249	241	205	178	171

As can be seen in the graph below (Figure 4), we cannot talk about an increase or decrease in the total number of microhabitats with altitude.

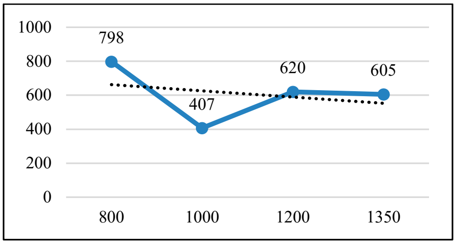


Figure 4. Variation in total number of microhabitats with altitude

However, the number of microhabitats encountered is very high at altitudes below 1000 m, their number decreases to an altitude of 1000 m to increase later and remain almost constant at altitudes of 1200 and 1350 m, respectively.
For two of the microhabitats, which are also the most numerous at the altitudinal level of 800 m, decreases of the number of microhabitats were observed with the increase of the altitude, almost on the entire altitudinal range analyzed; the exception is CV31 microhabitats at an altitude of 1350 m where a slight increase was found.
The number of microhabitats of type GR11 registers a constant decrease on the studied altitudinal range, reaching very small values identified at the altitudinal level of 1350 m (4 microhabitats of this type).
The variation of the number of microhabitats from CV32 and EP32 types is almost complementary to the variation of the types presented above. The number of micro-habitats of the CV32 type increases with the altitude up to 1200 m and registers a slight decrease at the altitude level of 1350 m.
EP 32 type microhabitats were recorded in very small numbers at altitudes of 800 and 1000 m (one microhabitat of this type at each altitude level), but at over 1000 m the increase is constant over the entire altitudinal range studied.
Regarding the other types of microhabitats identified in significant numbers, no relationship was observed between their number and the increase of the altitude.
However, in the case of three of the four types in the above figures (GR12, IN32, EP12) a decrease in the number of microhabitats was observed in the range 800-1000 m, similar to the decrease in the total number of microhabitats identified in this altitudinal range.
In the case of GR31, the increase in the number of microhabitats is constant between 800 and 1200 m, but suddenly decreases above this altitude, proving that the high altitude is not favourable for this type of microhabitat.

Frequency of TreMs and altitude

The relationship between altitude and frequency of TreMs was analyzed using the Pearson correlation coefficient. The Pearson correlation coefficients between the groups of TreMs and the altitudinal levels at which the test surfaces were located (800 m, 1000 m, 1200 m, 1350 m) are shown below:

- $r = -0.745$ for the cavity group (CV) - high inverse correlation;
- $r = 0.474$ for the group of injuries and wounds (IN) - reasonable direct correlation;
- $r = 0.929$ for the bark group (BA) - very high direct correlation;
- $r = 0.954$ for the group of crown deadwood (DE) - very high direct correlation;
- $r = -0.974$ for the group of in the root buttress cavities (GR) - very high inverse correlation;
- $r = 0.903$ for the group of fruiting bodies of fungi (EP) - very high direct correlation;
- $r = -0.244$ for the group of sap and resin run (OT) - very weak direct correlation.

The microhabitats in the cavity group (CV) show a decrease in number with increasing altitude, the high inverse correlation being related to the more difficult development of fungi and microorganisms that favour them, with increasing altitude. The number of injuries and wounds (IN) does not show a high correlation with the altitude, being rather the product of some events in the life of the natural forest (fillings, wounds caused by animals, etc.). For the bark group (BA) the direct correlation is very high, the number of microhabitats in this group increasing significantly with increasing altitude. A cause of this correlation can be given by the vulnerability to diseases and pests of trees that grow at the upper altitude limit of the area. The same happens in the case of microhabitats from the group of crown deadwood (DE), whose frequency registers a very high direct correlation with the increase of the altitude. The root buttress cavities (GR) are becoming less frequent with increasing altitude (very high inverse correlation), due to the shorter cycle of microorganism colonies on the soil surface at higher and average altitudes of higher annual temperatures. However, the fruiting bodies of fungi (EP) are more frequent with increasing altitude, which is explained only by the increased vulnerability of trees that grow at higher altitudes than the ecological optimum. Sap and resin run (OT) microhabitats are favoured by higher temperatures and longer vegetation seasons, the number of which decreases with increasing altitude, but their frequency correlation with altitude is weak (Fütterer et al., 2017).

Testing statistically using the t-student statistical test, the hypothesis that there is a statistical link between groups of certain types of TreMs and altitude, significant differences were found only between the altitudes minimum and maximum altitudes for microhabitats in the bark group (BA) (Table 3). Therefore, the amplitude of 550 m between the minimum and maximum altitudes in which observations were made, and the high altitude of the last altitudinal level, lead to significant differences in the frequency of microhabitats in the bark group (BA) in the "Izvoarele Nerei" Nature Reserve.

Table 3. T-student statistical test - values of p for testing differences in the number of microhabitats in the bark group (BA) at altitude levels ($p < 0.05$ - significant differences, $p < 0.01$ distinctly significant differences, $p < 0.001$ very significant differences)

Altitudinal level	800	1000	1200	1350
800	1	0.693	0.151	0.038
1000	0.693	1	0.454	0.082
1200	0.151	0.454	1	0.126
1350	0.038	0.082	0.126	1

Stationary conditions and their influence on TreMs

The site conditions have a determined role on the forest habitat, implicitly influencing the formation, development and maintenance of TreMs. Of these, in the analysed surfaces, the soil type and the forest site type are identical in all 8 plots. Stationary conditions such as slope and terrain exposure differ from case to case (Table 4), as does altitude. The latter was a criterion for the design of the research and the location of the test surfaces and was previously analysed in the context of TreMs.

Table 4. Microhabitats on their groups in the plots and some stationary conditions

	Altitude (m)	800		1000		1200		1350	
	Plot no.	114	116	110	112	101	102	118	119
	Cardinal orientation of the slope	V-NV	V-SV	NV	SE	S	V	NV	SV
	Cardinal orientation of the slope (sexagesimal degrees)	67.5	112.5	45	225	180	90	45	135
	Slope (degrees)	30	32.5	27.5	20	17.5	20	10	5
Group of microhabitats (no. of microhabitats per group)	Cavity (CV)	264	228	220	42	152	168	146	111
	Injuries and wounds (IN)	80	57	63	0	48	123	76	85
	Bark (BA)	13	25	33	24	23	69	123	51
	Crown deadwood (DE)	12	18	37	10	24	25	41	26
	Root buttress cavities (GR)	225	145	207	0	31	106	73	13
	Fruiting bodies of fungi (EP)	13	12	0	0	88	67	92	134
	Sap and resin run (OT)	0	0	19	0	0	0	0	0

As can be seen in Table 4, the exposure of the land in the test areas varies between orientations from 450 to 2250 in the N direction, covering half of the possible orientations, from NW to SE. Of the 7 most common groups of TreMs, only 4 of them can talk about a linear relationship between their number and orientation and having a coefficient of determination (R^2) with a reasonable value (Figure 5).

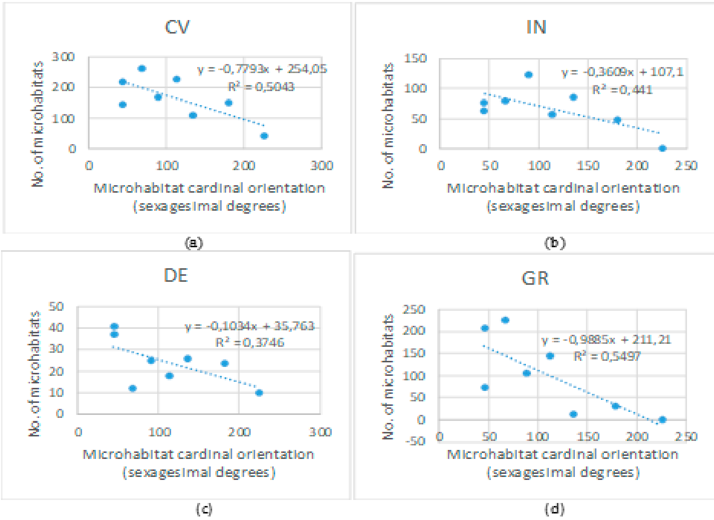


Figure 5. The relationship between the groups of microhabitats and the exposure of the land (a - cavities; b - injuries and wounds; c - crown deadwood; d - root buttress cavities)

As can be seen, the highest value of the coefficient of determination is recorded in the group of microhabitats such as root buttress cavities (GR). In all cases, however, the highest values are observed on exposures close to N, the frequency of microhabitats decreasing and reaching minimum values on S, SE and SV. Therefore, it is observed that insolation leads to a small number of microhabitats, inhibiting to a certain extent the development of decomposing microorganisms and fungi.

The groups of microhabitats for which the coefficient for determining (R^2) the linear relationship between the number of microhabitats and the slope, has reasonable values, are the cavities (CV), bark (BA), root buttress cavities (GR) and the fruiting bodies of fungi (EP) (Figure 6).

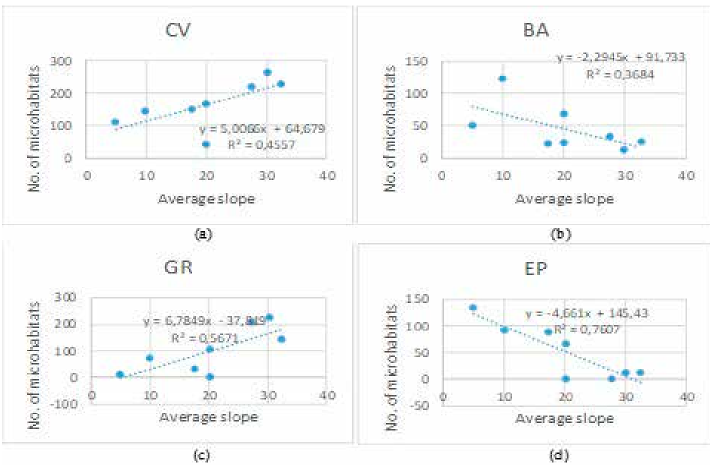


Figure 6. The relationship between the groups of microhabitats and the slope
(a - cavities; b - bark; c - root buttress cavities; d - fruiting bodies of fungi)

As can be seen, the increase in the slope causes an increase in the number of microhabitats in the cavity groups (CV) and the root buttress cavities (GR). Increasing the slope causes a decrease in the number of microhabitats in the bark groups (BA) and the fruiting bodies of fungi (EP).

CONCLUSIONS

This paper is one of the first attempts to address this research topic in our country. The main advantage consists in the certain natural value of the stands studied, the stands from Izvoarele Nerei, which have a very high degree of naturalness, and where they can be observed the characteristics and natural processes of beeches in the form least influenced by anthropogenic activities.
The most frequent microhabitats were:
-CV31 - Branch rot hole >= 5 cm;
-IN32 - Cracks and scars L >= 100 cm;
-GR11 - Root buttress cavities >= 5 cm;
-EP32 - Epiphytic lichens, coverage > 25%;
-GR12 - Root buttress cavities >= 10 cm;
-CV32 - Branch rot hole >= 10 cm.
The high amplitude between the extreme altitude levels among those analyzed and the high altitude of the last altitude level led to significant differences in the frequency of microhabitats in the bark group (BA) in the "Izvoarele Nerei" Nature Reserve.
Between the altitude and the frequency of the TreMs, the Pearson correlation coefficient shows that there are high direct or inverse correlations in most of the groups of microhabitats studied.
The highest frequency of microhabitats is recorded on lands with exposures close to N, and the lowest frequency on lands with exposures S, SE and SV.
Increasing the slope causes more injuries to the trunks and root buttress, which over time lead to microhabitats in the group of trunk cavities (CV) and root buttress cavities (GR). Increasing the slope leads to a decrease in the number of microhabitats in the bark groups (BA) and the fruiting bodies of fungi (EP).

ACKNOWLEDGEMENTS

This research work was carried out with the support of Ministry of Research, Innovation and Digitization (MCID) through “Programul 1 – Dezvoltarea sistemului naţional de cercetare - dezvoltare, Subprogram 1.2 – Performanţă instituţională - Proiecte de finanţare a excelenţei în CDI” - project “Creșterea capacității și performanței instituționale a INCDS „MarinDrăcea”) în activitatea de CDI - CresPerfInst“ (Contract no. 34PFE./30.12.2021) and it is part of doctoral thesis of Ciontu Cătălin Ionel entitled “Comparative study regarding the microhabitates - in the natural and cultivated beech forest”.

REFERENCES

Bădescu, B.; Vlaicu, M. (2011). Atlasul habitatului 8310 din situl Natura 2000 Semenic – Cheile Caraşului, *Editura Brumar*, Timişoara, 71 p.
Bouget, C., Larrieu, L., Brin, A. (2014). Key features for saproxylic beetle diversity derived from rapid habitat assessment in temperate forests*. Ecol. Indicat*. 36, 656–664.
Bouget, C., Larrieu, L., Nusillard, B., Parmain, G. (2013). In search of the best local habitat drivers for saproxylic beetle diversity in temperate deciduous forests. *Biodivers. Conserv*. 22, 2111–2130.
Bütler, R.; Lachat, T.; Larrieu, L.; Paillet, Y. (2013). Habitat trees: Key elements for forest biodiversity. In *Integrative Approaches as an Opportunity for the Conservation of Forest Biodiversity;* Kraus, D., Krumm, F., Eds.; European Forest Insititute: Joensuu, Finland; pp. 84–91.
Fütterer, S., Diener, E. M. (2017). Comparison of the microhabitats in virgin beech forest and managed forests in Semenic National Park, *Paper in the practical semester, Engineering of forestry*, University of Applied Sciences Weihenstephan-Triesdorf, Germany, 17 p.
Kraus, D., Bütler, R., Krumm, F., Lachat, T., Larrieu, L., Mergner, U., Paillet, Y., Rydkvist, T., Schuck, A., Winter, S. (2016). Catalogue of tree microhabitats – reference field list. In: *Integrate + Technical Paper. European Forest Insitute*, Freiburg, Germany.
Larrieu, L., Cabanettes, A., Brin, A., Bouget, C., Deconchat, M. (2014a). Tree microhabitats at the stand scale in montane beech-fir forests: practical information for taxa conservation in forestry. *Eur. J. For. Res.* 133, 355–367.
Larrieu, L., Cabanettes, A., Gonin, P., Lachat, T., Paillet, Y., Winter, S., Bouget, C., Deconchat, M. (2014b). Deadwood and tree microhabitat dynamics in unharvested temperate mountain mixed forests: a life-cycle approach to biodiversity monitoring. *For. Ecol. Manage.* 334, 163–173.
Larrieu, L.; Paillet, Y.; Winter, Susanne; Butler, Rita; Kraus, D.; Krumm, F.; Lachet, Th.; Michel, A.; Regnery, B.; Vandekerkhove, K., (2018). Tree related microhabitats in temperate and Mediterranean European Forests: A hierarchical typology for inventory standardization. *Ecological Indicators* 84, 194-207.

Schuck, A., Parviainen, J., Bücking, W. (1994). A Review of Approaches to Forestry Research on Structure, Succession and Biodiversity of Undisturbed and Semi-natural Forests and Woodlands in Europe, Europen Forest Institute, Working Paper 3.

Tomescu, R.; Târziu, D.; Gancz, V.; Petrila, M.; Teodosiu, M.; Turcu, D.O.; Brad, R.; Ştefca, I. (2004-2006). Studiul factorilor de stabilitate in ecosistemele forestiere naturale. Evaluarea posibilităţilor de ameliorare a practicilor silvice în vederea gospodăririi durabile a pădurilor/A Study of the Stability Factors in Natural Forest Ecosystems. Evaluation of the Possibilities to Ameliorate the Silvicultural Practices for the Sustainable Management of the Forests, Forest Research and Management Institute (ICAS) Bucharest, The Ministry of Agriculture, Forests and Rural Development, 3 volumes.

Turcu, D. O. (2012). Cercetări privind dinamica structurii făgetelor virgine şi a mortalității arborilor din Rezervaţia Naturală „Izvoarele Nerei" / Research on the structural dynamics of virgin beech forests and mortality of trees in the „Izvoarele Nerei" Nature Reserve, PhD thesis (in Romanian), "Transilvania" University Braşov, 156 p.

Veen, P.; Biriş, I.-A. (eds.) (2004). Inventory and strategy for sustainable management and protection of virgin forests in Romania – PINMATRA project, co-financed by the *Dutch Royal Society for Nature Conservation*, KNNV.

Winter, S., Höfler, J., Michel, A.K., Böck, A., Ankerst, D.P. (2015). Association of tree and plot characteristics with microhabitat formation in European beech and Douglas-fir forests. *Eur. J. Forest Res.* 134, 335–347.

*** 2005: Amenajamentul O.S. Nera (S.G., U.P. II, U.P. III), D.S. REȘIȚA.

www.integrateplus.org

www.field-map.com

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

MODELING OF INDICATORS OF ECONOMIC EFFICIENCY OF SECTORAL LAND USE

Oleksandr CHUMACHENKO, Ivan OPENKO, Yevheniia KRYVOVIAZ, Oleksiy ZHUK

National University of Life and Environmental Sciences of Ukraine,
17 Vasylkivska Street, Kyiv, Ukraine

Corresponding author email: zmenichka@ukr.net

Abstract

This article provides an in-depth analysis of the calculation of gross domestic product (GDP) by the production method which is based on gross value added by type of economic activity. The dynamics of indicators that determine the directions of state economic policy is studied. Multi-vector use of GDP, creates a basis for financial support from the IMF, the Maastricht convergence criteria, the forecast of public defense spending.
Assessing the contribution of each type of economic activity and each institutional sector of the economy to the creation of GDP, the study identified the following types of economic activity: agriculture; forestry; industry; construction; trade, transport; IT field; financial and insurance activities; scientific and technical, administrative activities; public administration, defense, education, health care and social services; other services (taxes, arts, entertainment and recreation). An important stage of the study was to find the relationships between economic indicators of profitability (average GDP per unit area) and the use of land resources, considering the institutional sectors of the economy. The analysis shows the level of dependence of the income of a particular sector of the economy on the area of land use involved in the formation of national economic benefits. Dependences of profitability of economic sectors on land resource potential are revealed. It is established that to ensure high economic indicators (GDP indicators), it is necessary to develop economic sectors that have a significant impact on the formation of national wealth.

Key words: *economic efficiency, GDP, land use, nature management.*

INTRODUCTION

The increase in the intensity of nature management in the context of the spread of economic benefits, negatively affecting the state of biodiversity, so over the past 400 global populations in the wild has decreased by 60%. According to research presented at the World Economic Forum (WEF, Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and Economy, New Nature Economy project, Geneva, 2020), more than half of the world's aggregate GDP (gross domestic product) depends on nature. The problem of the use of natural resources and the level of dependence of global and national economies on the intensity of nature use is acute in the context of climate change. Trends in losses and irreversible transformations of natural resource potential are most pronounced in countries whose economies are actively developing.

Global economic trends indicate that about one third of the GDP of India (33%), Indonesia (32%) and the African region (24%) is generated in industries that actively use natural resources (WEF, Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and Economy, New Nature Economy project, Geneva, 2020). The world's largest economies are characterized by the highest absolute amounts of GDP that depend on the natural sector, namely: China ($ 2.7 trillion), the EU ($ 2.4 trillion) and the United States ($ 2.1 trillion), i.e., even a relatively small share of their economy has a significant impact. In the formation of total value added in different industries there is an imbalance in intensity and dependence on nature (Figure 1). As can be seen from the diagram, the dependence of gross value added (GVA) in the first eight sectors of production is significant, the following industries are characterized by an average level of dependence. According to a study conducted by the World Economic Forum, about 44 trillion. US dollars in the structure of world GDP depends on natural capital assets, and therefore are potentially at risk. In general, the dependence of the global economy on natural resources in

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

terms of industries shows that the efficiency of production in some industries is strongly influenced by environmental dependence, their share in GDP is 15% (13 trillion US dollars). Partially dependent industries produce about 37% of world GDP (31 trillion US dollars). The most nature-intensive sectors of production form about 8 trillion. USD gross value added: construction - 4 trillion. dollars, agriculture - 2.5 trillion. USD and food industry - 1.4 trillion. US dollars. The peculiarity of nature use of these sectors of production is both the direct extraction of resources from the environment and the provision of ecosystem services (soil protection, conservation of water resources, etc.). Features of nature-intensive sectors of production suffer losses from the loss of ecosystem functions and its ability to recover.

Summing up, we can say that the formation of absolute economic indicators (GDP, GVA) in the structure of production is characterized by heterogeneity. Sectoral nature dependence is a deterrent to economic growth in the regions.

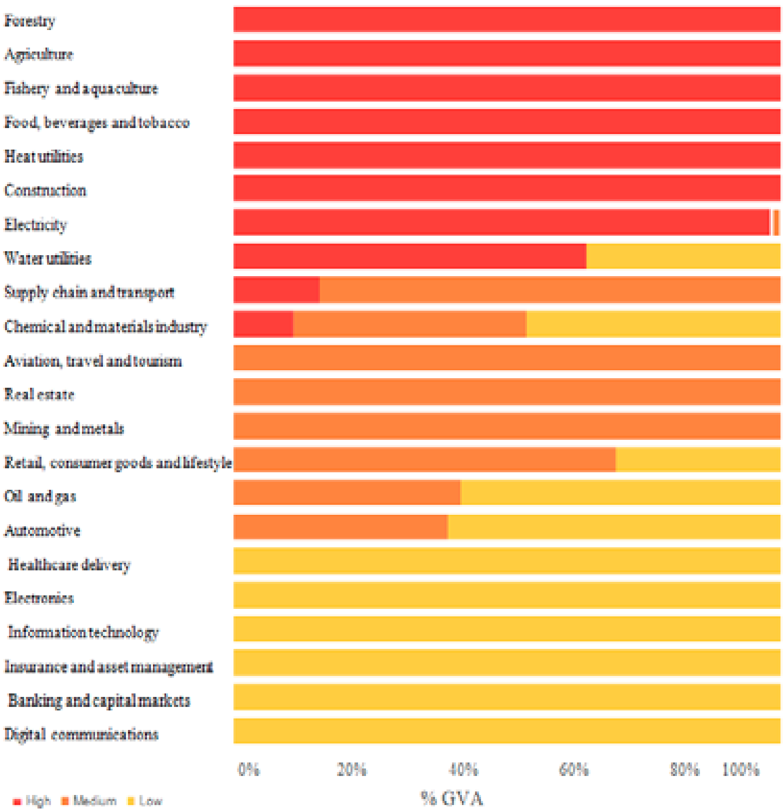


Figure 1. Sectorial nature and value added, % (WEF, Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and Economy, New Nature Economy project, Geneva, 2020)

MATERIALS AND METHODS

The study set the task of substantiating the dependence of financial and economic indicators on the efficiency of land use potential in the structure of land use in Europe.

It is worth noting that land resources are an integral part of natural resources and an important factor in economic growth on a par with capital, labor, and scientific and technological progress.

The study was based on data collection, based on documents available on the digital platform Scopus and other scientific databases. Thus, the study studied and analyzed the work in which the issues of managing growth and change of economic indicators (Vera Ferreira et al., 2022), modeling of GDP (Paolo Andreini et al., 2021), the problem of land use-resource potential (Chumachenko et al., 2021; Kryvoviaz et al., 2020). In the Scopus database, he searched for research papers on the keywords "land use", "gross domestic product", "economic efficiency", "sectoral production", as a mechanism for determining scientific products have already been published.

The sample was conducted from a list of documents published for the period from 2015 to October 2021. The result of this work was the verification of documents filtered by years, authors, affiliation, field of knowledge, journal documents, source and keywords. systematic analysis and study of selected articles.

The author's calculation of economic indicators was carried out in the research and their dependence was established on the basis of open data. Microsoft Office Excel software was used for the calculation. The methodology of the State Statistics Service of Ukraine was used to calculate GDP, which involves the use of one of the methods - production, which will be used as a basis for further research (Metodolohichni poiasnennia).

The essence of the method is to determine gross value added (GVA) by type of economic activity as the difference between the value of output at basic prices and the cost of material costs and services consumed in the process.

The amount of GVA of economic activities is equal to the GVA of the economy:

$$B.1g = \sum_{i=1}^{19} (P.1_i - P.2_i) \tag{1}$$

where:

- $B.1g$ - Airborne forces of the national economy as a whole at basic prices;
- $P.1_i$ - issue of the i-th type of economic activity in basic prices;
- $P.2_i$ - intermediate consumption of the i-th type of economic activity.

GDP for the economy as a whole in market prices is defined as the sum of gross value added of all economic activities in all institutional sectors of the economy in basic prices and taxes, except for subsidies on products:

$$B.1^*g = B.1g + D.21 - D.31 \tag{2}$$

where:

- $B.1^*g$ - GDP at market prices;
- $D.21$ - product taxes;
- $D.31$ - subsidies on products.

This method is important in analyzing the results of the economy. It allows us to characterize the contribution of each type of economic activity and each institutional sector of the economy to GDP. According to the methodology of the State Statistics Service of Ukraine, gross value added is calculated as the difference between output and intermediate consumption (Metodyka rozrakhunku valovoho vnutrishn'oho produktu za vyrobnychym metodom i za dokhodamy). It contains the primary income generated by the participants in production.

In the analysis of the study data was used multifactorial correlation - in the study of the dependence of GDP on the components of the economy and investigated the relationships between economic profitability and use of land resources, taking into account institutional sectors of the economy. Such an analysis estimates the strength of the relationship between the variables studied, and a multivariate statistical model is selected using multiple regression analysis to describe the relationship between the factors. In the study, a model of the influence of many factors on the performance variable described by the linear model was built:

$$Y = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \ldots + \alpha_m X_m + U \tag{3}$$

where:

- y - dependent variable;

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

- xi - independent variables (factors);
- ai - estimates of unknown parameters to be evaluated;
- u - random variable (error).

Also, the research methods were used, namely: grouping - in the formation of land use, taking into account the types of economic activity and institutional sectors of the economy and the formation of their respective types; synthesis - when the dependence of economic indicators on the use of land resources; component analysis - when establishing links between types of land use and their contribution to changes in economic indicators.

RESULTS AND DISCUSSIONS

Today, the measure of high living standards of the population of the country (region) and an indicator of economic prosperity is the indicator of gross domestic product (GDP). Derivative indicators, such as GDP per capita (per capita) in US dollars, are widely used to compare living standards and monitor economic convergence or disagreement within the European Union (EU) and other countries. The development of specific components of GDP and related indicators - economic production, imports, exports, domestic consumption, investment, redistribution of income and savings, contributes to the assessment of economic activity and EU policy.
The global economic crisis of 2009 led to a recession in the EU and other countries (USA, UK, Japan), only China's economy has been steadily growing (Figure 2). The next decline in GDP in the EU was recorded at 6.1% due to the spread of COVID-19.
The economic downturn in the Eurozone is in fact in line with the trend in the EU: the reductions recorded in 2009, 2012 and 2020 were 4.5%, 0.9% and 6.5% respectively. Thus, in the period 2005-2020, real GDP growth in the Eurozone (overall growth of 9.2%) was slightly weaker than in the EU as a whole (12.6%).
Within the EU, GDP growth can be described as heterogeneous (Table 1) (National accounts and GDP).
After the economic downturn of 2009, with the exception of Poland, growth was recorded in 2010-2011. With the onset of the COVID 19 pandemic in 2020, the growing dynamics of the EU economies has changed dramatically. Overall, the average annual growth of EU GDP over the last 15 years is 0.8%. The largest decline in production was experienced by the economies of Portugal to 7.6%, Malta - 7.8%, France - 7.9%, Croatia - 8.0%, Greece - 8.2%, Italy - 8.9% and Spain - 10.8%. The analysis shows that the Polish economy had a positive dynamic (by 2020 the average growth rate was 3.6%), Ireland maintained economic growth even during the crisis (average annual growth of 4.2% between 2005 and 2020). The negative rate of change in 2020 was the first since 2009 for Belgium, Bulgaria, Denmark, Germany, Estonia, France, Lithuania, Malta, Austria and Slovakia.

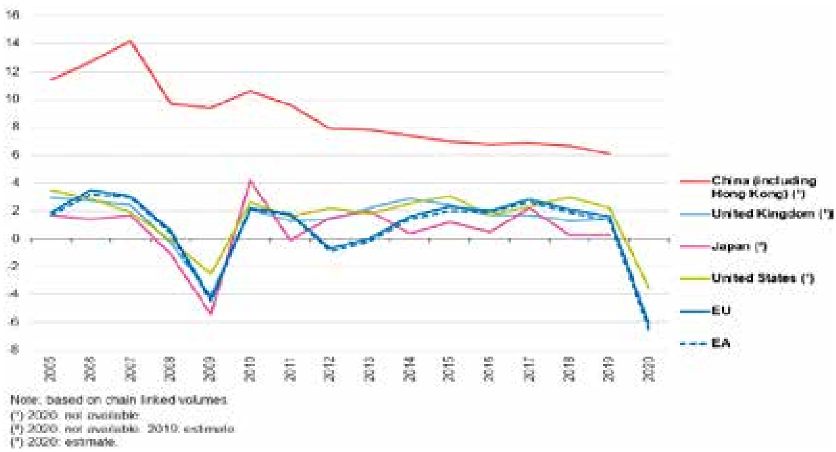


Figure 2. Rate of change in GDP, 2005-2020 (% compared to the previous year) (Eurostat)

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Table 1. GDP dynamics, % to previous year
(GDP and main components - output, expenditure and income)

Countries	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2005-2020**
Austria	1.8	2.9	0.7	0.0	0.7	1.0	2.0	2.4	2.6	1.4	-6.3	0.9
Belgium	2.9	1.7	0.7	0.5	1.6	2.0	1.3	1.6	1.8	1.8	*-6.3*	*0.9*
Bulgaria	0.6	2.4	0.4	0.3	1.9	4.0	3.8	3.5	3.1	3.7	-4.2	2.3
Greece	-5.5	-10.1	-7.1	-2.7	0.7	-0.4	-0.5	1.3	*1.6*	*1.9*	*-8.2*	*-1.8*
Denmark	1.9	1.3	0.2	0.9	1.6	2.3	3.2	2.8	2.2	2.8	-2.7	1.0
Estonia	2.7	7.4	3.1	1.3	3.0	1.8	3.2	5.5	4.4	5.0	-2.9	2.0
Ireland	1.8	0.6	0.1	1.2	8.6	25.2	2.0	9.1	8.5	5.6	3.4	4.2
Spain	0.2	-0.8	-3.0	-1.4	1.4	3.8	3.0	3.0	*2.4*	*2.0*	*-10.8*	*0.2*
Italy	1.7	0.7	-3.0	-1.8	0.0	0.8	1.3	1.7	0.9	*0.3*	*-8.9*	*-0.7*
Cyprus	2.0	0.4	-3.4	-6.6	-1.8	3.2	6.4	5.2	5.2	*3.1*	*-5.1*	*1.3*
Latvia	-4.4	6.5	4.3	2.3	1.1	4.0	2.4	3.3	4.0	2.0	-3.6	1.6
Lithuania	1.7	6.0	3.8	3.6	3.5	2.0	2.5	4.3	3.9	4.3	-0.9	2.6
Luxembourg	4.9	2.5	-0.4	3.7	4.3	4.3	4.6	1.8	3.1	2.3	-1.3	2.5
Malta	5.5	0.5	4.1	5.5	7.6	9.6	3.8	8.6	5.2	5.5	-7.8	3.8
Netherlands	1.3	1.6	-1.0	-0.1	1.4	2.0	2.2	2.9	2.4	*1.7*	*-3.7*	*1.1*
Germany	4.2	3.9	0.4	0.4	2.2	1.5	2.2	2.6	1.3	0.6	*-4.8*	*1.1*
Poland	3.7	4.8	1.3	1.1	3.4	4.2	3.1	4.8	5.4	4.7	*-2.7*	*3.6*
Portugal	1.7	-1.7	-4.1	-0.9	0.8	1.8	2.0	3.5	2.8	*2.5*	*-7.6*	*0.1*
Romania	-3.9	1.9	2.0	3.8	3.6	3.0	4.7	7.3	4.5	*4.1*	*-3.9*	*3.0*
Slovakia	5.9	2.8	1.9	0.7	2.6	4.8	2.1	3.0	3.7	2.5	-4.8	2.9
Slovenia	1.3	0.9	-2.6	-1.0	2.8	2.2	3.2	4.8	4.4	3.2	-5.5	1.4
Hungary	1.1	1.9	-1.4	1.9	4.2	3.8	2.1	4.3	5.4	*4.6*	*-5.0*	*1.4*
Finland	3.2	2.5	-1.4	-0.9	-0.4	0.5	2.8	3.2	1.3	1.3	-2.8	0.7
France	1.9	2.2	0.3	0.6	1.0	1.1	1.1	2.3	1.9	*1.8*	*-7.9*	*0.5*
Croatia	-1.3	-0.2	-2.4	-0.4	-0.3	2.4	3.5	3.4	2.8	*2.9*	*-8.0*	*0.4*
Czech Republic	2.4	1.8	-0.8	0.0	2.3	5.4	2.5	5.2	3.2	2.3	-5.6	1.9
Sweden	6.0	3.2	-0.6	1.2	2.7	4.5	2.1	2.6	2.0	2.0	-2.8	1.7
EU 27_2020	**2.2**	**1.8**	**-0.7**	**0.0**	**1.6**	**2.3**	**2.0**	**2.8**	**2.1**	**1.6**	**-6.1**	**0.8**

When estimating the level of well-being of the population of a country or region, GDP per capita is often used. Taking into account that the EU population as of 2020 was 447 million, the average GDP per capita for the EU (at current prices) was 29.7 thousand euros. The relative situation of individual EU countries is shown in Figure 3. Based on this indicator, the highest value among EU member states was recorded for Luxembourg, where GDP per capita was about 3.7 times higher than the EU average. The high level of GDP per capita in US dollars is typical for Ireland (81.6), Denmark (60.2), Sweden (52.6). The lowest rates are in Bulgaria (9.8), Romania (12.9). Thus, we see that gross domestic product (GDP), being the main generalizing indicator of economic development, reflects the total volume of production of goods and services for a given period. This indicator characterizes the economic activity in the country and determines its place in the world rankings.

As of 2020, the euro area accounted for 80.5% of EU GDP (compared to 84.8% in 2005). Thus, the share of the four largest economies of the EU member states: Germany, France, Italy and Spain, was slightly less than three-fifths (59.7%) of EU GDP. The German economy accounts for 22.4% (2020) of EU GDP in the year, down slightly from 22.5% compared to 2005.

The shares of the other largest Member States fell more sharply between 2005 and 2020, falling by 2.5% in Italy, 1.2% in Spain and 0.95 in France (Figure 3).

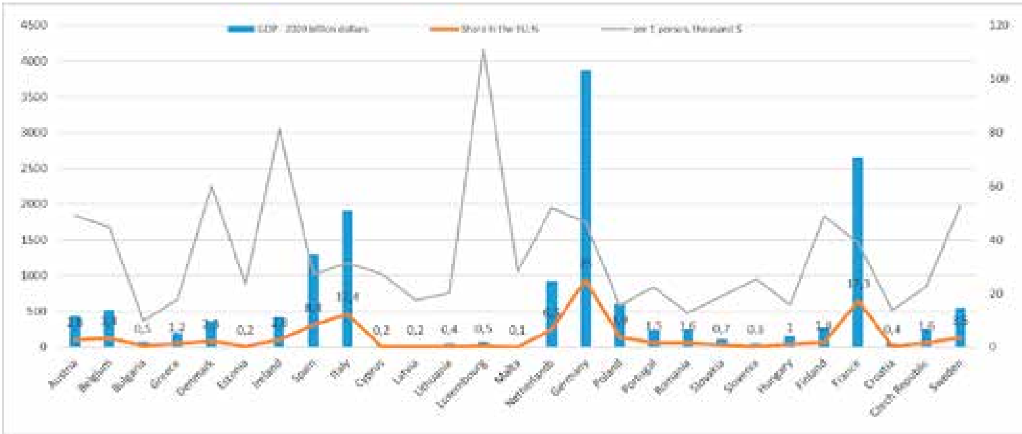


Figure 3. Structure of EU GDP, billion dollars USA (GDP and main components - output, expenditure and income).

Next, it is planned to study the indicators of GDP, their dependence, identify ties and establish their strength, taking into account the sectors of production.

In the study we identified the following types of economic activity: agriculture; forestry; industry; construction; trade, transport; IT field; financial and insurance activities; scientific and technical, administrative activities; public administration, defense, education, health care and social services; other services (taxes, arts, entertainment and recreation). The data are shown in Table 2.

Thus, we performed a correlation-regression analysis of the data (see Table 2) and established the corresponding correlation dependencies. The result is a correlation-regression matrix of indicators of GDP dependence on sectoral components of the economy (Table 3).

In the structure of EU GDP, the share of agriculture and water management has a Pearson correlation coefficient of r = 0.79 (respectively, the coefficient of determination R^2 = 0.64), which indicates a relatively weak direct relationship between the variables Y and X1 (see Table 3). The study shows that in most EU countries the share of agriculture and water in GDP is not significant. Carrying out a correlation-regression analysis of indicators of forestry and nature protection complex, it was found that the dependence of national GDP on this industry has a Pearson coefficient r = 0.59 (coefficient of determination R^2 = 0.34), which proves the absence of any significant effects on industry. most European countries. Correlation - regression analysis of economic indicators of industry r = 0.97 (coefficient of determination R^2 = 0.93); construction r = 0.99 (coefficient of determination R^2 = 0.99); trade, transport r = 0.99 (coefficient of determination R^2 = 0.98); IT sphere; financial and insurance activities r = 0.99 (coefficient of determination R^2 = 0.97); scientific and technical, administrative activities r = 0.98 (coefficient of determination R^2 = 0.96); public administration, defense, education, health care, social services r = 0.99 (coefficient of determination R^2 = 0.98) and fiscal system, cultural and entertainment industry r = 0.98 (coefficient of determination R^2 = 0.98) have a high correlation coefficient, which indicates a close direct relationship of indicators and their linear dependence. Evaluating the results of the analysis, we can conclude that the GDP of the EU does not depend on agriculture, forestry and water, and the economy is formed by all other sectors of the economy.

The next step of our study will be to determine the impact of the land use system on the sectoral components of the EU economies. To this end, we formed (grouped) land use, taking into account the types of economic activity and institutional sectors of the economy. Sources of data on the structure of land use in the EU and Ukraine were official sources: Eurostat (Land use overview by NUTS 2 regions. Eurostat.), State Geocadastre (Vidkryti dani. Derzhavna sluzhba Ukrainy z pytan heodezii, kartohrafii ta kadastru, 2021) and the State Statistics Service of Ukraine (Ekonomichna statystyka, 2021). Given the structure of land use of EU countries, the typification of land use was carried out taking into account the types of economic activity and institutional sectors of the economy and the corresponding types of land use were formed (Figure 4).

Table 2. Economic and static model of EU and Ukraine GDP for 2020, million USD (GDP and main components - output, expenditure and income)

	GDP, million US dollars									
	Total	Agriculture + fisheries	Forestry	Industry	Construction + real estate transactions	Trade, transport	Financial and insurance activities, IT	Scientific and technical, administrative activities	Public administration, defense, education, health and social services	other services (taxes, arts, entertainment and recreation)
	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9
Austria	435651,92	4458,03	1205,44	92793,86	79724,30	88001,69	35723,46	40951,28	81031,26	11762,60
Belgium	523365,32	4091,78	95,14	83738,45	81121,62	92635,66	58616,92	80074,89	114617,01	8373,85
Bulgaria	70345,88	2413,75	329,74	15265,06	10622,23	13365,72	9989,11	4783,52	12029,15	1547,61
Greece	192362,80	8981,59	59,47	27315,52	36933,66	44435,81	16927,93	9233,41	42896,90	5578,52
Denmark	361962,60	5368,43	417,19	64726,58	60387,37	68342,59	36883,30	38329,71	77382,61	10124,83
Estonia	31513,72	403,65	289,65	5861,55	4916,14	6523,34	4254,35	2993,80	5451,87	819,36
Ireland	425146,96	4226,90	24,57	166657,61	38263,23	38688,37	93532,33	37838,08	43364,99	2550,88
Spain	1302470,85	44449,64	1091,29	212090,66	245921,07	257631,60	107997,08	114502,93	266739,78	52046,79
Italy	1915850,20	40016,25	2132,46	373590,79	356348,14	379338,34	172426,52	183921,62	337189,64	70886,46
Cyprus	24175,56	505,18	2,50	1909,87	4182,37	5415,33	3674,69	2610,96	4883,46	991,20
Latvia	34027,44	815,62	647,56	5138,14	6737,43	7894,37	2858,30	2858,30	6124,94	952,77
Lithuania	56815,56	1765,32	334,76	11522,04	7946,23	17141,16	3632,56	4086,63	9194,93	1191,93
Luxembour	74405,88	104,89	43,92	4166,73	10119,20	10863,26	25372,41	9300,74	13169,84	1264,90
Malta	14875,84	74,38	0,00	1532,21	1621,47	2037,99	2856,16	2603,27	2722,28	1428,08
Netherlands	926461,84	16487,19	189,13	136189,89	123219,42	185292,37	107469,57	138969,28	201042,22	17602,77
Germany	3869252,19	27303,25	3619,84	885173,58	664846,53	610731,11	347884,81	432923,32	757615,81	139153,92
Poland	606718,28	14478,99	1902,41	149252,70	81906,97	151072,85	50964,34	56424,80	92827,90	7887,34
Portugal	234860,56	4311,67	1090,13	40630,88	42744,62	52843,63	20902,59	18084,26	48146,41	6106,37
Romania	253072,56	8426,27	2202,78	54916,75	40744,68	49855,29	25813,40	22523,46	41756,97	6832,96
Slovakia	106203,80	1962,91	585,98	24002,06	18479,46	22302,80	8071,49	9876,95	17736,03	3186,11
Slovenia	53704,52	903,99	331,21	14339,11	7357,52	10311,27	4457,48	5155,63	9666,81	1181,50
Hungary	157673,00	6157,98	306,61	38156,87	24439,32	27119,76	14505,92	15294,28	27435,10	4257,17
Finland	275461,72	2866,55	4846,37	53164,11	58948,81	40217,41	25893,40	25067,02	56745,11	7712,93
France	2643578,52	43639,28	3945,13	348952,36	491705,60	433546,88	251139,96	375388,15	618597,37	76663,78
Croatia	57168,28	1991,51	238,05	11090,65	9089,76	11433,66	6688,69	4630,63	10004,45	2000,89
Czech Repu	247845,60	3815,21	1389,55	71131,69	38663,91	43125,13	25528,10	17349,19	41638,06	5204,76
Sweden	547823,92	5169,50	3595,69	93677,89	87104,00	90938,77	70669,29	62451,93	118329,97	15886,89
Ukraine	155180,67	14028,33	574,17	27932,52	14431,80	32277,58	7759,03	7293,49	22035,66	23882,31
EU	***15162324,07***	***264760,00***	***30285,30***	***2922126,24***	***2568802,56***	***2705382,03***	***1506769,72***	***1684570,27***	***2999345,29***	***475316,88***

Table 3. Correlation-regression matrix of GDP dependence indicators

	y	x1	x2	x3	x4	x5	x6	x7	x8	x9
y	1.00									
x1	0.79	1.00								
x2	0.59	0.45	1.00							
x3	0.97	0.68	0.54	1.00						
x4	0.99	0.81	0.61	0.95	1.00					
x5	0.99	0.84	0.58	0.95	0.99	1.00				
x6	0.99	0.77	0.57	0.96	0.98	0.97	1.00			
x7	0.98	0.77	0.58	0.92	0.98	0.97	0.98	1.00		
x8	0.99	0.80	0.60	0.93	0.99	0.98	0.98	0.99	1.00	
x9	0.98	0.79	0.56	0.96	0.98	0.97	0.95	0.94	0.96	1.00

The relative indicators of the selected types of land use of the EU and Ukraine are shown in Figure 4, which shows that the share of food-forming lands of the EU is 39.6% of the area (Denmark - 64.1%, Ireland - 62.3%, Hungary - 61.1%, Romania - 55.6%) and the lowest rates (Finland - 7.6%, Sweden - 9.5%, Estonia - 24.7%, Slovenia - 27.6%). In Ukraine, this figure is 71.5%. The average rate of EU eco-stabilizing areas is 35.9%. The largest shares are characterized by land use in Finland (62.7%), Slovenia (59.8%), Sweden (56.6%), Estonia (55.8%), Latvia (51.7%), the smallest in Malta (0.1 %), Cyprus (6%), the Netherlands (8.4%), Ireland (9.1%), Denmark (13.8%). For Ukraine, this figure is 16.5%.

The share of land in EU social infrastructure is 3%. The largest areas of residential land, public areas, plots for real estate and real estate transactions in the land use structure of Malta (19.3%), Belgium (12.3%), the Netherlands (7.3%), the smallest in Spain (1, 2%), Bulgaria (1.2%), Finland (1.3%), Sweden (1.4%). In Ukraine, this figure is 8.0%. As these lands are closely connected with the processes of urbanization, in our opinion, they quite clearly characterize the level of urbanization of the country.

The complex of production - trade - economic forming territories is characterized by diversity and complexity of internal ties. Thus, the territories occupied by industrial facilities and other accompanying territories in the EU are 0.8% (Ireland - 2.5%, Germany - 1.2%, Portugal, Estonia, the Netherlands - 1.1% and Malta - 0.1%, Sweden, Croatia - 0.3%, Romania, Denmark - 0.4%).

In Ukraine, the share of such lands is - 09%, which indicates a relatively high level of industrial load on the territory. The EU average share of land involved in transport, logistics and trade is 3.0%. The highest rates were recorded in the Netherlands (12.4%), Belgium (6.2%), Luxembourg (5.5%), Germany (5.3%), Malta (4.7%), and Denmark (4.6%). %) and the smallest: Estonia (1.1%), Latvia (1.7%), Lithuania, Bulgaria (1.9%). Ukraine has the lowest rate of 1.1%, which can be considered insufficient compared to highly developed European countries. The lowest share of land supply has financial, insurance and IT activities 0.21% in the EU. However, in countries such as the Netherlands (1.4%), Denmark (0.73%), Belgium (0.63%), Germany (0.57%) it is relatively high, and the lowest in Luxembourg (0.004%), Malta, Slovakia (0.03%), Estonia (0.04%), Lithuania (0.05%).

In Ukraine, the share of such land use is 0.74%, which is quite high among European countries (higher only in the Netherlands). Land use related to scientific, technical and administrative activities in some European countries have a significant share in the land use system, which can be explained by the high level of development of territorial administration and stimulating the development of scientific and technical potential of countries. Thus, the highest rates were found in Cyprus (48.5%), Croatia (34.6%), Malta (29.8%), Greece (28.02%), Spain (25.5%), Italy and Sweden, respectively 24.5% and 2 3.2%. The smallest share of the studied type of land use is in Ukraine (0.02%), Luxembourg (1.35%), Germany (3.28%), Belgium (4.14%). The largest amounts of land in Luxembourg (1.89%), Sweden (1.36%), Germany and the Czech Republic (1.18%) were transferred to public administration, defense, education, health care and social services. the lowest rates are in Latvia (0.05%), Ireland (0.1%), Estonia (0.13%), the figure in Ukraine is 1.06%, which is almost twice as high as the EU average (0.59%).

After conducting research on land use in the field of entertainment and recreation, cultural events, fiscal services, etc., it was found that the share of total land use is the Netherlands (8.57%), Finland (6.59%), Sweden (5.33) %), Estonia (4.87%), Denmark (3.49%), the least in Romania (0.17%), Bulgaria (0.25%), Luxembourg (0.27%). In Ukraine, this figure is 0.07%, which is 2 orders of magnitude lower than the European average (2.02%).

Indicators of the use of land and resource potential of the territories of countries in certain sectors of the economy, allow us to analyze the contribution of each of them to the overall growth of economic indicators of the country (Kryvoviaz et al., 2020). We took as a basis the indicator of gross domestic product.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

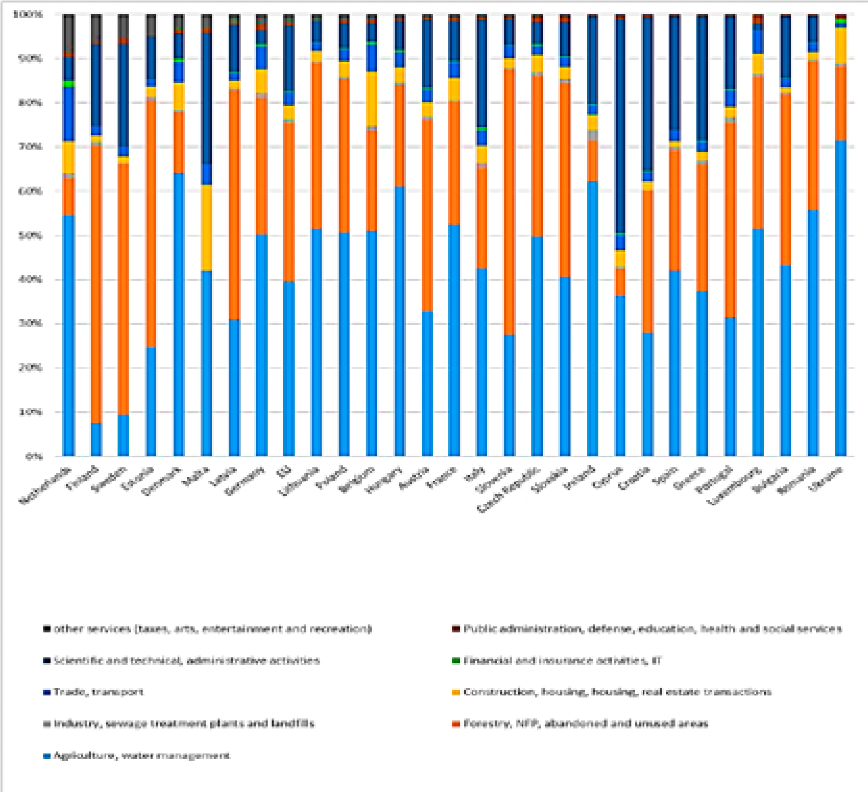


Figure 4. Typification of land use taking into account the institutional sectors of the economy, % (author's development)

The next step of the study involves finding relationships between economic indicators of profitability (average GDP per unit area) and the use of land resources, taking into account the institutional sectors of the economy. The data are shown in table 4.

The result of the correlation analysis is the matrix (Table 5) of the profitability of economic sectors from the land resource potential of the EU and Ukraine. The analysis shows how much the income of a particular sector of the economy depends on the area of land use involved in the formation of economic benefits. Thus, the analysis shows that variables with r = 0.7 and more have a relatively strong dependence of the amount of land involved in the industry and the profitability of the industry in the formation of overall GDP. The variable x5 r = 0.96 has the highest correlation coefficient, which is responsible for the transport, logistics and trade component of GDP and indicates a very strong impact of land use on the industry. The values of variable x2 (r = 0.75) in forestry land use, x3 (r = 0.79) in industrial lands, x8 (r = 0.78) in lands under public administration, defense, education, health care are characterized by a high degree of dependence. I, etc., x9 (r = 0.76) cultural, entertainment and recreational land use.

Land use in the agricultural and water sectors x1 (r = 0.69) has a slightly weaker correlation, which indicates a slightly lower impact of this type of land use on economic GDP. The study found that land for housing (x4, r = 0.62), financial, insurance, IT (x6, r = 0.49) and scientific, technical and administrative (x7, r = 0.57) sectors have weak correlations with the effective sign of the profitability of the sector from the use of land resources, which can be regarded as a weak dependence of income in the national, on the areas involved in the production or provision of services by the industry.

Table 4. Profitability indicators of land resource potential of economic sectors, thousand US dollars/ha

	Agriculture	Forestry	Industry	Construction, housing	Trade, transport	Financial and insurance activities, IT	Scientific and technical, administrative activities	Public administration, defense, education, health and social services	other services (taxes, arts, entertainment and recreation)	Yield is average, thousand dollars / ha
	x1	x2	x3	x4	x5	x6	x7	x8	x9	Y
Austria	1,62	0,33	1636,58	298,26	338,34	2685,97	31,60	3293,95	145,22	51,94
Belgium	2,62	0,14	2810,02	215,23	489,88	3021,49	629,97	4898,16	208,30	170,67
Bulgaria	0,50	0,08	228,18	77,65	62,34	1135,13	3,11	368,99	56,48	6,34
Greece	1,82	0,02	216,10	158,79	135,72	829,80	2,50	1600,63	120,23	14,61
Denmark	1,95	0,71	3424,69	223,00	343,43	1182,16	158,00	1984,17	67,59	84,32
Estonia	0,36	0,11	121,08	51,64	90,10	2658,97	6,78	924,05	3,71	6,95
Ireland	0,97	0,04	946,92	167,31	245,17	21751,70	27,23	6472,39	68,76	60,78
Spain	2,11	0,08	437,93	404,74	199,45	3068,10	8,99	2796,01	260,62	26,13
Italy	3,11	0,31	1147,74	295,90	356,52	1369,55	24,81	3681,11	265,49	63,42
Cyprus	1,50	0,04	289,37	132,35	160,22	1597,69	5,81	1017,39	202,29	26,13
Latvia	0,41	0,19	117,58	60,48	71,25	519,69	4,11	1914,04	6,30	5,27
Lithuania	0,52	0,14	362,33	54,43	137,13	1100,78	13,10	884,13	12,80	8,70
Luxembourg	0,78	0,49	2422,52	896,30	754,39	2537240,51	2649,78	2687,72	1807,00	286,73
Malta	5,59	100,00	51073,72	266,25	1358,66	285616,13	276,65	9074,26	1428,08	470,75
Netherlands	8,08	0,60	3413,28	463,06	398,99	2050,95	703,25	4821,16	54,97	247,86
Germany	1,52	0,33	1988,71	363,90	324,72	1719,65	369,07	1790,63	169,66	108,21
Poland	0,91	0,18	825,06	73,66	175,14	1068,43	32,40	432,16	17,73	19,45
Portugal	1,54	0,28	407,12	218,64	149,74	1236,84	12,39	1965,16	226,16	26,36
Romania	0,64	0,27	527,03	100,90	97,34	1253,08	15,89	877,25	170,82	10,62
Slovakia	0,98	0,27	506,37	146,31	198,42	4747,93	25,70	313,36	97,14	21,66
Slovenia	1,61	0,27	1303,56	169,96	181,22	1832,27	42,75	1972,82	67,13	26,49
Hungary	1,08	0,14	902,05	79,71	78,22	993,56	24,84	696,32	39,97	16,95
Finland	1,11	0,23	166,03	129,93	59,10	1056,87	4,02	636,87	3,46	8,14
France	1,51	0,26	1148,63	181,74	223,27	1889,69	76,14	1632,18	152,99	48,15
Croatia	1,25	0,13	606,05	96,28	89,96	704,07	2,37	357,30	87,00	10,10
Czech Repu	0,97	0,49	869,58	137,06	236,95	959,70	44,83	448,69	93,44	31,42
Sweden	1,22	0,14	756,69	138,17	91,07	2317,03	6,01	194,88	6,66	12,24
Ukraine	0,33	0,06	51,75	2,97	47,09	17,38	561,04	34,59	569,98	2,57
EU	**1,71**	**3,94**	**2913,14**	**207,47**	**260,99**	**106874,36**	**192,67**	**2138,36**	**216,30**	**69,27**

Author's development

Table 5. Matrix of dependence of profitability of economic sectors on land resource potential

	x1	*x2*	*x3*	*x4*	*x5*	*x6*	*x7*	*x8*	*x9*	*Y*
x1	1									
x2	0,47	1								
x3	0.52	1.00	1							
x4	0.38	0.08	0.13	1						
x5	0.58	0.81	0.85	0.56	1					
x6	-0.05	0.08	0.10	0.78	0.46	1				
x7	0.13	0.03	0.08	0.81	0.48	0.92	1			
x8	0.67	0.65	0.69	0.40	0.79	0.13	0.20	1		
x9	0.20	0.57	0.59	0.66	0.78	0.81	0.77	0.45	1	
Y	0.69	0.75	0.79	0.62	0.96	0.49	0.57	0.78	0.76	1

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Further research shows that land involved in finance, insurance and IT is the most profitable per hectare. Thus, the European leaders are Luxembourg - 2537240.51 thousand US dollars per hectare; Malta - 285,616.13 thousand US dollars per hectare, Ireland - 21,751.70 thousand US dollars per hectare. The smallest share of these activities is in: Greece - 829.80 thousand US dollars per hectare, Croatia - 704.07 thousand US dollars per hectare and Latvia - 519.69 thousand US dollars per hectare.

The EU average is 106,874.36 thousand US dollars per hectare. The figure in Ukraine is 17.4 thousand dollars.

The lowest weight in the formation of GDP are lands involved in agriculture and water. However, the most efficient agricultural land is used in: the Netherlands - 8.08 thousand US dollars per hectare, Italy - 3.11 thousand US dollars per hectare, Belgium - 2.62 thousand US dollars per hectare and Spain - 2.11 thousand dollars USA per ha.

The lowest share in the national income structure of the agricultural sector is in: Bulgaria - 0.50, Latvia - 0.41 and Estonia - 0.36 thousand US dollars per hectare. The indicator in Ukraine is 0.33, which indicates low economic efficiency of land use.

Lands under financial, insurance and IT institutions are used most economically (EU - 106874.36 UAH / ha).

Sectors sch as industry (EU - 2913.1 thousand dollars), public administration (EU - 2138.4 thousand dollars) are characterized by high economic effect per unit area.

We can consider low-efficiency: agricultural and water land use (EU - 1.71 thousand dollars), forest areas and NPF (EU - 3.94 thousand dollars).

CONCLUSIONS

In general, we can say that the lower the indicator "r", the lower the dependence of income on land used or used in production (land resource potential). To ensure high economic indicators (GDP indicators), it is necessary to develop sectors of the economy that have a significant impact (share) in the formation of national wealth. Preferring economic growth, it is necessary to ensure the support and development of environmental security and relevant areas (forest, nature reserves and other areas), food security as a basis for well-being and national prosperity (agricultural and fishery areas and lands), social and infrastructure facilities. projects and territories, etc.

During the study, it was found that the growth of economic efficiency from the use of land resources is proportional to the distance from food-forming (agricultural and water lands) and ecologically stabilizing (nature reserves, forests, dry, wetlands, neglected and unused areas) and approaching economic formative sectors of production, such as social and infrastructural (residential buildings, public areas, areas for development and real estate transactions) and production - trade - economic (areas under industrial facilities, warehouses and sewage treatment plants, facilities of transport, logistics and trade enterprises, financial, insurance, IT institutions, scientific and technical, administrative, administrative, defense, educational, medical and social, tax, cultural - artistic, entertainment, recreational and other services).

ACKNOWLEDGMENTS

The work was supported by the project "Development of mechanisms for mass real estate appraisal for effective regulation of land relations", state registration code and number of research № 110/8-pr-2019 № 0119U100827.

REFERENCES

Chumachenko A., Kryvoviaz Y., Zhuk O. (2021). Yevropeiskyi dosvid rozvytku zemelno-resursnoho potentsialu v umovakh hlobalizatsii. Zemleustrii, kadastr i monitorynh zemel. № 4. DOI: http://dx.doi.org/10.31548/zemleustriy2021.04.03

Ekonomichna statystyka. Derzhavna sluzhba statystyky Ukrainy. http://www.ukrstat.gov.ua;

GDP and main components (output, expenditure and income). Data Browser. Eurostat. https://ec.europa.eu/eurostat/databrowser/view/nama_10_gdp/default/table?lang=en

Kryvoviaz, E., Openko, I., Tykhenko, R., Shevchenko, O., Tykhenko, O., Tsvyakh, O., Chumachenko, O. (2020). Recovery of losses for inappropriate use of land. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering.* Vol. IX, pp. 175-182. Retrieved from http://landreclamationjournal.usamv.ro/pdf/2020/Art26.pdf (Accessed 02.03.2021)

Land use overview by NUTS 2 regions. Eurostat. https://ec.europa.eu/eurostat/databrowser/view/LAN_USE_OVW__custom_1401789/default/table?lang=en

Metodolohichni poiasnennia. Otrymano z: http://ukrstat.gov.ua/operativ/operativ2005/vvp/metod_nr.htm;

Metodyka rozrakhunku valovoho vnutrishn'oho produktu za vyrobnychym metodom i za dokhodamy. Otrymanoz: http://www.ukrstat.gov.ua/metod_polog/metod_doc/2004/610/met_vvp_vm_d.zip

National accounts and GDP. Eurostat (online data codes: naida_10_gdp and nama_10_gdp)

Paolo Andreini, Thomas Hasenzagl, Lucrezia Reichlin, Charlotte Senftleben-König, Till Strohsal (2021). Nowcasting German GDP: Foreign factors, financial markets, and model averaging, International Journal of Forecasting, ISSN 0169-2070, https://doi.org/10.1016/j.ijforecast.2021.11.009. (https://www.sciencedirect.com/science/article/pii/S0169207021001837)

Vera Ferreira, Ana Paula Barreira, Patrícia Pinto, Thomas Panagopoulos (2022). Understanding attitudes towards the adoption of nature-based solutions and policy priorities shaped by stakeholders' awareness of climate change, Environmental Science & Policy, Volume 131, pp. 149-159, ISSN 1462-9011, https://doi.org/10.1016/j.envsci.2022.02.007. (https://www.sciencedirect.com/science/article/pii/S1462901122000521)

Vidkryti Dani. Derzhavna sluzhba Ukrainy z pytan heodezii, kartohrafii ta kadastru. https://land.gov.ua/index.php/open-data/

WEF, Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and Economy, New Nature Economy project, Geneva, 2020. https://www3.weforum.org/docs/WEF_New_Nature_Economy_Report_2020.pdf.

https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Real_GDP_rate_of_change,_2005-2020_%28%25_change_compared_with_the_previous_year%29_NA2021.png

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

OAK REACTION TO FUTURE CLIMATE CHANGES IN CENTRAL AND EASTERN ROMANIA

Vlad CRISAN[1], Lucian DINCA[1], Cosmin BRAGA[1], Sorin DECA[2]

[1]National Institute for Research and Development in Forestry "Marin Drăcea", 13 Closca Street, Brasov, Romania
[2]Romanian Academy of Advanced Studies, 125 Calea Victoriei Street, Bucharest, Romania

Corresponding author email: vlad_crsn@yahoo.com

Abstract

The extent of changes in future climatic conditions for oak forest ecosystems has been determined using a climatic modelling software. The HYPE software is able to forecast how certain climatic factors that lie behind extreme climatic phenomena affect forest ecosystems. The software was used to study oak forest ecosystems across sample surfaces within the Transylvania and the Moldova plateaus. The following step was to create simulations for two future climatic scenarios. In the first scenario, the increase of green house gases would be moderate (rcp-4.5), while in the second scenario, the increase would be accentuated (rcp-8.5). After the data processing, there resulted an analysis which focuses on the future changes within the climate which affect forest ecosystems located in the studied area. By analyzing all six oak stands, we can conclude that the Traian stand will be the most vulnerable one. The oak forests will be more affected in Moldova plateau then in Transilvania plateau in the future decades. These results can be used for applying the best management measures for current stands as well as for establishing decisions for installing future stands at the regions studied.

Key words: *climate change, forest ecosystems, oak, Transylvania plateau, Moldova plateau.*

INTRODUCTION

In 1895, Arrhenius has calculated that if the amount of atmospheric CO_2 doubles, this can increase the average global temperature with 5-6°C (Arrhenius, 1896; Uppenbrink, 1996).
Early mathematical climate models have dealt with the issue of global warming by calculating the balance between the solar energy received and the heat output, trying to isolate the determinants. Astronomical cycles have clearly played a role according to Hide and Kuo (Hide, 1953; Kuo 1960).
The idea revived in the 1920s when Milankovic showed that three major astronomical cycles - the eccentricity of the Earth's orbit (a period of 100,000 years), the axial tilt of the Earth (a period of 41,000 years) and the precession of the Earth's axis (a period of 26,000 years) could explain recurrent climate change. These cycles interact, producing large variations of up to 20 or 30% in the amount of insolation at a given latitude (Muller and MacDonald, 2000).
It is difficult to study the climatic system by means of experimental methods because it is very complex and it requires a large time. Therefore, climatic models have been used by scientists (Edwards, 2010). Understanding climate has been made easier due to the use of conceptual models of the cycle of carbon. Chamberlin states that carbon dioxide is the main factor for the global climatic changes (Chamberlin, 1897; Chamberlin 1898). From 1964 onwards, Kasahara and Washington studied Global Climatic Models and they initiated three models between 1963 and 1980 (Harper, 2008; Leith, 1965; Kasahara and Washington, 1967; Washington et al., 1979). Because the first models were limited and generated errors, a number of experiments were run within the regional climatic simulation (Dickinson et al., 1989). In this way, scientists have reused the models's code in order to reduce time and model more complex tasks (Edwards, 2010).
The climatic model used in this study is known as "HYPE" and it was initiated and continuously developed by the Swedish Meteorological and Hydrologic Institute between 2005 and 2007. Two main characteristics of this model are the large array of users and a high resolution in assessing the

environment and climate changes for conditions in which no monitoring is realized.
In silviculture, climatic changes are more and more noticeable (Dincă et al., 2020; Ducci et al., 2021; Kutnar et al., 2021) having a negative impact on trees, soil, logging (Cantar et al., 2022) but also on wildlife and the entire regional landscape (Fedorca et al., 2020; Fedorca et al., 2021). One of the most affected species is the pine (Constandache & Dincă, 2019; Silvestru-Grigore et al., 2018; Vlad et al., 2019), the Norway spruce (Dincă et al., 2019; Murariu et al., 2021), as well as the the sea buckthorn (Constandache et al., 2016; Dincă et al. 2018).
The present research paper aims to analyze 6 oak forest ecosystems which are representative for the Transylvania and Moldova plateaus regarding the future climate changes (Figure 1).

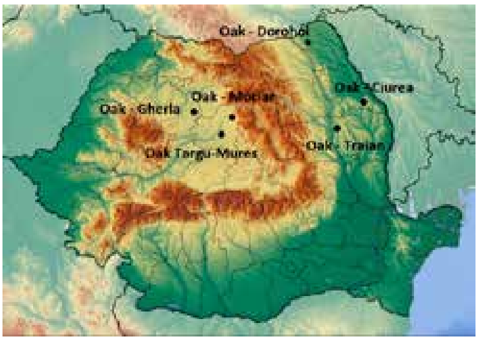


Figure 1. Location of oak plots

MATERIALS AND METHODS

The current paper uses the "HYPE" model and its software menus with the purpose of introducing entrance parameters. In this way, we introduced the coordinates of points (latitude and longitude), the indicator type (in our case temperature and precipitations) as well as the wanted climatic scenario.
The representative concentration pathway (RCP) estimates that global warming will vary between 1 and 3.7°C. Subsequently, the database to which the simulations refer (present day 1986-2005) will be exceeded with values between 1.0 (RCP 2.6) and 3.7°C (RCP 8.5) by the end of the 21st century (Quante and Colijn, 2016).
The HYPE software offers a range a of three scenarios: the greenhouse gases have a low growth ("Low - RCP 2.6"), a moderate growth ("Moderate - RCP 4.5") or a high growth ("High - RCP 8.5") (Figure 2).
After we chose the scenario, we had to choose a convenient timeframe (in our case 2100) and then we had to download the file from the "Download data" submenu.
The downloaded data are in the form of a Microsoft Excel table and represent monthly values. The data introduced in this software belongs to the six oak stands in the Transyilvania and Moldova plateaus.
The HYPE Software is related to a number of regional climatic models. REMO 2009 is a regional atmospheric model (REgional MOdel) which was originally developed by the Max Planck Institute for Meteorology (MPI-M) in Hamburg. Szépszó and Horányi assessed the performance of the REMO model for Hungary (Szépszó and Horányi, 2008).
The REMO 2009 model was chosen for this study because it is the most recent hydrostatic version (Jacob & Podzun, 1997; Jacob, 2001). The next step was to use Microsoft Excel for processing data, with the purpose of obtaining average monthly values for the studied period (1971-2100).

Figure 2. "HYPE" program menu

RESULTS AND DISCUSSIONS

The results obtained by means of the HYPE modelling program have been introduced in Microsoft Excel. After processing the data, mean annual precipitations and mean annual temperatures have been identified for each stand up to the year 2100. The two scenarios are represented in a graphical form: i.e. an average growth of greenhouse gasses (rcp-4.5) and a high growth of greenhouse gases (rcp-8.5). Each scenario has its own set of values for precipitations and for temperatures corresponding to each installed stand.

The oak species' variation of biological potential was taken into consideration according to ecological factors: temperature and precipitation (Şofletea & Curtu, 2008) (Table 1). In order to observe the effects of these two scenarios on the forest ecosystems under study, the oak was chosen as a species.

As such, oak – *Quercus robur* L has an adaptability to the continental climate being a mesothermic-euthermic species. The ecological optimum is found in areas where the average annual temperature is between 8-10 (10.5) °C and with an ecological precipitation optimum between 600-800 mm/year (Şofletea & Curtu, 2008) (Table 1).

Table 1. Ecologic card (Stănescu et al., 1997) *Quercus robur* L.

Ecologic factors	Values or states of ecologic factors													
	Variation of the species' biologic potential based on ecologic factors													
Average annual temperature (°C)	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
									l	s	o	o	o	o s
Average annual precipitations (mm)	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500		
		l s	o	o	o s	s	l							

where l represents the limit, s the suboptimum and o the optimum

The above data in Table 1 reflects the time period in which the annual average level of temperature and precipitation which is representative for the existence of oak. According to the future climatic scenarios there will be years when the annual averages do not confine within the species' existence interval.

Three intervals were established so as to observe how the oak forest ecosystems will be affected in the next 80 years. The three intervals correspond to three different impact levels: severe, medium and minimal. Consequently, oak forests will be severely affected by future changes if we discover that more than 40 values related to precipitation are below the limit (Table 1). The impact will be moderate if the number of values is between 20 and 40, and minimal if there are less than 20 values. The same intervals should be established for temperature: if there are more than 40 values which exceed 11°C (Table 1) the impact level is severe. If the number of values is between 20 and 40, the impact level is moderate and it it is less than 20, the impact level is minimal.

The Mociar oak stand can be analyzed from the perspective of annual average precipitations. The results show that the values under the established limits were present over periods of time with years characterized by a lack of precipitations (1974, 1975, 1978, 1981, 1982, 1985, 1988, 1994, 1998, 1999, 2000, 2005, 2011-2014 and 2018).

By applying the climatic scenarios resulting from the HYPE modelling program, we can notice that in the future there will be many years that record an annual deficiency of precipitations. Annual average temperatures do not predict a better future - starting from 2070, the average temperature will increase over the species' limit within the rcp-8.5 climatic scenario (Figure 3).

On the other hand, if we take into account the oak stand situated in Targu Mures, the annual precipitation values are lower than the tolerating threshold for both historical data and future simulations.

The oak stand installed in Târgu Mureș reveals a tendency towards an increase in temperature for the next decades (Figure 4). Nevertheless, this growth depends on the chosen scenario. With the passage of time, a major difference between the two scenarios is possible. When analyzing the evolution of the average annual temperature, the first scenario (rcp-4.5) does not reflect an alarming situation. However, for the second scenario (rcp-8.5), starting from 2068, each year will present annual average temperatures that exceed the superior limit for the survival of sessile oak.

Problems appear also in the case of precipitation for both scenarios, namely in the case in which greenhouse gases will increase significantly. As such, the program's prediction for both climatic scenarios (rcp-4.5 and rcp-8.5) shows us that oak stand from this area have low chances to survive in the following decades (Figure 4).

Regarding the oak stand in Cluj county from Gherla, it is different in terms of the values of the 2 climatic factors.

Concerning the precipitations, the following 80 years do not seem to pose any problems (Figure 5). Supposing the greenhouse gas concentration increases moderately (as in the rcp-4.5 climatic scenario), the annual average temperatures will not represent a problem for the Gherla oak stand.

The only situation in which the greenhouse gas concentration increases considerably is the rcp-8.5 scenario. In this case, the annual average temperature limit will be exceeded starting from the year 2069.

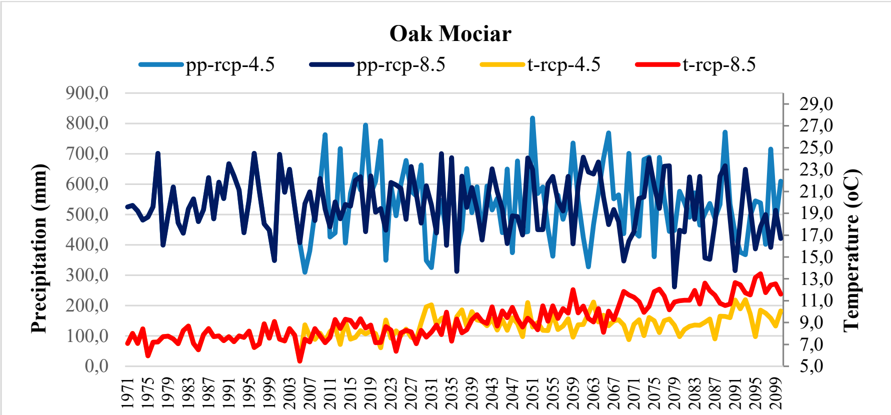


Figure 3. Climatic scenarios for the oak surface from Mociar (Reghin)

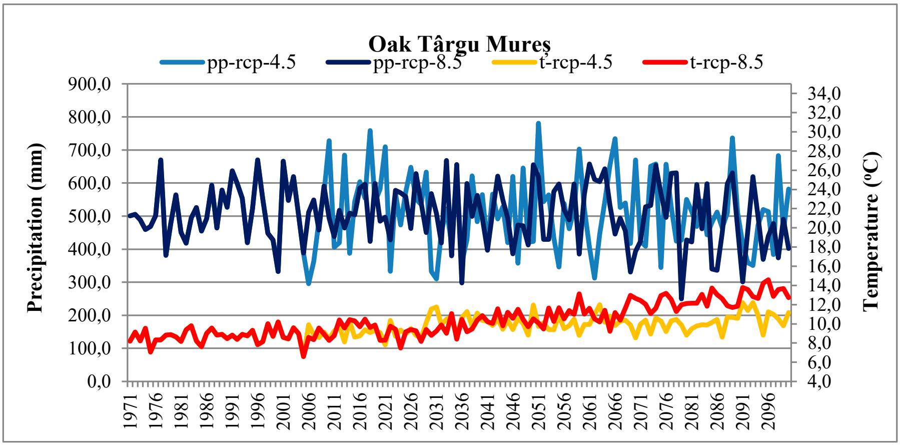


Figure 4. Climatic scenarios for the oak surface from Târgu Mureș

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

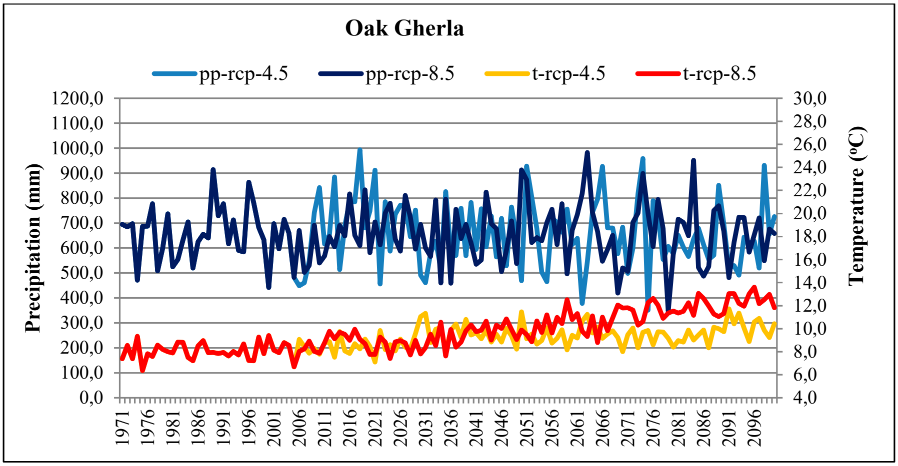


Figure 5. Climatic scenarios for the oak surface from Gherla

The oak stand in Gherla (Cluj County) reveals a different situation from the ones in the Mureș County and this is an advantage for oak forests because it means that there are areas that will not be so affected by climate change.

From all the oak surfaces installed in Transylvania, the Targu Mures oak stand will be the most severely affected in the future by the two climatic factors (precipitation and temperature). Various oak stands were also installed in the Moldova plateau at Traian (Bacau County), Ciurea (Iasi County) and Dorohoi (Botosani County).

The oak stand situated in Traian is characterized by lower values of annual precipitation under the tolerating threshold for both historical data and future simulations.

The average rainfall will be lower and lower, and even if there are extremely rainy years - they will not be able to compensate for the dry periods.

As such, the program's prediction for both climatic scenarios (rcp-4.5 and rcp-8.5) shows us that the oak stand from this area has low chances of survival in the future (Figure 6).

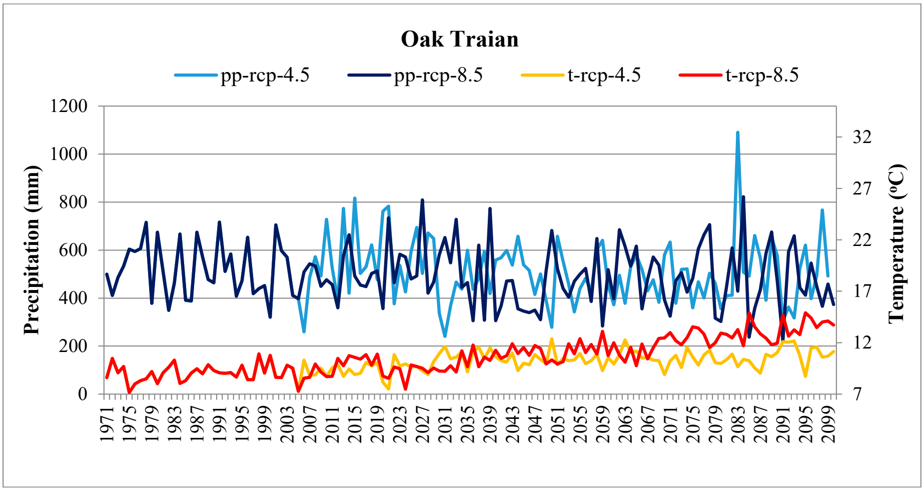


Figure 6. Climatic scenarios for the oak surface from Traian

The are no great difference between the oak stand from Ciurea and the one from Traian. When we apply the two climatic models, some major problems arise in relation to the temperature factor (Figure 7). In the second climatic scenario (rcp-8.5), the oak stand will be severely affected by temperature starting with the middle of 2050.

The HYPE software has calculated a number of years of low precipitations for both climatic scenarios, namely 31 and 35 years corresponding for rcp-4.5 and rcp-8.5.

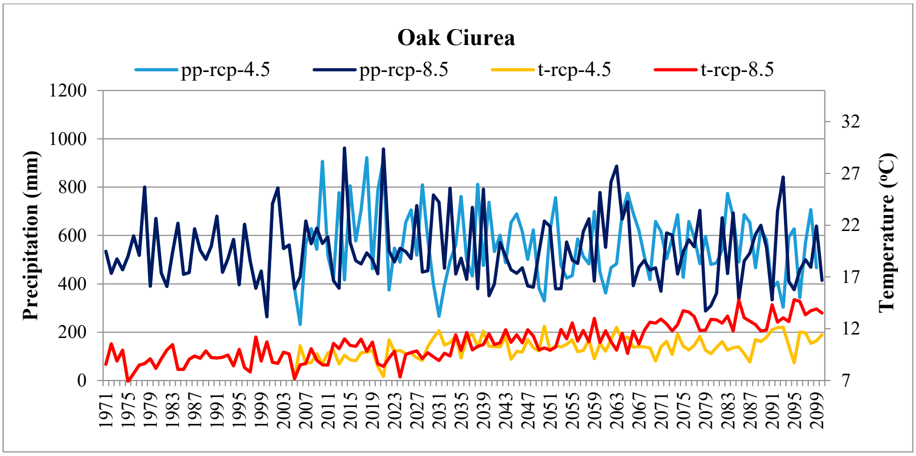


Figure 7. Climatic scenarios for the oak surface located at Ciurea

The Dorohoi oak stand is characterized by high annual average temperatures and low annual average precipitations in both climatic scenarios (rcp-4.5 and rcp-8.5). In this case, there will be 30 annual averages for rcp 4.5 and 29 for rcp 8.5 which will be lower than the limit (Table 1, less than 500 mm/year) of the species existence over the next 80 years (Figure 8). Starting with 2053, the temperature factor from the second scenario records annual exceedings of the 11°C limit (Table 1).

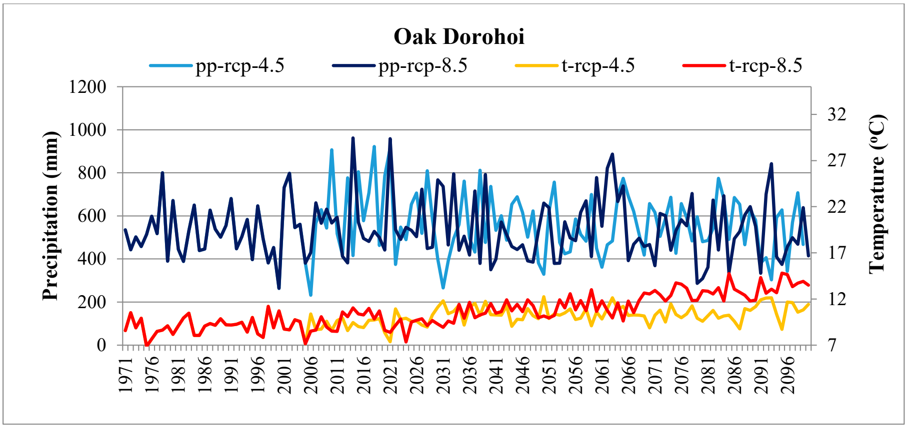


Figure 8. Climatic scenarios for the oak surface from Dorohoi

From all the oak surfaces installed in the Moldova plateau, the Traian oak stand will be the most severly affected in the following decades by the two climatic factors.

An important problem regarding the future climate conditions will be the productivity of the forest ecosystems, considering that, in the conditions of ecological optimum, the productivity of the oak forests is 7.5 m³/year/ ha at the age of 100 years (Șofletea & Curtu, 2008).

CONCLUSIONS

The research study has focused on future climatic scenarios in order to analyze the increasing effects of greenhouse gas concentrations on the oak forest ecosystems from the plateaus of Transylvania and Moldova. Over the next 80 years, two climatic scenarios have been aknowledged as plausible in the context of moderate and significant changes.

The Targu Mures stand from the Transylvania plateau and the Traian stand from the Moldova plateau will be the most affected in the future by these two climatic factors within all the oak stands.

For both the rcp-4.5 and the rcp-8.5 climatic scenarios, oak stands will be medium to severe affected by annual average precipitations with one exception - Gherla. In the same scenarios, the impact of temperatures will affect medium to severe plots, with 2 exceptions - Gherla and Mociar from Transylvania plateau.

Both scenarios reveal the fact there will be time periods when the annual average temperature is higher than normal and the annual level of precipitation will be rather low. These conditions imply that the survival of oak species is under threat. Provided the species survive, there will be a severe impact on the stand productivity.

It is absolutely necessary to verify and use future climatic scenarios as well, from other areas of our country in order to observe how other forest ecosystems will be affected. The conclusions which result from these studies will lead to taking the best forest management measures.

ACKNOWLEDGEMENTS

This research work was funded by the Romanian Ministry of Research, Innovation and Digitization, within National Institute of Research and Development in Forestry "Marin Dracea" through the Nucleu National Programme BIOSERV, Project-PN-19070506/Contract no. 12N/2019.

REFERENCES

Arrhenius S. (1896). On the influence of carbonic acid in the air upon the temperature of the ground. *Philosophical Magazine and Journal of Science*, 41, 237–276.

Cântar, I.C., Ciontu, C.I., Dincă, L., Borlea, G.F., Crișan, V.E. (2022). Damage and Tolerability Thresholds for Remaining Trees after Timber Harvesting: A Case Study from Southwest Romania. *Diversity*, 14, 193.

Chamberlin, T.C. (1897). A Group of hypotheses bearing on climatic changes. *J Geol*, 5, 653–683.

Chamberlin, T. C., (1898). The influence of great epochs of limestone formation upon the constitution of the atmosphere. *J Geol*, 6, 609–621.

Constandache, C., Dincă, L. (2019). The management of pine stands situated outside their habitat. *Scientific Papers: Management, Economic Engineering in Agriculture & Rural Development*, 19(4), 59-65.

Dickinson, R.E.; Errico, R.M.; Giorgi, F.; Bates, G.T., (1989). A regional climate model for the western United States. *Climatic change*, 15(3), 383-422.

Dincă, L., Holonec, L., Socaciu, C., Dinulică, F., Constandache, C., Blaga, T., Peticilă, A. (2018). "*Hipphophae Salicifolia* D. Don - a miraculous species less known in Europe". *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 46(2), 474-483, doi.org/ 10.15835/nbha46211155.

Dincă, L., Murariu, G., Enescu, C. M., Achim, F., Georgescu, L., Murariu, A., Timiș-Gânsac V., Holonec, L. (2020). Productivity differences between southern and northern slopes of Southern Carpathians (Romania) for Norway spruce, silver fir, birch and black alder. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 48(2), 1070-1084. doi.org/10.15835/ nbha48211824.

Dincă, L., Murariu, G., Iticescu, C., Budeanu, M., Murariu, A. (2019). Norway spruce (Picea abies (L.) Karst.) smart forests from the Southern Carpathians. *International Journal of Conservation Science*, 10(4), 781-790.

Ducci, F., Rogatis, A.D., Proietti, R., Curtu, L.A., Marchi, M., Belletti, P. (2021). Establishing a baseline to monitor future climate-change-effects on peripheral populations of Abies alba in central Apennines. *Annals of Forest Research*, 64(2), 33-66. DOI:10.15287/afr.2021.2281

Edwards, P.N., (2010). A vast machine: Computer models, climate data, and the politics of global warming. *Mit Press*.

Fedorca, A., Popa, M., Jurj, R., Ionescu, G., Ionescu, O., Fedorca, M., (2020). Assessing the regional landscape connectivity for multispecies to coordinate on-the-ground needs for mitigating linear infrastructure impact in Brasov – Prahova region. *Journal for Nature Conservation*. 58, 1-11.

Fedorca, A., Fedorca, M., Ionescu, O., Jurj, R., Ionescu, G., Popa, M., (2021). Sustainable landscape planning to mitigate wildlife-vehicle collisions. *Land*, 10(7), 737.

Harper, K.C. (2008). Weather by the Numbers: The Genesis of Modern Meteorology. Cambridge, *Mit Press*.

Hide R. (1953). Some experiments on thermal convection in a rotating liquid quarterly. *Quarterly Journal of the Royal Meteorological Society,* 79(339), 161.

Jacob, D., (2001). A note to the simulation of the annual and inter-annual variability of the water budget over the Baltic Sea drainage basin. *Meteorol. Atmos. Phys.*, 77, 61–73.

Jacob, D., Podzun, R., (1997). Sensitivity studies with the regional climate model REMO. *Meteorol. Atmos. Phys.*, 63, 119–129.

Kasahara, A., Washington W.M., (1967). NCAR global general circulation model of the atmosphere. *Mon Weather Rev*, 95; 389–402.

Kuo, H-L., (1960). Theoretical findings concerning the effects of heating and rotation on the mechanism of energy release in rotating fluid systems. In : Pfeffer RL, ed. Dynamics of Climate. New York. Pergamon Press, 78–85.

Kutnar, L., Kermavnar, J., Pintar, A.M. (2021). Climate change and disturbances will shape future temperate forests in the transition zone between Central and SE Europe. *Annals of Forest Research*, 64(2), 67-86.

Leith, C.E. (1965). Methods in Computational Physics. New York. *Academic Press*, 1965, 1–28.

Muller, R., MacDonald, G. J., (2000). *Ice Ages and Astronomical Causes. Data, Spectral Analysis, and Mechanisms*. Publisher. Springer-Praxis, London, 315.

Murariu, G., Dinca, L., Tudose, N., Crisan, V., Georgescu, L., Munteanu, D., Dragu, M.D., Rosu, B., Mocanu, G.D. (2021). Structural Characteristics of the Main Resinous Stands from Southern Carpathians, Romania. *Forests*, 12(8), 1029.

Quante, M., Colijn, F. (2016) *North Sea Region Climate Change Assessment*; Publisher: Springer, Cham, 153-160. https://doi.org/10.1007/978-3-319-39745-0

Silvestru-Grigore, C.V., Dinulică, F., Spârchez, G., Hălălișan, A.F., Dincă, L., Enescu, R., Crișan, V. (2018). The radial growth behaviour of pines (Pinus sylvestris L. and Pinus nigra Arn.) on Romanian degraded lands. *Forests,* 9(4), 213. doi.org/10.3390/f9040213

Stanescu, V., Sofletea, N., Popescu, O. (1997). Flora forestieră lemnoasă a României. *Editura Ceres*, Bucuresti, 451.

Szépszó, G., Horányi, A. (2008). Transient simulation of the REMO regional climate model and its evaluation over Hungary. *IDŐJÁRÁS Quarterly Journal of the Hungarian Meteorological Service,* 112(3–4), 203-231.

Șofletea N., Curtu L. (2008). Dendrologie, *Editura Pentru Viață*, Brașov, Romania, 418.

Uppenbrink J. (1996). Arrhenius and global warming. *Science*, 272(5265), 1122.

Vlad, R., Constandache, C., Dincă, L., Tudose, N.C., Sidor, C.G., Popovici, L., Ispravnic, A. (2019). Influence of climatic, site and stand characteristics on some structural parameters of scots pine (Pinus sylvestris) forests situated on degraded lands from east Romania. *Range Management and Agroforestry*, 40(1), 40-48.

Washington, W.M., Dickinson, R., Ramanathan, V., Mayer, T., Williamson, D., Williamson, G., Wolski, R. (1979). Preliminary atmospheric simulation with the thirdgeneration NCAR general circulation model: January and July. In: Lawrence W, ed. Report of the Joc Conference on Climate Models: Performance, Intercomparison, and Sensitivity Studies. Washington: WMO/ICSU Joint Organizing Committee & Global Atmospheric Research Programme; 95–138

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

FIELD ELM *(ULMUS MINOR* MILL.*)* STANDS THE MOLDAVIAN PLAIN

Lucian DINCĂ

National Institute for Research and Development in Forestry "Marin Dracea", 13 Closca Street, Brasov, Romania

Corresponding author email: dinka.lucian@gmail.com

Abstract

Field elm is a tree species widespread in many areas from Europe, including the Moldavian Plain. Due to its multiple qualities, field elm represents a valuable wood resource even though it has a reduced areal. The present article describes the environment and stand conditions for this species in the Moldavian Plain and is based on an inventory of all stand elements from this area that were extracted from forest management plans dating from the last decades.
Field elm is present in all forest districts from the Moldavian Plain, occupying a total surface of 369 ha. From an altitudinal perspective, the species is widespread from 25 m up to 440 m. The largest percentage is found between 100 and 200 m. The stands' age ranges between 5 and 100 years, with the largest percentage at 21-40 years. The stands have an average productivity, a relatively even-aged structure and a crown density of 0.8-0.9 with a current average growth of 0.5-0.7 m^3/ha. The characteristic soils are cambic chernozem and stagnic luvisol, while the forest types are represented by tug forests and tug holm.

Key words*: age, altitude, field elm, productivity class, soils.*

INTRODUCTION

Field elm is widespread in almost all Europe, including Romania (Figure 1). Filed elm stands have a high morphologic variability (Santini et al., 2012; Zebec et al., 2014) and genetic diversity (Buiteveld et al., 2016), even though it is highly affected by Dutch elm disease (O'callaghan et al., 1980; Ricard et al., 1983; Scheffer, 1989) or elm leaf beetle (Doane et al., 1973; Dreistadt et al., 1990; Meiners et al., 2005; Bosu et al., 2007; Ryall et al., 2010). As all other elm species, field elm has also been studied from a genetic perspective (Solla et al., 2002; Aleksic et al., 2004; Oyama, 2008).

Figure 1. Distribution of field elm in Europe (https://en.wikipedia.org/wiki/Ulmus_minor#/media/Fil: Ulmus_minor_range.svg)

Field elm is a valuable species, especially in the context of current climatic conditions (Ducci et al., 2021; Kutnar et al., 2021).
Field elm stands help in fixing landslides (Dincă et al., 2019), in regulating the water circuit (Tudose et al., 2020; Dincă et al., 2020), in the ecological reconstruction of degraded fields (Silvestru-Grigore et al., 2018; Vlad et al., 2019), and in providing non-wood forest products (Cazacu et al., 2014; Vasile et al., 2017; Vasile et al., 2018; Tiwary et al., 2020; Fedorca et al., 2020).
Moldavia Plain is situated in north-east Romania. From a climatic perspective, the area is characterised by average annual temperatures of 8-10°C and average annual precipitations of 400-500 mm (Apostol et al., 2011; Iordache, 2015; Ilie et al., 2016).
The main altitude is of approximately 200 metres while the characteristic soils for this region are chernozem, phaeozem and luvisol. These soils have a good biologic activity (Ailincai et al., 2015; Onet et al., 2019), being well supplied in nutritive elements (Sparchez et al., 2017; Crisan et al., 2021), but presenting a humidity deficit during summer (Dinca et al., 2018).

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

MATERIALS AND METHODS

The data used for the present article is represented by descriptions and inventories realised between 1995-2006 during the forest management activity from the Moldavian Plain (Anonymus).

The complete description of stands and environment factors from this database has allowed us to extract the data regarding field elm (381 data lines in an Excel table), namely: spreading, altitude, age, production class, structure, crown density, current growth, soil types and forest types. The large number of data ensures a good statistical representation of results.

The surfaces considered are the surfaces occupied by elm. For example, a stand with a composition of 8 Norway spruce - 2 field elm (the composition is appreciated based on the participation percentage of different tree species in the respective silvicultural parcel), with a surface of 10 ha, from which field elm occupies 2 ha. The corresponding calculations and graphics were obtained by using Excel and CorelDraw.

RESULTS AND DISCUSSIONS

Spreading of field elm in the Moldavian Plain: field elm is currently disseminated in stands from all the forest districts located in the Moldavian Plain. However, it has a more significant presence in Trușești (110 ha), Iași (71 ha), Botoșani (52 ha), and Darabani forest districts (39 ha) (Figure 2). Together, they occupy a total surface of 369 ha.

The altitude where field elm stands appear corresponds to the plain area; the species is distributed relatively homogenous on all altitude categories from the Moldavian Plain (Figure 3). The lowest altitude is of 25 m and was recorded in Raducaneni, while the highest one of 440 m was found in Flămânzi. Most stands belonging to this species are distributed at altitudes of 100-200 m.

The age of field elm stands from the Moldavian Plain ranges between 5 and 100 years. The oldest stands are found in Iași and Darabani forest district. Most of the stands are situated in the 21-40 year's age category (Figure 4).

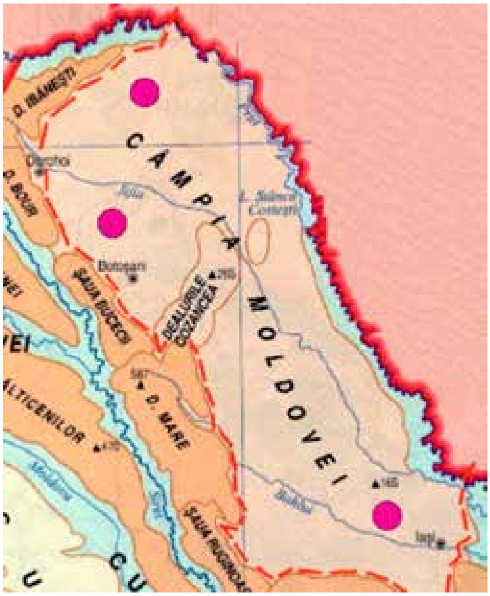


Figure 2. Distribution of field elm in the Moldavian Plain (https://sites.google.com/site/podisulmoldovei/relieful/hidrografie)

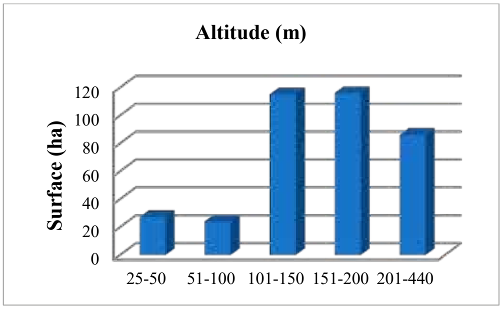


Figure 3. Altitude of field elm stands from the Moldavian Plain

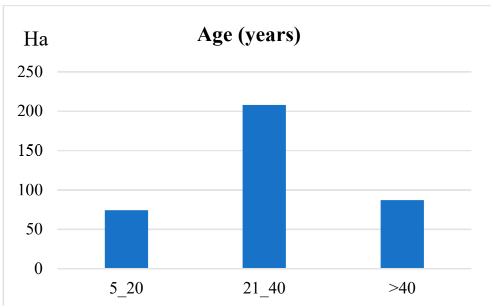


Figure 4. Age of field elm stands from the Moldavian Plain

Field elm stands from this area have in general an average **production class** (64%). Stands with a superior production class (1+2) occupy 12% of the total surface, while those in the inferior production classes (4+5) occupy 24% (Figure 5).

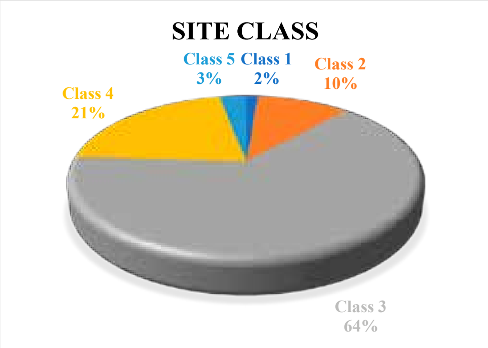


Figure 5. Site class of field elm stands from the Moldavian Plain

Stand structure is predominantly relatively even-aged (292 ha), with few stands having an even-aged (67 ha) or relatively uneven-aged structure (10 ha).
Stand crown density is appropriate, with the majority having a full consistency (0.9 = 128 ha; 0.8= 157 ha) or almost full (0.7 = 62 ha).
Current growth of field elm stands from the Moldavian Plain ranges between 0.1 m^3/ha and 7.8 m^3/ha, with a higher percentage between 0.5-0.7 m^3/ha (Figure 6).

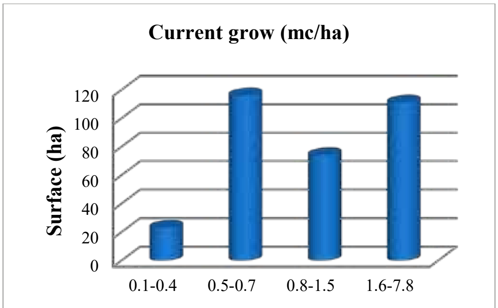


Figure 6. Current grow of field elm stands from the Moldavian Plain

The characteristic soils of field elm stand from the Moldavian Plain are: cambic chernozem (87 ha), stagnic luvisol (76 ha), luvisol (40 ha) and stagnic preluvisol (30 ha). These soils are rich in humus (Crişan et al., 2021) and nutritive elements (Spârchez et al., 2017), being well supplied with water (Dincă et al., 2018), and having a rich biologic activity (Oneț et al., 2019).
The forest types (a classification of stands based on tree species, soils and representative flora) characteristic for the field elms located in this area are: hill tug with superior productivity holm (22 ha), tug holm of average productivity (43 ha), hill tug with average productivity holm (33 ha), hill tug with holm and pedunculate oak of average productivity (40 ha), hill tug with average productivity oak (48 ha).

CONCLUSIONS

Romania has in its forests numerous tree species, including field elm. This species is also present in all forest districts from the Moldavian Plain, having a wider presence in Trusesti, Iasi and Darabani forest districts. Field elm is characterised in this area by varied ages, mainly between 21 and 40 years, and by average productivity classes. The stands have a full consistency, are relatively even-aged, with current low growths, in mixtures of holm and oak. The stational conditions are characterised by altitudes between 100-220 m and soil characteristic for the field area (chernozem and luvisol).

REFERENCES

Ailincăi, C., Filipov, F., Ciobăniţă, M. M. (2018). Efectele sistemelor de cultură anti-erozionale asupra eroziunii şi a proprietăților fizico-chimice ale solului în câmpia Moldovei. In *Agronomie şi agroecology*, Vol. 52, pp. 416-422.
Aleksić, J., Orlović, S. (2004). Ex situ conservation of genetic resources of field elm (Ulmus minor Mill) and European white elm (Ulmus laevis Pall). *Genetika*, *36*(3), 221-227.
Anonymous (1995-2006), Forestry arrangements-Amenajamentele ocoalelor silvice: Botosani (2004), Darabani (2006), Dorohoi (2005), Flamanzi (2004), George Enescu (1995), Harlau (1995), Iasi (2005), Mihai Eminescu (2004), Podu Iloaiei (1990), Raducaneni (2006), Trusesti (2005).
Apostol, L., Vieru, D. N. (2011). Annual variation of average monthly precipitation amounts at the Botosani meteorological station. *Present Environment & Sustainable Development*, *5*(1).
Bosu, P. P., Miller, F., Wagner, M. R. (2007). Susceptibility of 32 elm species and hybrids (Ulmus spp.) to the elm leaf beetle (Coleoptera:

Chrysomelidae) under field conditions in Arizona. *Journal of economic entomology*, *100*(6), 1808-1814.

Buiteveld, J., Vanden Broeck, A., Cox, K., Collin, E. (2016). Human impact on the genetic diversity of Dutch field elm (Ulmus minor) populations in the Netherlands: implications for conservation. *Plant Ecology and Evolution*, *149*(2), 165-176.

Cazacu, C., Adamescu, M.C., Ionescu, O., Ionescu, G., Jurj, R., Popa, M., Cazacu, R., Cotovelea Ancuta. Spatial and time trends based on long term data analysis of mammal populations in Romania. 2014. *Annals of Forest Research*, 57(1), 97-107.

Crișan, V.E., Dincă, L.C., Oneț, A., Bragă, C.I., Enescu, R.E., Teușdea A.C., Oneț C. (2021). Impact of windthrows disturbance on chemical and biological properties of the forest soils from Romania. *Environmental Engineering and Management Journal*, 20(7), 1163-1172.

Dinca, L., Badea, O., Guiman, G., Braga, C., Crisan, V., Greavu, V., Murariu, G., Georgescu, L. (2018). Monitoring of soil moisture in Long-Term Ecological Research (LTER) sites of Romanian Carpathians. *Annals of Forest Research*, 61(2): 171-188.

Dincă, L., Achim, F. (2019). The management of forests situated on fields susceptible to landslides and erosion from the Southern Carpathians. *Scientific papers series Management, Economic Engineering in Agriculture and Rural Development*, 19(3), 183-188.

Dincă, L., Timiș-Gânsac, V., Breabăn, I. G. (2020). Forest stands from direct accumulation and natural lakes slopes from the Southern Carpathians. *Present Environment and Sustainable Development*, 14(1), 211-218.

Doane, C. C., Dunbar, D. M. (1973). Field evaluation of insecticides against the gypsy moth and the elm spanworm and repellent action of chlordimeform. *Journal of Economic Entomology*, *66*(5), 1187-1190.

Dreistadt, S. H., Dahlsten, D. L. (1990). Relationships of temperature to elm leaf beetle (Coleoptera: Chrysomelidae) development and damage in the field. *Journal of economic entomology*, *83*(3), 837-841.

Ducci, F., De Rogatis, A., Proietti, R., Curtu, L.A., Marchi, M., Belletti, P. (2021). Establishing a baseline to monitor future climate-change-effects on peripheral populations of Abies alba in central Apennines. *Ann For Res*, 64(2): 33-66.

Fedorca, M., Ionescu, O., Sofletea, N., Fedorca, A., Curtu, A. L., Ionescu, G. (2020). Assessing the genetic structure of capercaillie (Tetrao urogallus) in Romania. *Annals of Forest Research*, *63*(2), 15-26.

Ilie, N., Apostol, L., Iordache, I. (2016). Temperatura suprafeței solului în podișul Sucevei și în câmpia Moldovei. In *Biodiversitatea în contextul schimbărilor climatice*, pp. 254-259.

Iordache, I. (2015). Utilizarea imaginilor Modis în derivarea unor indici climatici în câmpia Moldovei. In *Tendinţe contemporane ale dezvoltării ştiinţei: viziuni ale tinerilor cercetători* pp. 97-97.

Kutnar, L., Kermavnar, K., Pintar, A.M. (2021). Climate change and disturbances will shape future temperate forests in the transition zone between Central and SE Europe. *Ann For Res* 64(2), 67-86.

Meiners, T., Hacker, N. K., Anderson, P., Hilker, M. (2005). Response of the elm leaf beetle to host plants induced by oviposition and feeding: the infestation rate matters. *Entomologia Experimentalis et Applicata*, *115*(1), 171-177.

O'callaghan, D. P., Gallagher, E. M., Lanier, G. N. (1980). Field evaluation of pheromone-baited trap trees to control elm bark beetles, vectors of Dutch elm disease. *Environmental Entomology*, *9*(2), 181-185.

Onet, A., Dincă, L.C., Grenni, P., Laslo, V., Teusdea, A.C., Vasile, D.L., Enescu, R.E., Crisan V.E. (2019). Biological indicators for evaluating soil quality improvement in a soil degraded by erosion processes. *Journal of Soils and Sediments*, 19(5), 2393-2404.

Oyama, N. (2008). Progress and issues in understanding the physics of ELM dynamics, ELM mitigation, and ELM control. In *Journal of Physics: Conference Series*, Vol. 123, No. 1, p. 012002). IOP Publishing.

Ricard, J. L. (1983). Field observations on the biocontrol of Dutch elm disease with Trichoderma virie pellets. *European Journal of Forest Pathology*, *13*(1), 60-62.

Ryall, K., Silk, P. J., Wu, J., Mayo, P., Lemay, M. A., MaGee, D. (2010). Sex pheromone chemistry and field trapping studies of the elm spanworm Ennomos subsignaria (Hübner) (Lepidoptera: Geometridae). *Naturwissenschaften*, *97*(8), 717-724.

Santini, A., Pecori, F., Pepori, A., Brookes, A. (2012). 'Morfeo'Elm: a new variety resistant to Dutch elm disease. *Forest Pathology*, *42*(2), 171-176.

Solla, A., Gil, L. (2002). Influence of water stress on Dutch elm disease symptoms in Ulmus minor. *Canadian Journal of Botany*, *80*(8), 810-817.

Scheffer, R. J. (1989). Pseudomonas for biological control of Dutch elm disease. III. Field trials at various locations in the Netherlands. *Netherlands Journal of Plant Pathology*, *95*(6), 305-318.

Silvestru-Grigore, C.V., Dinulică, F., Spârchez, G., Hălălișan, A.F., Dincă, L., Enescu, R., Crișan, V. (2018). The radial growth behaviour of pines (Pinus sylvestris L. and Pinus nigra Arn.) on Romanian degraded lands. *Forests*, *9*(4), 213.

Spârchez, G., Dincă, L., Marin, G., Dincă, M., Enescu, R.E. (2017). Variation of eutric cambisols' chemical properties based on altitudinal and geomorphological zoning. *Environmental Engineering and Management Journal*, 16(12), 2911-2918.

Tiwary, A., Vilhar, U., Zhiyanski, M., Stojanovski, V., Dinca L. (2020). Management of nature-based goods and services provisioning from the urban common: a pan-European perspective. *Urban Ecosystems*, 23(3): 645-657.

Tudose, N. C., Ungurean, C., Davidescu, Ș., Clinciu, I., Marin, M., Nita, M. D., Davidescu, A. (2020). Torrential flood risk assessment and environmentally friendly solutions for small catchments located in the Romania Natura 2000 sites Ciucas, Postavaru and Piatra Mare. *Science of The Total Environment*, *698*, 134271.

Vasile, D., Dincă, L., Enescu C.M. (2017). Impact of collecting mushrooms from the spontaneous flora on forest ecosystems in Romania. *AgroLife Scientific Journal*, 6(1), 268-275.

Vasile, D., Enescu, C.M., Dincă L. (2018). Which are the main medicinal plants that could be harvested from Eastern Romania? *Scientific papers series Management, Economic Engineering in Agriculture and Rural Development*, 18(1), 523-528.

Vlad, R., Constandache, C., Dincă, L., Tudose, N.C., Sidor, C.G., Popovici, L., Ispravnic, A. (2019). Influence of climatic, site and stand characteristics on some structural parameters of scots pine (Pinus sylvestris) forests situated on degraded lands from east Romania. *Range Management and Agroforestry*, 40 (1): 40-48.

Zebec, M., Idžojtić, M., Poljak, I. (2014). Morphological variability of the field elm (Ulmus minor Mill. sensu latissimo) in continental Croatia. *Šumarski list*, *138*(11-12), 563-571.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

EFFICIENCY OF NEW FERTILIZERS BASED ON SEWAGE SLUDGE OF URBAN TREATMENT FACILITIES IN THE FODDER CROP ROTATION IN THE WESTERN FOREST-STEPPE OF UKRAINE

Vitaliy DYSHLYUK

National Scientific Center "Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky", 4 Chaikovska Street, Kharkiv, Ukraine

Corresponding author email: dyshlyuk_ve@ukr.net

Abstract

Sewage sludge (50-52% moisture) of a large regional city in the western part of Ukraine is characterized by a complex of agronomically valuable traits, but their direct incorporation into the soil as a non-traditional organic fertilizer is ecologically impractical due to a number of unfavorable factors, therefore, they should be processed into quality fertilizers of the new generation. The composition of complex organo-mineral fertilizers based on sewage sludge with mineral additives of different origin is developed and new three- and two-component organo-mineral fertilizers of prolonged action for multi-purpose use are obtained. In a field experiment (2017-2019) with a comparative study of the effectiveness of different types of fertilizers in the fodder crop rotation, it was found that new organo-mineral fertilizers with the main application in optimal doses on light gray forest soil in the Western Forest-Steppe of Ukraine had the same effect in the year of action and aftereffects as traditional and non-traditional organic fertilizers, as well as complete mineral fertilizers (in equivalent doses), and allow with a single application of the first crop rotation crop to grow the second and third crops without fertilizers 110% and 45% according to the control without fertilizers.

Key words: *efficiency, new organo-mineral fertilizers, fodder crop rotation, Western Forest-Steppe, Ukraine.*

INTRODUCTION

Currently, the problem of waste disposal is one of the most urgent problems of our time. Waste is a source of environmental pollution, as a result of their accumulation, the sanitary-hygienic and epidemiological indicators and aesthetic qualities of nature significantly are deteriorating. At the same time, wastes of certain industries have properties that determine the possibility of their reuse, which defines interest in them as a secondary material resource. These include sewage sludge (hereinafter - SS) from municipal wastewater treatment plants (hereinafter - WWTP), which are stored on the sludge sites of municipal wastewater treatment plants and dumps at risk to the environment and the population, creating technological problems in the process of wastewater treatment. Improper storage conditions lead to environmental pollution in urban and suburban areas, worsen water quality in water bodies, as in most cases WWTPs with sludge sites and landfills are located on river banks to discharge wastewater. According to scientists (Kireeva, 1996; Sevalnev, 2000; Nasirov et al., 2015) storage of production and consumption waste on sludge sites of WWTPs causes significant economic and environmental losses to society due to environmental pollution and degradation, lack of quality drinking water, disturbances of natural state of territories, loss of health of the population. Thus, SS is a source of environmental pollution and its disposal in storage and sludge sites, as a temporary way to solve this problem has long been exhausted. On the other hand, properly treated solid waste from municipal sewage treatment plants is a reserve of non-traditional organic fertilizers and ameliorants of local origin (according to requirements) and/or resource-intensive raw materials for their production that can be used in agriculture. Therefore, the development of innovative ways to safe SS disposal is one of the urgent tasks of mankind. Without solving the problem of safe utilization of organic waste, there is a risk of significant accumulation and catastrophic environmental pollution (Merzla, 2006; Dregulo et al., 2012; Dregulo et al., 2016; Manenko et al., 2020).

In Ukraine, the situation in the field of SS in large cities and industrial centers due to the formation of their large volumes and the lack of long-term adequate response to the danger they pose to the environment and human, is assessed as a crisis. According to estimates (Drozd et al., 2001; Melnichuk et al., 2003), 50-55 million tons of SS (in dry matter) have been accumulated in recent years; according to other data (Bagno et al., 2011), up to 1 billion tons of SS of long-term storage have been accumulated in the country. Every year, more than 25-30 million tons of liquid SS are formed, or 0.7-1.0 million tons in dry matter (Degodyuk et al., 2006; Bagno et al., 2011). In general, almost all volumes of SS in large cities and industrial centers are subject to disposal (Drozd et al., 2001; Melnychuk et al., 2003; Drozd et al., 2013), although the law provides for their recycling and disposal (Law, 1998). The total storage area of SS is more than 10 thousand hectares, waste is placed on sludge sites, storage facilities, quarries, temporary storage sites that do not meet environmental requirements. Due to the lack of safe practices for the management of SS in the places of its accumulation, it pollutes the environment and has a detrimental effect on public health (Kireeva, 1996; Sevalnev, 2000).

It was determined (Dyshlyuk et al., 2020) that SS of most large cities (22 cities with a population of over 200 thousand inhabitants and developed industrial potential in 20 oblasts, including 20 oblast cities), which was formed under the conditions of technogenesis in the pre-crisis period, after the final holding on sludge sites, mainly meet the requirements for ecological and sanitary indicators for use in agricultural production as a non-traditional organic fertilizer. There is a group of cities where SS is biologically contaminated and requires more effective decontamination, a sufficient level of which can be achieved by adhering to technological processes in the treatment cycle at sewage treatment plants, longer holding time on sludge sites, or by biothermal processing into quality biofertilizers.

As a result of assessing the degree of contamination with SS toxicants in large cities and industrial centers, formed under the conditions of technogenesis in the pre-crisis period, it was found that most of them exceed the permissible concentrations for fertilizing field crops. Therefore, depending on the actual content of toxicants in SS, 6 groups of cities are classified, according to which the technology of waste use for fertilizers is determined with restrictions on doses, frequency of application, areas of application (Dyshlyuk, 2000). In the last decade, due to the decrease in the share of industrial wastewater in the general sewage, the content of toxicants in the SS of large cities has decreased to acceptable levels, which determines the prospects of its use for fertilizer production (Skrylnyk, 2018).

In general, at present, the problem of disposal of SS in large cities and industrial centers in the country is typical and requires urgent measures to neutralize them while maintaining the ecological balance of the environment. According to H.Ye. Merzlaya (2006) at the current pace of urbanization and agglomeration to solve the situation of rational disposal of SS in large cities and industrial centers is possible only with the implementation of innovative technologies for municipal wastewater treatment, treatment and processing into complex organo-mineral fertilizers of the new generation.

It is obvious that the use of this secondary constantly renewable organic raw material for the production of modern quality fertilizers is one of the most promising areas of soil enrichment with organic matter of humic origin, macro- and micronutrients and restoring soil fertility.

The processing of SS into complex organo-mineral fertilizers of the new generation will reduce environmental pollution and conserve natural resources, reduce energy consumption and land for sludge sites for the disposal of SS, to obtain material benefits from the use of fertilizers.

The purpose of the work:

- study the qualitative indicators of SS in a large regional city in the western part of Ukraine and to find out the possibility of using them for the production of new generation fertilizers;
- create on the basis of SS new complex organo-mineral fertilizers of new generation for use in agriculture;

- study the effectiveness of new complex organo-mineral fertilizers based on SS in the crop rotation chain on soils of eluvial type of soil formation in the Western Forest-Steppe of Ukraine.

MATERIALS AND METHODS

Objects of research: sewage sludge of a large city in the western part of Ukraine, assessment of the suitability of waste for use as organic raw material for the production of new generation fertilizers, the effectiveness of new fertilizers on eluvial soils. In the field experiment (2017-2019) we studied the effectiveness of the effect and aftereffect of new generation fertilizers in the form of organo-mineral mixtures (hereinafter - OMM) based on SS with mineral additives (mineral fertilizers, natural sorbent - agroperlite) compared to complete mineral fertilizers, traditional and non-traditional organic fertilizers in equivalent doses. The experiment was carried out in the Western Forest-Steppe of Ukraine (Lviv oblast, Pustomitivskyi district, Obroshyne village, research field of the Institute of Agriculture of the Carpathian region of National Academy of Agrarian Sciences of Ukraine (hereinafter - NAAS) on light gray forest surface gleyed coarse-dusty-light loamy soil in 4 fodder crop rotation in the chain with the alternation of crops: corn for green fodder - spring barley with sowing of meadow clover - meadow clover. The experiment consists of 6 options. The total area of the site is 26 square meters (4 m x 6.5 m), repetition in the experiment - three times. The location of the options is single-tiered, consistent.

Scheme of the experiment:

1 - without fertilizers (absolute control);

2 - complete mineral fertilizer in the dose of $N_{150}P_{90}K_{90}$;

3 - cattle manure in a dose of N_{total} 150 kg/ha;

4 - SS in a dose of N_{total}. 150 kg/ha;

5 - OMM (organo-mineral mixtures) 1 based on the dose of $N_{150}P_{90}K_{90}$;

6 - OMM 2 based on the dose of N_{total} 150 kg/ha.

The following fertilizers were used in the experiment: half- decomposed manure of cattle (straw litter), dried thermophilic-fermented SS after 5-6 years of storage on sludge sites, industrial fertilizers: ammonium nitrate (34.5%), simple granular superphosphate (19.5%) and potassium magnesium (28%), two types of new mixtures: OMM 1 (SS + industrial fertilizers (ammonium nitrate, superphosphate, potassium magnesium) + natural sorbent (agroperlite) and OMM 2 (SS + natural sorbent (agroperlite) in certain ratios. The experimental batch of new OMM was obtained by mixing in certain proportions the above components and the subsequent physical and physicochemical interaction of activated organic matter and the elemental composition of SS with mineral components. Patents of Ukraine were obtained for new types of complex OMM based on SS with mineral additives (Patents, 2017).

Doses of fertilizers were equalized by the content of total nitrogen and applied to the soil when laying the experiment in the spring of 2017 in one go in a continuous manner (scatter) before plowing for the first crop rotation.

In 2017, we studied the effectiveness of fertilizers on corn on the green mass (hybrid Pioneer - P8529), in 2018 - the aftereffect of the 1st year of fertilizers on spring barley (Galician variety) with sowing meadow clover (variety Predkarpatska 6), and in 2019, respectively, the effectiveness of the aftereffect of the 2nd year of fertilizers for sowing meadow clover (variety Predkarpatska 6) of the 1st year of use.

By setting up an experiment and conducting research, they were guided by generally accepted methods. Soil samples for research were taken from the arable layer (0-20 cm) of soil in spring and at the end of the growing season. Agrochemical, physicochemical and ecological-toxicological indicators were determined in the samples of manure of cattle, SS and OMM 1 and 2 according to the current normative documents. Assessment of the degree of contamination of SS with toxicants and new OMM was performed according to State Standard of Ukraine (DSTU 7369:2013), the level of soil micronutrients according to the Guidelines (1976), the level of soil contamination with toxicants and the suitability of plant products for for feeding agricultural animals by heavy metal content according to Departmental Normative Documents (1999).

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

RESULTS AND DISCUSSIONS

It is established that SS of a large regional city in the western part of Ukraine after drying and storage on silt sites is characterized by quite high fertilizing properties.
$N\text{-}NH_4$ and P_2O_5, which are contained in amounts of 285 and 366 mg/kg, respectively, predominate in SS among mobile forms of nutrition. Agrochemical indicators of SS meet the requirements of the current regulatory document (DSTU7369: 2013) (Table 1).

Table 1. Agrochemical composition of SS (average data)

Indicators	Content[1]	Norm [2]
Mass fraction of dry matter	35.85	-
Mass fraction of organic matter	47.67	No >40
Mass fraction of total carbon, C total	24.77	-
Mass fraction of total nitrogen, N	1.87	No >1.5
Mass fraction of total phosphorus, P_2O_5	1.37	No >0.7
Mass fraction of total potassium, K_2O	0.44	-
pH aqueous	7.72	6.5-7.5
Correlation C:N	13.3	-

1 - in % on dry matter

2 - standards of agrochemical indicators of SS according to DSTU 7369.

SS has high reclamation rates: the content of gross and water-soluble calcium varies between 3.8-4.2% and 0.20-0.38%, respectively, the ratio of Ca: Na in the salt composition of SS reaches 32 units. In the particle size distribution of SS, the content of physical clay is 13-15%, including sludge (coarse and fine) and colloids - 1.9-2.4%. The number of fractions with a particle size > 0.05 mm (fine, medium and coarse sand) is 65-76%. The number of fractions involved in the structure of the soil as a passive material (large, medium and fine dust) is 22-32%. According to the classification of soils according to the granulometric composition of SS with a physical clay content of 13-15% can be conditionally equated to the soil, which is characterized by sandy granulometric composition. The established indicators and properties of SS give grounds to attribute them to the material characterized by a set of agronomically valuable features.

In this regard, SS can be used as a local raw material, which has both fertilizing value and properties characteristic of ameliorant (neutral and slightly alkaline reaction of the environment, high content of gross and soluble calcium, high calcium activity, which is important for land reclamation gray forest soil: to reduce the acid reaction (actual soil pH - 4.4) and saturation of the soil-absorbing complex with calcium (the degree of saturation of the soil with bases - 34-37%). That is, it is a substrate that can improve soil properties and act as a barrier to toxicants. However, SS has an unbalanced ratio of basic nutrients (N:P:K = 1: 0.73: 0.23), increased concentrations of some toxic chemical elements with a high proportion of mobile forms, which is due to the application of these substrates in high doses/ha) can cause phytotoxic effects, translocation of heavy metals from soil to plants, etc. (Manenko AK et al., 2020). Due to these shortcomings, SS is unsuitable for direct application as a non-traditional organic fertilizer and it is advisable to use it as secondary organic raw materials for processing into high-quality organo-mineral fertilizers of the new generation.
The new OMM 1 and 2, which are based on SS with mineral additives, represent a new generation of complex organo-mineral fertilizers containing organic substances and minerals, macro- and microelements and are characterized by high fertilizing properties, high cation exchange capacity and prolongation of action, as well as the ability to convert mobile forms of heavy metals into a fixed state.
In the technological process of obtaining OMM, mineral nutrients form organo-mineral complexes with humic compounds of the organic component of fertilizers, which are able to supply plants with easily digestible forms of nutrients for a long time. Agrochemical indicators of OMM 1 and 2 meet the requirements of the current regulatory document (DSTU, 2013), fertilizers are characterized by a significantly higher fertilizing potential (especially OMM 1) than the original SS. Samples of fertilizers have low humidity (19-29%), which is important to save costs for their transportation and simplifies agricultural practices for the application of OMM in the soil (Table 2).

Table 2. Agrochemical composition of OMM (average data)

Indicators	OMM 1	OMM 2
	Content[1]	
Mass fraction of dry matter	71.11	80.52
Mass fraction of organic matter	40.25	43.50
Mass fraction of total nitrogen, N	4.53	2.24
Mass fraction of total phosphorus, P_2O_5	5.97	2.85
Mass fraction of total potassium, K_2O	4.39	0.79
pH aqueous	5.60	6.07
Correlation C:N	4.5	8.0

1 - in % on dry matter

OMM 1 and 2 differ from the original SS in a more balanced ratio of basic nutrients (for OMM 1 ratio N: P: K = 1: 1.32: 0.97; and for OMM 2 ratio N: P: K = 1: 1, 27: 0.35), high content of mobile nutrients (OMM 1), the presence of a wide range of macro-. and trace elements and the best physicochemical properties.

Thanks to the new positive qualities of OMM 1 and 2, their application allows reducing fertilizer application doses, balancing the ratio of nutrients in the soil, to prolong the action of fertilizers, which generally increases feed yields and product quality. In an experiment to study the effectiveness and aftereffects of OMM 1 and 2 compared to complete mineral fertilizers, traditional and non-traditional organic fertilizers in equivalent doses, it was found that the use of new fertilizers (OMM 1 and 2) in crop rotation at optimal doses provided obtaining an increase in plant products of regulatory quality: in the year of fertilizer application - 26.0 - 31.9 t/ha of green mass of corn, in the aftereffect of the 1st year of fertilizer - 0.90-0.95 t/ha of spring barley grain, in the after effect of the 2nd year of fertilizer - 13.2-15.0 t/ha of green mass of meadow clover (total increase for 2 slopes) compared to the control without fertilizers (yield under control: in the year of fertilizer application - 24.1 t/ha of green mass of corn; in the aftereffect of the 1st year of fertilizers - 0.84 t/ha of spring barley grain and in the aftermath of the 2nd year of fertilizers - 31.1 t/ha of green mass of meadow clover) and in efficiency they were not inferior to organic and mineral fertilizer systems.

CONCLUSIONS

New OMM based on SS with mineral additives are characterized by increased agrochemical and agrienvironmental value and high efficiency for the first crop and have a residual effect on subsequent crops of crop rotation on soils of eluvial type of soil formation (light gray forest soil).

New OMM based on SS with the main application in optimal doses on light gray forest soil are not inferior in efficiency to the year of action and aftereffects of complete mineral fertilizers, traditional and non-traditional organic fertilizers (in equivalent doses) and thanks to new positive qualities allow for single application OMM for the first crop to grow the second and third crops without the application of NPK with a yield increase of 120% (in the year of fertilizer application), 110% (the aftereffect of the 1st year of fertilizers) and 45% (of the aftereffect of the 2nd year of fertilizers) on average, respectively, according to the control without fertilizers.

Due to its high metabolic and sorption capacity, the use of natural sorbents in new OMM allows them to be considered as an effective tool for optimizing the fertilizing and reclamation properties of fertilizers, reducing unproductive losses of plant nutrients (nitrogen), preventing contamination by toxicants of plant and natural plant environment.

The establishment of new local self-government bodies creates an opportunity for the purposeful transformation of organic raw materials of man-made origin, increasing soil fertility and land productivity, preserving the ecological balance of the environment, creating additional jobs and so on.

ACKNOWLEDGMENTS

The author is grateful for the close cooperation in the implementation of this scientific topic to Academician of NAAS H.M. Sedilo, Doctor of Agricultural Sciences H.S. Konyk, PhD (Agricultural Sciences) Yu.M. Olifir. and other employees of the Institute of Agriculture of the Carpathian region of NAAS.

REFERENCES

Bagno A.O., Voloshin M.D. (2011). Investigation of the qualitative composition of municipal wastewater sludge depending on the shelf life on silt maps. Bulletin of NTU "Kharkiv Polytechnic University", 57-63.

Departmental Normative Documents 33-5.5-06-99. Protection of water, soil and plant resources from heavy metal pollution under irrigation. K.: State Water Management of Ukraine. 26 p.

Degodyuk Ye.G, Degodyuk S.Ye. (2006). Ecological and technogenic security of Ukraine. K.: Ekmo, 235-238.

Dyshlyuk V.Ye. (2000). Microelement composition and use of sewage sludge from urban treatment plants as organo-mineral fertilizers. *Bulletin of Dnipropetrovsk State Agrarian University*, 1-2, 61-62.

Dyshlyuk V.Ye, Garkavy S.I. (2020). Ecological and hygienic aspects of the use of sewage sludge in large cities and industrial centers of Ukraine as non-traditional organic fertilizers in agriculture. *Agricultural Microbiology*, 31, 3-15.

Dregulo A.M., Panova N.Ye. (2012). Assessment of the negative impact on the environment of landfills for storing sediments from biological treatment facilities. *Ecology and Industry of Russia*, 8, 43-45.

Dregulo A.M., Kulibaba V.V., Gildeeva I.M. (2016). Sludge beds as specific objects of past environmental damage (in the private basin of the Gulf of Finland). *Society. Enviroment. Development*, 3, 115-119.

Drozd G.Ya., Zotov N.I., Maslak V.N. (2001). Sewage sludge as a fertilizer for agriculture. *Water supply and sanitary engineering*, 12, 33-35.

Drozd G.Ya., Bizirka I.I. (2013). Involvement of deposited sewage sludge in economic circulation. *Water supply and sanitary engineering*, 4, 11-17.

DSTU 7369: 2013 Sewage. Requirements for wastewater and its sediments for irrigation and fertilization. [Effective from 2013-08-22]. K.: Ministry of Economic Development of Ukraine. pp. 8 (National Standard of Ukraine).

Kireeva I.S. (1996). Actual hygienic problems of environmental protection of industrial cities of Ukraine. Urban Environment: Nature and Human Health, 33-36.

Law of Ukraine "On Waste". №187 / 98-BP.

Manenko A.K., Tkachenko G.M., Kasiyan O.P., Yurchenko S.T. (2020). Hygienic substantiation of the possibility of using sludge from wastewater treatment plants as an organic fertilizer. *Hygiene and Sanitation*, 99, 3, 259-264.

Merzlaya G.E. (2006). Use of organic waste in agriculture. Resource-saving technologies, 10, 21-31.

Methodical instructions and recommendations on biotechnological methods of processing and use of organic waste of cities/For general ed. D.O. Melnichuk and M.M. Gorodny (2003). K.: LLC "Alefa", 51-70.

Nasyrov I.A., Mavrin G.V., Shaikhiev I.G. (2015). Problems of disposal of sludge from sewage treatment plants. *Bulletin of the Kazan Technological University*, 2, 42-47.

Patent of Ukraine №114648 (2017). Method of production of organo-mineral fertilizer based on sewage sludge for soil cultivation / V.Ye. Dyshlyuk, Ye.H. Degodyuk, V.L. Kurilo, L.V. Ostapchuk, *Bulletin "Industrial Property"*, 5, 5 p.

Patent of Ukraine №114649 (2017). Method of production of organo-mineral fertilizer based on sewage sludge for fertilization of crops / V.Ye. Dyshlyuk, Ye.H. Degodyuk, V.L. Kurilo, L.V. Ostapchuk. *Bulletin "Industrial Property"*, 5, 6 p.

Sevalnev A.I., Remzhin O.O., Bogdanovsky V.V., Sklyarov V.G. (2000). Problems of health care and the environment due to the accumulation of industrial waste in Zaporozhye. *Scientific Bulletin of the National Agrarian University*, 26, 48-50.

Skrylnyk Ye.V., Maksymenko N.V., Ryzhkova Ja.S, Ryzhkov V.A. (2018). Agroecological characteristics of sewage sludge in Kharkiv. Human and the environment. *Problems of Neoecology*, 1-2 (29), 112-118.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

OVERVIEW OF THE BULGARIAN NATIONAL ENERGY TRANSITION TARGETSBY SECTORS

Daniela KOSTOVA-IVANOVA

University of Food Technologies, 26 Maritza Blvd., Plovdiv, Bulgaria

Corresponding author email: daniela_kostova07@abv.bg

Abstract

The publication presents an overview of the national energy targets by sectors, emphasizing the goals of energy transition by analysing the national legislation, strategic documents and action plans in Bulgaria. A brief introduction is presented on the current energy data, what actions in terms of energy efficiency, savings and decarbonisation have been implemented so far and their impact. The publication analyses the government's action plans to move to a low-carbon economy by implementing short-term and long-term measures in the different economic sectors. For the purposes of the analysis, the energy consumption sectors are defined according to the guidelines of the Sustainable Energy Development Agency for the development of municipal plans and programs to promote the use of energy from renewable sources and bio-fuels and energy efficiency, as well as the guidelines for developing a Sustainable Energy and Climate Action Plans of the Covenant of Mayors, as follows: Buildings, Industry, Transport and Agriculture sectors.
This review will serve for further analysis and assessment of energy transition scenarios. The expected impact from the implementation of the national plans for achieving the European targets is analysed.

Key words: *energy transition, energy targets, energy strategies, sustainable energy and climate plan.*

INTRODUCTION

Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems. Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen (IPCC, 2014). The urgent need to reduce greenhouse gas emissions, as outlined in the climate objectives of the Paris Agreement, necessitates deep decarbonisation of the energy sector, which will require a fundamentally different approach to previous strategies that sought to stabilize or halve emissions (IRENA, 2000).
The EU is committed to reducing greenhouse gas emissions to 80–95 % below 1990 levels by 2050 in the context of necessary reductions by developed countries as a group (European Commission, 2011), defining the great goal to be a climate neutral continent or to reach energy transition until 2050. All 27 EU countries have committed themselves to making the Union the first climate-neutral continent by 2050. To achievethis, they have committed themselves to reducing emissions by at least 55% by 2030 compared to 1990 levels (European Union, 2021).
A number of Bulgarian researchers work have been identified in the field of energy efficiency increasing and energy transition in buildings (Komitov et al., 2020; Valchev & Mihaylov, 2020; Zlateva at al., 2020; Iliev at al., 2021) and various installations and processes in the industrial sector (Georgieva at al., 2018; Georgieva at al., 2019; Penkova & Mladenov, 2020; Kolev at al., 2017; Rasheva at al., 2020).

EUROPEAN STRATEGIC ENERGY FRAMEWORK

The Clean Energy for All Europeans package with new rules being adopted in the first half of 2019 marks a significant step towards the creation of the Energy Union and delivering on the EU's Paris Agreement commitments. This package includes 8 different legislative acts empowering European consumers to become fully active players in the energy transition, and include:

- A revised Energy Performance of Buildings Directive (EPBD, 2018/844, which establishes a clear path towards a low and zero-emission building stock in the EU by 2050). Buildings are responsible for around 40% of energy consumption and 36% of CO_2 emissions in the EU, making them the single largest energy consumer in Europe. By making buildings more energy efficient, the EU can more readily achieve its energy and climate goals. The Energy Performance of Buildings Directive (EU 2018/844) outlines specific measures for the building sector to tackle challenges, updating and amending many previous rules (Directive 2010/31/EU) (Clean energy for all Europeans package. Retrieved from https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en).
- A recast of the Renewable Energy Directive (2018/2010, which ensures that the share of energy from renewable sources in the Union's gross final consumption of energy in 2030 is at least 32%).
-An amendment of the Energy Efficiency Directive (EED amendment, 2018/2012, to ensure that the Union's 2020 headline targets on energy efficiency of 20% and its 2030 headline targets on energy efficiency of at least 32.5% are met).

The objective and scope of the Clean Energy for all Europeans scenarios is to analyse the feasibility of the 2030 climate targets. The scenarios mainly envision a decarbonisation compatible with the 2°C climate target by modelling "the achievement of the 2030 climate and energy targets as agreed by the European Council in 2014 (the first scenario with a 27% energy efficiency target and the second with a 30% energy efficiency target) ".With the EU reference scenario as a starting point, the following, more ambitious, EUCO scenarios aim to assess a very specific range of climate and energy targets, those being: - reduction of overall GHG emissions compared to 1990: 40% until 2030 and 80-85% until 2050; - emissions reduction from ETS sectors: 43% in 2030 and 90% in 2050 compared to 2005; - non-ETS emissions reduction: 30% in 2030 compared to 2005; - energy efficiency: reduction of primary energy demand by 27% - 30% in 2030 compared to 2007.

The Energy Transition Roadmap 2050 scenarios focus on sustainability, competitiveness and security of the EU energy system. The main drivers and decarbonisation routes noted in the Energy Roadmap are built around four key technological developments: energy efficiency, renewable energy, nuclear energy and carbon capture and storage, which form a roadmap consisting of seven energy transition scenarios until 2050. These scenarios include assumptions on a wide portfolio of technologies, the role of consumers and investors and outlooks of existing regulatory frameworks (Hainsch et al., 2022).

The green transition is one of the EU's main ambitions to tackle the global challenge of mitigating the adverse effects of climate change. That is why in December 2019, the President of the European Commission Ursula von der Leyen presented the European Green Deal, which aims to make Europe the first climate-neutral continent by 2050 (Council of Ministers of the Republic of Bulgaria, 2020).

The European Green Deal is a response to the climate challenges as well. It is a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use (European Commission, 2019).

To meet the EU's energy and climate targets for 2030, EU countries need to establish a 10-year integrated National energy and climate plan (NECP) for the period from 2021 to 2030. Introduced under the Regulation on the governance of the energy union and climate action (EU/2018/1999), the rules required the final NECP to be submitted to the Commission by the end of 2019.

All Parties to the Paris Agreement are invited to communicate, by 2020, their mid-century, long-term low greenhouse gas emission development strategies. The Regulation on the governance of the energy union and climate action (EU/2018/1999) sets out a process for the Member States to prepare these strategies and new strategies every 10 years thereafter. The long-term strategies should be consistent with Member States' integrated national energy and climate plans for the period 2021-2030.

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

BULGARIAN STRATEGIC ENERGY FRAMEWORK

The state policy in the field of energy efficiency and renewable energy sources (RES) is implemented by all national and local authorities through developing and adopting National and Municipal energy efficiency programs, as well as National and Municipal programs to promote the use of energy from renewable sources and bio-fuels, who both has to be in line with the objectives of the above mentioned acts and are developed taking into account the strategic objectives and priorities of the specific regional development plans of the respective regions.
The sustainable energy development policies in Bulgaria are defined in the following main energy acts - the Energy Efficiency Act and the Energy from Renewable Sources Act, which are requiring the development of a number of national documents, which has to be followed by all regional governments, namely:
1) National action plan for energy efficiency;
2)National plan for net zero energy buildings (NZEBs) - Regional governments are obliged to deploy NZEBs according to the National Plan for Nearly Zero Energy Buildings 2015-2020, which aims to turn the concept of nearly-zero energy buildings into a practically viable alternative to the future construction of new buildings in Bulgaria, as well as to deploy a proven cost-effectiveness approach in the renovation of existing buildings for the various sub-buildings categories. On the other hand, municipalities are also developing plans to increase the number of NZEBs, which most probably have to deploy photovoltaic's (PVs), to reach the 2030 climate change targets. All these strategies are in line with the clear direction for the complete decarbonisation of the European building stock until 2050.
3) National Strategy for Adaptation to Climate Change - outlines the strategic framework and priorities for adaptation to climate change until 2030.
4) National plan for improvement of the energy characteristics of the heated and/or cooled state-owned buildings;
5) National long-term investment promotion program for the implementation of measures to improve the energy performance of buildings - support the renovation of the national building stock of residential and non-residential buildings by 2050. The document defines the strategic vision and priorities of the country to achieve energy efficient and de-carbonized building stock by 2050. In accordance with Directive (EC) 2018/844, the strategy has developed a roadmap with indicative milestones for 2030, 2040 and 2050 regarding the renovation of residential and non-residential buildings in the Republic of Bulgaria. The indicative target for the period 2021-2030 is the renovation of residential and non-residential buildings with a total area of over 22 million m^2, as the expected savings in energy consumption are estimated at 2,917 GWh/year and carbon emissions - 1,306 $ktCO_2$/year until 2030. The strategy envisages policies and measures for long-term development in terms of increasing the energy efficiency of the building stock in the country.
6) Annual reports on the implementation of national energy efficiency action plans.
7) Integrated plan in the field of energy and climate of the Republic of Bulgaria 2021-2030 (NECP) - defines the main goals of the country to stimulate low-carbon economic development, development of competitive and secure energy and reduce dependence on imports of fuels and energy. In order to fulfil the goals set in NECP, complex actions are needed in all areas of socio-economic relations. This is particularly true of economic sectors, where the potential of existing industries to enter new technologies must be used to the full, ensuring a smooth and equitable transition to a climate-neutral circular economy, such as the hydrogen economy.
In this regard, NECP envisages consumption of green hydrogen produced through the use of energy from renewable sources, incl. electricity produced from wind and solar energy. As a basis for the development of hydrogen capacities in Bulgaria, NECP has set a goal by 2030 to develop a pilot project for hydrogen production with a total installed capacity of 20 MW.
8) National Recovery and Sustainability Plan - The main objective of the Recovery and Sustainability Plan is to facilitate economic and social recovery from the crisis caused by the COVID-19 pandemic. The green transition occupies a leading position in the Bulgarian

Recovery and Sustainability Plan, concentrating 45.8% of the total projected costs, with a minimum set of 37% of the European Commission regulation. In this way, Bulgaria contributes to the implementation of the pan-European goals for gradual decarbonisation. In addition, efforts are focused on three main areas:

- Creating conditions for the accelerated introduction of renewable energy sources and hydrogen;
- Enhanced action to increase the energy efficiency of the economy;
- Sustainable mobility.

9) Strategy for sustainable energy development of the republic of Bulgaria until 2030 with a horizon until 2050 - reflects the state's vision for the development of the energy sector by 2030, with a horizon of 2050, in line with the current European framework of energy policy and global trends in the development of new energy technologies. The strategy clearly reflects trends, measures and policies in the field of energy security, energy efficiency, the liberalization of the electricity and gas markets and their integration into the common European energy market, the development and implementation of new energy technologies. These policies are also reflected in the Integrated Plan in the field of energy and climate of the Republic of Bulgaria 2021-2030, with a horizon of 2050.

OVERVIEW OF THE NATIONAL TARGETS FOR ENERGY TRANSITION AND CURRENT ENERGY DATA

In order to ensure a coordinated and coherent EU-wide approach and implementation of the Energy Union strategy Bulgaria has elaborated its National energy and climate plan (NECP). The plan sets out the main goals and measures for the implementation of the national energy and climate policies, which are in the context of the European legislation, principles and priorities for energy development. Bulgarian energy priorities, set in the NECP can be summarized as follows:

- Enhancing energy security and diversifying energy supply;
- Development of an integrated and competitive energy market;
- Development of RES capacities, according to the available resources, network capacity and national specifics;
- Improving energy efficiency (EE) by developing and implementing new technologies to achieve modern and sustainable energy;
- Protecting consumers by ensuring fair, transparent and non-discriminatory conditions for the use of energy services.

Based on the Bulgarian NECP, in 2030, Bulgaria plans to achieve a reduction in primary energy consumption of 27.89% and a reduction of 31.67% in the final energy consumption, compared to the PRIMES 2007 benchmark. It also intends to reach a share of 27.09% in the share of RES in gross final energy consumption by 2030, to reach 30.33% share of renewable electricity, as well as to reach a share of 42.60% of renewable heating and cooling energy.

Currently use of local energy resources (Ministry of Energy, 2021):

- **Coal:** Based on data from the Strategy for sustainable energy development of the republic of Bulgaria until 2030 with a horizon until 2050coal is the energy resource that has the largest share of local energy resources. The availability of this local resource is a guarantee for the stability and security of the country's energy system. This means that in the coming years, coal-fired power producers are expected to face significant challenges arising from the new legislative framework requiring the transition to a new low-carbon market model. Coal is the energy resource with the largest share of local energy resources. In 2019 local coal provides 39% of the country's gross energy production. The strategy says that given the strategic nature of coal-fired thermal power plants to ensure the country's energy security, Bulgaria will continue to rely on the efficient operation of these facilities in the future.
- **Natural gas:** So far, no significant natural gas deposits have been discovered on the territory of the Republic of Bulgaria. Currently, production in the country is limited, covering just over 1% of annual consumption. The production of natural gas in the country in 2019 amounts to 29 million m^3, and the trend is for rapid depletion of existing fields. To meet the needs of Bulgarian consumers for natural gas relies mainly on imports. In 2019, the Russian

Federation imported 2,778 million m^3 of natural gas, which represents 85.7% of the total natural gas imported into the country. High dependence on natural gas imports is one of the main risk factors for the country's energy security. In this regard, alternative solutions are being sought and action has been taken to explore and search for new natural gas fields, both on land and on the Black Sea shelf.

- **Nuclear energy:** Nuclear energy plays an important role in ensuring national, regional and European energy security, while providing affordable energy and is a key element in the transition to a low-carbon economy. In 2019, the share of nuclear energy in the structure of electricity produced by type of energy in the country is 37%. The Strategy says that the state will continue to support the development of nuclear energy in the country by providing institutional assistance for the implementation of an investment project for the construction of two new nuclear units, each with a capacity of 1,000 MW, which will be phased in after 2030.
- **Renewable sources:** Another local energy resource available to the country is energy from renewable sources (water, wind, solar, geothermal and biomass energy). The share of energy from renewable sources in primary energy production in 2018 is 21.52% (according to National Statistical Institute (NSI) data).

In 2012, Bulgaria achieved the mandatory national target of 16% share of renewable energy in the gross final energy consumption in the country for 2020. In 2018, the gross final consumption of energy from renewable sources is 20.8% (Ministry of Energy, 2021).

The Republic of Bulgaria has committed to continue the policy pursued to increase the use of renewable energy in the sectors: electricity, heat and cooling, and transport. The country has untapped potential for renewable energy production, which will be used until 2030 and beyond, which will ensure effective implementation of the national target for the share of renewable energy in gross final energy consumption by 2030 in a cost-effective manner.

The national energy efficiency targets and policies show that Bulgaria puts energy efficiency first and plans to reduce primary energy consumption by 27.89% and reduce final energy consumption by 31.67% compared to the PRIMES 2007 reference scenario.

Energy targets in the building sector

To achieve a highly energy efficient and de-carbonized building stock, a Long-term national strategy is being developed to support the renovation of the national building stock of residential and non-residential buildings by 2050. The strategy provides measures for construction of new buildings and transformation of existing ones to zero energy consumption, improving the energy performance of residential and non-residential buildings and promoting the introduction of smart technologies and renewable energy sources in the building sector.

As part of the Long-term strategy for renovation of the national building stock of residential and non-residential buildings by 2050, a roadmap has been developed that sets out the indicators for measuring the results achieved for the following periods: 2021-2030, 2031-2040 and 2041-2050, which reflect the milestones of the process. The Table 1 presents the indicators and energy targets for buildings for the three periods:

Table 1. Indicators and milestones for renovation of residential and non-residential buildings

Indicator	Unit	2021-2030	2031-2040	2041-2050
Total saved energy	GWh	2917	6502	7329
Residential buildings	GWh	2477	5694	6294
Non-residential buildings	GWh	440	808	1035
Renovated area	m^2	22 203 509	49 570 668	55 823 015
Residential buildings	m^2	19 026 656	43 735 175	48 343 297
Non-residential buildings	m^2	3 176 852	5 835 493	7 479 718
Renovated area from existing building stock	%	8	18	20
Saved CO_2 emissions	tons	1 306 435	2 891 610	3 274 453
Residential buildings	tons	1 065 184	2 448 461	2 706 441
Non-residential buildings	tons	241 251	443 149	568 012

(*Source: Integrated Energy and Climate Plan of Republic of Bulgaria 2021-2030*)

It is expected that by 2050, 60% of the housing stock and nearly 17% of the non-housing stock will be renovated. The area of renovated buildings from the entire building stock will be over 45% (Ministry of Energy, 2021).

The analysis in the Long-term National Strategy for Support the Renovation of the National Building Fund until 2050 shows that

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

in order to achieve the quantitative dimensions of the indicators, the renovation policies must be focused primarily on buildings with energy classes E, F and G for all categories of buildings. For this purpose, the period of validity of the NECP is envisaged to continue the stimulation for the use of energy from renewable sources in buildings. The Energy from Renewable Sources Act sets requirements for the use of energy from renewable sources in the construction of new or reconstruction, major renovation, overhaul or reconstruction of existing buildings, when this is technically possible and economically feasible. It is envisaged that at least 15% of the total amount of heat and cooling energy needed for the building to be produced by renewable energy sources by introducing: district heating using biomass or geothermal energy; individual biomass combustion facilities with conversion efficiency of at least 85% for residential and commercial buildings and 70% for industrial buildings; solar thermal installations; heat pumps and surface geothermal systems (Ministry of Energy, Ministry of Environment and Water, 2020).

Energy targets in the industry sector

In 2018 Industry sector has a share of 28.0% and it is the second most important sector in the structure of final energy consumption by sectors in Bulgaria (Ministry of Energy, Ministry of Environment and Water, 2020). Bulgaria continues to be the most energy-intensive economy and the economy with the highest greenhouse gas emissions in the EU, far ahead of the rest countries. The high energy intensity of the economy and the slow progress towards the energy efficiency targets have a negative impact on productivity and competitiveness. There are opportunities for significant energy savings through targeted investment in the industrial sector, as well as for increasing investment in clean energy infrastructure (Council of Ministers of the Republic of Bulgaria, 2020). Investment needs in the field of energy and climate remain significant - Bulgaria is still the most energy-intensive economy in the EU, and inefficient use of energy hinders the competitiveness of Bulgarian SMEs. Bulgaria is lagging behind in its progress towards its indicative national energy efficiency target for 2020. In 2018, Bulgaria is outside the target by approximately 8% in terms of primary energy consumption and 11% in terms of final energy consumption, both gaps increasing compared to 2016 levels. Only 33.4% of SMEs have an energy efficiency policy (Analysis of the state of SMEs, conducted for the purposes of the National Strategy for SMEs 2021-2027). Bulgaria remains the economy with the highest greenhouse gas emissions in the EU. In 2016, the intensity of greenhouse gases in the Bulgarian economy was 4.3 times higher than the EU average (EC 2017). Only 6.5% of Bulgarian enterprises use green energy in their production processes (Analysis of the state of SMEs, conducted for the purposes of the National strategy for SMEs 2021-2027). There is a significant need to continue supporting SMEs in order to achieve better energy and resource efficiency (Ministry of Economy, 2021).

The measures set in the NECP for the industrial sector are aimed at:

- Higher energy efficiency in the industry sector and reduction of heat losses;
- Increasing the use of natural gas in industry through new gas infrastructure
- Use of alternative fuels;
- Creation of a technology parks - introduction of incentives to encourage the private sector to invest in research and development and innovation of widely used production methods aimed at optimal resource efficiency;
- Encouraging the exchange of good practices between enterprises regarding the efficient use of raw materials in production;
- Monitoring systems for energy use in industry
- Energy efficiency audits and implementation of recommended measures (Ministry of Energy, Ministry of Environment and Water, 2020).

Under the Competitiveness and Innovation in Enterprises Program, targeted measures for improving energy efficiency in enterprises are envisaged, incl. мeasures for the introduction of energy management systems and systems for monitoring and control of energy consumption, the Program for Economic Transformation in the Recovery and Sustainability Plan, Decarbonization direction, will provide additional support to promote the use of energy from renewable sources for own consumption, as well as its subsequent storage. Insofar as in the field of energy efficiency improvement and the use of renewable sources there are significant investment needs in different economic sectors, the implementation of each of these types of interventions in their entirety will allow to use the full range of available measures. an enterprise will be able to decide which measures to apply and in what combination.

The target value for realized energy savings by 2029 from the above mentioned measures in enterprises is 377 716 MWh/year (summarized for both categories of regions, according to the Competitiveness and Innovation in Enterprises Program). From the Strategy for Sustainable Energy Development until 2050 it can be seen that the forecasted final energy consumption in the Industry sector for the period 2020-2030 in two scenarios (base and targeted) envisages an increase, which is a result of the expected economic growth. As regards the Industry sector, the forecast for the final energy consumption in the Target Scenario is lower than in the Baseline Scenario, by 0.677% in 2030 and 0.95% in 2050, respectively (Table 2).

Table 2. Forecast for the final energy consumption in the Industry sector for the period 2030-2050

Year	Baseline scenario	Target scenario	Difference between baseline and target scenario
	without additional measures /	With additional measures	
	GWh	GWh	%
2020	33039	33030	0.027
2025	34094	33904	0.557
2030	34696	34461	0.677
2035	34414	34103	0.904
2040	34497	34191	0.887
2045	34416	34103	0.909
2050	34539	34210	0.953

(*Source: Sustainable Energy Development until 2050 (B)EST model, E3-Modelling*)

Energy targets in the Transport sector

Transport generates effects with a negative impact on the environment and people through emissions of harmful substances and greenhouse gases. Their limitation is an element of the sustainable development of the transport system. The main indicators for assessing the negative impact of transport on the environment and human health are energy consumption, emissions of harmful substances (ozone precursors, acidifying substances and PM10 precursors) and greenhouse gas emissions. The general trend for the transport sector in Bulgaria is towards an increase in final energy consumption. The main consumer of fuels and energy in transport is road transport, as its share in 2018 reached 94.3% of total consumption of the sector.

In 2018, compared to 2017, energy consumption in the transport sector increased by 1.4%, which is entirely due to the growth of road transport consumption by 2.9% (Ministry of Transport and Communications, 2017). Integrated Transport Strategy in the period up to 2030 - The strategy outlines the main directions for the development of the national transport system in the period up to 2030.

The document defines 3 strategic objectives, which cover nine strategic priorities, each of which contains a framework of specific objectives (tasks). On this basis, measures have been identified that are most appropriate for achieving the respective objectives.

The strategic goals of the transport policy until 2030 are:

- Increasing the efficiency and competitiveness of the transport sector;
- Improving transport connectivity and accessibility (internal and external);
- Limiting the negative effects of the development of the transport sector.

NECP sets a projected 14.2% share of energy from renewable sources in the transport sector until 2030, the achievement of which will encourage the entry of hydrogen and renewable electricity (Ministry of Energy, 2021).The energy used from renewable sources in transport in 2018 is 218.6 ktoe. The achieved share of energy from renewable sources in final energy consumption in the transport sector is 8.06%. Compared to 2017, the consumption of energy from renewable sources increased by 15.7%, and compared to 2011 it increased more than 12 times. In 2018, conventional biofuels (131.7 ktoe), new generation biofuels (11.25 ktoe) and electricity from renewable sources (8.23 ktoe) were used in the transport sector (Ministry of Energy,2020).Achieving a 14.20% share of renewable energy in the transport sector will encourage the entry of new generation biofuels, renewable liquid and gaseous transport fuels of non-biological origin, recycled carbon fuels and renewable electricity supplied to the road and rail transport sector. Emphasis will also be placed on the possibilities for stimulating the absorption and use of new energy sources and technologies for their utilization. Consumption of these fuels and energy should contribute to achieving the policy objectives of energy diversification and decarbonisation of the transport sector. For the use of electricity from renewable sources in transport, efforts will be focused on developing electric mobility, developing and stimulating the use of public electric transport, as well as accelerating the integration of modern technologies in the railway sector (Ministry of Energy, 2021).

From the Strategy for Sustainable Energy Development until 2050 it can be seen that the forecasted final energy consumption in the Transport sector for the period 2020-2050 in twoscenarios (base and targeted) envisages an increase,which is a result of the expected economic growth. The projected final energy consumption for the period 2020-2050 in both scenarios envisages an increase, which is a result of the expected economic growth is presented in Table 3.

Table 3. Forecast for the final energy consumption in the Transport sector for the period 2030-2050

Year	Baseline scenario without additional measures /	Target scenario With additional measures	Difference between baseline and target scenario
	GWh	GWh	%
2020	42168	42162	0.014
2025	43643	43594	0.112
2030	43590	43447	0.328
2035	42031	42001	0.071
2040	40689	40619	0.172
2045	39969	39902	0.168
2050	40129	40258	-0.321

(*Source: Sustainable Energy Development until 2050 (B)EST model, E3-Modelling*)

A slight increase is observed in 2050 under the Target Scenario in the transport sector, where consumption increases by 0.3% compared to the Baseline Scenario.

Energy targets in the Agriculture sector

The measures in the Third National Action Plan for Climate Change 2013-2020 are aimed at reducing emissions from the main sources in the Agriculture sector. The measures are in line with the state of the sector and the main priorities of the Common agricultural policy (CAP) for the period 2014-2020. One of the main challenge CAP is facing, is to find a solution to the deteriorating production conditions in agriculture due to climate change and the need for farmers to reduce their share of greenhouse gases, to play an active role in mitigating climate change and in providing energy from renewable sources. Based on the analysis of the main sources of emissions in agriculture, the following two main objectives are identified: (1) Reduction and / or optimization of emissions from the agricultural sector; (2) Raising awareness and knowledge of both farmers and the administration regarding actions and their impact on climate change.

The measures related to agriculture sector, provided in the Third National Action Plan on Climate Change, which are scheduled to last until 2030 and the National Program for Air Pollution Control 2020-2030, include:

- Stimulating the use of appropriate crop rotations, especially with nitrogen-fixing crops;
- Management of degraded agricultural lands through: biological reclamation with grassland species typical of the region and application of erosion control measures and tillage methods;
- Introduction of technologies for irrigation and saving of water and energy, promotion of extensive agriculture;
- Measures to reduce methane emissions from biological fermentation in animal husbandry;
- Improving the management and use of manure;
- Introduction of low-carbon manure treatment practices, e.g. composting, conversion of manure into biogas under anaerobic conditions;
- Improving farmers' awareness and knowledge of the possible use of crop residues and the threats posed by stubble burning;
- Implementation of the Code of Good Agricultural Practice for the control of ammonia emissions from agricultural sources.

As regards the greenhouse gas emissions in the agricultural sector, a significant increase in expected GHG emissions in the agricultural sector by about 20% will be a result of the expected growth of the sector according to the forecast provided by the Ministry of Agriculture, Food and Forestry.

NECP does not provide further clarification on how the goal of increasing negatives is achieved emissions from sequestration by 2050 in the sector "Rural, forest and other land use" (AFOLU), and also how land use patterns are changing by 2050. The government cites six measures in NECP that could potentially contribute to negative emissions in the sector, namely 1) the use of "unfrosted areas intended for afforestation" in forest areas; 2) afforestation of abandoned agricultural lands, bare and deforested areas, eroded and endangered areas outside forest areas; 3) increasing the area for urban and suburban parks and green areas; 4) restoration and sustainable management of wetlands, protection and conservation of wetlands in forest areas, peat lands and swamps; 5) restoration and maintenance of protective forest belts and new anti-erosion afforestation; and 6) increasing the density of the listed natural and artificial plantations.

However, no further details are provided on the scope of these measures, as well as the deadlines for their implementation, in order to quantify their impact on negative emissions. Still, specific financing measures under the Sustainable Agriculture component are set out in the National Recovery and Development Plan (Council of Ministers of the Republic of Bulgaria, 2020). The component aims to increase the sustainable governance and competitiveness of the agricultural sector through measures to improve the economic sustainability of agricultural holdings and the industry as a whole in the context of climate change and the preservation of environmental characteristics (CSD, 2021).

CONCLUSIONS

Bulgaria has defined a state's vision for the development of the energy sector by 2030, with a horizon of 2050, in line with the current European framework of energy policy and global trends in the development of new energy technologies. The main goals of the country to stimulate low-carbon economic, development of competitive and secure energy and reduce dependence on imports of fuels and energy are prescribed in the National Energy and Climate Plan and other strategic documents. Specific goals have been set for the different economic sectors. Based on different scenarios and analysis, some indicators and milestones have been projected until 2050 for the presented sectors. For the building sector indicators have been set for total saved energy, renovated area and saved CO_2 emissions for three periods: 2021-2030; 2031-2040 and 2041-2050. As regards the Industry and Transport sectors, a forecast for the final energy consumption, based on two scenarios: with and without measures, has been presented for seven 5-years periods. The measures and financial expectations are described in the NECP and the National Recovery and Resilience Plan of the Republic of Bulgaria. There are no presented numbers for expected final energy consumption until 2050 in the Agriculture sector, although specific measures are set and planned in the National Recovery and Resilience Plan of the Republic of Bulgaria.

There are still no in-depth analyzes of the expected impact in terms of energy, environmental, social and financial aspects from the implementation of the specific actions and measures planned in the presented sectors. There is a need of energy modeling and evaluation of specific scenarios for energy transition at national and local level.

REFERENCES

Council of Ministers of the Republic of Bulgaria (2020). National Recovery and Resilience Plan of the Republic of Bulgaria, available at: https://www.nextgeneration.bg/14. Accessed on 2021-11-08

CSD (2021). Green recovery pathways to Bulgaria's carbon neutrality by 2050. Sofia, Available at:https://csd.bg/publications/publication/green-recovery-pathways-to-bulgarias-carbon-neutrality-by-2050/, Accessed on 2021-11-08

European Commission (2011). Energy Roadmap 2050, Luxembourg: Publications Office of the European Union

European Union (2021). European green deal. Achieving our goals, ISBN 978-92-76-39492-1 doi:10.2775/729348

European Commission (2019). The European Green Deal, COM(2019) 640 final, 11 December. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/

Georgieva, M.G., Tashev, A.I. & Atanasov, D G. (2018). Energy Efficiency of Impulse Drying Regimes of Beetroot. *Bulgarian Chemical Communications, Volume 50, (Special Issue G),ISSN 0324-1130, 230-235*

Georgieva, M., Raynov, P., Atanasov, D. &Tashev, I. (2019). Analytical and Numerical Investigation of

Heat Exchange in Fin-tube Refrigerating Hear Exchanger. *IOP Conference Series: Materials Science and Engineering Journal, 595 (1). ISSN 1757-899X*

Hainsch K., Löffler K., Burandt T., Auer H., Crespo del Granado P., Pisciella P.&Zwickl-Bernhard S. (2022). Energy transition scenarios: What policies, societal attitudes, and technology developments will realize the EU Green Deal? *Energy*, Vol. 239, Part C, 15 January 2022, 122067, https://doi.org/10.1016/j.energy.2021.122067

https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en

https://www.seea.government.bg/documents/Otchet_NPDEE_2019_22.07.2020.pdf, Accessed on 2021-11-08

Iliev, I.K., Terziev, A.K., Beloev H.I., Nikolaev, I. & Georgiev, A.G. (2021). Comparative analysis of the energy efficiency of different types co-generators at large scales CHPs. *Energy 221C*, DOI: 10.1016/j.energy.2021.119755

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

IRENA (2020), Scenarios for the Energy Transition: Global experiences and best practices, International Renewable Energy Agency, Abu Dhabi. ISBN: 978-92-9260-267-3 www.irena.org/publications

Kolev, Z.D., Kadirova, S.Y., & Nenov, T.R. (2017). *Research of reversible heat pump installation for greenhouse heating. INMATEH - Agricultural Engineering, 2017, No 2, pp. 77-84*,http://www.scimagojr.com/journalsearch.php?q=21100204508&tip=sid&clean=0).

Komitov, N., Shopov,N., & Rasheva, V. (2020). Model of a building heating system with renewable energy sources. *E3S Web of Conferences*, Volume 207, 02006, https://doi.org/10.1051/e3sconf/202020702006

Ministry of Energy, Ministry of Environment and Water (2020). National Energy and Climate Plan of Republic of Bulgaria 2021 – 2030, Sofia, Council of Ministers of the Republic of Bulgaria, Available at: https://www.me.government.bg/files/useruploads/files/national_energy_and_climate_plan_bulgaria_clear_22.02.20.pdf . Accessed on 2021-11-08

Ministry of Energy (2021). Strategy for Sustainable energy development of the Republic of Bulgaria until 2030 with horizon to 2050, Sofia, Available at: https://www.strategy.bg/PublicConsultations/View.aspx?lang=bg-BG&Id=5872, Accessed on 2021-11-08

Ministry of Energy, Ministry of Regional Development and Public Works, Agency for Sustainable Energy Development, Fund Manager of Financial Instruments in Bulgaria, with the support of the European Bank for Reconstruction and Development (2021). Long-Term National Strategy to Support the Renovation of The National Building Fund of Residential And Non-Residential Buildings Until 2050, Sofia, Available at: https://www.me.government.bg/themes/dalgosrochna-strategiya-za-obnovyavane-na-nacionalniya-sgraden-fond-ot-jilishtni-i-nejilishtni-sgradi-do-2050-g-2271-1545.html, Accessed on 2021-11-08

Ministry of Economy (2021). Annex V Competitiveness and Innovation In Enterprises – Version 4, Sofia, Available at: https://opic.bg/uploads/2022/02/nov-programen-period-2021-2027-g-27.pdf, Accessed on 2021-11-08

Ministry of Transport and Communications (2017). Integrated Transport Strategy for the period until 2030, Sofia, Available at: https://www.mtc.government.bg/en/category/42/integrated-transport-strategy-period-until-2030 , Accessed on 2021-11-08

Ministry of Energy (2020). Annual Report on the Implementation in 2019 of the National Energy Efficiency Action Plan 2014-2020, Sofia, Available at:https://www.seea.government.bg/documents/Otchet_NPDEE_2019_22.07.2020.pdf

Penkova, N., & Mladenov, B., (2020). Investigation of the possibilities for energy economy in continuous dryers through reduction of the drying time. *E3S Web of Conferences 207, 01011*, https://doi.org/10.1051/e3sconf/202020701011

Rasheva, V., Komitov, G., Binev, I., & Valtchev, G. (2020). Structural and Technological Features of an Installation for Recovery of End-of-life Automobile Tires. *E3S Web of Conferences 180, 01016,*https://doi.org/10.1051/e3sconf/202018001016

Valchev, S.E. & Mihaylov, I.M. (2020). Analysis of energy efficiency of air handling unit with integrated air to air heat exchanger in heating mode. E3S Web of Conferences, https://doi.org/10.1051/e3sconf/202020701002

Zlateva, P., Penkova, N., & Krumov, K. (2020). Analysis of combustion efficiency at boilers operating on different fuels. DOI: 10.1109/EEAE49144.2020.9278784

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

EVALUATION OF POTENTIALLY TOXIC ELEMENTS IN BLACK SEA FISHERY RESOURCES: A REVIEW

Diana-Nicoleta MINZALA, Ira-Adeline SIMIONOV, Ștefan-Mihai PETREA, Alina ANTACHE, Victor CRISTEA, Anca-Nicoleta SAVESCU

"Dunarea de Jos" University of Galati, 47 Domneasca Street, Galati, Romania

Corresponding author email: diana.minzala@ugal.ro

Abstract

Environmental pollution is a worldwide problem and heavy metals (HM) constitute one of the most important challenges. Due to industrialization and urbanization, Black Sea is considered as one of the most polluted seas in the world. The aim of the current study is to provide a state-of-the-art review related to the evaluation of potentially toxic elements in fishery resources from Black Sea. As a result, various data sources were revised and the appropriate information was centralized in order to acquire a clear sight on concentrations dynamics and accumulation tendency of the most hazardous HM and metalloids, as it follows: Ni, Cd, Zn, Hg, Fe, As, Cr and Pb. Accordingly, the aforementioned multitude of chemical pollutants bio-accumulates in fishery resources and are being a particular concern in relation to their harmful effects on human health.

***Key words**: heavy metals, fishery resources, Black Sea.*

INTRODUCTION

Marine environment is constantly under increasing pressure, due to a large category of human activities, as waste water discharges and sea-based activities (shipping, mariculture, seabed mining, dredging of sediment and dumping at sea) (Tornero and Hanke, 2016).
The Black Sea is overload by excessive amounts of nutrients and hazardous substances from the anthropogenic activities and the major rivers that flow into it (Danube, Dniper and Dniesta) (Krutov, 2019).
Its waters have been widely perceived as being heavily contaminated, although thus far there are little reliable data about the number of contaminants that are being discharged in the Black Sea, or about their concentrations in water, sediment or biota.
Pollutants like fertilizers, pesticides, pharmaceutical chemicals, microplastics, heavy metals, and petroleum hydrocarbons are harmful for the environment (Auta et al., 2016).
Generally, a density of at least 5 g cm^{-3}, an atomic mass higher than 23 either an atomic number exceeding 20, are used to define a heavy metal (Koller et al., 2018). Also, heavy metals are considered if their density is five times higher comparing to water density (Simionov et al., 2019).

Literature classifies heavy metals in two categories: essential heavy metals (Cu, Mg, Zn, Fe, Se, Co) which are biodegradable and decay quickly into harmless or less harmful forms (Bat et al., 2019) and non-essential heavy metals (Cd, Pb, Al, Sb, Sn, As, Bi) that are described as potentially toxic trace elements (Simionov et al., 2019) which are non-biodegradable and remain for a long time in biota (Bat et al., 2019).
Heavy metals are regularly listed as one of the most toxic element from marine environment, due to their persistence in the ecosystem, their toxicity and bioaccumulative nature (Khan et al., 2018).
The European Union consider any chemical which have a wet mass bioconcentration factor (BCFw) >100, as potentially accumulator in consumers moreover is considered as being destructive for aquatic biota and food chain (Jitar et al., 2015). Marine organisms like bivalves and fish, accumulate heavy metals most often higher concentrations than sediment or water (Karsli, 2021). Even so, the heavy metals accumulation in biota is influenced by the bioavailability of the metal in the water, the type of the metal, size, sex or reproductive cycle, and also the environmental hydrodynamics (Simionov et al., 2019). Thus, heavy metals brought about through the food

chain as a consequence of pollution are potential chemical hazards and threaten consumers (Karsli, 2021).
The Black Sea fishery resources, that is shared by Romania, Georgia, Bulgaria, Russia Federation, Turkey and Ukraine, are an integral part of those societies, and make important contribution to social health and economic (Kevern and Serge, 2009).
This study provides kinds information that are available in literature and contributes to a better comparison of the potentially toxic elements from the Black Sea fishery resources.
Therefore, keeping in view of the potentially toxic elements, as well as metal concentrations in fishery resources from the Black Sea it is considered necessary to acquire a baseline environmental data, to ensure consumer protection and consequent compliance with food safety regulations.

MATERIALS AND METHODS

This study systematically reviews a multitude of studies on potentially toxic elements in the Black Sea fishery resources. Eight heavy metals including Pb, As, Cd, Cr and Hg were comprehended in this study, all of which are priority pollutants, designated by The Food and Agricultural Organisation (FAO) of the United Nations. A total of 89 indexed publications were gathered, but it was required to narrow the searching area, in order to achieve an appropriate number of articles for review. From the main literature databases in addition to Science Direct, Research Gate, Web of Science, Google Scholar, PubMed and international standards from FAO, this review gather only papers that presented results about heavy metal concentrations from fishery resources. Using a mixture of searching methods (electronic and manual), this review collected data about heavy metal concentration of 73 samplings sites from the Black Sea. Each of these findings just studied a single species or a few species, across different points from the Black Sea. The data used in the centralised table (Table 1) includes concentration values retrieved form the scientific literature published in the timeline 2010 to 2022 (older scientific paper were considered to be obsolete). Therefore, the aim of the present study was to assess the potentially toxic elements in the Black Sea fishery and associated risks of heavy metals, identified in recent past. The metal concentrations of fishery resources from the Black Sea have been widely reported in the recent literature. This review provides a national scale assessment through bringing together all the data of these literatures.

RESULTS AND DISCUSSIONS

With the increased use of the Black Sea fishery resources, is essential to frequently update the inventory of the types and also the quantities of potentially toxic elements released in the sea. Along these lines, is essential to find out the relative influence of all human activities and how they interact to the impact of marine ecosystems.
This review, present in an easy way, an appraisal of a few heavy metals like: Ni, Cd, Zn, Hg, Fe, As, Cr and Pb, their concentrations from: *Engraulis encrasicolus*, *Merlangius merlangus*, *Trachurus trachurus*, *Sarda sarda*, *Mullus barbatus*, *Mugil cephalus*, *Psetta maxima*, *Pomatomus saltatrix*, *Sprattus sprattus*, *Mytillus galoprovincialis* and *Rapana venosa* as well as possible effects on humans after consuming of them.
The statistics of the concentrations of heavy metals detected in the Black Sea fishery resources of this review are given in Table 1.
Methods to measure and assess the effects of heavy metals concentrations in aquatic ecosystems are very complex by factors that are both: external and internal to the organism, along with the interrelatedness of the toxic elements themselves (Burger, 2007).
Individual organisms and species are affected differently depending on their breeding cycle, foraging methods, and geographical ranges.
The Black Sea is a semi-closed sea, and is having shared stocks, moreover all the countries that share the Black Sea, are required to manage fishery resources with common measures.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Table 1. Data regarding heavy metals concentrations in different fish species according to different authors

Fishery resources	Reference	Heavy Metals								Area
		Ni	Cd	Zn	Hg	Fe	As	Cr	Pb	
Engraulis encrasicolus	Nisbet et al (2010)	**3.12***	**0.035***	**26.25***	-	**26.06***	-	-	**0.7***	Turkish coast of the Middle Black Sea
	Aygun and Abanoz (2011)	-	**0.2***	**175.15***	-	**34***	-	-	**0.4***	Samsun coasts in Middle Black Sea
	Görür et al. (2012)	**0.01***	-	**15.05***	-	**13.41***	**2.08***	**0.1***	**0.02***	Middle Black Sea (Turkey)
	Alkan et al. (2013)	**0.48***	**0.3***	**8.22***	-	-	**1.85***	**0.73***	**0.03***	Southeastern area of the Black Sea
	Bat et al (2014)	-	-	**9.05****	-	-	**0.61****	-	-	Sinop (Turkey)
	Bat et al (2014)	-	-	**11.3****	-	-	**0.66****	-	-	Samsun (Turkey)
	Bat et al (2014)	-	-	**12.2****	-	-	**0.54****	-	-	Fatsa (Turkey)
	Bat et al (2014)	-	-	**12.35****	-	-	**0.605****	-	-	Batumi (Georgia)
	Gundogdu et al. (2016)	**0.69***	**0.47***	**38.39***	-	**20.59***	-	-	**0.905***	Coast of Sinop in the Middle Black Sea (Turkey)
	Alkan et al. (2016)	**0.48***	**0.3***	-	-	-	**1.85***	-	-	Southeastern area of the Black Sea.
	Plavan et al. (2017)	**0.234****	**0.0435****	-	-	-	-	**0.017****	-	Romanian territorial area of the Black Sea
	Baltas et al. (2017)	**4.16***	**0.003***	**2.32***	-	**227.2***	-	-	**0.02***	Rize Harbor (Turkey)
	Karsli (2021)	**0.0055****	**0.0135****	**20.55****	**0.02****	**9.605****	**1.285****	**0.03****	**0.02****	Black Sea coasts of Turkey, Georgia, and Abkhazia
Merlangius merlangus	Nisbet et al. (2010)	-	**0.002***	**31.34***	-	**11.59***	-	-	**0.58***	Turkish coast of the Middle Black Sea
	Mendil et al. (2010)	-	**0.18***	**20.6***	-	**27.7***	-	**0.82***	**0.46***	Turkish coast
	Aygun and Abanoz (2011)	-	**0.2***	**58***	-	**9.9***	-	-	**0.9***	Samsun coasts in Middle Black Sea
	Görür et al. (2012)	**0.03***	-	**0.51***	-	**16.06***	**1.32***	**0.16***	**0.01***	Middle Black Sea (Turkey)
	Bat et al. (2015)	-	**0.02****	**3.4****	**0.05****	**0.87****	**1.24****	-	**0.05****	Sinop Coastal Waters (Turkey)
	Alkan et al. (2016)	**0.61***	**0.031***	**21.5***	-	-	**6.34***	**0.62***	**0.024***	Samsun coasts in Middle Black Sea (Turkey)

Fishery resources	Reference	Heavy Metals								Area
		Ni	Cd	Zn	Hg	Fe	As	Cr	Pb	
Trachurus trachurus	Nisbet et al (2010)	-	**0.012***	**27.7***	-	**21.17***	-	-	**0.6***	Turkish coast of the Middle Black Sea
	Mendil et al. (2010)	-	**0.22***	**25.7***	-	**36.4***	-	**0.95***	**0.64***	Turkish coast
	Alkan et al. (2013)	**0.53***	**0.27***	**18.12***	-	-	**2.58***	**0.74***	**0.03***	Southeastern area of the Black Sea.
	Makedonski et. al. (2015)	**0.008****	**0.008****	**0.6****	**0.16****	-	**0.73****	-	**0.06****	Coastal waters of Bulgarian Black Sea
	Gundogdu et al. (2016)	**0.49***	**0.07***	**23.685***	-	**25.47***	-	-	**0.55***	Sinop in the Middle Black Sea (Turkey)
	Plavan et al. (2017)	**0.32****	**0.0163****	-	-	-	-	**0.013****	**0.102****	Romanian territorial area of the Black Sea
Sarda sarda	Nisbet et al. (2010)	**3.04***	**0.025***	**19.55***	-	**25.96***	-	-	**0.9***	Turkish coast of the Middle Black Sea
	Mendil et al. (2010)	-	**0.35***	**21***	-	**25.5***	-	**0.64***	**0.28***	Turkish coast
	Bat et al. (2012)	-	**0.025****	**15.155****	-	-	-	-	**0.16****	Sinop Coastal Waters (Turkey)
	Makedonski et al. (2015)	**0.11****	**0.015****	**0.13****	**0.13****	-	**0.41****	-	**0.06****	Coastal waters of Bulgarian Black Sea
Mullus barbatus	Nisbet et al. (2010)	**2.47***	**0.02***	**23.71***	-	**29.17***	-	-	**0.92***	Turkish coast of the Middle Black Sea
	Mendil et al. (2010)	-	**0.23***	**17.8***	-	**41.4***	-	**0.99***	**0.4***	Turkish coast
	Jitar et al. (2014)	**0.27***	**0.02***	-	-	-	-	**0.02***	**0.32***	Romanian coastline of Black Sea
	Bat et al. (2015)	-	**0.02****	**3.2****	**0.05****	**2.3****	**1.3****	-	**0.05****	Sinop Coastal Waters (Turkey)
	Alkan et al. (2016)	**0.46***	**0.018***	**19.7***	-	-	**14.75***	**0.56***	**0.02***	Samsun coasts in Black Sea (Turkey)
	Gundogdu et al. (2016)	**0.47***	**0.11***	**15.085***	-	**16.84***	-	-	**0.28***	Sinop in the Middle Black Sea (Turkey)
Mugil cephalus	Bat et al. (2012)	-	**0.025****	**36.765****	-	-	-	-	**0.14****	Sinop Coastal Waters (Turkey)
	Stancheva et al. (2013)	-	**0.024****	-	**0.08****	-	**0.9****	-	**0.07****	Bulgarian Black Sea coast
	Engin et al. (2015)	**0.044***	-	**13.545***	-	**1.157***	**2.011***	**4.806***	-	Bulancak (Turkey)
	Engin et al. (2015)	**0.063***	-	**13.07***	-	**2.692***	**2.42***	**9.073***	-	Giresun port (Turkey)
	Engin et al. (2015)	**0.699***	-	**6.726***	-	**1.067***	**0.928***	**0.165***	-	Waste area of Giresun (Turkey)
	Engin et al. (2015)	**0.042***	-	**10.609***	-	**0.752***	**1.573***	**3.966***	-	Unye (Turkey)
	Engin et al. (2015)	**0.47***	-	**4.279***	-	**1.007***	**0.855***	**0.147***	**0.03**	Samsun port (Turkey)
	Makedonski et al. (2015)	**0.009****	**0.012****	**5.2****	**0.05****	-	**1.1****	-	**0.05****	Coastal waters of Bulgarian Black Sea

Fishery resources	Reference	Heavy Metals								Area
		Ni	Cd	Zn	Hg	Fe	As	Cr	Pb	
Psetta maxima	Nisbet et al. (2010)	**3.22***	**0.022***	**24.83***	-	**21.72***	-	-	-	Turkish coast of the Middle Black Sea
	Simionov et al. (2019)²	**0.105***	**0.3***	**12.18***	-	**9.13***	**3.81***	-	-	Romanian coastline of the Black Sea
Pomatomus saltatrix	Nisbet et al. (2010)	**1.91***	**0.025***	**25.51***	-	**23.81***	-	-	-	Turkish coast of the Middle Black Sea
	Makedonski et al. (2015)	**0.009****	**0.008****	**10****	**0.09****	-	**0.77****	-	-	Coastal waters of Bulgarian Black Sea
Sprattus sprattus	Bat et al (2012)	-	**0.07****	**41.845****	-	-	-	-	**0.26****	Sinop Coastal Waters (Turkey)
	Alkan et al. (2013)	**0.3***	**0.25***	**0.87***	-	-	**2.58***	-	**0.01***	Southeastern area of the Black Sea
	Jitar et al. (2014)	**0.25***	**0.06***	-	-	-	-	**0.05***	**0.07***	Romanian coastline of Black Sea
	Makedonski et al. (2015)	**0.028****	**0.005****	**0.05****	**0.12****	-	**0.73****	-	**0.08****	Coastal waters of Bulgarian Black Sea
	Plavan et al. (2017)	**0.158****	**0.018****	-	-	-	-	**0.019****	-	Romanian territorial area of the Black Sea
Mytillus galoprovincialis	Jitar et al. (2014)	**1.05***	**0.22***	-	-	-	-	**0.89***	**1.36***	Romanian coastline of Black Sea
	Rosioru et al. (2016)	**8.62***	**1.95***	-	-	-	-	**4.56***	**0.11***	Romanian coastline of Black Sea
	Tepe and Süer (2015)	**12.7***	-	**69.06***	-	**161.1***	**3.16***	**0.56***	**31.6***	Giresun coasts of the Black Sea (Turkey)
	Strungaru et al. (2017)	**0.53****	**0.193****	-	-	-	-	**1.52****	**0.088****	Romanian-Ukraine border of the Black Sea
Rapana venosa	Jitar et al. (2014)	**0.52***	**1.1***	-	-	-	-	**0.88***	**1.29***	Romanian coastline of Black Sea
	Mülayim and Balkıs (2015)	-	**0.85***	-	**1.1***	-	-	**0.15***	**0.4***	Thrace Coast of the Black Sea (Turkey)
	Strungaru et al (2017)	**0.156****	-	-	-	-	-	**0.03****	**0.012****	Romanian-Ukraine border of the Black Sea

- not measured; * based on dry weight; ** based on wet weight.

The Black Sea is a semi-closed sea, and is having shared stocks, moreover all the countries that share the Black Sea, are required to manage fishery resources with common measures. Some targeted species, such as shellfish, may be relatively stable and thus considered fully resident in national waters for management purposes. The major capture fisheries in the Black Sea, on the other hand, migrate within the Black Sea and are shared with other Black Sea stakeholders. In the near future, international agreements and national initiatives may compel countries to develop common fisheries management plans. As a result, every country should be prepared for such actions.

Nickel concentration in various fishery resources from the Black Sea area

Nickel is an important nutrient for organisms, although at high concentrations, it can be toxic. (Rosioru et al., 2011). The toxicity of nickel-containing substances, like that of other metals, is thought to be related to the bioavailability of the metal ion (Ni^{2+}) at systemic or local target sites. (Goodman et al., 2011). Considering there are no bioavailability normalization approaches for Ni in marine systems, all of the data presented here are expressed as dissolved concentrations.

The maximum permissible limit value of Ni, accepted by FDA is 80 µg/g and the WHO (World Health Organization, 1992) recommends 100-300 µg Ni for daily intake for human adults.

The highest concentration of Ni was found in *Mytillus galoprovincialis* (12.7 µg/g in wet weight) in Giresun coasts of the Black Sea (Turkey coastline) and the lowest concentration was registered in *Trachurus trachurus* (0.008 µg/g in wet weight) in coastal waters of Bulgarian Black Sea (Figure1).

Nickel allergic contact dermatitis, respiratory carcinogenicity, reproductive toxicity, and non-cancer respiratory effects are the main human health effects of concern associated with Ni exposure. As a result, the European Union's (EU) nickel restriction (REACH, Annex XVII, Entry 27) is based on nickel release rather than nickel content. (Buxton et al., 2019)

The consequence and effects of nickel in the environment are well known; however, metals rarely occur singly in the aquatic environment, but rather in mixtures with other metals and toxic elements. When heavy metals develop together, they can interact with one another or with other receptors (for example, DOC), potentially affecting the bioavailability and toxicity within each individual component (Buxton et al., 2019).

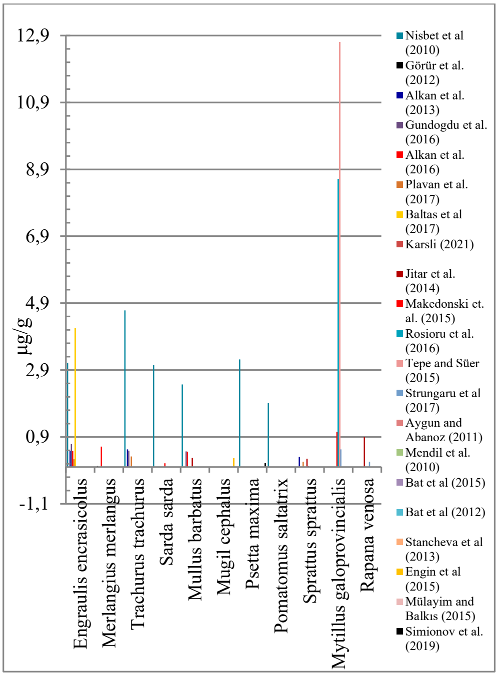


Figure 1. The Ni concentration in different fish species in the Black Sea area according to different authors

Cadmiu concentration in various fishery resources from the Black Sea area

Cadmiu (Cd) is a toxic heavy metal which has had serious health consequences on organisms. It is a natural element in the earth's crust and is usually found as a mineral with several other elements. Cd can be found through all type of soils and rocks, as well as coal and mineral fertilizer, likewise is commonly found in the aquatic environments at low levels and is not an essential element for animals and humans (Bat and Arici, 2018).

The Joint FAO/WHO Expert Committee on Food Additives mentioned a PTWI (Previsional Tolerable Weekly Intake) for Cd, of 0.007 µg/g/body weight/week, and 0.025 µg/g/body weight/month (FAO/WHO, 2010, 2011) The

EU Maximum Residue Limit (MRL) legally concentration permitted in fish is 0.1-0.3 µg /g (Bat and Arici, 2018) additionally, the Turkish Food Codex settled the maximul level at 0.10 µg/g for sea fish (Turkish Food Codex, 2008).

The highest concentration of Cd was registered also (as the concentration of Ni and Pb) in *Mytillus galoprovincialis* (1.95 µg/g dry weight) in Romanian coastline of Black Sea and the lowest concentration was found in *Merlangius merlangus* (0.002 µg/g in dry weight), in Turkish coast of the Middle Black Sea (Figure 2).

According to research, increasing salinity tends to increase Cd absorption by aquatic macrophytes, and increasing salinity leading to the formation of cadmium chloride, which cannot be absorbed by plants. If the salinity concentration rises further, the Cd in the chlorides suspended in the water will be replaced by Na, resulting in an increase in Cd concentration (Simionov et al., 2019).

Chronic exposure to high levels of cadmium can result in liver damage, bone degeneration, blood damage, and renal dysfunction. There are ample confirmations in humans for the cancer-causing nature that results from the presence of both Cd and Cd compound. (Vardhan et al., 2019)

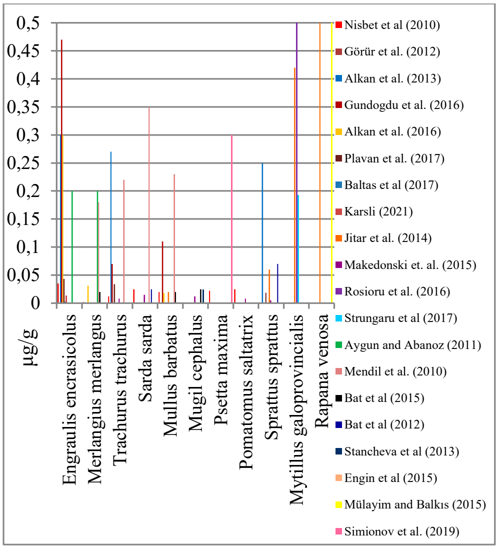


Figure 2. The Cd concentration in different fish species in the Black Sea area according to different authors

Zinc concentration in various fishery resources from the Black Sea area

Zinc (Zn) is a rare element in nature, but it has a long history of use due to its availability in limited deposits and ease of extraction from ores. It is an essential element *and* is available in multitudinal minerals, including ZnS, ZnO, $ZNCO_3$, Zn_2SiO_4 (Vardhan et al., 2019).

The Turkish Food Codex set down the maximum Zn level tolerated of 50 µg/g for fish (Turkish Food Codex, 2008), although the Joint FAO/WHO established the Zn provisional tolerable weekly intake (PTWI) for 7 µg/g body weight (World Health Organization, 2007). The highest concentration of Zn (Figure 3) was registered in *Engraulis encrasicolus* (175.15 µg/g in dry weight), in Samsun area, Turkish Black Sea coast. Meanwhile, *Engraulis encrasicolus* and *Mytillus galoprovincialis* (with a concentration of Zn- 69.06 µg/g in dry weight), were the only reported Zn concentration which exceeds the maximum limit established by Turkish Food Codex (Turkish Food Codex, 2008).

Vomiting, dehydration, drowsiness, abdominal pain, nausea, lack of muscular coordination, and renal failure are all symptoms of acute Zn toxicity in humans. A chronic dose of Zn increase the risk of developing anemia, pancreas damage. Workers who have been exposed to Zn fumes from smelting or welding have developed a short-term illness known as mental fume fever (Sharma et al., 2005).

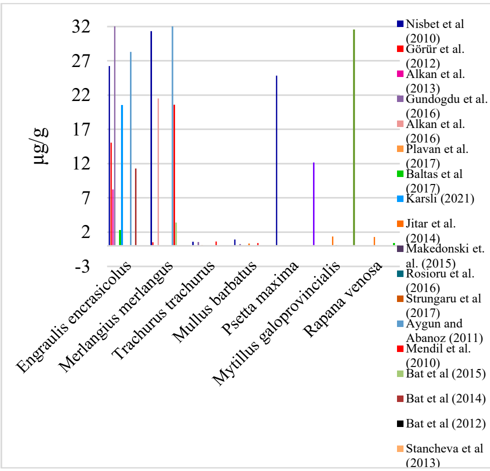


Figure 3. The Zn concentration in different fish species in the Black Sea area according to different authors

Mercury concentration in various fishery resources from the Black Sea area

Mercury is the most toxic non-essential metal for organisms. In the environment, Hg exists in three forms: elemental Hg, organic Hg as well as inorganic Hg (Jaishankar et al., 2014).

Except for *Mullus* species and *Sarda sarda*, which have a maximum permitted level of 1.0 µg/g wet weight, European legislation established a maximum level of admitted Hg concentration in fish muscle tissue of 0.5 µg/g wet weight (EC, 2006). For human adults, WHO established a provisional tolerable weekly intake (PTWI) of 0.0016 µg/g body weight (World Health Organization, 2007).

Hg concentrations were found to be highest in *Rapana venosa* (1.1 µg/g in dry weight), found in Thrace Coast of the Black Sea (Turkey), Figure 4. *Rapana venosa* is a macrobenthic organism, used commonly as biomonitor of heavy metal pollution. (Bat and Öztekin, 2016).

Human exposure to high levels of Hg can cause pulmonary edema, pneumonia, and a variety of other symptoms of lung damage. In human adults, low-level Hg exposure causes depression, tremors, skin rashes, memory loss, and peeling off hands and feet, as well as redness (Sharma and Agrawal, 2005).

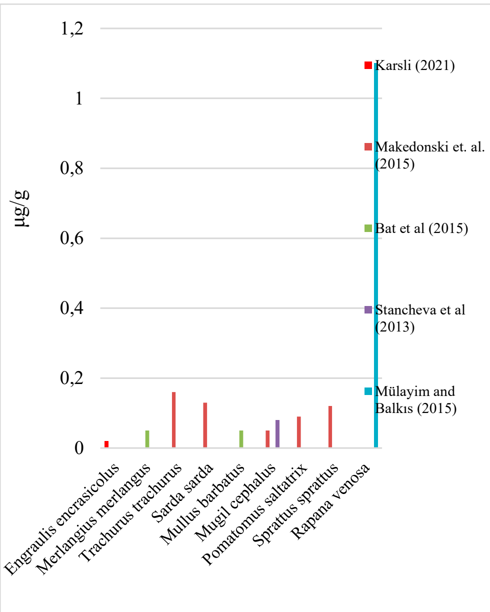


Figure 4. The Hg concentration in different fish species in the Black Sea area according to different authors

As concentration in various fishery resources from the Black Sea area

Arsenic (As) is a common environmental pollutant, and human exposure occurs through contaminated water and soil, as well as through arsenic-rich food (e.g., garlic, marine food). (Florea and Büsselberg, 2006).

Human health concerns about the high levels of arsenic found in some seafood have increased interest in marine ecosystems. For example, Alkan et al., (2016) found the highest concetrations of As from all the papers that were reviewed (14.75 µg/g in dry weight) in *Mullus barbatus*, in Samsun coasts in Middle Black Sea (Turkey). Therefore, the lowest concentration of As was registered in *Sarda sarda* (0.41 µg/g in wet weight), in coastal waters of Bulgarian Black Sea (Figure 5). According to Makedonski et al. (2015), the concentrations of As that he found in his study, was generally low in all the species, compared to data in the literature and world food standards.

Arsenic in its inorganic form is a known carcinogen. Low to moderate amounts of As exposure lead to diabetes, renal and hepatic dysfunction, also neurological problems. Women are more prone to As induced skin diseases than males because their skin is more vulnerable to As and causes dermatitis (Sharma and Agrawal, 2005).

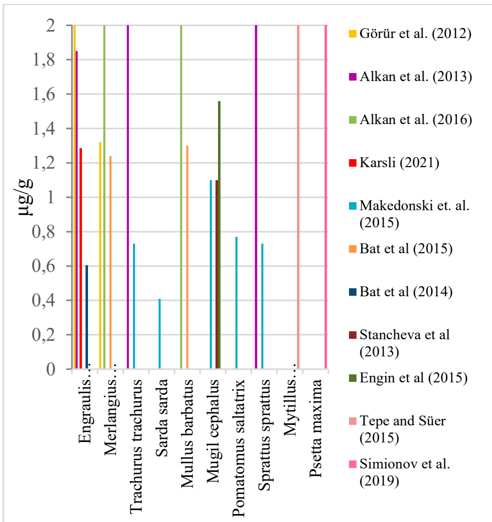


Figure 5. The As concentration in different fish species in the Black Sea area according to different authors

Iron concentration in various fishery resources from the Black Sea area

Iron (Fe) is an essential element, necessary for life, also an important component of many proteins and many enzymes, including many that participate in the generation of high energy metabolites.

In case of Fe (Figure 6), the highest concentration was registered in *Engraulis encrasicolus* (227.2 µg/g in wet weight) in Rize Harbor (Turkey), followed by *Mytillus galoprovincialis* (161.08 µg/g in wet weight) in Giresun (Turkish coast). Though the Joint FAO/WHO established the limit of the maximum permissible amount of Fe at 425.5 µg/g.

According to Simionov (2019), essential metals, such as Fe, accumulate at a higher concentration than non-essential metals, which can be explained by their role in metabolism function. In the case of fish, the existing mechanism for metal uptake from the environment implies the interaction of proteins and amino acids. Consumption of ascorbic acid-containing foods may increase Fe availability (Stancheva et al., 2010).

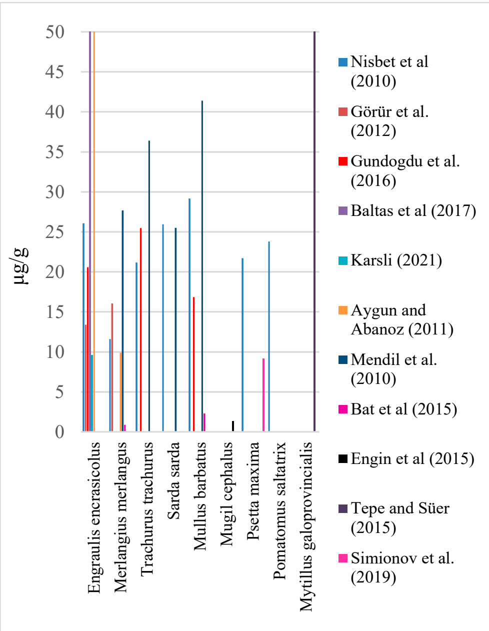


Figure 6. The Fe concentration in different fish species in the Black Sea area according to different authors

Cr concentration in various fishery resources from the Black Sea area

Elemental chromium (0) did not actually exist in nature. Trivalent chromium (III) is a trace metal that is required for the forming of glucose tolerance factor as well as the metabolism of insulin. (Barceloux, 1999) and can have a toxic effect when is present in very large quantities (Baruthio, 1992).

According to the EFSA, (European Food Safety Authority, 2014) the maximum Cr level permitted is established at 0.3 mg/kg. The highest concentration of Cr was registered in *Mugil cephalus* (9.073 µg/g in dry weight) in Giresun port of Turkey (Figure 7). The lowest concentration was recorded in *Mullus barbatus* (0.002 µg/g in dry weight), in Romanian coastline of the Black Sea. Cr participate in lipid metabolism and insulin function (Simionov et al., 2019).

The most significant hazardous effects of hexavalent chromium compounds after contact, inhalation, or ingestion: Dermatitis, allergic and eczematous skin reactions, ulcerations of the skin and mucous membranes, perforation of the nasal septum, allergic asthmatic reactions, bronchial carcinomas, gastro-enteritis (Baruthio, 1992).

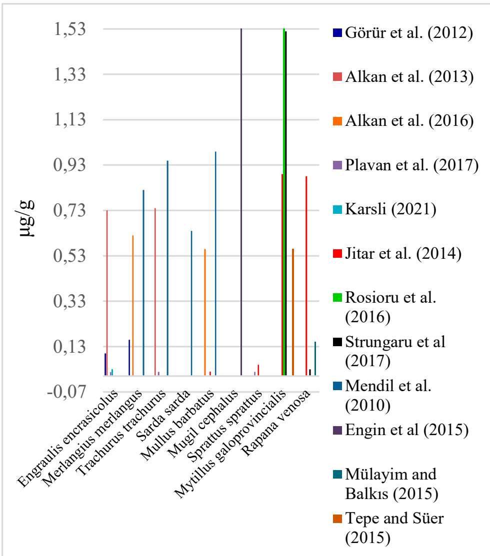


Figure 7. The Cr concentration in different fish species in the Black Sea area according to different authors

Lead concentration in various fishery resources from the Black Sea area

Lead (Pb) is considered as a toxic heavy metal, although it was widely used for more than 5000 years because this metal is corrosion resistant, dense, ductile and malleable. Therefore it was deployed for building materials, pigments to glaze ceramics, ammunition, ceramics glazers, glass and crystals, paints, protective coatings, acid storage batteries, gasoline additives, cosmetics. Due to its wide use, humans are exposed to lead derivatives and have a daily eat intake by food, drinking water and by inhalation (Florea and Büsselberg, 2006).

The European legislation (EC, 2006) dispose the maximum level of Pb permitted in the muscle tissue of fish of 0.30 mg/kg wet weight, also, the Joint FAO/WHO suggest a provisional tolerable weekly intake (PTWI) of 0.025 mg/kg body weight, for human adults (World Health Organization, 2007). The highest Pb concentration was found in *Mytillus galoprovincialis* (31.6 µg/g in wet weight), in the Giresun coasts of the Black Sea (Turkey) (Figure 8). It is the only reported Pb concentration that exceeds the established maximum limit.

Pb has serious effects on the body even at low concentrations. Pb interferes with a variety of processes, including protein folding, inter- and intracellular singling, enzyme regulation, and cell adhesion, apoptosis. Hypertension is caused by a high level of Pb exposure.

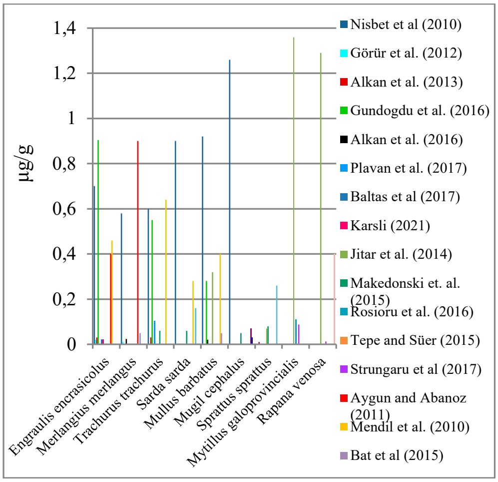


Figure 8. The Pb concentration in different fish species in the Black Sea area according to different authors

CONCLUSIONS

The outcome of the present study identified that consuming fish and molluscs from Romania, Ukraine, Bulgary, Turkey and Georgia, may not have a harmful impact on human health. Nonetheless an increase in the number of fish and seafood servings consumed per week may cause mercury, lead and arsenic-related health problems for consumers across the board. The growing global population is causing people to seek out new foods in order to obtain adequate and balanced nutrition. Seafood is one of the most important foods consumed to meet peoples protein requirements. They do, however, play an important role in the transmission of various pollutants, including heavy metals, to humans. As a result, determining toxic substance levels in edible parts of fishery resources on a regular basis is critical for both, food and environmental safety. Clearly, this is not intended to be a complete and definitive list of potentially toxic elements in Black Sea fishery resources, but rather a consolidated starting point for acknowledging chemical pollution from coastal to open sea environments.

The mean concentrations of the investigated heavy metals were found to be the highest for Zn (175.15 µg/g), followed by Pb (31.6 µg/g), and the lowest for Fe (227.2 µg/g), followed by Ni (12.7 µg/g). Comparing the average values recommended of heavy metals with European Food Safety Authority, World Health Organization, European legislation, and Turkish Food Codex, it was found that Zn, Cd, Hg, Cr, and Pb exceeded the highest permitted values.

As a result, the Black Sea receives a large amount of pollution from multiple sources. This demonstrates the importance of pollution control not only from the six Black Sea riparian countries, but also from all of the countries within the Black Sea basin. In this regard, every country in the basin bears some responsibility for the Black Sea pollution. As a result, coordinated and collaborative efforts are required. Commitment fulfillment and adherence to Strategic Action Plan recommendations are critical to achieving the goals of reduced pollution and improved water quality.

Another conclusion to be drawn from the current review is that the metal concentrations of fishery resources from the Black Sea have been barely reported in the recently literature, thus is a lack of information about the real status of HM pollution in the Black Sea region.

In order to stop and prevent pollution in the Black Sea, countries in the Black Sea Basin, must implement additional deterrent legislation. Furthermore, continuous pollution measuring stations in the Black Sea must be established at specific points to monitor pollution and create an inventory.

Hence, the Black Sea pollution sources are numerous, and the effects on aquatic organisms should be determined periodically.

REFERENCES

Alkan N, Alkan A, Gedik K, Fisher A. (2013). Assessment of metal concentrations in commercially important fish species in Black Sea. *Toxicol Ind Health*. 32(3), 447-56.

Alkan, A., Alkan, N., Akbaş, U. (2016). The factors affecting heavy metal levels in the muscle tissues of whiting (Merlangius merlangus) and red mullet (Mullus barbatus). *Tarım Bilimleri Dergisi*. 22. 349-359

Auta, H.S., Emenike, C.U., Fauziah, S.H. (2017). Distribution and importance of microplastics in the marine environment: a review of the sources, fate, effects, and potential solutions. *Environ. Int.* 102, 165–176

Aygun, S., and Abanoz, F. (2011). Determination of Heavy Metal in Anchovy (Engraulis encrasicolus L 1758) and Whiting (Merlangius merlangus euxinus Nordman, 1840) Fish in The Middle Black Sea. *Kafkas Universitesi Veteriner Fakultesi Dergisi*. 17. S145-S152.

Baltas H, Kiris E, Sirin M. (2017). Determination of radioactivity levels and heavy metal concentrations in seawater, sediment and anchovy (Engraulis encrasicolus) from the Black Sea in Rize, Turkey. *Mar Pollut Bull*. 116(1-2), 528-533

Barceloux D.G. (1999). Chromium. *Journal Toxicol Clin Toxicol*. 37(2)

Baruthio F. (1992). Toxic effects of chromium and its compounds. *Biol Trace Elem Res*. 32:145-53

Bat, L., Murat, S., Üstün, F., Sahin, F. (2012). Heavy Metal Concentrations in Ten Species of Fishes Caught in Sinop Coastal Waters of the Black Sea, Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*. 12. 371-376.

Bat, L., & Yalçın, K., Öztekin, H.C. (2014). Heavy Metal Levels in the Black Sea Anchovy (Engraulis encrasicolus) as Biomonitor and Potential Risk of Human Health. *Turkish Journal of Fisheries and Aquatic Sciences*. 14. 845-851.

Bat, L. Öztekin, H., Üstün, F.. (2015). Heavy Metal Levels in Four Commercial Fishes Caught in Sinop Coasts of the Black Sea, Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*. 15. 399-405.

Bat, L., Öztekin, H.C. (2016). Heavy metals in mytilus galloprovincialis, Rapana venosa and Eriphia verrucosa from the Black Sea coasts of turkey as bioindicators of pollution. 13. 715-728.

Bat, L. and Arici,E. (2018). Heavy Metal Levels in Fish, Molluscs, and Crustacea From Turkish Seas and

Potential Risk of Human Health in Handbook of Food Bioengineering. *Academic Press*, 5, 159-19

Bat, L., Arıcı, E., Öztekin, A. (2019). Heavy metals health risk appraisal in benthic fish species of the Black Sea. *Indian Journal of Geo-Marine Sciences*. 48. 163-168.

Brewer, G.J (2010). Risks of Copper and Iron Toxicity during aging in humans. *Chemical Research in Toxicology*

Burger J. (2007). A framework and methods for incorporating gender-related issues in wildlife risk assessment: gender-related differences in metal levels and other contaminants as a case study. *Environ Res*. 104(1).

Buxton, S., Garman, E., Heim, K.E., Lyons-Darden, T., Schlekat, C.E., Taylor, M.D., Oller, A.R. (2019). Concise Review of Nickel Human Health Toxicology and Ecotoxicology. *Inorganics*. 7(7):89

Directive, (2006), Directive 2006/1881/EC the Comission of the European Communities Setting maximum levels for certain contaminants in foodstuffs (Text with EEA relevance), Official Journal of the European Union, L 364/5, 20.12.2006

EFSA (European Food Safety Authority), (2014) Scientific Opinion on the risks to public health related to the presence of chromium in food and drinking water. *EFSA J*, 12, 3595.

Engin, M.S., Uyanik, A., Cay, S., Kir, I. (2016). Evaluation of trace metals in sediment, water, and fish (*Mugil cephalus*) of the central Black Sea coast of Turkey, Human and Ecological Risk Assessment: An International Journal, 22:1, 241-250

FDA (U.S. Food and drug administration), (2007). Action Levels, Tolerances and Guidance Levels for Poisonous or Deleterious Substances in Seafood, Section IV, Chapter II.04. National Shellfish Sanitation Program Guide for the Control of Molluscan Shellfish. USA: FDA.

Florea, A.M., Büsselberg, D. (2006). Occurrence, use and potential toxic effects of metals and metal compounds. *Biometals*, 19, 419-427.

Food and Agricultural Organization of the United Nations and World Health Organization, (2011), Joint FAO/WHO Expert Committee on Food Additives Summary and Conclusions, Issued 4, JECFA/74/SC.

Goodman, J.E., Prueitt, R.L., Thakali, S., Oller, A.R. (2011). The nickel ion bioavailability model of the carcinogenic potential of nickel-containing substances in the lung. *Crit Rev Toxicol*. 41(2)

Görür, F.K., Keser, R., Akçay,N., Dizman,S. (2012). Radioactivity and heavy metal concentrations of some commercial fish species consumed in the Black Sea Region of Turkey, *Chemosphere*,87 (4), 356-361.

Gundogdu, A., Culha, S.T., Kocbas, F., Culha, M. (2016). Heavy metal accummulation in muscles and total bodies of Mullus barbatus, Trachurus trachurus and Engraulis encrasicolus captured from the coast of Sinop, Black Sea, Pakistan Journal of Zoology, 48 (1), 25-34.

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary toxicology*, *7*(2), 60–72.

Jitar, O., Teodosiu, O., Oros, A., Plavan, G., Nicoara,M. (2015). Bioaccumulation of heavy metals in marine organisms from the Romanian sector of the Black Sea, *New Biotechnology*, 32 (3), 369-378.

Karsli, B. (2021). Determination of metal content in anchovy (Engraulis encrasicolus) from Turkey, Georgia and Abkhazia coasts of the Black Sea: Evaluation of potential risks associated with human consumption. *Mar Pollut Bull*. 165:112108.

Kevern, L.C. & Serge, M.G. (2009). A fishery manager`s guidebook- second edition. *The Food and Agriculture Organization of the United Nations and Wiley-Blackwell.*

Khan, S, Cao, Q, Zheng, Y.M, Huang, Y.Z, Zhu, Y.G. (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environmental Pollution*, 152.

Koller, M., & Saleh, H.M. (2018). Introductory Chapter: Introducing Heavy Metals. In H.E M. Saleh, & R.F. Aglan (Eds.), Heavy Metals. *IntechOpen*.

Krutov A. (2019). State of the Environment of the Black Sea (2009-2014/5). *Publications of the Commission on the Protection of the Black Sea Against Pollution (BSC) 2019*, Istanbul, Turkey, 811 pp. Retrieved February 15, 2022, from (http://www.blacksea-commission.org/Inf.%20and%20Resources/Publications/SOE2014/)

Makedonski, L., Peycheva, K, Stancheva, M. (2015). Determination of some heavy metal of selected black sea fish species. *Food Control*. 72.

Mee, L.D. (1992). The Black Sea in crisis: a need for concerted international action. *Ambio* 21, 278–286.

Mendil,D., Zafer Demirci, Z., Tuzen, M., Soylak, M. (2010). Seasonal investigation of trace element contents in commercially valuable fish species from the Black sea, Turkey, *Food and Chemical Toxicology*, 48 (3).

Mülayim, A. Balkıs, H. (2015). Toxic metal (Pb, Cd, Cr, and Hg) levels in Rapana venosa (Valenciennes, 1846), Eriphia verrucosa (Forskal, 1775), and sediment samples from the Black Sea littoral (Thrace, Turkey), *Marine Pollution Bulletin*, 95 (1), 215-222

Nisbet, C., Terzi, G., Pilgir, O., Sarac, N. (2010). Determination of Heavy Metal Levels in Fish Samples Collected from the Middle Black Sea. *Kafkas Universitesi Veteriner Fakultesi Dergisi*. 16. 119-125.

Plavan, G., Jitar, O., Teodosiu, C., Nicoara, M., Micu, D., Strungsru, S.A. (2017). Toxic metals in tissues of fishes from the Black Sea and associated human health risk exposure. *Enviroon Sci Pollut Red* 24, 7776-7787

Rosioru, D.M, Oros, A., Lazar, L. (2016). Assessment of the heavy metals contamination in bivalve mytilus galloprovincialis using accumulation factors. 17. 874-884.

Sharma, R.K, and Agrawal, M. (2005). Biological effects of heavy metals: an overview. *J Environ Biol*. 26.

Simionov, I.A, Cristea, V., Petrea, M.P, Sirbu, E.B (2019). Evaluation of heavy metals concentration dynamics in fish from the black sea coastal area: an overview. *Environmental Engineering and Management Journal*, 18 (5), 1097-1110.

Simionov, I.A, Cristea, V., Petrea, M, Mogodan Antache, A., Nicoara, M., Baltag, E., & Strungaru, S.A., Faggio, C. (2019). Bioconcentration of Essential and Nonessential Elements in Black Sea Turbot (Psetta Maxima Maeotica Linnaeus, 1758) in Relation to Fish Gender. *Journal of Marine Science and Engineering*. 12. 1-18.

Stancheva, M., Makedonski, L., Elitsa, P.P. (2013). Determination of heavy metals (Pb, Cd, As and Hg) in Black Sea grey mullet (Mugil cephalus). *Bulgarian Journal of Agricultural Science*. 19. 30-34.

Strungaru, S.A., Nicoara, M., Teodosiu, C., Micu, D., Plavan, G. (2017). Toxic metals biomonitoring based on prey-predator interactions and environmental forensics techniques: A study at the Romanian-Ukraine cross border of the Black Sea, *Marine Pollution Bulletin*, 124 (1), 321-330.

Tepe, Y., Süer, N. (2016). The levels of heavy metals in the Mediterranean mussel (Mytilus Galloprovincialis Lamarck, 1819); Example of Giresun coasts of the Black Sea, Turkey. *Indian Journal of Geo-Marine Science (IJMS)*. 45. 283-289.

Tornero V., Hanke G., (2016). Chemical contaminants entering the marine environment from sea-based sources: A review with a focus on European seas, *Marine Pollution Bulletin*,112 (1-2), 17-38.

Turkish Food Codex, (2008). Notification about determination of the maximum levels for certain contaminants in food stuff of Turkish Food Codex *Official Gazette of Republic of Turkey*

Vardhan, K.H, Kumar,P.S. Panda, R.C (2019). A review on heavy metal pollution, toxicity and remedial measures: Current trends and future perspectives, *Journal of Molecular Liquids*, 290.

World Health Organization, (1992), International programme on chemical safety, *Environmental Health Criteria*, 134.

World Health Organization, (2007). Exposure of children to chemical hazards in food. *European Environment and Health Information System*, Fact Sheet No. 4.4.

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

STUDY ON THE OPTIMIZATION OF CONCRETE SCREEDS IN ZOOTECHNICAL FARMS

Marta Ioana MOLDOVEANU, Daniela Lucia MANEA, Elena JUMATE, Radu FECHETE, Maria Loredana ȚINȚIȘAN, Adrian Cristian SIOMIN

Technical University of Cluj-Napoca, 28 Memorandumului Blvd, Cluj-Napoca, Romania

Corresponding author email: Marta.Moldoveanu@ccm.utcluj.ro

Abstract

Nowadays we are faced on a daily basis with the idea of being involved as much as possible in assuring the wellbeing of our planet. We are striving to implement a way of thinking that would eventually be a way of life, present in the zoo-technological farms as well. Our aim is to accomplish two main goals, firstly to have a civic contribution by strengthening the 3RE principals (Recycle - Reuse - Reduce) recycling used tires, giving them a brand-new purpose. Second, we want to improve the comfort of livestock by changing the mortar screed quality, found in cattle's stables. Optimising the Screed Mortar, we will manage to satisfy the needs of both farmers and livestock, all being an integral part of this research.

Key words: *concrete screed, recycling, waste.*

INTRODUCTION

Farmers, while trying to bring together, practicality and livestock comfort have reached the conclusion that a new way of cleaning filth is required, thus, they implemented the use of a rubber mat (Figure 1) over the 10-12 cm thick screed which had a layer of capillarity breakage of around 15 cm (Frederiksen et al., 2010). Conversely, researchers showed a spike in the number of afflictions found in bovines who were stepping and on concrete floors alone. According to Bergsten (1994), hard concrete floors increase the risk of subclinical laminitis (Figure 2) which makes young cattle limp.

Comparing a group of bovines brought up in a barnyard with rubber mat protection with another group of bovines raised in similar barnyard conditions but with a hard concrete floor, it was shown that the animals raised on the hard concrete floor had a lot more bleeding near the white line.

A fracture of the already loosened hemorrhagic wall, whilst the animal was rotating determined a fissure between the wall and hoof near the white line determining the formation of an abscess (Gîscă, 2011).

Figure 1. Concrete berth with rubber mat (Frederiksen et al., 2010)

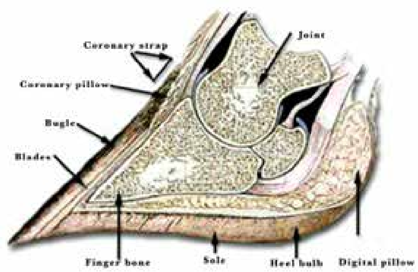


Figure 2. Section through the main tab (Gîscă, 2011)

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

The animal's comfort is of the highest importance, not just bovines, but of all animals. Cattle spend up to 15 hours in the resting zone, therefore their ability to relax greatly influences their behaviour and production. As it is expected discomfort in the resting zone, determines bovines to sit on all fours increasing the load, especially in the back feet, leading to bleeding of the hoofs and sever inflammation. An analogy can be made with the feeding or breeding grounds, where a lack of comfort can have similar consequences.

MATERIALS AND METHODS

The purpose of this paper is to highlight an innovative mortar recipe that intends to improve the comfort of livestock, just like the rubber mat did, focusing on eliminating the disadvantages of the rubber cover, such as slipping. According to Sârbu (2010), the surface on which the animals sleep, needs to be elastic, because a hard surface will determine not only hoof problems but also mammary afflictions. The surface also needs to be resistant to chemical agents found in animal waste and most importantly not be slippery. The rubber mat or mattresses from the shelters (https://www.rotaguido.it/dot%C4%83ri-pentru-stabula%C5%A3ie-liber%C4%83) used in the past, do not cover all the requirements highlighted above.

Proper collection of fecal materials, needs a 3% inclination (Figure 3), this has to be taken into consideration during the development of animal shelters, both in fixed and free stable (Vătămanu V., 2019).

We propose a floor mortar recipe which contains 5% natural hydraulic lime mortar NHL5 and rubber flakes in the same 5% proportion. This recipe, called MV5 5% F 5%, derived from the mortar recipe composed of Portland Cement 42.5 R, water and 5 types of sand (0.08-0.16; 0.16-0.5; 0.5-1; 1-2; 2-4), (Figures 4, 5).

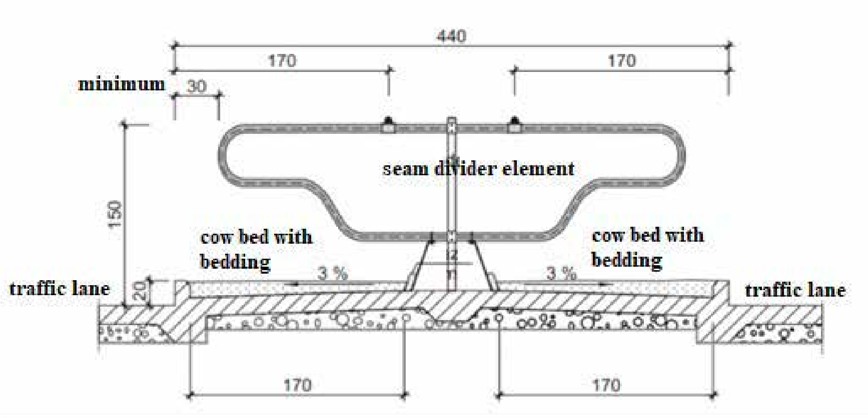


Figure 3 Detail of the cow shelter system
(Frederiksen et al., 2010)

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Figure 4. Sand gauge

Figure 5. Rubber flakes recovered from the processing of used tires

Tests were performed for both recipes in order to compare bending and compression stress thus validating the difference in elasticity and resistance.
Eventually we performed an adherence (Figure 6) test as well, ever so important for the stability of the bovines on a wet surfaces (Cadar, 2022) caused by their manure.

Figure 6. Standard mortar adhesion test

Quantification methods and statistical analysis was used in interpreting the results.
The survey was another common method that we used in our research, collecting data from companies involved in the recycling of used tires.

RESULTS AND DISCUSSIONS

The results obtained are as anticipated, namely an increase in both elasticity and resistance and an improvement in regards to adherence. In the following we showcase our findings in a comparative manner for easier understanding (Table 1, Figure 7).

Table 1. Bending and compression tests for Standard Mortar (MS) and NHL5 and 5% and Rubber Flakes 5% (MV5 5% F 5%) - 3, 7 and 28 Days

Recipe	**Days**	**Bending**		**Compression**	
		F [kN]	R [N/mm^2]	F [kN]	R [N/mm^2]
MS	3	1570	367.97	28.42	17.01
	7	1690	401.53	29.42	18.13
	28	1790	432.81	31	19.79
MV5 5% F 5%	3	1210	310.97	16.45	10.27
	7	1296.67	349.53	21.38	13.36
	28	1810	450.81	32.66	20.41

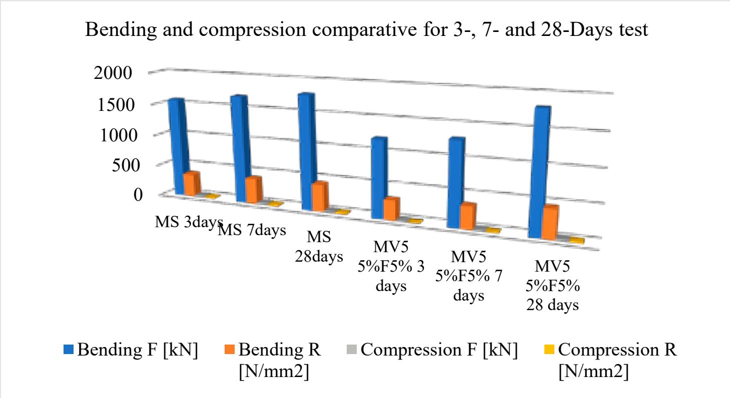


Figure 7. Bending and compression comparative for 3, 7 and 28-Days test

Comparing attempts at 3, 7 and 28 days we can observe that standard mortar shows better values, however as anticipated the most relevant tests were the ones performed at 28 days. It is well known that mortar resistance increases with the passage of time, as such 5% natural hydraulic lime mortar NHL5 with 5% rubber flakes shows the best values (Table 2 and Figure 8).

Table 2. Bending and compression tests for Standard Mortar (MS) and NHL5 5% and Rubber Flakes 5% (MV5 5% F 5%) - 28 Days

No.	Bending	Compression			
	F [kN]	F [kN]	R [N/mm²]	F [kN]	R [N/mm²]
MS	1790	31	19.79	30.58	18.79
MV5 5% F 5%	1810	32.66	20.41	30.59	19.34

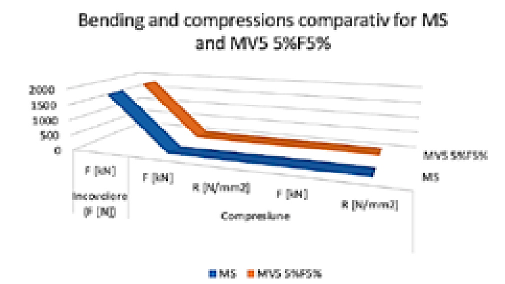


Figure 8. Bending and compression comparative for MS and MV5 5% F 5% at 28 Days

A slight increase of both bending and compression resistance can be seen for the MV5 5% F 5%, at the 28 days mark. Valuable information was also obtained in terms of adhesion tests at the 28 days mark (Table 3 and Figure 9).

Table 3. Adhesion tests for Standard Mortar (MS) and NHL5 5% and Rubber Flakes 5% (MV5 5% F 5%) - 3 and 28 Days

Adhesion	Compression	
	3 days	28 days
MS	2	119
MV5 5% F 5%	8	81

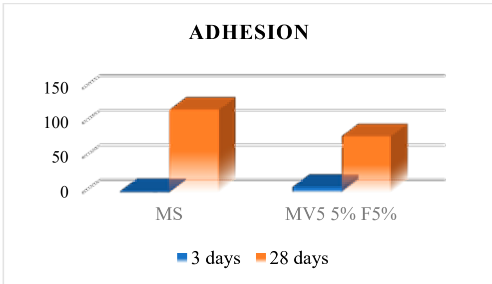


Figure 9. Adhesion test for MS and MV5 5% F 5% - 3 and 28 Days

CONCLUSIONS

The results of our research showed that the improved recipe had better result for both compressions and bending ((SR) EN 196). The mortar screed had higher elasticity and bigger load potential throughout the tests performed ((SR) EN 1015-11:2002/A1:2007).
Adherence was also showed to be better. The fact that we can now use an anti-slip surface will greatly improve the wellbeing of cattle. Another satisfactory conclusion is that the principal of the 3 RE (Recycle - Reuse - Reduce) can be uphold with ease, we can recycle and reuse rubber materials contributing to a cleaner environment.

We have taken steps towards improving our recipe by adding natural latex, enhancing the connection between components and yielding better overall results. Using latex will not only provide us with a more elastic material, but will also enable us to maintain the eco path on which we set out, giving bio-constructions a great alternative to traditional materials.

We are keen on employing only natural additives and natural coupling agents in order to improve the lifespan of animals breed in zoo-technological farms. Natural polymers are present in many of the articles published in the last couple of years, following a steady trend of returning to ecological materials (Aciu C. et al., 2018; Jumate E. et al., 2017). This has to do with both economic factors and planet saving concerns.

Why both factors are so important? In addition to the ecological aspect, we consider that the economic aspect is also very important, because the elaboration of a new material with the presented benefits must be cost efficient, otherwise it will not be sold in the market, which makes our product unfeasible. Thus, the price / benefit ratio must be a winning one. Following this situation, we can discuss profit and capital for permanent improvements, regarding the new patented ecological material.

For a large-scale use of the optimized recipe, we consider it appropriate because any additional resistance to both bending and compression, as well as adhesion.

The cost incurred by our recipe and mortar quantities are not so different but the overall result is way better. We can only recommend it due to the multiple advantages it has over the classical format.

There is more and more talk about green houses and passive houses, which represent a clear future direction towards our return to nature.

One cannot sufficiently emphasis how important it is to go back to traditional construction materials, optimized for bio-constructions which permits ecological building projects that in turn improve our ecosystem.

REFERENCES

Aciu C., Manea D.L., Molnar L. M., Jumate E. (2015). Recycling of polystyrene waste in the composition of ecological mortars, *Procedia Technology*, 498-505.

Bergsten, C. (1994). Haemorrhages of the sole horn of dairy cows as a retrospective indicator of laminitis: An epidemiological study. *Acta Vet. Scand*. 35:55–66.

Cadar D., Manea D.L, Moldovan D., Jumate E., Fechete R. (2022). Behavior Analysis of One–Component Waterproofing Mortars by Mechanical and NMR Investigations, The *15th International Conference Interdisciplinarity in Engineering*, Springer International Publishing,

Equipments for free housing, https://www.rotaguido.it/dot%C4%83ri-pentru-stabula%C5%A3ie-liber%C4%83, accesed on March 8, 2022.

Frederiksen H., Blaga L.I., Mașinistru M.C., Greculescu A.I. (2010). Sisteme de adăpost pentru bovine – volumul 2. Exemple de construcții (Cattle shelter systems - volume 2. Examples of constructions), Vol. 2:8-9, https://portal.afir.info/Uploads/GHIDUL%20Solicitantului/PNDR2020/Standarde_de_ferma/Vaci%20vol%202_Exemple%20de%20constructii%20vaci_by%20EC_WEB.pdf, accesed on March 9, 2022.

Gîscă D. (2011). *The Vet Magazine: Science and Practice*, 2nd series. No. 2:11, https://issuu.com/veterinarul/docs/veterinarul_seria_ii_nr_2_op?fbclid=IwAR1yazWskPNCBgike2WLgqSnXxLYDaasfHct0C8vasvPfSjzi_4zL2Iidlg, accesed on March 11, 2022.

Jumate E., Aciu C., Manea D.L., Moldovan D., R. Chelcea R., Fechete R. (2017). Plastering mortar with antibacterial and antifungal properties studied by 1H NMR relaxometry, *AIP Conference Proceedings*.

Sârbu M. (2010). *Agricultural constructions*, 5th Edition, ISBN: 973-656-842-3, Risoprint Publishing House: 65-66.

Vătămanu V. (2019). Exploitation of cows in free and tied system, https://www.agrimedia.ro/ articole/exploatarea-vacilor-in-sistem-liber-si-in-sistem-legat, Accesed on March10, 2022.

(SR) EN 1015-11:2002/A1:2007, Methods of test for mortar for masonry. Part 11: Determination of flexural and compressive strength of hardened mortar., https://pdfcoffee.com/sr-en-1015-11-a1-2007-pdf-free.html, Accesed on March 5, 2022.

(SR) EN 196, Methods of testing cement, Part 1: Determination of strength, https://standards.iteh.ai/catalog/standards/cen/37b8816e-4085-4dcc-a642-a383d9bddd6c/en-196-1-2016, Accesed on March 5, 2022.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

PHYTOREMEDIATION CAPACITY AND PHOSPHORUS MASS BALANCE IN A BASIL-STURGEONS AQUAPONICS INTEGRATED RECIRCULATING SYSTEM

Ștefan-Mihai PETREA, Ira-Adeline SIMIONOV, Alina ANTACHE, Aurelia NICA, Maxim ARSENI, Adrian ROȘU, Dragoș CRISTEA, Mihaela NECULIȚĂ

"Dunărea de Jos" University of Galati, 47 Domneasca Street, Galati, Romania

Corresponding author email: stefan.petrea@ugal.ro

Abstract

The long-term increased demand for animal-based protein had determined the practice of intensive farming technologies, strategy that may rise environmental sustainability issues. Aquaculture food production industry manages both to satisfy market demand for fish and contributes to restocking programs conducted in order to support biodiversity conservation programs. Integrating aquaponics techniques into already existing recirculating aquaculture production systems may represent a solution for limiting the environmental impact, while maintain a high production intensity. The present study targets to identify the basil phytoremediation potential by evaluating its phosphorus removal capacity from the technological water resulted by practicing intensive sturgeons aquaculture. The P mass balance is identified in order to determine the sustainability of the tested, aquaponics based, water treatment solution, by considering the P concentrations of fish feed, solid waste, wastewater, technological water, fish and plants biomass. The results indicate that basil presents high P removal capacity and both hydraulic parameters and regimes are important parameters to be considered in the phytoremediation technology optimization process. Similar studies are recommended to be performed by testing both aquaponics deep water and nutrient film techniques.

Key words: *phytoremediation, basil, phosphorus, aquaponics, mass balance.*

INTRODUCTION

According to recent study (White, 2017), the aquaculture industry is predicted to continue increasing production by intensifying the existing aquaculture practices and increasing the number of farms.

Then negative effects of wastes discharges, from aquaculture, to aquatic environment are a subject of high interest, although they represent only a small part to land-based pollutants. According to some authors (Boyd et al., 2015), the aquaculture effluents are associated to a range between 2 and 3% of total anthropogenic nitrogen (N) and phosphorus (P) entering natural waters. Cao et al. (2007) emphasized that properly planned use of aquaculture waste alleviates water pollution problems and not only conserves valuable water resources but also takes advantage of the nutrients contained in effluent. Some authors (Cochard, 2017) pointed out that the discharges from intensively operated fish farms are known for their high concentration of nutrients, suspended solids, oxygen-demanding substances and chlorophyll a and these high levels of nutrients may cause eutrophication and affect fisheries adversely (White, 2017).

The aquaculture feed inputs are the main source of the above-mentioned structure of the effluents of intensive aquaculture facilities. Recent study (Prüter et al., 2020) emphasized that up to 80% of carbon (C), 76% N and 82% of P from total feed input in aquaculture can be lost to the environment.

The new European Union (EU) requirements in terms of increasing the sustainability of aquaculture generates restrictions in intensive fish rearing technologies in terms of fish stocking densities and feed input, solutions that are meant to keep the pollution loadings under environmental capacity. Although, according to Martins et al. (2010), intensive recirculation aquaculture systems (RAS) have the potential to become one of the most sustainable animal protein production systems, improvements are required for better discharges management.

According to Herath & Satoh (2015), discharges of N and phosphorous P have received a great deal of attention, during the last decade, from scientists and environmentalists as they disturb the natural balance of aquatic ecosystems. Lazzari et al. (2008) revealed that these two nutrients (N and P) are considered the main end-products of fish loading, and can affect not only the rearing water, but also the environment as a whole. The N and P originate, within aquaculture production systems, from fertilizers, feeds, and metabolic processes, such as uneaten feed, ingested but undigested food (faeces), or food ingested and eliminated as excretion during production (Wang et al., 2020). However, according to Stratful et al. (2001), phosphorus is often the most critical nutrient in eutrophication of freshwater.

Barak & van Rijn (2000) revealed that P is supplied together with feed, particularly compound feeds and its accumulation in the aquaculture technological water results from it not being fully assimilated by fish. It is pointed out that phosphorus compounds accumulate in the water during intensive fish culture in recirculation systems (Zarski et al., 2008).

Several efforts to reduce P concentrations in aquaculture systems had been made, mostly focused on improving the bioavailability of phosphorus in fish feed (Barak & van Rijn, 2000). The P excretion in RAS are usually 69-86% of dietary P, therefore, some authors suggest of phytase in fish feeds, in order to reduce P waste (Lazzari et al., 2008). Recycling of P from feed input in aquaculture systems gains increasing importance (Schröder, 2005), especially relating to the requirement of EU related to shifting to sustainable aquaculture practices.

Phytoremediation is also an environmentally friendly and cost-efficient method compared to other remediation technologies which target the reduction of P discharges from aquaculture (Khan et al., 2004). According to Pilon-Smits (2005), there are six types of phytoremediation methods: phytoextraction, phytodegradation, rhizofiltration, phytostabilisation, phytovolatilization and using plants to remove pollutants from the air. The phytoextraction method is based on the use of plants to remove metals or organic matter from the soil by accumulating them in the harvestable parts of the plant (Pilon-Smits, 2005). Also, Pilon-Smits (2005) defines phytoremediation as the removal or neutralisation of pollutants from the environment by using plants and pointed out that some plant species are known to have a high ability to concentrate elements in their biomass tissue.

Therefore, this P removal method can be adapted to already existing RAS systems by integrating aquaponics modules. Also, Ju et al. (2014) emphasized that, in constructed wetlands, P is removed primarily by plant and microbial uptake during growth, precipitation, and sediment adsorption. Considering phytoremediation, it must be revealed that these P is one essential element for organism growth and a key factor limiting the primary production of plants in various ecosystems, including aquaponics (Elser et al., 2007).

However, the P removal by using plant biomass process optimization depends on a multitude of variables as plant root system capacity, effluent flow rate (hydraulic loading rate - HLR and hydraulic retention time - HRT of the effluents within the plants biomass surface) (Tyson et al., 2004), light quality and quantity and water quality matrix. It is known that leafy greens as basil (*O. basilicum*), spinach (*S. oleracea*) or lettuce (*L. sativa*) have high potential in accumulation nutrients and are suitable plant species for aquaponics. Also, since most aquaculture investors/farmers targets a dual purpose by implementing phytoremediation techniques within their farms, namely the increase of both environmental and economic sustainability, basil seems to accomplish these desiderata due to both high nutrient absorption rate and economic value.

The present study aims to reveal opportunity to implement P phytoremediation solutions, based on aquaponics techniques, to an already existing sturgeon farm, considering a variety of technological scenarios which implies different P concentrations in the aquaculture effluent and different hydraulic regimes, respectively.

MATERIALS AND METHODS

Experimental design

The experimental trial lasts 29 days and was performed by integrating of the aquaponics modules based on light expended clay aggregate (LECA) substrate techniques in an already existing sturgeon RAS (Figure 1 and

Figure 2). The detailed description of integrated aquaponic system is presented in a previous study (Petrea et al., 2021.).

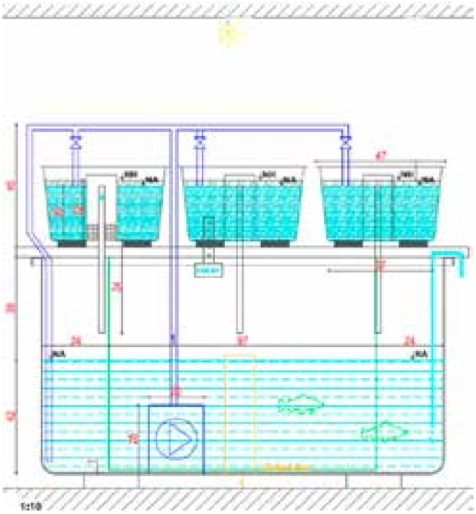


Figure 1. The side-view of the integrated aquaponics solution (IAS)

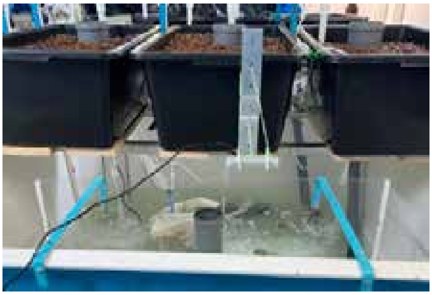


Figure 2. The front view of IAS

The aquaponic modules, in triplicate, are placed above each of the rearing units. Two hydraulic regimes were used (flood and drain - FD and continuous flow - CF, respectively). Before starting the experiment, the activation of LECA substrate was made as described by Petrea et al. (2021).
A constant luminous power of 5800 lm, measured with TESTO 545 light meter, was assured during the entire experimental period (Petrea et al., 2021).
The plants culture density was 74 crops/m^2 (Figure 3), while fish stocking density was 93 kg/m^3.

Fish were divided in two groups and a feeding rate of 1% (LR) and 2% (HR), respectively, of their total biomass weight (BW) were applied.
Therefore, a number of 4 experimental variants were defined, in triplicate, as follows: *HR - FD* (the variant with high feeding rate - high P input in RAS effluent and flood and drain hydraulic regime), *HR - CF* (the variant with high feeding rate and continuous flow hydaulic regime), *LR - FD* (the variant with low feeding rate - low P input in RAS effluent and flood and drain hydraulic regime) and *LR - CF* (the variant with low feeding rate and continuous flow hydraulic regime).

Figure 3. The upper-view of IAS

Water quality matrix

The water quality matrix of the effluents presents the following mean values, during the experimental trial:

Table 1. Water quality matrix during the experimental trial

Water quality parameter	Aquaculture effluents	
	LR	***HR***
$N\text{-}NH_4$ (mg/L)	0.14±0.05	0.16±0.06
$N\text{-}NO_2$ (mg/L)	0.07±0.02	0.09±0.03
$N\text{-}NO_3$ (mg/L)	126.2±33.6	173.2±45.2
pH (upH)	7.44±0,88	6.95±0.94
Turbidity (NTU)	2.83±0.54	3.35±0.79
EC (µS/cm)	1194.4±184.23	1248.9±200.54
Cl (mg/L)	70.08±5.95	69.34±2.76
Mn (mg/L)	0.59±0.23	0.81±0.16
Fe (mg/L)	0.53±0.12	0.77±0.10
K (mg/L)	15.56±2.85	16.58±3.97
Mg (mg/L)	31.74±11.84	35.5±15.35
Ca (mg/L)	88.46±20.45	90.56±21.45
BOD5 (%)	27.74±4.24	43.64±7.95
DO (mg/L)	8.44±1.34	7.81±0.85
COD (mg/L)	72.41±15.97	80.52±25.76
TSS (mg/L)	0.031±0.01	0.042±0.02
Temperature (ºC)	19.49±1.21	19.44±1.23

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Sampling and analysing methods

Technological water analysis was performed by using Spectroquant Nova 400 spectrophotometer, with Merk compatible kits. Samples of water were collected once a week from both the outlet and inlet of each aquaponic unit.

The phosphorus removal rates for each experimental variant were presented as average of the triplicate aquaponic units. The following equation was used in order to determine phosphorus removal rates (Petrea et al., n.d.), (eq. 1):

$$PR = \left[\frac{Q}{V} \times (C_{in} - C_{out}) - \frac{\Delta C_{out}}{\Delta t}\right] \times d.. \quad (1)$$

where: PR is phosphorus removal rate (g/m^2/day), Q is the flow rate (m^3/day), V is the system volume (m^3), C is the concentration of phosphorus (g/m^3), d is the water depth (m) and t is the time (days).

The fish faeces were collected as described in (Petrea et al., n.d.) by using a EHEIM water vacuum cleaner provided with a mesh compartment for solids retention. Phosphorus concentration in fish muscle tissues and basil biomass and fish faeces was determined by using the SR ISO 2294:2009 reference method.

Statistical methods

The software IBM SPSS Statistics 20 for Windows was used for the statistical analysis revealed in present paper.

The T test (α=0.05) was applied in order to identify the statistical differences between treatments, after the Kolmogorov-Smirnov normality test was performed. The ANOVA test (post-hoc Duncan test) was performed in order to compare variants

The P balance stream diagrams were performed by using Python's Plotly function.

RESULTS AND DISCUSSIONS

Technological water P_2O_5 concentration

The P_2O_5 concetration in technological water emphasizes high values attributed to HR experimental variants, durring the first part of the trial, due to higher feed input (a 2% BW feeding rate) and, therefore, higher P input into the integrated multi-trophic system (Figure 4). Also, it seems that, in case of both LR and HR technological scenarios, the FD hydraulic regime is recommended to be used as it performs better during long-period production cycles, compared to CF (Figure 4). However, the LR-CF registers the highest P_2O_5 concetration in technological water, at the aquaponics units outlet. These findings emphasizes that the prediction of P_2O_5 concetration in technological water, as dependent variable, should imply both independent data variables related to both RAS effluent quality matrix and technological scenario peculiarities related to feed input.

Thus, a average P_2O_5 concentration in technological water output of the aquaponics modules revealed a 15.66±7.37 mg/L at LR-FD, 17.14±9.76 mg/L at LR-CF, 15.96±7.47 mg/L at HR-FD and 16.06±8.21 mg/L at HR-CF, respectively (Figure 4).

Statistically significant differences ($p<0.05$) were recorded between the LR-CF and LR-FD experimental variants.

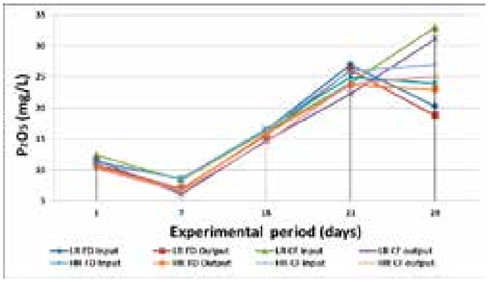


Figure 4. The dynamics of P_2O_5 concentration in water inlet and water outlet, during the experimental period

The dynamics of technological water P_2O_5 concentration reveals an accumulation trend during the experimental trial for all variants, except LR-FD, emphasizing the limiting phytoremediation capacity of the aquaponics system used in present study. Therefore, by analyzing the water quality matrix (Table 1) and the P dynamics (Figure 4), it can be stated that a decision to increase the aquaponics culture surface is suitable to be adopted in order to improve the environmental sustainability of already existing RAS and to limit its environmental impact in terms of P discharges, especially if HR technological scenarios are applied.

The P_2O_5 removal rate

The dynamics of P_2O_5 removal rate for each trial, during the experimental period (Figure 5), emphasizes highest values after the first 7 days of the trial, most probably due to the increase demand for phosphorus manifested by leafy greens, especially basil, in the preliminary stage of the growing cycle. The HR-CF experiment is the most consistent in terms of P removal rate during the entire trial period (Figure 5), with an average of 17.35±4.32 $g/m^2/day$. Also, upward trends, in the second part of the experiment trial period, can be also observed for both LR-CF and LR-FD, although the first variant records lower P removal performance (10.51±4.37 $g/m^2/day$), compared to the second variant (16.15±5.03 $g/m^2/day$). Statistically significant differences ($p<0.05$) were recorded between the group formed from LR-CF + HR-FD and LR-FD + HR-CF, respectively.

Therefore, the results related to P removal rate confirms that the FD aquaponic technique is recommended for maximizing the P phytoremediation capacity of basil for LR, while the CF offers better results in HR technological scenarios.

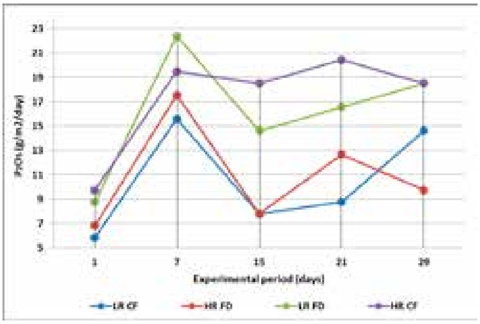


Figure 5. The dynamics of P_2O_5 removal rate for each trial, during the experimental period

The dynamics of P_2O_5 input by administrated feed

During the experimental trial, an input of 25.44 g P was recorded in each of the LR experimental variants, while 54.51g were attributed to each HR experimental variants (Figure 6). The input was provided by administrating fish feed at a feeding rate of 1% BW (LR) and 2% BW (HR), respectively. The administrated feed had a protein content of 41% and a P concentration of 0.9%. After the first 13 days of the experimental trial the feed input was increased due to sturgeons biomass gain since feeding rate in aquaculture production systems must be adjusted in relation to biomass weight.

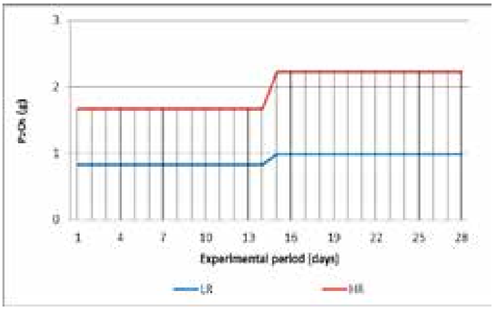


Figure 6. The dynamics of P_2O_5 inputs by feed

The P_2O_5 concentration in fish wastes and fish muscle tissue

The dynamics of P_2O_5 concentration in fish wastes revealed a higher upward trend at HR, compared to LR experimental variants (Figure 7). Also, statistically significant differences ($p<0.05$) were recorded between LR and HR in terms of P concentration in fish faeces.

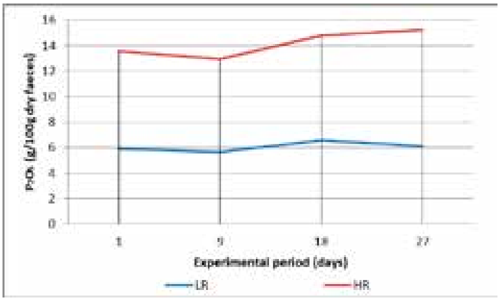


Figure 7. The dynamics of P_2O_5 concentration in fish wastes

Therefore, an average concentration of 6.08±0.39 g/100 g dry faeces was recorded at LR, while a 14.13±1.05 g/100 g dry faeces are attributed to HR experimental variants. The results are higher compared to the findings of other authors (Petrea et al., 2021.), which reports P_2O_5 concentration in fish wastes of 5.47±1.01 g/100 g dry faeces. However, feed chemical composition and fish metabolism can be considering determinant factors in terms of sturgeons P assimilation.

An increase of average P_2O_5 concentration in fish muscle tissue was observed for HR experimental variants, from an initial average concentration of 190.59±13.38 mg/100 g fresh muscle tissue, to 216.46±9.66 mg/100 g fresh muscle tissue (Figure 8). However, for LR variants, a decrease of 1.37% was recorded, to an actual average P_2O_5 concentration of 187.98±9.29 mg/100 g fresh muscle tissue.

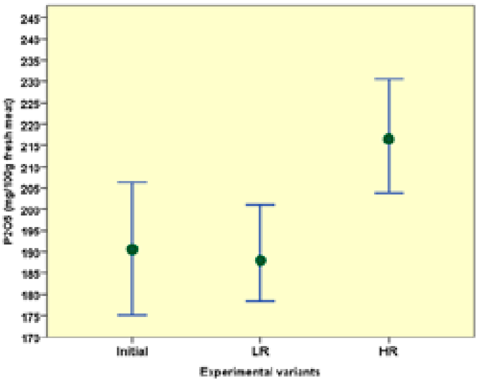


Figure 8. The P_2O_5 concentration in fish muscle tissue

At the end of the trial, the following average P_2O_5 concentrations in basil leaves were recorded: 58.73±3.56 mg/100 g fresh basil at HR-FD, 87.84±7.03 mg/100 g fresh basil at HR-CF, 84.10±4.48 mg/100 g fresh basil at LR-FD, 51.91±2.94 mg/100 g fresh basil at LR-CF. Before the experimental trial, the basil seedlings P_2O_5 concentration had an average of 25.23±1.76 mg/100 g fresh basil (Figure 9).

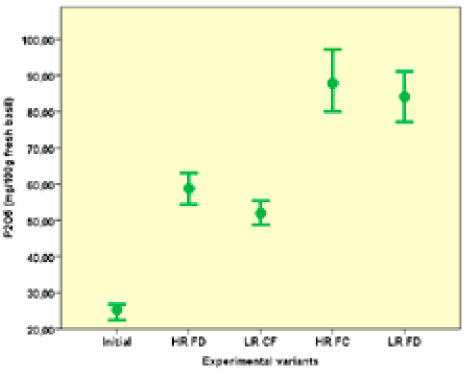


Figure 9. The P_2O_5 concentration in basil biomass

The basil P concentration confirms the P removal rate results and highlights the need of considering the relation between hydraulic regime and aquaculture effluents P concentrations, in order to maximize aquaculture environmental sustainability.

The P_2O_5 mass balance

The analysis of P mass balance reveals the most efficient integrated multi-trophic production system from all 4 tested variants. This analysis was performed since it is important to reveal the utility of the findings related to phytoremediation potential of aquaponics basil production and to characterize the entire multi-trophic system (both fish and plants production modules) in order to identify the variant which can better valorize the symbiotic technological approach.

Therefore, it reveals that HR-CF is the most efficient experimental variant in terms of phytoremediation capacity (12.06% of total P content being recovered in basil biomass) (Figure 10).

However, the most significant percent of total P is recovered in fish wastes, situation which can rise long-term sustainability issues. This can be amplified by the high percentage of unrecorded P (43.77%).

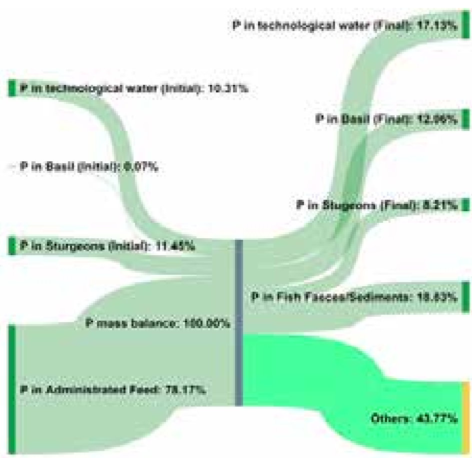


Figure 10. The P_2O_5 mass balance diagram from HR-CF

The LR-FD experimental variant reveals a 7.01% P recovery rate in aquaponics basil biomass (Figure 11). However, considering that the variant performs good in terms of P removal rate (Figure 5) and the percentage of unrecorded P is lower (40.15%) (Figure 11) compared to HR-CF (Figure 10), this variant can successfully compete as one of the most environmentally sustainable solution for an integrated multi-trophic system. However, as a drawback, the lower degree of production intensively will probably decrease the economic sustainability of LR-FD multi-trophic system.

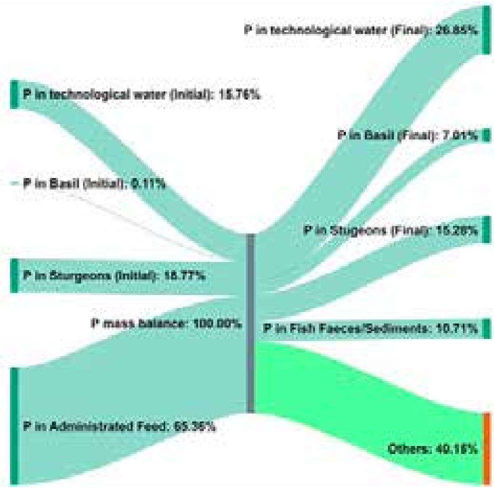


Figure 11. The P_2O_5 mass balance diagram from LR-FD

The HR-FD experimental variant reveals a 10.14% P recovery rate in aquaponics basil biomass (Figure 12), which places it on the second place among the studied scenarios and solutions. Also, the percentage of unrecorded P is the lowest among the analysed variants (37.63%).

However, the high percentage of P recovered in fish wastes decreases the environmental sustainability of HR-FD.

The LR-CF experimental variant reveals the lowest percentage of P recovery rate in aquaponics basil biomass (2.43%) (Figure 13). Considering the lowest P phytoremedion rate attributed to this variant (Figure 5) and low production intensivity, it can be stated that LR-CF is classed in the fourth place among the analysed scenarios, both in terms of economic and environmental sustainability.

Other authors (Chapman & Boucher, 2020) have tested plants as *Pteris vittata*, *Lemna minor*, *Rumex orbiculatus*, *Rumex verticillatus* and *Typha* × *glauca* for evaluating their P mitigation potential and reported a maximum P removal rate of 90% for *Rumex verticillatus* (0.46 g P/shoot, 1.93 g P/plant = root + shoot) and 84% for *T. glauca* (3.7-12.67 g P/plant). However, the experiments were performed in laboratory conditions, compared to the trial from present research paper, which can be considered as being performed in micro-production conditions.

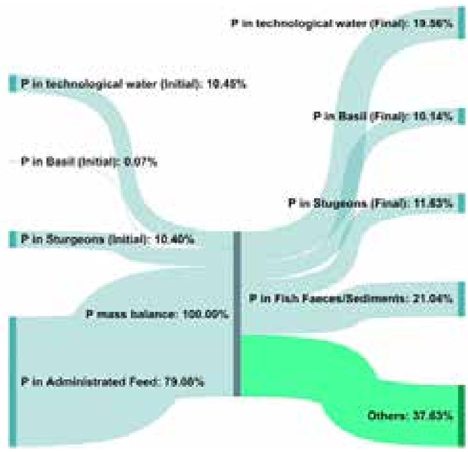


Figure 12. The P_2O_5 mass balance diagram from HR-FD

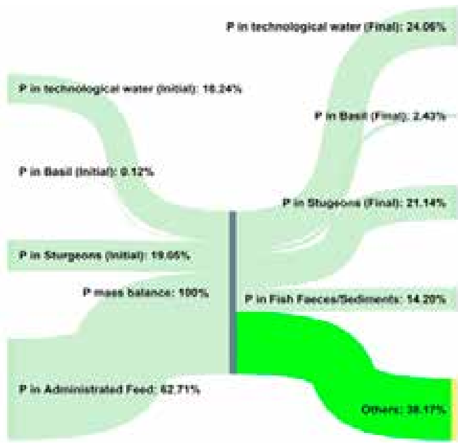


Figure 13. The P_2O_5 mass balance diagram from LR-CF

Future research can be performed during a longer period of time as P has a clear accumulation trend in RAS and, as emphasized by Li et al. (2021), high P concentrations, as well as N/P ratio in wastewater can directly decrease the nutrient uptake rate of plants.

On the other part, practicing phytoremediation within a low nutrients aquaculture facility can limit plants growth and, therefore, phosphorus removal (Adler et al., 2003).
According to (Tyson et al., 2004) optimum absorption of nutrients by plants depends on plant root system capacity, water pH - an important factor that impact the nitrogen fixing bacteria and the solubility of some nutrients in water (Mattson & Heinrich Lieth, 2019) and photoperiodism - should follow the temperature manipulation to achieve a healthy life cycle simulation of the plant (Raven et al., 2005). In addition, according to Stratful et al. (2001) the pH is an important factor for chemical precipitation of P when combined with Mg or other salts, as the solubility of their precipitates varies with pH.
Other authors (Endut et al., 2016) revealed the importance of the surface area of the roots for the removal of nutrients and concluded that leafy greens as spinach, known for their larger surface area roots) recorded a nutrients removal rate of 88.99 % for orthophosphates. Also, other authors (Hefni Effendi, Bagus A. Utomo, 2015) evaluated the decrease of nutrients in aquaponic systems of *Cherax quadricarinatus* - *I. aquatica* and identify a removal rate of 44.4% for orthophosphates.
Rakocy et al. (2004) revealed that a low HRL can cause a decrease of OD, while a high HRL can reduce the retention time of water, that can cause a decrease in the assimilation of nutrients by the crops' roots and the washing of the bacterial biofilm thus, the deterioration of water quality.
Previous studies related to basil culture in aquaponics conditions (Espinosa Moya et al., 2016) emphasized that a 57 g/day/m^2 of basil production can be sustainable in an aquaponic system, at a feed input ratio of 99.6 g/day/m^2.
Also, Adler et al. (2000) concluded that basil can be used as part of the biological filters and has the ability to remove significant concentration of N and P.

CONCLUSIONS

The present study reveals that basil presents high P removal capacity and the symbiotic approach of both hydraulic regimes and intensive feeding technological scenarios must be considerd in order to maximize the sustainability of multi-trofic aquaculture systems in terms of P discharges.
Also, it is recommended to practice continuous flow hidraulic regime is high the fish rearing technology requires high feed input and high P concetrations in effluents, respectively. However, is less intensive feeding technologies are applied, flood and drain hydraulic regime is recomanded for achieving high sustainability in terms of P discharges.
Similar studies are suggested to be performed by testing both aquaponics deep water and nutrient film techniques. Also, future studies which analysis the P mass balance within integrated multi-trophic RAS systems during multiple production cycles (long-term) are suggested to be conducted in order to reveal long-term sustainability of the recommended solutions.

ACKNOWLEDGEMENTS

This work was supported by a grant of the Ministry of Research, Innovation and Digitization, CNCS/CCCDI - UEFISCDI, project number 51 PTE - PN-III-P2-2.1-PTE-2019-0697, within PNCDI III.
The present research was supported by the project An Integrated System for the Complex Environmental Research and Monitoring in the Danube River Area, REXDAN, SMIS code 127065, co-financed by the European Regional Development Fund through the Competitiveness Operational Programme 2014-2020, contract no. 309/10.07.2021.

REFERENCES

Adler, P.R., Harper, J.K., Takeda, F., Wade, E.M., & Summerfelt, S.T. (2000). Economic evaluation of hydroponics and other treatment options for phosphorus removal in aquaculture effluent. In *HortScience* (Vol. 35, Issue 6). https://doi.org/10.21273/hortsci.35.6.993
Adler, P.R., Summerfelt, S.T., Glenn, D.M., & Takeda, F. (2003). Mechanistic approach to phytoremediation of water. *Ecological Engineering*, *20*(3). https://doi.org/10.1016/S0925-8574(03)00044-2
Barak, Y., & van Rijn, J. (2000). Biological phosphate removal in a prototype recirculating aquaculture treatment system. *Aquacultural Engineering*, *22*(1–2). https://doi.org/10.1016/S0144-8609(00)00036-4

Boyd, C.E. and McNevin, A.A. (2015). Water Pollution. (2014). *Aquaculture, Resource Use, and the Environment*, 211–234. https://doi.org/10.1002/9781118857915.CH10

Cao, L., Wang, W., Yang, Y., Yang, C., Yuan, Z., Xiong, S., & Diana, J. (2007). Environmental impact of aquaculture and countermeasures to aquaculture pollution in China. In *Environmental Science and Pollution Research* (Vol. 14, Issue 7). https://doi.org/10.1065/espr2007.05.426

Chapman, K., & Boucher, J. (2020). Phosphorus phytoremediation using selected wetland plants in constructed floating mats. *Applied Water Science*, *10*(6). https://doi.org/10.1007/s13201-020-01215-1

Cochard, R. (2017). Coastal Water Pollution and its Potential Mitigation by Vegetated Wetlands: An Overview of Issues in Southeast Asia. In *Redefining Diversity and Dynamics of Natural Resources Management in Asia* (Vol. 1). https://doi.org/10.1016/B978-0-12-805454-3.00012-8

Elser, J.J., Bracken, M.E.S., Cleland, E.E., Gruner, D.S., Harpole, W.S., Hillebrand, H., Ngai, J.T., Seabloom, E.W., Shurin, J.B., & Smith, J.E. (2007). Global analysis of nitrogen and phosphorus limitation of primary producers in freshwater, marine and terrestrial ecosystems. *Ecology Letters*, *10*(12). https://doi.org/10.1111/j.1461-0248.2007.01113.x

Endut, A., Lananan, F., Abdul Hamid, S.H., Jusoh, A., & Wan Nik, W.N. (2016). Balancing of nutrient uptake by water spinach (Ipomoea aquatica) and mustard green (Brassica juncea) with nutrient production by African catfish (Clarias gariepinus) in scaling aquaponic recirculation system. *Desalination and Water Treatment*, *57*(60). https://doi.org/10.1080/19443994.2016.1184593

Espinosa Moya, E.A., Angel Sahagún, C.A., Mendoza Carrillo, J.M., Albertos Alpuche, P.J., Álvarez-González, C.A., & Martínez-Yáñez, R. (2016). Herbaceous plants as part of biological filter for aquaponics system. *Aquaculture Research*, *47*(6). https://doi.org/10.1111/are.12626

Hefni Effendi, Bagus A. Utomo, G.M.D. (2015). Phytoremediation of freshwater crayfish (Cherax (Ipomoea aquatica) in aquaponic system. *International Journal of the Bioflux Society (AACL Bioflux)*, *8*(3).

Herath, S.S., & Satoh, S. (2015). Environmental impact of phosphorus and nitrogen from aquaculture. In *Feed and Feeding Practices in Aquaculture*. https://doi.org/10.1016/B978-0-08-100506-4.00015-5

Ju, X., Wu, S., Zhang, Y., & Dong, R. (2014). Intensified nitrogen and phosphorus removal in a novel electrolysis-integrated tidal flow constructed wetland system. *Water Research*, *59*. https://doi.org/10.1016/j.watres.2014.04.004

Khan, F.I., Husain, T., & Hejazi, R. (2004). An overview and analysis of site remediation technologies. *Journal of Environmental Management*, *71*(2). https://doi.org/10.1016/j.jenvman.2004.02.003

Lazzari, R., Baldisserotto, B., de Nitrogênio, E., Fósforo, E., & Resumo, E.P. (2008). Nitrogen and Phosphorus Waste in Fish Farming. *Lazzari e Baldisserotto B. Inst. Pesca*, *34*(344).

Li, X., Li, Y., Li, Y., & Wu, J. (2021). The phytoremediation of water with high concentrations of nitrogen and phosphorus contamination by three selected wetland plants. *Journal of Water Process Engineering*, *40*. https://doi.org/10.1016/j.jwpe.2020.101828

Martins, C.I.M., Eding, E.H., Verdegem, M.C.J., Heinsbroek, L.T.N., Schneider, O., Blancheton, J.P., d'Orbcastel, E.R., & Verreth, J.A.J. (2010). New developments in recirculating aquaculture systems in Europe: A perspective on environmental sustainability. In *Aquacultural Engineering* (Vol. 43, Issue 3). https://doi.org/10.1016/j.aquaeng.2010.09.002

Mattson, N., & Heinrich Lieth, J. (2019). Liquid culture hydroponic system operation. In *Soilless Culture: Theory and Practice Theory and Practice*. https://doi.org/10.1016/B978-0-444-63696-6.00012-8

Petrea, Ștefan-M., Simionov, I.-A., Mogodan, A., Nica, A., Neculita, M., & Sebastian CRISTEA, D. (2021). *The influence of crop density on phosphorus dynamics in an integrated stellate sturgeon-spinach recirculating production system*.

Pilon-Smits, E. (2005). Phytoremediation. *Http://Dx.Doi.Org/10.1146/Annurev.Arplant.56.032604.144214*, *56*, 15–39. https://doi.org/10.1146/Annurev.Arplant.56.032604.144214

Prüter, J., Strauch, S.M., Wenzel, L.C., Klysubun, W., Palm, H.W., & Leinweber, P. (2020). Organic matter composition and phosphorus speciation of solid waste from an African catfish recirculating aquaculture system. *Agriculture (Switzerland)*, *10*(10). https://doi.org/10.3390/agriculture10100466

Rakocy, J.E., Shultz, R.C., Bailey, D.S., & Thoman, E.S. (2004). Aquaponic production of tilapia and basil: Comparing a batch and staggered cropping system. *Acta Horticulturae*, *648*. https://doi.org/10.17660/ActaHortic.2004.648.8

Raven, P.H., Evert, R. Franklin., & Eichhorn, S.E. (2005). *Biology of plants.* (7th ed.). W.H. Freeman.

Schröder, J. (2005). Revisiting the agronomic benefits of manure: A correct assessment and exploitation of its fertilizer value spares the environment. *Bioresource Technology*, *96*(2). https://doi.org/10.1016/j.biortech.2004.05.015

Stratful, I., Scrimshaw, M.D., & Lester, J.N. (2001). Conditions influencing the precipitation of magnesium ammonium phosphate. *Water Research*, *35*(17). https://doi.org/10.1016/S0043-1354(01)00143-9

Tyson, R.V., Simonne, E.H., White, J.M., & Lamb, E.M. (2004). Reconciling Water Quality Parameters Impacting Nitrification in Aquaponics: The pH Levels. *Proceedings of the Florida State Horticultural Society*, *117*.

Wang, X., Cuthbertson, A., Gualtieri, C., & Shao, D. (2020). A review on mariculture effluent: Characterization and management tools. In *Water*

(Switzerland) (Vol. 12, Issue 11). https://doi.org/10.3390/w12112991

White, P. (2017). Aquaculture Pollution: An Overview of Issues with a Focus on China, Vietnam, and the Philippines. In *Aquaculture Pollution*.

Zarski, D., Kucharczyk, D., Targońska, K., Chyła, B., & Dobrołowicz, A. (2008). Dynamics of changes in nitrogen and phosphorus compounds during intensive rearing of ide, leuciscus idus (L.), in a recirculating system. *Archives of Polish Fisheries*, *16*(4). https://doi.org/10.2478/s10086-008-0033-1

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

MONITORING OF ENVIRONMENTAL POLLUTION AS A RESULT OF THE ACTIVITY OF REARING AND PRODUCTION OF SWINE

Roxana-Gabriela POPA, Emil-Cătălin ȘCHIOPU, Irina-Ramona PECINGINĂ

"Constantin Brancusi" University of Targu Jiu, 30 Geneva Street, Targu Jiu, Gorj, Romania

Corresponding author email: roxanna_popa@yahoo.com

Abstract

The Danish company Premium Porc Group is the second largest producer of pork on the local market, the production activity being carried out in the 12 pig farms in Vrancea, Brăila, Constanta, Olt, Sibiu, and Brasov and since 2013 also within the Negreni farm in Olt County. The two lagoons for the storage and biological treatment of the liquid dejections have the bottoms and the soles waterproofed with geotextile membrane, and, to prevent the distribution of odours in the village, the dejections stored in these two ponds are permanently covered with a waterproof membrane. The solid dejections storage platform is located at a distance of 35 m from the two liquid dejections storage lagoons. To highlight how the activity of rearing and production of swine within Premium Porc Negreni Company from Olt County affects the quality of environmental factors, samples of air, rain water and groundwater were collected during 2018-2020 and subjected to analysis. The following quality indicators were analysed and monitored: NH_3 and H_2S emission (long-lasting 24 h and short-term 30-minute averages), pollutant emissions from combustion gases from the natural gas thermal power plant (particulate, CO, NO_2 and SO_2) and the noise in the air; pH, total suspended particulates (TSM) and total petroleum hydrocarbons (THP) from meteoric/pluvial water discharged into the Negrișoara stream; pH, nitrites and nitrates species in groundwater.

Key words*: air, rearing, swine, waste, water.*

INTRODUCTION

The Danish company Premium Porc Group is the second largest producer of pork on the local market, with an annual production of 400,000 heads in Romania, in the 12 pig farms in Vrancea, Brăila, Constanta, Olt, Sibiu and Brașov counties. Premium Porc Group has been operating in Romania since 2006, when pig production began with the acquisition of The Suintest farm in Goleşti commune, Vrancea County. In 2011, Premium Porc Group acquired the Fantanele and Sibioara farms in Constanta County, and in 2013 took over the Negreni farm in Olt County (Șchiopu, 2020).

The Danish Premium Porc Negreni swine farm in Olt County is structured in the following areas (Figure 1):

- the pig-rearing area, where the 12 shelter halls and related feeding and watering facilities are located (Figure 2);
- solid dejections storage area;
- liquid dejections storage and treatment area (made up of two waterproofed lagoons) (Figure 3);
- administrative area consisting of office buildings.

In order to characterize the evolution of milk production, the following indicators were used: number of cattle stocks, of which dairy cows and heifers, milk yield and milk production, milk consumption per inhabitant, number of dairy farms and cow density per ha.

The period analysed in this study was 1990-2010.

The data, collected from Ministry of Agriculture and Rural Development, have been statistically processed and interpreted, building the trend line and setting up the forecast based on simulation models for the period 2012-2015.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Figure 1. Areas related to the swine farm Premium Porc Negreni Company (production halls, solid dejections storage platform, liquid dejections storage lagoons, conservation lagoon/pond)

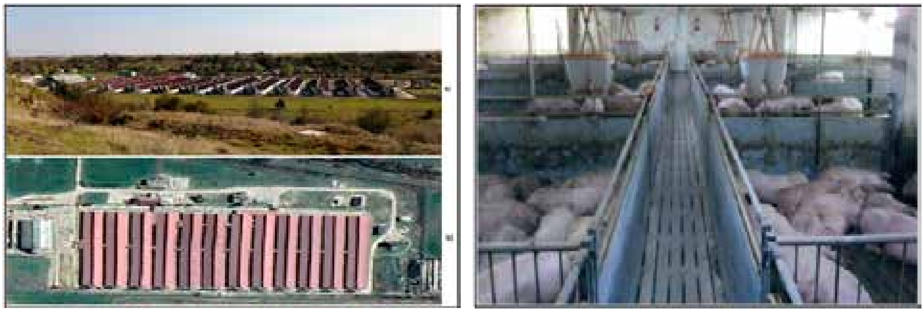


Figure 2. Location of the 12 pig rearing halls owned by SC Premium Porc Negreni Company (field image and satellite image taken with the help of Google Earth) and the interior of the intensive production and pig farming hall

Figure 3. Solid dejections storage platform and waterproof lagoon for liquid dejections storage

The technological flow related to the swine rearing and production within SC Premium Porc Negreni COMPANY is, as follows (Authorization integrity environmental, 2018):

- preparation of the halls for population: the cleaning and sanitization of the halls is carried out according to the production cycles (after the depopulation of the halls and before a new population); in the first stage, the liquid fraction flow systems are unlocked, producing a vacuum which ensures a rapid and efficient emptying of this fraction from the waste collection basins; removal of solid dejections from collecting basins, placed under the grates of the halls, cleaning of the floor, feeders and channels for the dejections discharge (using pressure water); sanitization of all hall compartments (with biodegradable disinfection solutions); the resulting waste water is routed and pumped into the two biological degradation basins;
- supply, storage and distribution of food: prepared feeding stuffs are purchased for use

directly for the pigs feeding, transported by special trucks equipped with pneumatic loading system; storing the feed in the bunkers adjacent to the halls (three for the C5 and C6 breeding halls and two for the other 10 fattening halls C1 - C4, C7 - C12);

- supply of weaned piglets (weighing 7 to 9 kg);
- pig rearing: in special purpose halls C5 and C6, by ensuring a lifestyle regime specific to this weight group;
- pig fattening: transfer piglets from the breeding halls, in series, to the 10 fattening halls, where they are housed until the optimum weight for delivery is reached;
- delivery of fattened pigs: by car to various beneficiaries, for slaughtering;
- carcase storage: collected and transferred daily to a refrigeration room; the services of an authorised operator are used;
- discharge of liquid and solid dejections with a frequency that depends on the weight of the animals: at 30 days (category 7-30 kg), at 20 days (category 25-50 kg) and at 100 days (weight greater than 50 kg);
- separation and temporal storage of dejections: collection of the mixture of liquid and solid dejections (in a concrete pool covered with geomembrane); separation of the two fractions; elimination of the solid fractions (on a concrete platform for temporary storage), the discharge of liquid fractions (by means of a concrete basin covered with geomembrane, to a two-compartment basin for filling and emptying the two lagoons covered with concrete plate); temporary storage of the liquid fraction (in two waterproofed lagoons and covered with geomembrane);
- waste valorisation: the two fractions resulting from the mechanical separation of the mixture of dejections and technologically waste water are periodically removed with specialized machinery for administration on agricultural land.

MATERIALS AND METHODS

The two lagoons for storage and biological treatment of the liquid dejections are located on the hill on the western part of the 12 pig-rearing halls. They have the bottom and soles waterproofed with geotextile membrane, and to prevent the distribution of odours in the village, the dejections stored in these two ponds are permanently covered with a waterproof membrane.

The solid dejections storage platform is located at a distance of 35 m from the two liquid dejections storage lagoons.

In order to highlight the way in which the activity of swine breeding and production within SC Premium Porc Negreni COMPANY in Olt County affects the quality of the environmental factors, in October 2020, field visits were made to identify the possible unpleasant smells.

In addition, in order to determine whether the rearing and production activity of swine contributes to environmental pollution in 2018-2019 were collected air, rainwater and groundwater samples and were subjected to analysis (Popa & Pecingină, 2008)

For air were investigated:

- ammonia NH_3 and hydrogen sulphide H_2S emissions (long-lasting 24 h and 30-minute short-term averages) by means of UV-VIS spectrometry;
- pollutant emissions from the combustion gases of the natural gas thermal power plant (particulate - by gravimetric method, carbon monoxide CO, nitrogen dioxide NO_2 and sulphur dioxide SO_2 - by automatic method with the help of the analyser equipped with specific sensors MULTILYZER NG);
- noise level - with the sonometer.

For meteoric/pluvial water discharged into the Negrişoara stream were monitored:

- pH using automatic pH-meter, total suspended particulates (TSM) by gravimetric method and total oil hydrocarbons (THP) by chromatographic method.

For groundwater were monitored:

- pH using automatic pH-meter, nitrites and nitrates by UV-VIS spectrometry.

RESULTS AND DISCUSSIONS

In the areas related to Premium Porc Negreni Company in Olt County, no unpleasant odour has been reported, so the quality of the environment and life in that area is not affected due to this organoleptic indicator, taking into account the following:

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

- the lagoon pond is in a state of conservation (Figure 4);
- the Negrișoara stream is dried up and the riverbed is polluted with waste from anthropogenic activities, especially PETs (Figure 5);
- the human settlements in the area are protected by forest curtains consisting of acacia, ulmus and willow.

Figure 4. Conservation-based lake and armoured pipe through which animals' dejections were transported in the past

Figure 5. Negrișoara creek polluted by waste from human activity, and forest curtain surrounding a property

The monitoring of air quality indicated the following aspects:

- ammonia NH_3 (long-lasting 24 h) (Figure 6) and 30-minute short-term averages (Figure 7) and hydrogen sulphide H_2S (long-lasting 24 h (Figure 8) and 30-minute short-term averages (Figure 9) did not exceed the maximum permitted limits according to STAS 12574/1987;
- pollutant emissions from combustion gases from the natural gas thermal power plant: particulate (Figure 10), carbon monoxide CO (Figure 11), nitrogen dioxide NO_2 (Figure 12) and sulphur dioxide SO_2 (Figure 13) did not exceed the maximum limits set by Order 462/1993);
- the equivalent noise level recorded at the limit of the functional unit of Premium Porc Company does not exceed the limit of 65 dB (SR 10009/2017) (Figure 14);

Regarding the ***analysis and monitoring of the quality of rainwater*** discharged into the Negrișoara stream, the following have been concluded:

- the pollutants in the meteoric/pluvial water discharged into the Negrișoara stream (total suspended materials and total THP oil hydrocarbons), do not exceed the maximum permitted limits of NTPA 001/2005 - Normative setting limits for the loading of industrial and urban waste water with discharge into natural receptors (Figure 15, Figure 16 and Figure 17).

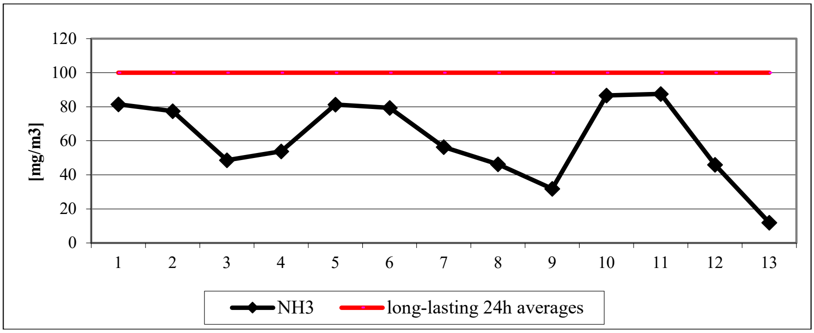


Figure 6. Variation in the concentration of NH_3 emission (long-lasting 24 h averages)

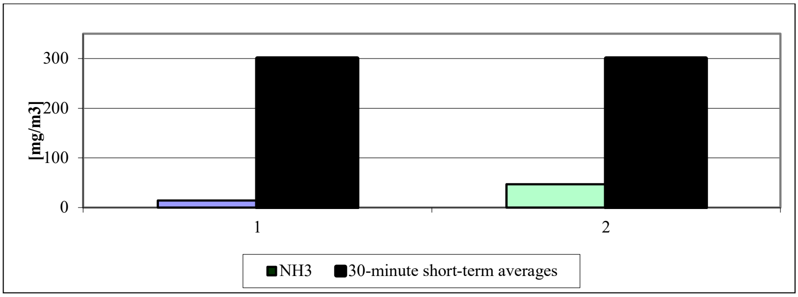


Figure 7. Variation in the concentration of NH_3 emission (30-minute short-term averages)

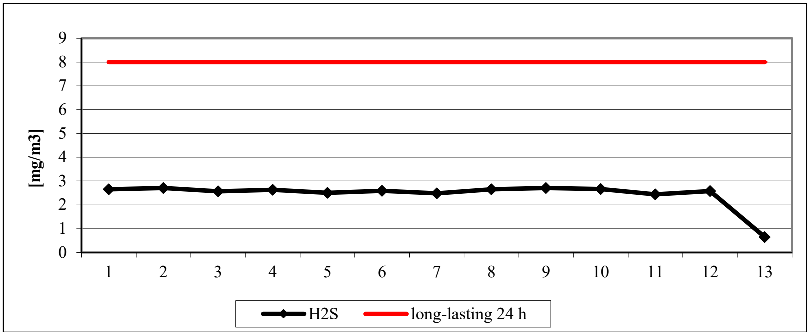


Figure 8. Variation in H_2S emission concentration (long-lasting 24 h averages)

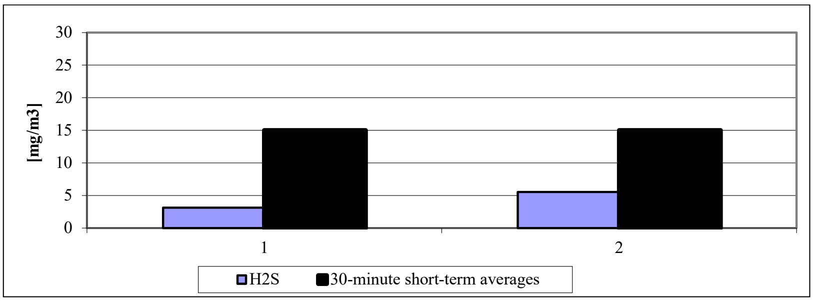


Figure 9. Variation in H_2S emission concentration (30-minute short-term averages)

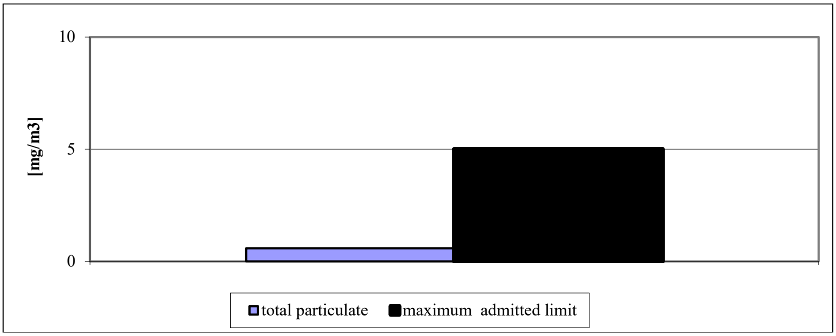


Figure 10. Variation in the concentration of total particulate from the combustion gases discharged by the power plant exhaust chimney

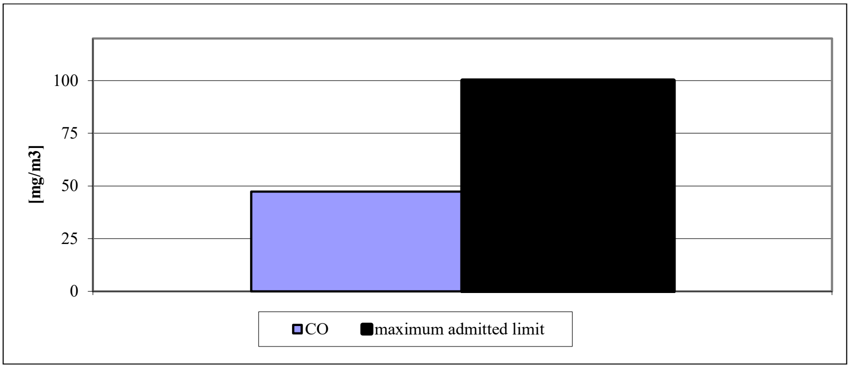


Figure 11. Variation in the concentration of carbon monoxide (CO) from the combustion gases discharged by the power plant exhaust chimney

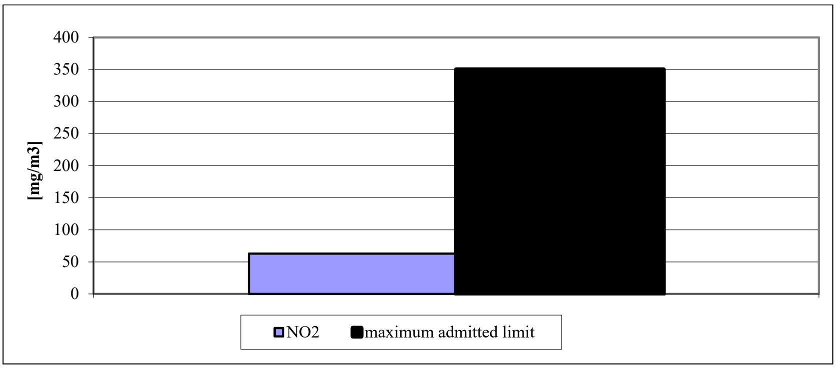


Figure 12. Variation in the concentration of nitrogen dioxide (NO_2) in the combustion gases discharged by the power plant exhaust chimney

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

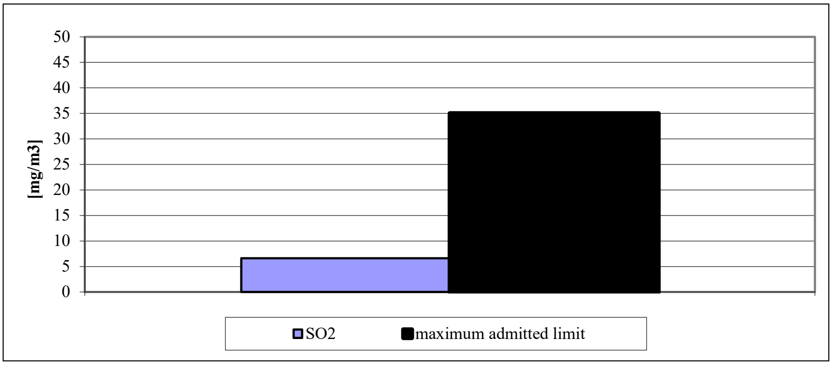


Figure 13. Variation in the concentration of sulphur dioxide (SO_2) in the combustion gases discharged by the power plant exhaust chimney

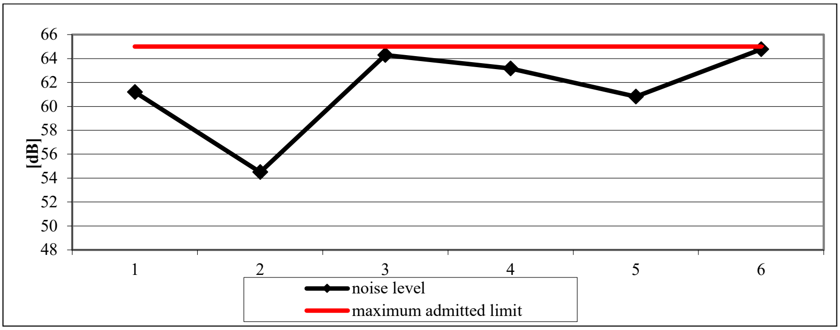


Figure 14. Noise level recorded at the boundaries of the functional unit of Premium Porc Company

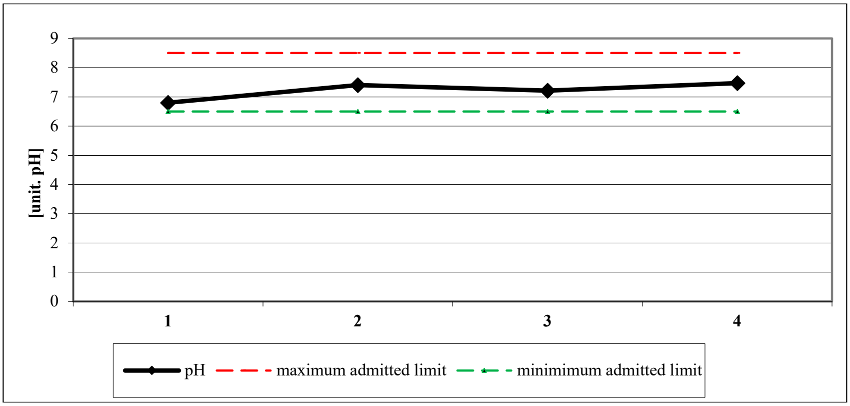


Figure 15. pH changes in meteoric/pluvial water

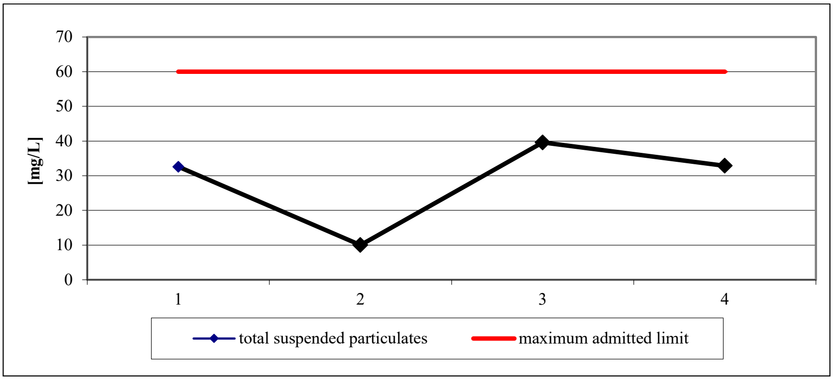


Figure 16. Total suspended particulates changes in meteoric/pluvial

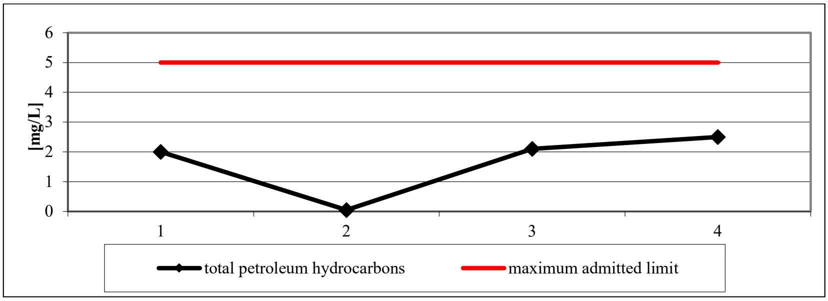


Figure 17. Variation of total petroleum hydrocarbons (THP) in meteoric/pluvial water

Analysis of groundwater indicated that pH and nitrogen pollutant species (nitrite, nitrate) levels do not exceed limits imposed by legislations (Law 458/2002), (Figures 18-20). F1-F6 represents the forages made in six groundwater collecting points.

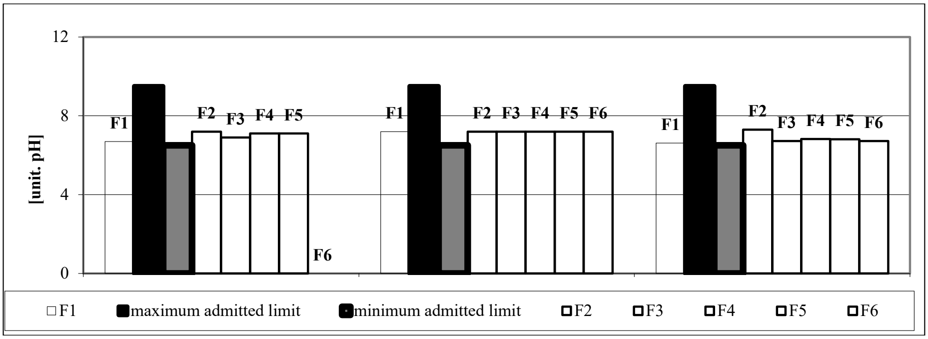


Figure 18. pH variation in groundwater

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

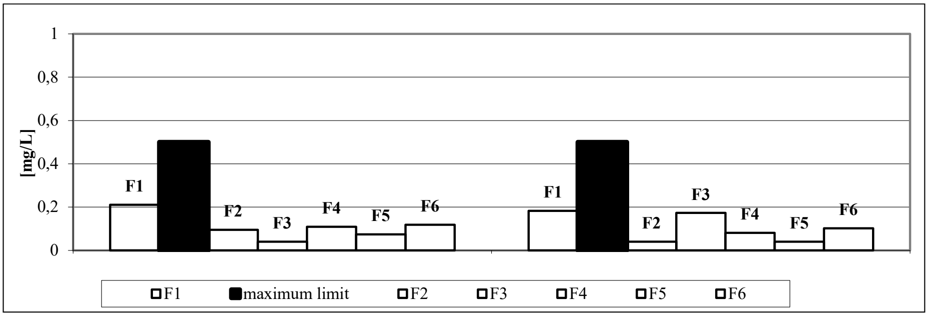


Figure 19. Nitrite - NO_2^- variation in groundwater

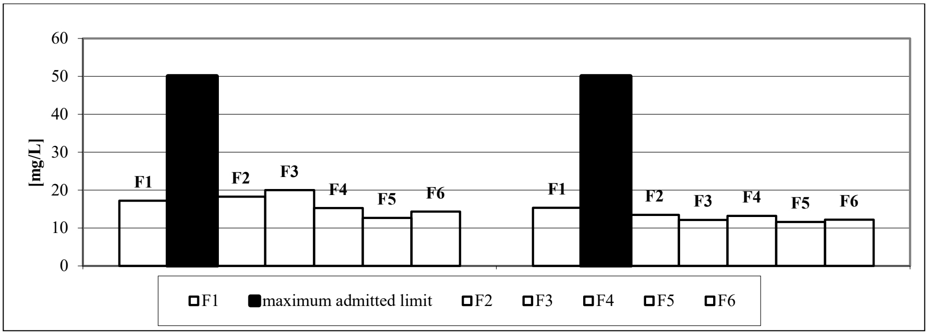


Figure 20. Nitrate - NO_3^- variation in groundwater

CONCLUSIONS

According to the monitoring and analyses performed in order to evaluate the pollution level generated by activity of swine farming and production, the following conclusions could be drawn:

- investigated quality indicators and pollutants levels did not exceeded maximum admitted levels according to legislation
- the lack of pollution is due to the application of the best available techniques for the prevention of environmental pollution in the zootechnical field, called Best Available Techniques in the national and European legislation
- leaks, emissions are formed, to contribute at the pollution of the environmental factors.

REFERENCES

Popa R.G., Pecingină I.R. (2008). *Water quality analysis. Pollution and depollution*, Publishing Sitech, Craiova.

Șchiopu, E.C. (2020) *Extrajudicial expertise report*, Negreni Farm, Scornicești, Olt.

Authorization integrity environmental, no. 1/19.02.2018

Law regarding the quality of drinking water, no. 458/2002.

STAS 12574/1987. *Air from protected areas. Quality conditions.*

SR 10009/2017. *Acoustics. Permissible ambient noise levels.*

NTPA 001/2005. *Norm on establishing the loading limits with pollutants of industrial and urban wastewater at the discharge into natural receptors.*

Order 462/1993 *for the approval of the technical conditions regarding the protection of the atmosphere and the methodological norms regarding the determination of the emissions of atmospheric pollutants produced by stationary sources.*

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ENVIRONMENTAL POLLUTION DUE TO ROAD VEHICLES, ALTERNATIVE SOLUTIONS (ELECTRIC VEHICLES, HYBRIDS, BICYCLES) SUSTAINABILITY OF CROWDED CENTERS OF CITIES

Marcel RUSCĂ[1], Levente DIMEN[1], Liviu MĂRCUȚĂ[2]

[1]"1st December 1918" University of Alba Iulia, 5 Gabriel Bethlen Street, Alba Iulia, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest,
59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: rusca.marcel@gmail.com

Abstract

Currently, the level of air pollution, especially in big cities, is above the allowed limits and this affects the health of the inhabitants and the environment. High levels of air pollution can cause a few respiratory and cardiovascular diseases. Based on these considerations, we draw attention to the major importance of research in the field of pollution, finding solutions to improve and minimize the negative effects of air pollution in general on the planet. Greater attention needs to be paid to actions to identify the sources of air pollution and its chemical composition, as well as to establish measures to monitor and improve the quality of the atmosphere. It is known that the level of air quality is influenced by the level of pollutant emissions. In the air we breathe, these emissions come from both stationary and mobile sources of pollution. Mainly road traffic, but also heating installations that use fossil fuels are the main suppliers of polluting emissions.
The rapid evolution of technology, as well as fierce competition from car manufacturers, is having an increasing impact on global consumption trends, and in the coming years, until 2025, several major changes are announced. Carbon dioxide emissions are expected to decrease due to fuel efficiency and the use of ultra-efficient hybrid cars. It is estimated that by 2025, almost a third of the car's carbon dioxide emissions will be reduced, so a natural question about the resource consumption of these cars will be higher or lower. Europe is made up of 50 states, in 31 of which natural gas, compressed or liquefied, is used as fuel for light or heavy commercial vehicles. According to studies carried out by the European Environment Agency, it has been concluded that the change in pollutant emissions is directly related to the speed of traffic. Thus, the carbon emissions increase 1.5 - 2 times during the acceleration / braking cycles and up to 25 times in the case of idling and the concentration of the emission of noxious substances increases in proportion to the speed.

Key words: *alternative transport, electric, environment, hybrid, pollutant emissions.*

INTRODUCTION

The atmosphere can be likened to a large chemical reactor that contains a multitude of chemicals. Among the anthropogenic activities, encountered mainly in urban areas, those that make a significant contribution to air pollution are industrial activities, means of transport, thermal power plants etc., which emit considerable amounts of pollutants into the atmosphere such as: suspended dust, carbon oxides, sulfur dioxides, nitrogen oxides. Dry air represents 99.964% of the total air. If water vapor is removed from the air, as well nitrogen, oxygen, argon, the remaining 0.036% air is the standard composition of the lower atmosphere and consists of carbon dioxide (0.0325%), neon (0.00182%), helium (0.000524%), methane (0.00015%), krypton (0.000114%), hydrogen (0.00005%). The other three dominant gases in the atmosphere are nitrogen (78.84%), oxygen (20.946%), argon (0.934%) (Green Paper 2007).

Today, the investigation of the level of air and environmental pollution is in a period of great interest because the problems related to urbanization and industrialization, negatively influence life in an increasingly aggressive way by increasing the level of pollution, by changing the climate, but also by multiplying extreme phenomena.

In the process of degradation of air quality, natural sources also contribute to some extent, but the major cause of environmental pollution are anthropogenic activities, more and more intense, namely industrial activities, means of transport, thermal power plants etc., which emit considerable amounts of pollutants into the atmosphere, such as suspended dust and gases, mainly carbon oxides, sulfur dioxide, nitrogen oxides etc. (Development Strategy, 2014-2020; Preliminary Reports, 2015-2019; Ruscă, 2022).

MATERIALS AND METHODS

Solving the problem of air pollution in big cities is still a thorny issue even for experienced states. Reducing environmental pollution requires a multidisciplinary approach in which specialists in various fields must be trained: environmental protection, chemistry, specialists in the field of urban planning and landscaping, public health, police, environmental research, computer science, engineering, media, non-governmental organizations, etc. In urban centers where there are many cars, it is very important for the health of the inhabitants to reduce the pollution due to the cars. It is known that about 15% of the EU's CO_2 emissions are due to cars and buses, as well as other vans. The EU has passed a law to strengthen gas emission standards, introducing a CO_2 reduction target of 37.5% for new cars and 31% for new vans by 2030.

Two methods are mainly used to determine particles in the atmosphere, namely:

Gravimetric method - a pump draws from the ambient air a constant flow, in a special device where the particles are separated depending on the size; the filtered particles are then collected on a special filter which is then weighed; weighing takes place in a controlled environment in terms of temperature and humidity; the total volume of aspirated air is known, and by weighing and performing the difference in weight of the filter, before and after sampling (measured in μg/ m^3);

Optical methods - photometry is the part of optics in which the intensity of radiation sources is studied, as well as some quantities related to this intensity (luminous flux - Φ, intensity of scattered light, intensity of absorbed light). Photometers are composed of a sensor, which changes certain electrical properties under the action of lighting, placed in a suitable electronic circuit to detect those changes.

Particle analyzers - new generations, perform real-time measurements of aerosol fractions; The advantage of this device is that the model of this photometer combines the functions of a photometer with an optical particle counter; it records several dimensions of the optical particles and calculates their mass on several mass fractions measured simultaneously (Monitor Aerosol DUST TRAK).

The measurements on the level of air pollution caused by heavy traffic were made in the city of Alba-Iulia. Measurement areas have been established based on heavy traffic criteria and the importance of air quality in certain more special areas, such as near schools and hospitals.

To establish the air quality measurement points in Alba Iulia, we started from the idea of performing two stages of measurements: one in spring to summer and one in autumn to winter, to have different climatic conditions.

In both stages, the establishment of points with heavy traffic in the municipality was considered, as well as the establishment of measuring points with a high degree of impact, is sensitive areas for the population (schools and kindergartens, hospitals, agri-food market).

RESULTS AND DISCUSSIONS

The main pollutants found in the measurement areas are carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM_{10}, $PM_{2.5}$), sulfur dioxide (SO_2), volatile organic compounds (VOCs). The sources of these substances are different, as is the impact on human health, which makes air pollution a difficult and complex process to combat. PM_{10} is primarily caused by road activity, burns and fuel emissions, due to brake wear, tires, and the removal of anti-skid material from the road (Suciu, 2015).

We will present the results obtained in the two stages in which the values of the fine particles PM_{10} and $PM_{2.5}$ were determined for the chosen points, the analysis and interpretation of the results and finally the conclusions that can be drawn from these determinations.

The following conclusions can be drawn regarding the two stages in which 10 measurement points were established each time:

the average values of $PM_{2.5}$ suspended particles were 37.60 μg/m^3; the average values of PM_{10}

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

suspended particles were 34.70 µg/m^3; the mean value of volatile organic compounds VOC was 1.201 mg/m^3; the average value of the carbon dioxide was 570.60 ppm. These results can be seen in the Figures 1, 2, 3 and 4. The centralization of measurements are presentet in Tables 1 and 2.

Table 1. Centralization of measurements in the first stage

Measuring point	$PM_{2,5}$ µg/m^3	PM_{10} µg/m^3	COV mg/m^3	CO_2 ppm	Nr. Auto-vehicles
1	36	25	6.7	607	59
2	27	28	0.6	559	48
3	45	57	1.3	556	65
4	29	28	1.4	557	46
5	33	32	0.3	553	57
6	39	31	0.2	581	55
7	40	40	0.3	537	44
8	39	38	0.5	562	57
9	41	36	0.3	555	48
10	47	32	0.4	639	50
Average value	37.60	34.70	1.201	570.6	52.9

Table 2. Measurement summary in the second stage

Measuring point	$PM_{2,5}$ µg/m^3	PM_{10} µg/m^3	COV mg/m^3	CO_2 ppm	Nr. Auto-vehicles
1	73	95	6.4	608	74
2	72	93	9.0	686	73
3	68	90	4.1	448	68
4	66	82	3.1	448	64
5	45	48	0.2	445	48
6	46	39	0.2	597	-
7	45	45	0.2	399	-
8	43	44	1.6	415	48
9	45	42	0.2	405	-
10	68	87	1.4	562	63
Average value	57.10	66.50	2.62	501	65.3

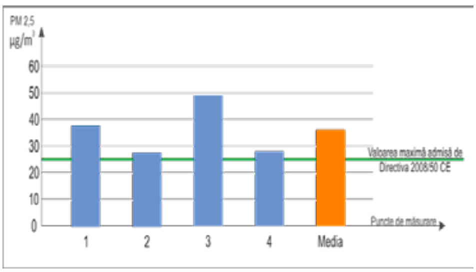


Figure 1. Representation of values $PM_{2.5}$ in the first stage

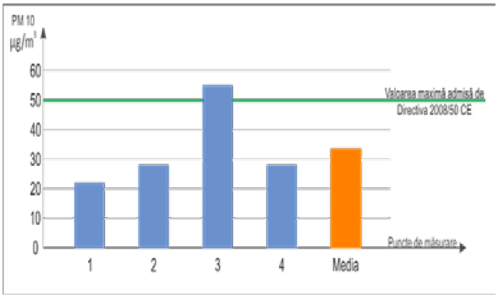


Figure 2. Representation of values PM_{10} in the first stage

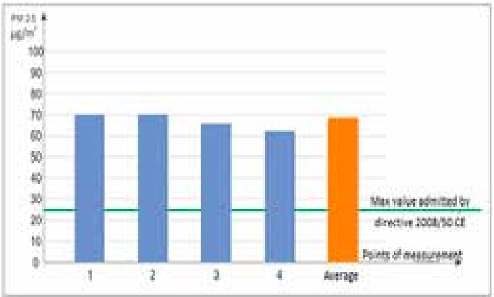


Figure 3. Representation of values $PM_{2.5}$ in the second stage

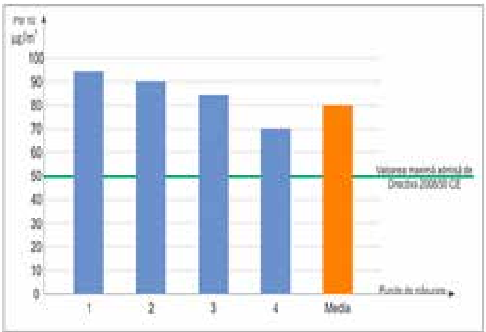


Figure 4. Representation of values PM_{10} in the second stage

It is found that even at this stage:
- the average values of $PM_{2.5}$ suspended particles were 57.10 µg/m^3,
- the average values of PM_{10} suspended particles were 66.50 µg/m^3,
- the mean value of VOC volatile organic compounds was 2.62 mg/m^3,
- the average value of the carbon dioxide was 501 ppm (Development Strategy, 2014-2020; Preliminary Reports, 2015-2019; Ruscă, 2022).

Alternative transport - benefits and necessity

Solving the problem of air pollution in big cities is still a thorny issue even for experienced states. Reducing environmental pollution requires a multidisciplinary approach in which specialists in various fields must be trained: environmental protection, chemistry, specialists in the field of urban planning and landscaping, public health, police, computer science, engineering, media, non-governmental organizations etc.

In urban centers where there are many cars, it is very important for the health of the inhabitants to reduce the pollution caused by the cars. It is known that the cars and buses, as well as vans cause about 15% of the EU's CO_2. EU adopts law to strengthen gas emission standards, introducing a CO_2 reduction target of 37.5% for new cars and 31% for new vans by 2030.

The main measures to reduce road traffic pollution in urban centers could be the following:

- reduction of road traffic through the locality;
- control of industrial pollutant emissions, as well as the establishment of clear rules on the accepted level of emissions from motor vehicles;
- develop and update local and regional action plans that set out the conditions to be taken to improve air quality;
- use of electric vehicles;
- use of catalytic converters;
- maintaining street cleaning;
- placement of sound-absorbing and sound-insulating panels.

The serious problem is that pollutants gases are eliminated very close to the ground, which leads to the achievement of high concentrations at very low levels, in the area of human respiration, even for these gases that have a low density and high diffusion capacity in the atmosphere.

From an environmental point of view, it is necessary to keep in mind that "alternative" fuel sources are not enough. Fuels must come from renewable sources if we want to have a viable transportation system. Among a wide range of options, the focus is on processed organic fuel, namely biofuels. They offer some gains to the transport sector. Car transport removes up to 50% of the number of hydrocarbons in the atmosphere, being considered the main pollutant with organic substances in urban areas (www. carbon solutions lobal.com). It is estimated that in the European Union, about 28% of greenhouse gas emissions are caused by transport, 84% of which come from road transport. Traffic in urban areas of the European Union accounts for more than 10% of carbon emissions. Pollution regulations are intended to reduce the polluting emissions of motor vehicles (Green Paper 2007; Tănăsescu, 2012; Vasile N., 2010).

Around 65% of the EU population is exposed to unacceptably high noise levels, mostly caused by urban traffic, causing discomfort and health problems (higher heart rate, mental and sleep disorders, hearing problems, stress, etc.) The energy sector will only halve the number of emissions needed to limit global warming by 2 degrees Celsius by 2050.

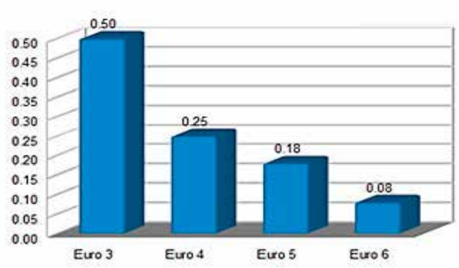


Figure 5. Emission limit of vehicles with diesel engines (g/km), https://www.e-automobile.ro/categorie-motor/19-diesel/140-adblue-motor-diesel-uree-scr.html

The EU must to improve energy efficiency and to promote renewable energy sources in order to significantly reduce CO_2 emissions, by 80-95% compared to 1990 levels, such that avoid catastrophic changes in the natural environment.

Around 98,000 electric vehicles were sold in EU during the year 2016. In 2020, at the level of the EU, a number of 538,772 electric cars were registered, which means an increase of 117.4% compared to 2019. In other words, the result translates as follows: one of 20 cars registered last year in the EU it was an electric one (Tănăsescu, 2012; Vasile N., 2010; Preliminary Reports, 2015-2019).

The electric cars are more efficient and more environmentally friendly, but their impact will depend on the way that electricity is produced.

If the electricity is produced by wind, solar or nuclear energy, carbon dioxide emissions will disappear, as a result air quality will improve and, in addition, the costs of producing electricity will be lower than those for the purchase of fuel (Figure 6).

Figure 6. Power supply stations
(https://cleantechnica.com/2012/08/26/solar-powered-electric-vehicle-charger-launched/)

Given that the purchase price of an electric car can exceed by more than 100% the price of a conventional car, whether it is petrol or diesel, it is unlikely that in the near future there will be a change in the perception of buyers.

A particularly important problem facing electric cars, apart from the high price, is their autonomy, which can reach a maximum of 500 kilometers (Tesla cars) under certain conditions, and the usual ones at a maximum of 100 kilometers.

However, the growth of the new electric car fleet in 2021 was a total success, with the number of new vehicles sold this year approaching the value of the national electric car fleet at the end of 2020 (Figure 7).

A number of 6340 vehicles were registered in total, of which 398 were used vehicles.

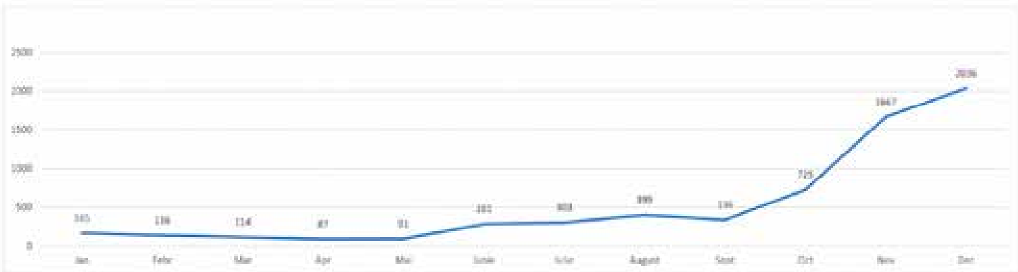


Figure 7. Romanian situation of vehicle registration in 2021
(https://electromobilitate.com/situatia-inmatricularii-autovehiculelor-electrice-noi-in-2021/)

On the other hand, many European countries want a major boost to the development of cycling infrastructure and will ban car access to central areas as an additional measure in its fight against road traffic pollution. The annual economic value of the benefits of cycling in the European Union has recently been calculated based on data provided by the European Cycling Federation.

At the European level, the manufacture of bicycles brings revenues of about 4.3 billion euros, their sale and repair generate transactions of almost 1 billion euros, and tourism and other small businesses also benefit from the use of the bicycle (Horizon 2014-2020; Green Paper 2007; Vasile N., 2010).

Furthermore, giving up cars, the citizens save fuel worth almost 3 billion euros. By increasing the proportion of walking, cycling, car sharing programs and by introducing mobility plans, work flexibility, training and awareness, the following benefits are obtained: less congestion in cities; low CO_2 emissions; increased skills and quality of life, productivity at work and a longer life; decrease in cases of obesity caused by inactivity, heart disease, health costs; avoiding new and expensive infrastructure by making full use of existing capacity; increasing job stability for employees. Authorities are encouraged to make the transition to renewable energy, improve public transport and manage their natural resources sustainably. In addition, these are encouraged to create the necessary conditions for sustainable and inclusive economic growth, social and cultural development, and the protection of the environment.

The transport policy aims to promote efficient and safe transport services, but also responsible in terms of environmental protection and social

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

implications. Under these conditions, all cities in Romania have the opportunity to switch to a green public transport. However, non-reimbursable financing comes with some requirements. In the case of the purchase of new vehicles, the existence of a public service contract between the operator and the competent authority is strictly necessary. In addition, the private companies carrying out local public transport must have a fleet of 50% of electric vehicles starting with 2020. In the explanatory memorandum, the parliamentarians also provided some interesting statistics, according to which, in the European Union, 28% of greenhouse gases are emitted by means of transport, and 10% of them come from urban traffic. Most cities in Romania will have to buy electric buses (Horizon 2014-2020; Vasile N., 2010).

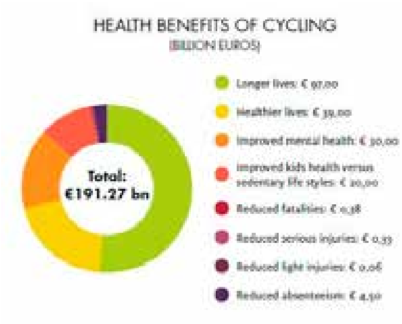


Figure 8. Economic benefits due to the use of the bicycle (https://cyclingindustry.news/ecf-presentation-to-place-cyclings-economic-contribution-at-e1000-per-head-per-year-across-eu-28/)

Figure 9. Electric buses, means of transport in the future (http://europa.eu/!hd87pN)

Heliox a manufacturer of electric batteries, has combined decades of experience in power generation with environmental skills specific to today's era and has invented a fast-charging battery system for zero-emission public transportation. This great manufacturer saw the potential for a sustainable solution and built an innovative technology that could charge an electric bus in just 2-5 minutes, an invention that creates the premises for a non-stop public transport system with zero emissions and fully powered by renewable energy. The manufacturer has developed integrated electrical networks for trucks. These systems will supply green electricity to the refrigeration system of goods, to increase fuel efficiency and reduce emissions during long-distance travel in the EU. From our point of view, the monopolization of the market with electric vehicles would significantly reduce the impact that the transport activity has on the environmental factors. This would substantially reduce greenhouse gas emissions, as those caused by road transport account for 84% of total emissions from transport activity.

The need for electric and hybrid vehicles

It is not a novelty that in our country most of the electricity is produced by thermal power plants, which is a major disadvantage, because to charge our car, we will pay a really high price. The LPG system outperforms petrol and diesel cars, but electric cars are the future of the automotive industry; the road to production at a reasonable cost and with minimal impact on the environment is quite long. Based on these realities, we believe that at the moment the best solution is to buy a petrol car, which we will later equip with LPG, and thus we have a more environmentally friendly vehicle, which ends up eliminating around 100 grams of carbon dioxide per kilometer, instead of 150 grams per kilometer, as it produces in the classical system. Hybrid engines (thermal engine + electric motor) combine the advantages of both thermal and electric motors and can be designed to achieve different objectives: low fuel consumption or high dynamic performance. A car with a hybrid propulsion system maintains and even increases the autonomy of a classic car with thermal engine. In the case of a hybrid car, the heat engine is designed to run optimally in terms of consumption. Also, the kinetic energy during the car's braking (mechanical energy) is

recovered (electricity) and stored in batteries (chemical energy) for later use. In situations where strong accelerations of the car are required, the electric motor can assist the thermal engine for a short time when the car leaves the place, the propulsion is purely electric, and while the car is parked the thermal engine is stopped, to avoid unnecessary consumption of fuel during idling (idling). The main disadvantage of hybrid cars is the high price, well above the level of a conventional car with similar consumption and dynamic performance (Green Paper 2007; Vasile N., 2010; www.e-automobile.ro).
Electric cars are powered by electric motors, powered by electricity stored in batteries.
A peculiarity of electric motors, used for the propulsion of cars, is given by the fact that they can also operate in generator mode. Thus, when braking or descending long slopes, electric cars produce electricity that is stored in batteries. The advantage of electric cars is the absence of pollutant emissions, quiet operation and lower maintenance costs. All these advantages are overshadowed by a number of disadvantages: high price (mainly due to the battery) and low battery life. A large proportion of electric cars (and a growing number of combustion-engine cars) have braking energy regeneration systems, which convert the energy lost during braking into electricity. A major increase in the future use of these systems is expected.

Benefits

1. Consumes little fuel - 0 l/km, even when running on range extender - 6.5 l/100 km (petrol).
2. They have a phenomenally fast start due to the torque available fully instantly in electric mode.
3. Overtaking is done very quickly also due to the torque.
4. The feeling of floating on the asphalt.
5. The electric cars are silent.
6. You don't pollute the city, even if you still don't save the planet. But you breathe easier, and as electricity is produced from renewable resources, you really become “eco”.
7. The heating systems run very fast; they do not depend on the engine heating.
8. Reliability - electric motors are much simpler than combustion engines.
9. The electric cars are a lower center of gravity; the roll is absent and you feel crank in short maneuvers.
10. Overall, an electric car is always fun, regardless of generation.
11. The great advantage of 100% electric cars (so powered only by electric motors, powered by batteries, without other auxiliary propulsion systems) is that they do not pollute during operation. This also applies to cars that use hydrogen, because during operation such a car only removes water vapor.

Disadvantage

1. They lose value quickly because they age quickly - the autonomy doubles every 4 years, the SF interiors yesterday are gone today, and the autonomy of the old batteries decreases from year to year.
2. The autonomy of electric cars is still low to be the only family car.
3. They are generally heavy machines, if they are not built from scratch as electric machines (i3 gets rid of this shortcoming).
4. They are rigid, which can affect comfort.

In the case of electric batteries, the most polluting part of current lithium-ion technology is the extraction and processing of lithium. In the worst case, we could say that this component is equivalent, in terms of pollution, to the production of fossil fuels. In other words, the electricity needed for batteries is slowly but surely becoming more and more "green", meaning that it is becoming less and less polluted for its production. It is known that in the case of an electric car, almost half of its price is attributed to the propulsion system, of which the largest share of the cost is the battery, while the electric motor and other electronic components (especially the inverter) are more expensive. However, the decline in production prices is dizzying compared to conventional propulsion technologies, and electric cars are rapidly becoming competitive. It's all about the low energy density of current batteries, which leads to drastic limitations on battery life. In principle, most current electric cars offer a maximum range of 200 km (Tesla Model S is better, with up to 500 km of theoretical range, but we are also talking about a price 3-4 times higher than other electric cars). Charging from a normal 220V outlet

takes 6-8 hours, while special fast charging systems take 20-30 minutes, providing only 80% of the battery capacity.
In other words, today's electric cars are not suitable for long journeys, but only for short escapades (specific to commuting) or urban transport (Horizon 2014-2020; Vasile N., 2010; www.e-automobile.ro).

CONCLUSIONS

The values set to reduce the level of pollutant emissions provide for a reduction of about 40% by 2030 of pollutant emissions and the use of green energy in a percentage of at least 30%.
It is also necessary to implement and comply with standards for the level of particulate emissions with certain dimensions, also for ozone, sulfur dioxide, carbon dioxide, carbon monoxide nitrogen oxides, lead, VOCs and other pollutants which have a detrimental effect on human health or natural ecosystems.
There is a need to develop and update local and regional action plans that set out the conditions to be taken to improve the quality of the atmosphere.
Some low-emission areas should be established, restricting the access of vehicles with high levels of pollution.
Increasing the green surfaces within the localities by expanding the existing ones and creating new green spaces through the national program to improve the quality of the environment by creating green spaces in the localities, financed by the environmental fund.
The market potential of connected cars will increase in volume almost fourfold by 2023.
The development of new studies on smart cars, connected to the Internet, will dominate the car market in the next five years as an estimated 80 million new vehicles connected to the Internet by the end of 2023.
From the economic point of view related to pollution, in the short and medium term all electric cars would be 100% advantageous over hydrogen cars.
Smart cars, connected to the internet, will dominate the car market for the next 20 years. Estimates show that by 2025 there will be 38.6 billion networked devices, and by 2050 there are an estimated 50 billion connected devices, according to a study. The car industry is now working hard to develop internet-connected cars. Approximately 250 million vehicles connected to the network will already be on the road by 2025. In 2016, 12 million new vehicles were produced, which include these network functions, in 2020 their number reached 60 million pieces.
The market potential of connected cars will increase in volume and by the end of 2025 an increase of up to 100 million new vehicles is estimated to be equipped with such devices. By 2030, the network of connected cars could reach up to 115 billion euros, the largest growth segments would be the autonomous driving area, the safety zone (warnings of possible accident), as well as the one in the wellness area.
From an economic point of view related to pollution, in the short and medium term all electric cars are 100% more advantageous than hydrogen cars.
The degree of pollution of electric cars is closely related to the degree of pollution of sources of electricity, which is not equivalent to saying that "electric cars pollute more than conventional cars", because electricity does not come only from combustion fossil fuels, but also from renewable sources.
Urban pollution triggers symptoms of autism and schizophrenia, urban pollution is the trigger for many diseases, some of which can be fatal. Pollution in big cities also contributes to global warming.
Urban pollution triggers the symptoms of autism and schizophrenia, it is also the trigger for many diseases, some of which can be fatal.
Pollution in big cities also contributes to global warming.

REFERENCES

Green Paper (2007). Towards a new culture of urban mobility, Brussels, 25.09.2007.
Horizon 2020 - European Union Framework Program for Research and Innovation, 2014-2020.
Rusca M. (2022). Doctoral Thesis - The impact of road transport on the environment in urban areas
Suciu A. (2015). Doctoral thesis - Studies and research on the determination of suspended material particles in the urban environment.
Tanasescu F.T. (2012). The works of the 7th edition of the Annual Conference of Astr. 2012, Urban Electric Transport in large urban agglomerations. present and perspectives.

Vasile N. (2010). The electric car. A product of technological innovation, sustainable development and the international economic and geopolitical situation, *Romanian Journal of Innovation*, No. 6-7, Bucharest.

* * * Alba County Development Strategy 2014-2020

* * * Preliminary reports on ambient air quality for 2015-2019 in Alba County.

https://www.e-automobile.ro/categorie-motor/19-diesel/140-adblue-motor-diesel-uree-scr.html

https://electromobilitate.com/situatia-inmatricularii-autovehiculelor-electrice-noi-in-2021/

http://europa.eu/!hd87pN

https://cyclingindustry.news/ecf-presentation-to-place-cyclings-economic-contribution-at-e1000-per-head-per-year-across-eu-28/

https://cleantechnica.com/2012/08/26/solar-powered-electric-vehicle-charger-launched/

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE USE OF *PECTINATELLA MAGNIFICA* AS BIOINDICATOR FOR HEAVY METALS POLLUTION IN DANUBE DELTA

Ira-Adeline SIMIONOV, Mădălina CĂLMUC, Alina ANTACHE, Valentina CĂLMUC, Ștefan-Mihai PETREA, Aurelia NICA, Victor CRISTEA, Mihaela NECULIȚĂ[3]

"Dunarea de Jos" University of Galati, 47 Domneasca Street, Galati, Romania

Corresponding author email: ira.simionov@gmail.com

Abstract

Water pollution with heavy metals is a persistent and hazardous issue, due to these pollutants incapacity to decompose and their tendency to accumulate in biota. These effects extend on the aquatic ecosystems from Danube Delta, which are subjected to anthropogenic pressures, due to intensive agriculture practices, intense tourism activities and the lack of sewage systems. In the context of global warming effects, alien species are developing in the waters of Danube Delta, such as Pectinatella magnifica. The present study explores the hypostasis according to which the aforementioned bryozoan can be used as a suitable bioindicator for heavy metals pollution in Soschi Lake, Danube Delta. Samples of water, sediments and biota were collected from the study area and the following metals were analysed: cadmium, lead, nickel, chromium, iron, zinc, copper, manganese and cobalt. The bioaccumulation factor was calculated, in order to highlight the accumulation potential of the bryozoan. The obtained values of metals concentration were compared to the national regulation related to the quality of surface waters. The following accumulation trend was identified in the bryozoan: Fe>Zn>Mn>Cu>Ni>Cr>Co>Cd>Pb.

Key words: *bioindicator, Danube Delta, bryozoan, heavy metals.*

INTRODUCTION

Water resources are essential for sustaining human and animal life (Zamora-Ledezma et al., 2021). However, the quality of water resources is compromised by the global pollution crisis generated by urbanization and industrialization (Dai et al., 2022). Heavy metals are ubiquitous and persistent pollutants in an aquatic ecosystem due to their inability to decompose (Obinna & Ebere, 2019). Even though heavy metals are those metallic elements from the periodic table with an atomic density higher than water, a hazardous potential poses mainly lead (Pb), cadmium (Cd), nickel (Ni), and chromium (Cr), (Kinuthia et al., 2020).

In aquatic ecosystems, heavy metals represent a group of pollutants of priority concern, due to the associated health risks that they can pose on human consumers through transfer via the food chain (Dey et al., 2021). Also, the presence of heavy metals in water systems is considered an efficient tool for assessing the health of the ecosystem and levels higher after a certain limit can cause deleterious effects on the resident biota (Hasan et al., 2022). Thus, the need to monitor and assess water quality is well justified (Poshtegal & Mirbagheri, 2019). However, continuous monitoring of aquatic ecosystems involves the coverage of high spatial and temporal dimensions, which generate high economic costs (Rao et al., 2013).

In order to optimize the economic sustainability of the water quality monitoring activities, the scientific community proposes the use of bioindicators to assess the impact of a certain contaminant on the aquatic environment in which is present (Kadim & Risjani, 2022; Parmar et al., 2016; Zaghloul et al., 2020). Biological indicators are represented by any living organism (microorganisms, plants and animals) that is used as an instrument to detect pollutants in a target ecosystem (Zaghloul et al., 2020). The use of bioindicators for heavy metals water pollution has a series of advantages including the identification of early stages of pollution at relatively low concentrations (Kadim & Risjani, 2022; Parmar et al., 2016).

The ecological importance of Danube Delta is well known, being the largest river delta

wetland in Europe and due to its abundant species biodiversity (Gómez-Baggethun et al., 2019; Güttler et al., 2013). Also, given the fact that global warming positively influences the spread of non-native species beyond their native habitat, it is expected that new species will arise as bioindicators for the invaded ecosystem (Finch et al., 2021).
Therefore, the present study aims to establish if an invasive bryozoan can be used as an efficient bioindicator for heavy metals pollution in Soschi Lake, Danube Delta.

MATERIALS AND METHODS

Samples of water, sediments and bryozoans were collected from Soschi Lake, Danube Delta (Figure 1) in September 2020.
The biological material used in the present paper is represented by the bryozoan *Pectinatella magnifica* (Leidy, 1851), which was retrieved from Soschi Lake, Danube Delta. This is the first time that the presence of this organism is reported in the Sfântu Gheorghe branch part of the Danube Delta. *P. magnifica* is a freshwater invertebrate specie, native to Mississippi River, eastern part of North America (Kollar et al., 2016; Todorov et al., 2020).
The magnificent bryozoan develops around submerged vegetation by forming large gelatinous colonies with ciliated tentacles. Each layer of zooids is attached to the firm and transparent jelly (Wang et al., 2016). The presence of this organism in water systems generates an increase in water transparency due to its feeding behaviour (Todorov et al., 2020).
The magnificent bryozoan feeds through water filtration and it consumes high quantities of autotrophic and heterotrophic organisms such as diatoms, green algae, cyanobacteria, dinoflagellates, rotifers, protozoa, small nematodes, microscopic crustaceans (Năstase et al., 2017).
The biological material was stored in polyethylene bags and kept on ice until transportation to the laboratory (MoRAS Research Centre, "Dunărea de Jos" University of Galați) (Figure 2).

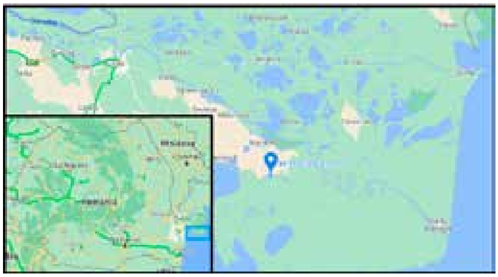


Figure 1. Study area – Soschi Lake, Danube Delta

Figure 2. *Pectinatella magnifica* (Leidy, 1851); (Bryozoa: Plumatellida:Pectinatellidae)

Sediment samples were place in Petri dishes and dried for 24 hours at 105ºC (Figure 3).

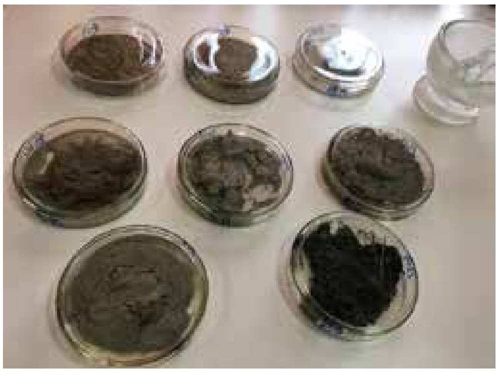


Figure 3. Dried sediment samples

Prior to analysis all samples were digested using nitric acid (Suprapure HNO_3 65-69%) and hydrogen peroxide (H_2O_2 38-40% for EMSURE Analysis) in a 5 step digestion program and by using TopWave equipment by Analytik Jena, Germany (Table 1).

Table 1. Techical parameters of the digestion program

Step	Temperature	Pressure	Ramp	Power
1	180	50	6	90
2	50	0	1	0
3	50	0	1	0
4	50	0	1	0
5	50	0	1	0

The digested sediment samples were filtered before analysis (Figure 4).

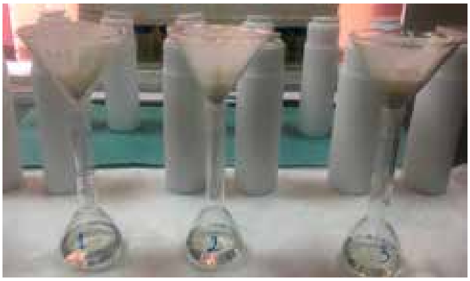


Figure 4. Sediment samples filtration

For the quantification of metals in the samples, the high resolution continuum source atomic absorption spectrometry was used (flame and graphite furnace techniques). The following elements were determined from the samples: potassium (K), sodium (Na), magnesium (Mg), iron (Fe), zinc (Zn), nickel (Ni), copper (Cu), chromium (Cr), manganese (Mn), cobalt (Co), lead (Pb) and cadmium (Cd).
In order to highlight the accumulation potential of *Pectinatella magnifica* the bioaccumulation factor (BAF) was calculated:

$$BAF = \frac{concentration\ of\ element\ in\ organism\ (\mu g\ g)}{concentration\ of\ element\ in\ sediments\ (\mu g\ g)}$$

RESULTS AND DISCUSSIONS

Macro-elements such as K, Na and Mg play an important role in heavy metals toxicity in aquatic environments. It is well known that the aforementioned ions compete with heavy metals for binding spots and that high concentrations of water hardness decreases the toxicity of heavy metals. The concentration of K, Na and Mg was significant much higher in the water (dissolved state) compared to the sediments (Figure 5). For instance, the concentration of Na registered values 20 times higher in the water compared to the sediments. The same phenomenon was observed in case of K and Mg. In case of iron concentration, the values registered in the sediments (9857 µg/g) were much higher than those in the water (26.98 µg/L). This could be explained by the fact that in highly oxygenated waters the iron dissolved in the water precipitates as $FeOH_3$.

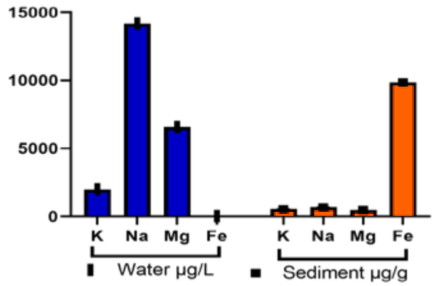


Figure 5. The concentration of K, Na, Mg and Fe in water and sediment samples

In case of the rest analysed heavy metals, it is highlighted that they concentrate in the sediments. For instance, the hydro-solubility of Cu is relatively low and this element tends to accumulate in the sediments (Weber et al., 2013). This phenomenon was observed in the present study also. As well, high amounts of Cu accumulate in water ecosystems due to the use of fungicides in agricultural activities, and the use of copper sulphate in the irrigation channels (Micó et al., 2006).
The toxicity of Zn decreases in waters with high alkalinity and salinity. Thus, in the present study it can be assumed that Zn precipitates in the sediments (25.97 µg/g) due to the high concentration of Na in the water column. Another metal which has the tendency to accumulate at the level of sediments was Mn and it registered values 7 times higher (110.27 µg/g) than those in the water (16.7 µg/L).
The toxicity of Ni is positively influenced by low values of water hardness and pH. In an aquatic ecosystem, Ni is found in trace amounts at the level of the water column and more than 90% of its concentration is associated to the particulate matter in the sediments. This phenomenon is highlight in our study also and the values in the sediments were approximately 20 times higher (37.330 µg/g) compared to those registered in the water matrix (1.781 µg/L).

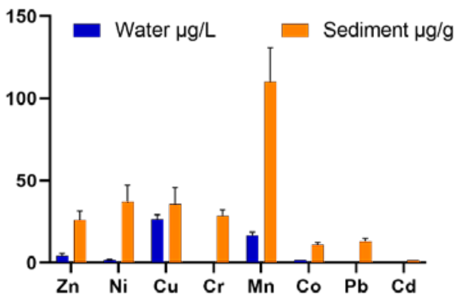


Figure 6. The concentration of different metals in water and sediment samples

The values registered for Cd and Pb concentrations were the lowest in the water samples (0.09, 0.06 µg/L respectively), compared to the sediments.
In the water column the analysed metals presented the following concentrations trend: K>Mg>K>Fe>Cu>Mn>Zn>Co>Ni>Cd>Pb.
In case of sediments samples, the accumulation trend registered the following decreasing values Fe>Na>K>Mg>Mn>Ni>Cu>Cr>Zn>Pb>Co>Cd.

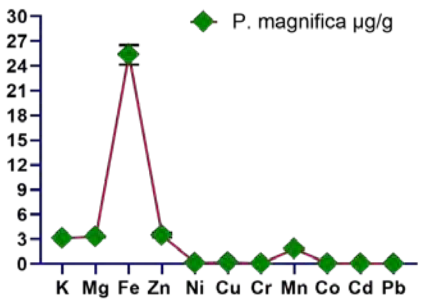


Figure 7. The concentration of elements in *P. magnifica*

The accumulation trend of the analyzed elements in the statoblasts of *Pectinatella magnifica* was as it follows: Fe>Zn>Mg>Na>Mn>Cu>Ni>Cr>Co>Cd>Pb.
Some metals are essential for the normal functioning of the living organism and they are involved especially in the enzymatic system. However, concentrations above a certain limit may become toxic. The highest concentration from all the analyzed metals, in the freshwater bryozoan was in case of Fe (25.337 µg/g) and the lowest was in case of Pb (0.015 µg/g). Iron is a component of some antioxidant enzymes such as catalase and peroxidase (Ben Salem et al., 2014). The toxicity of Fe in water ecosystems is enhanced by low values of pH and dissolved oxygen concentration.
The second most abundant metal in the *P. magnifica* was Zn (3.492 µg/g). According to (Trifan et al., 2015) Zn is a co-factor for over 200 enzymes and proteins involved in the redox process within the organism. The accumulation of Zn by aquatic organisms is dependent on the concentrations of nitrates within the surrounding environment (Anu et al., 2018).
In case of Cd and Pb, even low concentrations can pose a risk on the wellbeing of contact biota. In the living organism, Pb and Cd are not involved in any biological process, and thus, their presence in tissues can generate the inhibition of mineral absorption (through competing with the minerals for binding spots), disrupt the enzyme activity and deactivate the sulfhydryl antioxidant bonds. In natural waters, Cd and Pb are present in trace amounts and they are generated by natural phenomenon such as weathering of rocks. Both Cd and Pb are present in the aquatic environment as soluble and insoluble forms.
The bioaccumulation factor (BAF) was calculated only for the metals with the highest toxicity potential and are presented in Table 2.

Table 2. Results for the bioaccumulation factor

Element	BAF
Ni	0.003
Cu	0.006
Cr	0.001
Mn	0.01
Co	0.002
Fe	2.68
Zn	0.14

The BAF factor was computed as the ratio between the concentrations of elements in the *P. magnifica* to the concentrations in the sediment matrix. In this study it was chosen to use the sediment matrix instead of the water matrix due to the fact that the freshwater bryozoan develops on submerged vegetation, very close to the sedimentary substrate. The BAF is a reliable instrument for assessing the risks that heavy metals pose in the environment in which they are found in. Values for BAF above 1 indicate that accumulation is probable however only values greater than 100 are considered significant (Feng et al., 2020).

Thus, as it can be observed in Table 2, accumulation is probable only in the case of Fe. Meanwhile, in case of the rest analyzed metals (Ni, Cu, Cr, Mn, Co, Zn) the BAF registered values below 1 (Table 2), which indicates that accumulation is not manifested.

According to Jain et al. (2010) a suitable bioindicator presents specific characteristics such as:

- indication ability (has a measurable response to the presence of a certain contaminant);
- abundant and common in the study area
- well-studied (taxonomy well studied)
- be available all the year (in all seasons) in the study area.

Given the fact that the gelatinous mass of the freshwater bryozoan dissolves when water temperature drops, it should be considered that the accumulation of contaminants would be ceased during cold season. Thus, the data provided can not be reliable. This phenomenon is highlighted in the present study by the low values of BAF registered for the metals with highest toxicity potential.

CONCLUSIONS

Even though the freshwater bryozoan *Pectinatella magnifica* showed a potential for Fe accumulation, it can be concluded that it cannot be considered a suitable bioindicator in Danube Delta due to low BAF values for Ni, Cu, Cr, Mn, Co and Zn. Further studies are needed in order to apply more complex accumulation factors that can provide more information on heavy metals accumulation pattern of the studied organism.

ACKNOWLEDGEMENTS

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CNCS/CCCDI – UEFISCDI, project PN -III-P2-2.1-PTE-2019-0697, within PNCDI III.

This work was supported by a grant of the Ministry of Research, Innovation and Digitization, CNCS/CCCDI – UEFISCDI, project number PN-III-P1-1.1-TE-2019-2062, within PNCDI III.

REFERENCES

Anu, P.R., Bijoy Nandan, S., Jayachandran, P.R., Don Xavier, N.D., Midhun, A.M., & Mohan, D. (2018). Toxicity effects of zinc on two marine diatoms, under varying macronutrient environment. *Marine Environmental Research*, *142*, 275–285. https://doi.org/10.1016/j.marenvres.2018.10.013

Ben Salem, Z., Capelli, N., Laffray, X., Elise, G., Ayadi, H., & Aleya, L. (2014). Seasonal variation of heavy metals in water, sediment and roach tissues in a landfill draining system pond (Etueffont, France). *Ecological Engineering*, *69*, 25–37. https://doi.org/10.1016/j.ecoleng.2014.03.072

Dai, C., Tang, J., Li, Z., Duan, Y., Qu, Y., Yang, Y., Lyu, H., Zhang, D., & Wang, Y. (2022). Index System of Water Resources Development and Utilization Level Based on Water-Saving Society. *Water*, *14*(5), 802. https://doi.org/10.3390/w14050802

Dey, M., Akter, A., Islam, S., Chandra Dey, S., Choudhury, T.R., Fatema, K.J., & Begum, B.A. (2021). Assessment of contamination level, pollution risk and source apportionment of heavy metals in the Halda River water, Bangladesh. *Heliyon*, *7*(12), e08625. https://doi.org/10.1016/j.heliyon.2021.e08625

Feng, W., Wang, Z., Xu, H., Zhang, D., Zhang, H., & Zhu, W. (2020). Species-specific bioaccumulation of trace metals among fish species from Xincun Lagoon, South China Sea. *Scientific Reports*, *10*(1), 21800. https://doi.org/10.1038/s41598-020-77917-y

Finch, D.M., Butler, J. L., Runyon, J.B., Fettig, C.J., Kilkenny, F.F., Jose, S., Frankel, S.J., Cushman, S.A., Cobb, R.C., Dukes, J.S., Hicke, J.A., & Amelon, S.K. (2021). Effects of Climate Change on Invasive Species. In T.M. Poland, T. Patel-Weynand, D.M. Finch, C.F. Miniat, D.C. Hayes, & V.M. Lopez (Eds.), *Invasive Species in Forests and Rangelands of the United States: A Comprehensive Science Synthesis for the United States Forest Sector* (pp. 57–83). Springer International Publishing. https://doi.org/10.1007/978-3-030-45367-1_4

Gómez-Baggethun, E., Tudor, M., Doroftei, M., Covaliov, S., Năstase, A., Onără, D.-F., Mierlă, M., Marinov, M., Doroșencu, A.-C., Lupu, G., Teodorof, L., Tudor, I.-M., Köhler, B., Museth, J., Aronsen, E., Ivar Johnsen, S., Ibram, O., Marin, E., Crăciun, A., & Cioacă, E. (2019). Changes in ecosystem services from wetland loss and restoration: An ecosystem assessment of the Danube Delta (1960–2010). *Ecosystem Services*, *39*, 100965. https://doi.org/10.1016/j.ecoser.2019.100965

Güttler, F.N., Niculescu, S., & Gohin, F. (2013). Turbidity retrieval and monitoring of Danube Delta waters using multi-sensor optical remote sensing data: An integrated view from the delta plain lakes to the western–northwestern Black Sea coastal zone. *Remote Sensing of Environment*, *132*, 86–101. https://doi.org/10.1016/j.rse.2013.01.009

Hasan, M., Rahman, M., Ahmed, A. al, Islam, Md. A., & Rahman, M. (2022). Heavy metal pollution and ecological risk assessment in the surface water from a marine protected area, Swatch of No Ground, north-western part of the Bay of Bengal. *Regional Studies in Marine Science*, *52*, 102278. https://doi.org/10.1016/j.rsma.2022.102278

Jain, A., Singh, B.N., Singh, S.P., Singh, H.B., & Singh, S. (2010). Exploring Biodiversity as Bioindicators for Water Pollution. *Nd May*, 7.

Kadim, M.K., & Risjani, Y. (2022). Biomarker for monitoring heavy metal pollution in aquatic environment: An overview toward molecular perspectives. *Emerging Contaminants*, *8*, 195–205. https://doi.org/10.1016/j.emcon.2022.02.003

Kinuthia, G.K., Ngure, V., Beti, D., Lugalia, R., Wangila, A., & Kamau, L. (2020). Levels of heavy metals in wastewater and soil samples from open drainage channels in Nairobi, Kenya: Community health implication. *Scientific Reports*, *10*(1), 8434. https://doi.org/10.1038/s41598-020-65359-5

Kollar, P., Šmejkal, K., Salmonová, H., Vlková, E., Lepšová-Skácelová, O., Balounová, Z., Rajchard, J., Cvačka, J., Jaša, L., Babica, P., & Pazourek, J. (2016). Assessment of Chemical Impact of Invasive Bryozoan Pectinatella magnifica on the Environment: Cytotoxicity and Antimicrobial Activity of P. magnifica Extracts. *Molecules (Basel, Switzerland)*, *21*(11), E1476. https://doi.org/10.3390/molecules21111476

Micó, C., Recatalá, L., Peris, M., & Sánchez, J. (2006). Assessing heavy metal sources in agricultural soils of an European Mediterranean area by multivariate analysis. *Chemosphere*, *65*(5), 863–872. https://doi.org/10.1016/j.chemosphere.2006.03.016

Obinna, I.B., & Ebere, Enyoh Christian. (2019). A review: Water pollution by heavy metal and organic pollutants: Brief review of sources, effects and progress on remediation with aquatic plants. *Analytical Methods in Environmental Chemistry Journal*, *2*(03), 5–38. https://doi.org/10.24200/amecj.v2.i03.66

Parmar, T.K., Rawtani, D., & Agrawal, Y.K. (2016). Bioindicators: The natural indicator of environmental pollution. *Frontiers in Life Science*, *9*(2), 110–118. https://doi.org/10.1080/21553769.2016.1162753

Poshtegal, M.K., & Mirbagheri, S.A. (2019). The Heavy Metals Pollution Index and Water Quality Monitoring of the Zarrineh River, Iran. *Environmental and Engineering Geoscience*, *25*(2), 179–188. https://doi.org/10.2113/EEG-1996

Rao, A.S., Marshall, S., Gubbi, J., Palaniswami, M., Sinnott, R., & Pettigrovet, V. (2013). Design of low-cost autonomous water quality monitoring system. *2013 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*, 14–19. https://doi.org/10.1109/ICACCI.2013.6637139

Todorov, M., Kenderov, M., Botev, I., Hubenov, Z., & Trichkova, T. (2020). First Records of Pectinatella magnifica (Leidy, 1851) (Bryozoa: Plumatellida: Pectinatellidae) in the Bulgarian Shoreline Zone of the Danube River. *Acta Zoologica Bulgarica*, *72*, 611–617.

Trifan, A., Breabăn, I., Sava, D., Bucur, L., Toma, C.-C., & Miron, A. (2015). Heavy metal content in macroalgae from Roumanian Black Sea. *Revue Roumaine de Chimie*, *60*, 915–920.

Wang, B., Wang, H., & Cui, Y. (2016). Pectinatella magnifica (Leidy, 1851) (Bryozoa, Phylactolaemata), a biofouling bryozoan recently introduced to China. *Chinese Journal of Oceanology and Limnology*, *35*. https://doi.org/10.1007/s00343-017-6052-2

Weber, P., Behr, E. R., Knorr, C.D.L., Vendruscolo, D.S., Flores, E.M.M., Dressler, V.L., & Baldisserotto, B. (2013). Metals in the water, sediment, and tissues of two fish species from different trophic levels in a subtropical Brazilian river. *Microchemical Journal*, *106*, 61–66. https://doi.org/10.1016/j.microc.2012.05.004

Zaghloul, A., Saber, M., Gadow, S., & Awad, F. (2020). Biological indicators for pollution detection in terrestrial and aquatic ecosystems. *Bulletin of the National Research Centre*, *44*(1), 127. https://doi.org/10.1186/s42269-020-00385-x

Zamora-Ledezma, C., Negrete-Bolagay, D., Figueroa, F., Zamora-Ledezma, E., Ni, M., Alexis, F., & Guerrero, V.H. (2021). Heavy metal water pollution: A fresh look about hazards, novel and conventional remediation methods. *Environmental Technology & Innovation*, *22*, 101504. https://doi.org/10.1016/j.eti.2021.101504

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE USING OF OVER DEEP PLOWING FOR RECLAMATION OF SALT-AFFECTED SOILS

Ludmila VOROTYNTSEVA, Sviatoslav BALIUK, Maryna ZAKHAROVA

National Scientific Center "Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky", 4 Chaikovska Street, Kharkiv, Ukraine

Corresponding author email: vorotyntseva_ludmila@ukr.net

Abstract

The life on Earth depends on the health of soils. Ukraine joined to the implementation of the European Green Deal for the ensure climate neutrality, protect soils, ecologization and improve human well-being. Soil salinity influences on the soil quality, ecosystem services, productivity and food security. The results of studying the effectiveness of over deep plowing (on 75 cm) with the manure (100t/ha) for reclamation of salt-affected chernozem ordinary are given. Such processing ensures the extraction of reserves of calcium salts from deep layers to the soil surface. This technique is called self-amelioration of saline soils. In this variant soil decompaction, improvement of water-physical properties and an increase of the humus horizon were established. The soil buffer capacity against alkalinization increased as a result of an increase of the calcium content (up to 8.3-8.7%) and the saturation of the soil absorbing complex with calcium. The content of absorbed sodium and potassium cations decreased from 6.6-7.0 to 4.3-5.2% of the total absorbed cations. The yield of crops on this variant increased on 21-38%. This agromeliorative technique had a longer effect than ameliorants.

***Key words**: alkalinisation, over deep plowing, reclamation, salt-affected soil, soil absorbing complex.*

INTRODUCTION

The life on Earth depends on the health of soils. Ukraine joined to the implementation of the European Green Deal for the ensure climate neutrality, protect soils, ecologization and improve human well-being, ensuring sustainable development of Ukraine. Soils play a central role in achieving the goals of the European Green Deal. Human health and wellbeing are closely connected with soil health and sustainable soil management (Montanarella, 2020).

Soil salinity is one of the main global environmental problems in arid and semi-arid regions (Justo, 2021; Tedeschi, 2020; Zhang, H. 2020). It presents a serious challenge that requires co-ordination between countries that share common water and land resources (Handbook, 2018). Salt-affected soils are a global issue. It needs special attention during agriculture.

Therefore the issues of classification of salt-affected soils, their influence on soil properties and fertility, elaboration of measures to improve the productivity and quality of these soils are very actual for many countries (Pankova et al., 2018; Justo et al., 2021; Dhima, 2021; Vorotyntseva, 2016; Baliuk, 2020).

As an answer to all these threats, the Global Soil Partnership (GSP) has launched the International Network of Salt-Affected Soils (INSAS) to deal with these crucial issues.

FAO held the Global Symposium on Salt-affected Soils (GSAS21) «Halt soil salinization, boost soil productivity» in October 2021. A recent FAO estimate reported that a large portion of total global soil resources are degraded and this problem is persistently expanding (The state, 2011; Kramer, 2020; Baliuk et al., 2017; Baliuk et al., 2021).

Salt-affected soils are subdivided into two groups:

1) Saline soils without Natric/Solonetzic/Sodic horizon;
2) Alkaline soils with a well-developed Natric/Solonetzic/Sodic horizon, which is the diagnostic horizon of this group (Figure 1).

The former group includes Solonchaks and other saline soils without the solonetzic horizon, the latter – Solonetz and solonetzized soils (Handbook, 2018).

Figure 1. Salt-affected soils in Steppe zone of Ukraine

Salinization has a serious impact on soil functions such as its ability to act as a buffer and filter against pollutants, its participation in the water and nitrogen cycles and its ecosystem services in supporting the health of the environment and biodiversity (Handbook, 2018). Soil salinity influence on the soil quality, ecosystem services, soil health, productivity and food security of a country (Abrol et al., 1988; Novikova, 1984). The effects of salinity on plants include ion toxicity, osmotic stress, impaired growth, mineral deficiencies, photosynthetic imbalance, and combinations of these effects (Tedeschi, 2020).
Saline soils in Ukraine constitute a relatively small area (7%) - 1.92 million hectares. 1.71 million hectares of them are used in agriculture. There are about 350 thousand hectares of salt-affected soils on irrigated lands (Baliuk et al., 2020; Handbook, 2018). 70-100 thousand hectares of them are secondary salt-affected soils. Without proper management this expansion can result in environmental problems of irrigation induced soil salinization.
Alkaline soils contain a certain amount of sodium and potassium cations in the absorbing complex. It gives soils unfavourable chemical, physicochemical and water-physical properties. The area of alkaline soils in Ukraine is 2.8 million hectares. Solonetzes do not form continuous massifs, but occur as individual spots of various sizes and configurations among zonal soils, forming complexes.
Soil salinity and alkalinization are the most prevalent and widespread problem limiting crop productivity in irrigated agriculture (Tomaz et al., 2020; Kramer et al., 2020; Baliuk et al., 2009; Handbook, 2018).
Management of salt-affected soils is imperative for achieving most of the Sustainable Development Goals (SDGs) of the United Nations. It is necessary for achieving the «Zero Hunger» (SDG2) and «Life on Land» (SDG15) among other SDGs (Singh, 2021).
A complex of reclamation measures should be applied for increase the fertility of salt-affected soils, The Concept of sustainable management of soil resources of ameliorative lands has been developed in Ukraine (Concept, 2020). The system of sustainable management of irrigated lands was described in it. It ensures a balanced and controlled use of ameliorative lands, preventing of degradation processes in the soil and achieving their neutral level.
Applications for irrigation of limited and unsuitable water leads to the salinization and alkalinization process (Vorotyntseva, 2021). The study of the salt regime and the composition of the soil absorbing complex are especially relevant for reducing the negative impact of salts and absorbing sodium on soil properties and developing a complex of reclamation measures to improve their fertility.
The purpose of is to develop practices for and their sustainable management.
The purpose of our researches is to develop practices for reclamation fertility and rehabilitation of secondary salt-affected soils and their sustainable management on diagnostics and monitoring to improve the ecological land state, reduce soil degradation and rationally use them.
In this article we will consider the effectiveness of over deep plowing (self-reclamation method), its effect on the physical and physico-chemical properties of irrigated chernozem ordinary secondary medium salt-affected (Chernozems Chernic, WRB). This measure has not been studied on irrigated secondary salt-affected soils.

MATERIALS AND METHODS

The researches were conducted in field experiment in the Northern Steppe zone of secondary medium-saline Ukraine (in Yasinovatsky District of Donetsk Region). The researches were carried during eight years. Repetition of experiment variants was sixfold. In this article we present the results of the three variants of the field experiment: 1 - Control, 2 - Rotted manure (100 t/ha) into 0-25 cm plow horizon; 3 - Over deep plowing (on 75cm) + the rotted manure (100 t/ha) into 0-25 cm plow horizon (Figure 2).

Figure 2. Over deep plowing

Over deep plowing was done when laying an experiment and then its aftereffects were studied. Rotted Manure in the soil (0-25 cm) was applied once on laying the experiment.
The experimental field soil is chernozem ordinary low-humus light clay on loess (Chernozem Chernic, WRB).
The soil on layer 0-25 cm was characterized by such properties and chemical parameters. Groundwater was located at a depth more 10 m. The content of physical clay (< 0.01mm) in layer 0-25 cm of chernozem ordinary was 65%. The soil was characterized by light clay granulometric composition. Humus content was 4.4%, pH_{water} - 8.0, total calcium carbonate ($CaCO_3$) - 1.6%. Total content of water-soluble salts was 0.10%. Content of toxic salts was 0.06%. The content of water-soluble local pond calcium in the water extract was 0.46 mmol (equiv.) /100 g of soil, water-soluble sodium was 0.59 mmol (equiv.) /100 g of soil. The Ca:Na ratio was 0.8. Content of mineral nitrogen was 18.5 mg/kg of soil, P_2O_5 - 240 mg/kg of soil, K_2O - 198 mg/kg of soil (the Machigin method, State standard of Ukraine DSTU 4729:2007). Content of exchangeable cations Ca was 38.8 mg/kg of soil, exchangeable cations Na - 2.9 mg/kg of soil.
Irrigation in the field experiment was carried water from a local pond. On national classification (State standard of Ukraine 2730:2015) the irrigation water is classified as unsuitable for irrigation on the dangers of soil alkalinization and limited suitable on the dangers of soil salinization.
In the experiment winter wheat - buckwheat - corn for grain - barley with sowing of alfalfa - alfalfa 1 year - alfalfa 2 year. Irrigation rates ranged from 800 to 1200 m^3/ha depending on the crops grown and climatic conditions.
On the field experiment the influence of irrigation and over deep plowing on soil processes, properties and morphology of chernozems was studied.
Pits were laid to a depth of 1.5 m. We study morphological profile of chernozem ordinary. We took soil samples on the genetic horizon.
In the field every year before sowing crops (in spring) and after harvesting (in autumn) soil samples were taken in layers 0-25, 25-50, 50-75, 75-100 cm.
The soluble salt content in water extracts and pH of water suspensions (with the soil-to-solution ratio of 1:5) were determined. The composition of exchangeable bases was determined after extraction from the soil with 1 mol/dm^3 ammonium acetate solution (pH 7.0).
The humus content was determined by the Tyurin method. Humus carbon was oxidized with a solution of potassium bichromate and sulfuric acid to obtain CO_2. The excess carbon was titrated with Mohr's salt.
$CaCO_3$ in the soil carbonates were determined by the Sokolovich method using sodium fluoride.

RESULTS AND DISCUSSIONS

The differentiated complex of measures for amelioration of salt-affected soils was developed in Ukraine. It includes the following groups: 1) hydrotechnical - drainage systems and soil leaching to remove salts, 2) agricultural - crop rotation systems, fertilization systems and soil tillage systems including ameliorative deep plowing and 3) chemical - chemical amelioration treatments of irrigation waters and soils (Chemical, 2012).
High efficiency of ameliorative plantage plowing on natural saline dark chestnut and chestnut soils was established (Gavrilivich, 2006; Drozd, 2009; Drozd, 2015; Novikova, 1984). Deep plowing carried out in compliance with the requirements can provide a positive

impact on soil properties and crop productivity for 50 years (Baliuk, 2014).

In this article we will consider the effectiveness of over deep plowing, its effect on the physical and physico-chemical properties of irrigated chernozem ordinary. This measure has not been studied on irrigated secondary salt-affected soils. Over deep plowing is a special tillage with a plantation plow to a depth greater than the boiling depth of 10% hydrochloric acid by 10-15 cm. During such system the soil reserves of calcium salts contained in the transition horizon are removed to the surface. It are the ameliorants of salt-affected soils (self-reclamation method). The upper humus layer moves to the depth of the transition horizon. As result in the first years after plowing the humus content in the arable layer decreases, while in the deeper layers it accumulates. This measure has a long effect because there is a gradual dissolution of calcium compounds (Chemical, 2012).

The chemical composition of irrigation water is one of the main factors determined the degree of soil properties changes. The chemical composition of irrigation water is presented in Table 1.

Table 1. Chemical composition of irrigation water (averaged datas)

Mineralization of water, g/dm^3	pH	Ion content, meq/dm^3					
		HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	$Na^+ + K^+$
3.0	8.1	7.6	13.0	25.2	7.9	10.5	27.4

The mineralization of the irrigation water was 3.0 g/dm^3; pH - 8.1; type of salt - magnesium and sodium chlorides and sulphates. On national classification (State standard of Ukraine 2730:2015) the irrigation water was classified as unsuitable for irrigation on the dangers of soil alkalinization and limited suitable on the dangers of soil salinization.

During the over deep plowing soil layers and horizons were moved. This led to a change in the natural structure of the profile of common chernozem ordinary and its morphological indicators. The soil section on the variant with over deep plowing was laid 8 years later. Morphological characteristics of horizon of the soil profile is given in Figure 3.

Genetic horizon/ depth, cm	Morphological characteristics
Phkpl 0-25	the upper arable layer of the over deep plowing soil, dark fawn, heterogeneous in color, loose, lumpy-powdery, carbonate, violently boils from 10% HCl, permeated with plant roots, there are shrews; the transition is gradual in color and density
Hpkpl 25-50	transitional horizon, heterogeneous in color, darker than the upper horizon, dark gray spots alternate with dark brown, lumpy-mountainous, moist, loose, permeated with plant roots, weakly boils from 10% HCl, there are shrews; the transition is gradual in color
HP(k)pl 50-75	lower transitional plantation horizon, darker than the upper, loose, moist, lumpy-nutty, densely permeated with plant roots, weakly boiling from 10% HCl; the transition is sharp in color and density
P(h)k 75-115 and deeper	loess, yellow-pale, moist, dense, hints of humus, variegated from white stars, violently boils from 10% HCl

Figure 3. Chernozem ordinary morfological profile after over deep plowing

In variant 3 soil decompaction, improvement of water-physical properties and an increase of the humus horizon were established.

In the practice of salt-affected soils fertility improvement content and depth of $CaCO_3$ accumulation play an important role. This is confirmed by studies other researches (Boaghe, 2021; Novikova, 1984; Drozd, 2015). The distribution of calcium carbonates $CaCO_3$ in the soil of different variants is shown in Figure 4.

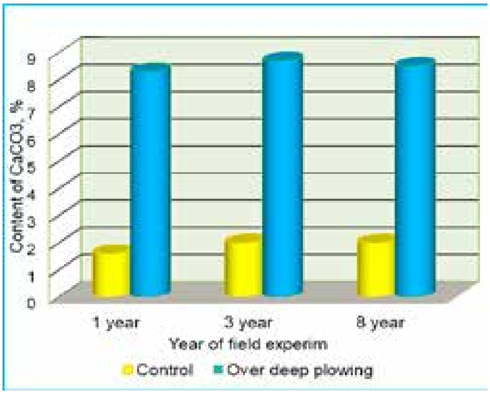


Figure 4. Content of calcium carbonates in the soil of field experiment (0-50 sm)

On the control its content was insignificant in the topsoil. $CaCO_3$ was 1.6-2.0%. In the subsoil their content increases. As a result of the extraction of calcium carbonates during over deep plowing from the horizon of their accumulation to the surface their concentration sharply increased to 8.3-8.7% in the 0-50 cm layer. Natural calcium compounds gradually dissolve in irrigated soil. Therefore they have a long-term ameliorative effect. $CaCO_3$ indicator determines the high potential buffer capacity of chernozem ordinary to irrigation alkalinization. The anti-salt capacity of irrigated ordinary chernozem by mineralized unsuitable water was increased.

The increase calcium carbonates in the soil of 3th variant had a positive effect on the physical and physico-chemical properties of irrigated soil.

The quality of irrigation water is one of the main factors determined the direction of soil processes and regimes, physical, physico-chemical, biological properties of irrigated soil and its ecology-agromeliorative state. In the control variant on irrigation by saline water the accumulation of salts in the soil profile occurred. The concentration of toxic salts in the 0-50 cm layer was rises to 0.11%. The soil was classified as slightly saline.

The reclamation effect of over deep plowing in the direction of soil desalinization was established. The content of toxic salts during this period reached an equilibrium concentration at the level of the control variant (Vorotyntseva, 2015). Seasonal and annual fluctuations in salt content and their distribution in the soil profile were observed. Type of salts was sulfate-soda calcium-sodium.

The pH of the soil variant 3 ranged from 7.9 to 8.1 (layer 0-50 cm). The reaction of water extract of chernozem ordinary was alkaline.

Organic matter content is an important indicator of soil fertility. In the control soil the content of organic matter gradually decreases from the upper horizon to the parent rock. Distribution of organic matter in soil profile of control is characteristic for given subtype of soil. Its content decreases from the upper to deeper horizon.

In 3th variant compared the 2th variant and control, the profile distribution of humus changed due to the movement of the upper humus layers in the lower ones. As a result the thickness of the humus horizon increased. This has a positive effect on plant growth.

Therefore in the first years of researches there was a decrease in the values of this indicator in the arable layer. In the variant with plowing 100 t/ha of the rotted manure was added to the stock so that the humus content in the soil did not decrease.

For the 6th year of the aftereffect of over deep plowing the content of total humus in 0-25 cm layer has not yet reached the level of the control. It was 3.3% (in control - 4.6%). In the lower layers of the planted soil its content increased to 4.9 %.

On irrigated by saline water alkalinization develop in the soil. Especially in the upper layer (0-50 cm) in the soil complex the content of absorbed sodium and potassium cations increases, adsorbed calcium vice versa decreases. On the content of alkaline sodium and potassium cations the soil of control variant was characterized by middle level of alkalinization. Prior the field experiment soil was used in the intensive irrigated crop rotation long time.

Significant qualitative and quantitative changes in the soil absorbing complex took place in the plantage plowing soil. This affected on the soil processes and the fertility of chernozem ordinary. In 1 year after over deep plowing, the saturation of the soil absorbing complex with calcium increased, and the saturation of sodium on the contrary decreased (layer 0-50 cm).
The dynamics of the content of absorbed sodium and calcium in the soil of the variants of the field experiment is shown in the Figures 5 and 6.

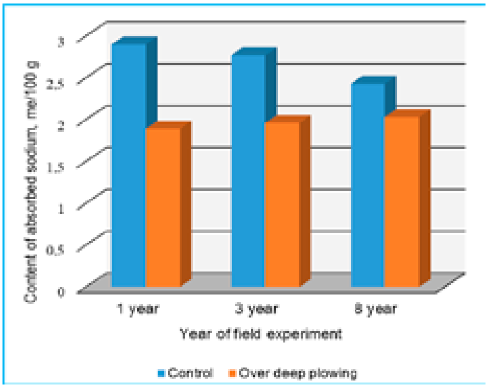


Figure 5. Content of absorbed sodium in the chernozem ordinary (0-50 cm)

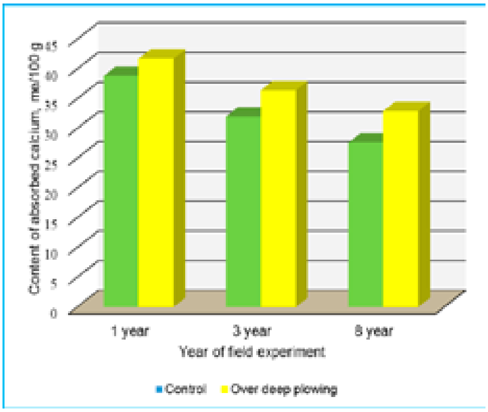


Figure 6. Content of absorbed calcium in the chernozem ordinary (0-50 cm)

The content of absorbed calcium in the plantage plowing soil was higher than in the control. This trend was clearly observed throughout the eight-year period of the experiment. No cessation of the positive effect of the over deep plowing was established.

At the same time with an increase in the duration of the aftereffect of plowing its concentration increased. Content of absorbed calcium in 1 year increased by 6%, in 3 years by 14%, in 8 years by 19% compared to control. In the soil of control variant, the content of absorbed sodium and potassium was 6.6-7.0% of the sum of absorbed cations. The soil was characterized by medium degree of alkalinity. In the variant with plantage plowing its content decreased to 4.3-5.2% of the sum of absorbed cations. The soil alkalinity decreased to a low degree.
Improvement of the cationic composition of the soil absorbing complex on the 3th variant had a positive effect on the physical, physico-chemical properties of chernozem ordinary.
Researcher Naydenova determined the microbiological activity of the soil in this field experiment. The degree of soil degradation decreased with the use of ameliorative over deep plowing (Vorotyntseva et al., 2012).
The results showed that in the plantage plowing soil with the manure the indicators were initially lower than in the control. With an increase in the duration of the aftereffect of this agroameliorative method the number of microflora increased and the degree of degradation decreased.
The lower efficiency of the plantation in the first years is associated with a decrease in the humus content in the layer of 0-25 cm and, consequently, a decrease in the total number of microflora. One of the indicators of the effectiveness of agroameliorative methods in the experiment is the yield of grown crops. In the control the yield of crops was lower than on the variant with plantage plowing.
In field experiment the increase of yield of cultivated crops in the 3th variant with over deep plowing was 21-38% (Figure 7).
The growth of green mass of alfalfa 2 years of cultivation was the highest than other crops. It amounted to 38%. This is due to the fact that alfalfa has a long root system. It penetrates deeper horizons and uses nutrients. The root layer has increased in the plantage plowing soil. The lower horizons are characterized by a high content of humus and nutrients. This had a positive effect on the growth of crops. Other crops grown in the field experiment were characterized by a less deep root system. Therefore, the increase in yield was lower.

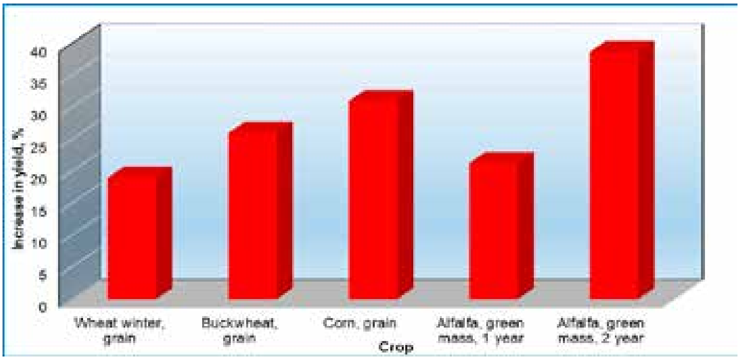


Figure 7. Increase of yield crops in the 3th Variant with over deep plowing (in relation to control)

In a field experiment during eight years the aftereffect of a single over deep plowing on chernozem ordinary was traced. And the termination of its action was not determined. Our studies have established that the aftereffect of chemical ameliorants on this soil lasted from 1 to 5 years depending on their dose.

CONCLUSIONS

Long-term studies in the field experiment was established over deep plantation plowing (with the introduction of 100 t/ha of humus) is an effective technique for reclamation of salt-affected soils. This technique is called self-amelioration of soils. During the over deep plowing soil layers and horizons were moved. This led to a change in the natural structure of the profile of common chernozem ordinary and its morphological indicators.

Deep plowing brought to the surface a carbonate accumulation horizon. In the control carbonates content in the arable layer was insignificant. $CaCO_3$ was 1.6-2.0%. In the bowels of their content increases. In the variant with plantation plowing, the content of carbonates increased sharply to 8.3-8.7% in the 0-50 cm layer.

An increase in the content of $CaCO_3$ in the soil contributed to the improvement of the properties of salt-affected chernozem ordinary. In variant 3 soil decompaction, improvement of water-physical properties and an increase of the humus horizon were established.

The reclamation effect of over deep plowing in the direction of soil desalinization was established.

In 3th variant compared the 2th variant and control, the profile distribution of humus changed due to the movement of the upper humus layers in the lower ones. As a result the thickness of the humus horizon increased. This has a positive effect on plant growth.

On irrigated by saline water alkalinization develop in the soil. On the content of alkaline sodium and potassium cations the soil of control was characterized by middle level of alkalinization. Prior the field experiment soil was used in the intensive irrigated crop rotation long time. In the plantage soil significant qualitative and quantitative changes in the soil absorbing complex took place. This affected on the soil processes and the fertility of chernozem ordinary. In 1 year after over deep plowing, the saturation of the soil absorbing complex with calcium increased, and the saturation of sodium on the contrary decreased (layer 0-50 cm).

The content of absorbed calcium in the plantage plowing soil was higher than in the control. This trend was clearly observed throughout the eight-year period of the experiment. The content of absorbed sodium and potassium cations decreased from 6.6-7.0 to 4.3-5.2% of the total absorbed cations. The degree of soil degradation decreased with the use of ameliorative over deep plowing.

The increase of yield of cultivated crops in the variant 3 with over deep plowing was 21-38%.

In a field experiment during eight years the aftereffect of a single over deep plowing on chernozem ordinary was traced. The termination of its action was not determined. The aftereffect of chemical ameliorants on this soil lasted from 1 to 5 years depending on their dose.

REFERENCES

Abrol I.P., Yadav, J.S.P., Massoud, F.I. (1988). *Salt-Affected Soils and their Management*. FAO Soils bulletin, 39. FAO, Rome.

Baliuk, S., Romashchenko, M., Stashuk, V. (2009). *The scientific basis for the protection and management of irrigated land in Ukraine*. Kiev, 619.

Baliuk, S., Zakharova, M., Vorotyntseva, L. (2020). Change of chernozems salt regime in irrigated and post-irrigated periods. *Scientific papers. Series A. Agronomy,* LXIII (1), 21–27.

Baliuk, S.A., Medvedev, V.V., Vorotyntseva, L.I., Shimel, V.V. (2017). Modern problems of soil degradation and measures on achievement of neutral its level. *Bulletin of Agricultural Science,* 8, 5-11.

Baliuk, S.A, Medvedev, V.V., Solovey, V.B., Vorotyntseva, L.I., Janse L.A. (2021). Ukrainian Chernozem – 140 years after V.V. Dokuchaev: state, evolution and management. Kharkiv, 191.

Baliuk, S.A., Drozd O.M., Gavrilovich, N.E. (2014). Complex estimation of agrogenic changes of properties of solonetz of Steppe Ukraine. *Bulletin of Agricultural Science,* 9, 44-48.

Boaghe, L., Filipciuc, V., Rozloga, Iu., Cojocaru, O. (2021). Research of the physical and chemical properties of the automorphic chernozem solonetzs on the territory of the republic of Moldova. *Scientific Papers. Series A. Agronomy,* LXIV (1), 23-32.

Chemical amelioration of soils (conception innovation development) (2012). Eds. S.A. Baliuk, R.S. Truskavetskiy, Yu.L. Tsapko. Kharkiv, 129. 208.

Concept of sustainable management of soil resources of ameliorative lands (2020). Eds. L.I. Vorotyntseva. Kharkiv, 46.

Dhima, K., Vasilakoglou, I., Paschalidis, K., Karagiannidis, N., Ilias, I. (2021). Salinity tolerance evaluation of barley germplasm for marginal soil utilization. *Italian Journal of Agronomy*, 16 (3).

Drozd, O.M. (2009). Modern tendencies of post-ameliorative development of solonetzic soils of the south of Ukraine. *Bulletin of Kharkiv national agrarian university named after V.V. Dokuchaev*, 2, 44-47.

Drozd, O. (2015). Meliorative soil tillage effect on properties of dark chestnut alkaline soil in dry Steppe zone. *Agrochemistry and Soil Science*, 84, 101-105.

Gavrilovich, N.E., Drozd O.M. (2006). Modern evolution of solonetz soils of south Ukraine on influence of plantage plowing. *Bulletin of Kharkiv national agrarian university named after V.V. Dokuchaev*, 7, 104-106.

Handbook for saline soil management (2018). Eds. R.Vargas, E.I. Pankova, S.A. Baliuk, P.V. Krasilnikov and G. Khasankhanova, FAO and Lomonosov Moscow State University, 144.

Justo, J.A., Barreto, A.C., da Silva, J.F., Ferreira, M., Sa, F.V.D., de Oliveira, R.P. (2021). Identification and diagnosis of salt-affected soils in the Baixo-A & ccedil;u irrigated perimeter, RN, Brazil. *Revista Brasileira de Engenharia Agricola e Ambiental*, 25 (7), 480-484.

Kramer, I., Mau, Y. (2020). Soil Degradation Risks Assessed by the SOTE Model for Salinity and Sodicity. *Water resources research*, 56 (10). 111-120.

Montanarella, L. (2020). Soils and the European Green Deal. *Italian Journal of Agronomy*, 15 (4), 262-266.

Novikova, A. (1984). *Cultivation of alkaline soils*. Kiev, Crop, 205.

Pankova, E.I., Gerasimova, M.I., Korolyuk, T.V. (2018). Salt-Affected Soils in Russian, American, and International Soil Classification Systems. *Eurasian Soil Science*, 51 (11), 1297-1308.

Singh, A. Soil salinization management for sustainable development: A review (2021). *Journal of environmental management*, 277.

Tedeschi, A. (2020). Irrigated Agriculture on Saline Soils: A Perspective. *Agronomy, 10* (11), 1630.

The state of the world's land and water resources for food and agriculture. Managing systems at risk (2011). FAO, 285.

Tomaz, A., Palma, P., Fialho, S., Lima, A., Alvarenga, P., Potes, M., Costa, M., Salgado, R. (2020). Risk Assessment of Irrigation-Related Soil Salinization and Sodification in Mediterranean Areas. *Water,* 12 (12).

Vorotyntseva, L., Baliuk, S., Zakharova, M. (2021). Effect of irrigation on the exchangeable cations composition in chernozems. *Scientific Papers. Series A. Agronomy*, LXIV (1), 171-179.

Vorotyntseva, L.I. (2015). Plantage plowing as measure cultivation alkalization chernozem ordinary. *Bulletin of Kharkiv national agrarian university named after V.V. Dokuchaev,* 1, 12-19.

Vorotyntseva, L.I. (2016). Transformation of properties of chernozem ordinary under irrigation by waters of different quality. *Bulletin of Agricultural Science,* 1, 56-60.

Vorotyntseva, L.I., Naidenova, O.E. (2012). Influence of agroameliorative measures and heavy metals pollution on the properties of irrigated chernozem ordinary. *Agrochemistry and Soil Science,* 77, 43-49.

Zhang, H., Pang, H., Zhao, Y., Lu, C., Liu, N., Zhang, X., Li, Y. (2020). Water and salt exchange flux and mechanism in a dry saline soil amended with buried straw of varying thicknesses. *Geoderma, 365 (3)*.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THEORETICAL RESULTS BY DETERMINING THE POWER OF THE DRIVEVIBRO-OIL PRODUCER

Aleksandr YASHIN, Yrii POLYVYANII, Julia KULIKOVA, Kirill BAXMETIEV

Penza State Agrarian University, 30 Botanicheskaya Street, Penza, Russia

Corresponding author email: yashin.av@pgau.ru

Abstract

A vibratory oil maker to produce environmentally friendly butter is presented. A constructive scheme and design of a butter maker with a churning mechanism in the form of a flexible vibration drive (a membrane that is also the bottom of the container, which performs periodic oscillatory movements by means of a crank mechanism) has been developed, which reduces the energy intensity of churning and loss of butter due to its sticking to the churning mechanism. A force analysis is presented, in which the forces acting in the oil maker during its operation are considered and a formula is obtained for determining the power to drive the vibratory oil maker, considering the division of masses into rotational and reciprocating masses of the vibratory oil maker knocking down mechanism. The power for the drive of the vibratory oil maker was calculated considering the change in the angle of rotation of the crank φ = 0...360 degrees. The obtained values are presented as a graph of the dependence of the power on the drive on the angular velocity and radius of the crank at given angles of rotation of the crank. The maximum (peak) value of power per drive is determined - 125 W. At the same time, the energy intensity of butter churning of the vibratory oil maker was Es = 3.84 Wh/kg with a productivity of Qm = 11.25 kg/h, and the degree of use of milk fat S = 99.6%, which corresponds to the waste of fat into buttermilk 0.4% and does not exceed the requirements of GOST. The maximum (peak) value of power per drive is determined - 125 W. At the same time, the energy intensity of butter churning of the vibratory oil maker was Es = 3.84 Wh/kg with a productivity of Qm = 11.25 kg/h, and the degree of use of milk fat S = 99.6%, which corresponds to the waste of fat into buttermilk 0.4% and does not exceed the requirements of GOST. The maximum (peak) value of power per drive is determined - 125 W. At the same time, the energy intensity of butter churning of the vibratory oil maker was Es = 3.84 Wh/kg with a productivity of Qm = 11.25 kg/h, and the degree of use of milk fat S = 99.6%, which corresponds to the waste of fat into buttermilk 0.4% and does not exceed the requirements of GOST.

Key words*: butter, crank mechanism, environmentally friendly, membrane, vibration drive.*

INTRODUCTION

Much attention has been paid to the research of batch oil producers (Melken, 1991; Yashin et al., 2017-2021). This is evidenced by the analysis of literary sources, reviewing various methods for obtaining oil grains, based on which a wide variety of oil producers was obtained. Of greatest interest are the designs of batch oil makers, in which the working bodies are made in the form of a rotating container. Such designs are less perfect, since churning is carried out for a long time from 30 to 120 minutes, because of which the productivity of the oil maker decreases and power costs increase (Shumaev et al., 2020; Shumaenv et al., 2021).

Buttermakers with rotating working bodies eliminate the existing shortcomings of the previously described designs, however, the waste of fat into buttermilk increases and ranges from 1 to 3%.

Relevant and practically significant for the agro-industrial complex is the problem of reducing the energy intensity of churning butter and increasing the degree of fat utilization, which is solved by improving the designs of butter makers.

To eliminate existing shortcomings, such as increased losses of butter due to its sticking to the churning mechanism and increased churning energy intensity, a butter maker design was developed with a churning mechanism, which is a membrane, which is also the bottom of the container. The membrane performs periodic oscillatory movements by means of a crank mechanism and an electric motor (Parfenov, 2014; Patents 2012, 2017).

MATERIALS AND METHODS

The developed design of the vibratory oil maker (Figure 1) works as follows. The cylindrical container 9 is filled with cream through the open filling hole 4. After that, the hole 4 is closed with a shutter 5 and locked with a lock 6. The electric motor 14 is started, because of which the crank 13 and the connecting rod 12 transmit periodic vibrations to the elastic funnel-shaped membrane 10, and from it to the cream itself.

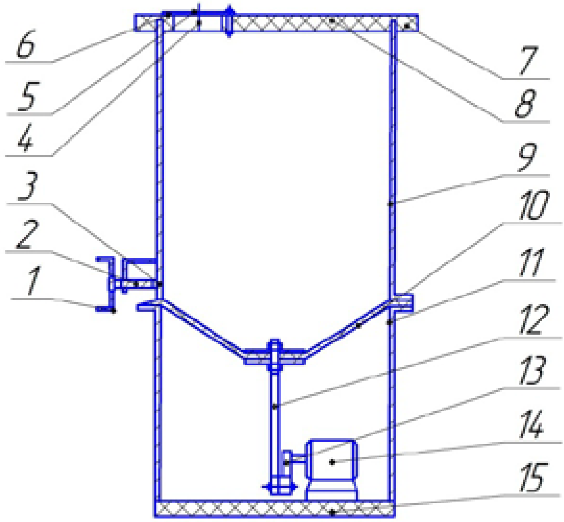


Figure 1. General view of the vibratory oil maker:
1 - handle; 2 - rod; 3 - unloading valve; 4 - loading window; 5 - damper; 6 - retainer; 7 - clamp; 8 - cover;
9 - container; 10 - membrane; 11 - frame; 12 - connecting rod; 13 - crank;
14 – electric drive; 15 - vibration damper

Intensive mixing is carried out under the action of a vibrational impulse, which contributes to the emergence of a turbulent movement of the cream. As a result, the process of forming butter grains is accelerated, the time for churning butter is significantly reduced, productivity increases and energy consumption decreases.

Visualization of the oil grain formation process is carried out by means of a cover 8 made of a transparent material. The unloading of the finished oil layer is carried out by opening the discharge valve 3, which also serves to remove excess moisture from the oil layer. Its opening occurs because of rotation of the handle 1 of the rod 2.

As a result, the motor 14 is turned off. If the oil grain needs to be refined to the desired consistency, then it is necessary to reduce the oscillation frequency of the flexible vibration drive, or use an oil homogenizer, if available.

RESULTS AND DISCUSSIONS

To determine the drive power of a vibratory oil maker, it is necessary to consider the forces acting during its operation (Figure 2).

Let us assume that container 5 is filled with a certain volume of cream with a height H.

The knocking mechanism consists of a membrane 4 with a rigid center 3, a connecting rod 2 and a crank 1.

The pressure force on the knocking mechanism acts vertically downwards, and its modulus is determined by the formulas 1, 2, 4, 9 and 10:

$$F_p = p \cdot S\underline{ef}., \text{H} \quad (1)$$

where:

- p - pressure on the membrane with a rigid center, Pa;
- $S_{ef.}$ - effective area of the membrane with a rigid center, m^2.

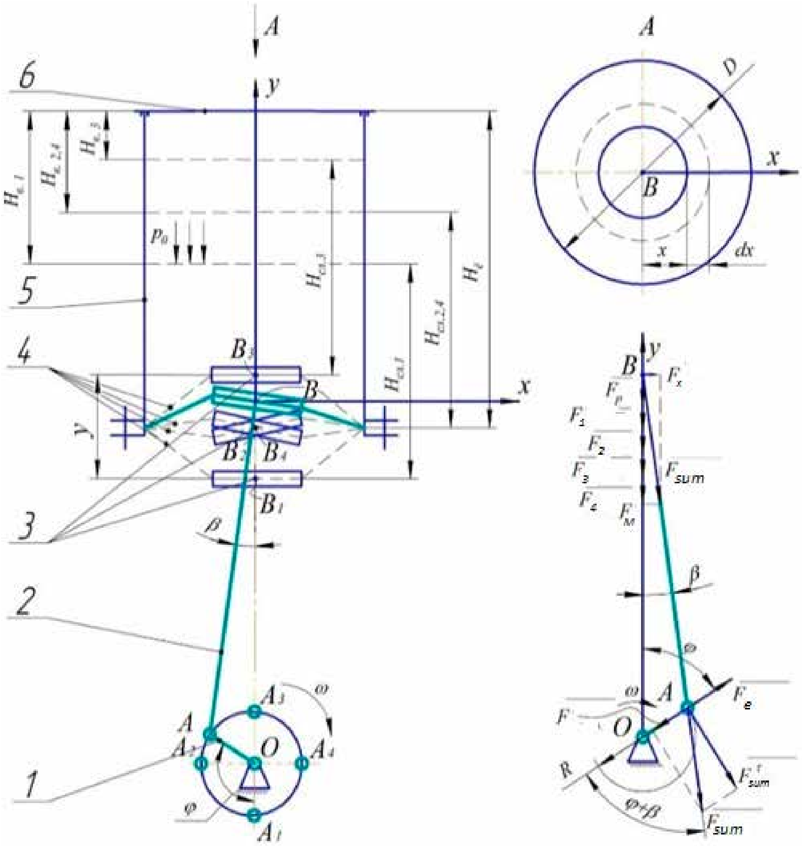


Figure 2. Scheme for determining the required power for the drive of the vibratory oil maker: a) - scheme of the vibratory oil maker for determining the pressure force at point B of the rigid center; b) - view A of the scheme of the vibratory oil maker from above with the cover removed to determine the force of internal friction of the cream; c) - diagram of the forces acting in the vibratory oil maker: 1 - crank (F_1); 2 - connecting rod (F_2); 3 - hard center (F_3); 4 – membrane (F_4); 5 - capacity; 6 - cover

In this case, the effective area of a membrane with a rigid center is the area, the value of which characterizes the ability of the membrane to convert pressure into axial force 1, 2, 4, 9, 10:

$$S_{ef.} = \frac{\pi}{12}(D^2 + Dd + d^2)\text{, m}^2 \qquad (2)$$

where:

- D - membrane (tank) diameter, m;
- d -rigid center diameter, m

In order to determine the magnitude of the forces of inertia that are formed during the movement of the parts of the crank mechanism, it is important to determine the corresponding masses. To this end, we replace the real masses of the moving parts with a system of masses dynamically equivalent to the real system. Since the connecting rod performs a complex plane-parallel motion, we would replace its mass with three masses concentrated at the point of attachment of the connecting rod to the membrane with a rigid center m_{1con}, reciprocating with respect to the crank m_{2con}, performing rotational motion, as well as in the center of mass of the connecting rod m_{3con} performing plane-parallel motion. As a result of this, it becomes clear that the mass of the connecting rod at the center of mass m_{3con} is negligible compared to the indicated masses. To move to a dynamically equivalent system, several restrictions must be observed, such as:

– the sum of all masses is equal to the mass of the connecting rod:

$$m_{con} = m_{1con} + m_{2con}, \text{ kg} \tag{3}$$

where:

- m_{1con} -the mass of the connecting rod concentrated at the place of its attachment to the membrane with a rigid center, kg;
- m_{2con} -the mass of the connecting rod concentrated at the place of its attachment to the crank, kg.

– with the center of gravity of all masses must coincide with the center of gravity of the connecting rod:

$$m_{1con} \cdot l_1 = m_{2con} \cdot (L - l_1) \tag{4}$$

where:

- l_1-distance from the center of mass of the connecting rod to the place of its attachment to the membrane with a rigid center, m;
- L -connectingrodlength, m

– the sum of the moments of inertia of all forces about the axis passing through the center of gravity of the connecting rod:

$$I_{сиրт} = m_{1con} \cdot l_1^2 + m_{2con} \cdot (L - l_1)^2, \text{ kgm} \tag{5}$$

– the masses must be located on one straight line passing through the center of gravity of the connecting rod.

Let us determine by the formula the mass of the connecting rod concentrated at the place of its attachment to the membrane with a rigid center m_{1con} and the mass of the connecting rod, concentrated in the place of its attachment to the crank m_{2con}:

$$m_{1con} = m_{con} \cdot \frac{L - l_1}{L}, \text{ kg} \tag{6}$$

$$m_{2con} = m_{con} \cdot \frac{l_1}{L}, \text{ kg} \tag{7}$$

Then the third constraint, formula (5), considering (6) and (7) will take the following form:

$$I_{con} = m_{con} \cdot l_1^2 \cdot \left(1 - \frac{l_1}{L}\right) + m_{c\,on} \cdot \frac{l_1 \cdot (L - l_1)^2}{L}, \text{ kgm} \tag{8}$$

In this case, the restriction is not satisfied, since the mass of the connecting rod is replaced by two masses, i.e. to obtain a dynamically substituting system, it would be necessary to the system of masses m_{1con}, m_{2con} add a negative moment of inertia. Since it has an insignificant impact, it can be excluded from further consideration.

Let us determine the mass of the connecting rod concentrated at the place of its attachment to the membrane with a rigid center m_{1con} and the mass of the connecting rod, concentrated in the place of its attachment to the crank m_{2con} taking into account the formulas (6), (7) and with respect $\frac{l_1}{L} = \frac{2}{3}$ according to the formulas:

$$m_{1con} = \frac{1}{3} \cdot m_{con}, \text{ kg} \tag{8}$$

$$m_{2con} = \frac{2}{3} \cdot m_{con}, \text{ kg} \tag{9}$$

The force of inertia of the reciprocating masses is directed opposite to the movement of the listed elements. It includes the mass of the membrane, the mass of the rigid center, the mass of the connecting rod concentrated at the point of its attachment to the membrane with a rigid center. Let us determine the module of the inertia force of the reciprocating motion of the masses by the formulas 1, 2, 4, 9, 10:

$$F_м = m_м \cdot \ddot{y}, \text{ H} \tag{10}$$

where $m_м$- mass of reciprocating moving elements, kg;

The mass of reciprocating elements is defined as their sum

$$m_м = m_{мем} + m_c + m_{1con}, \text{ kg} \tag{11}$$

where:

- $m_{мем}$ is the mass of the membrane, kg;
- m_c is the mass of the rigid center, kg;
- m_{1con}- the mass of the connecting rod concentrated at the place of its attachment to the membrane with a rigid center, kg.

Taking into account the formulas (8), (10) And (eleven) in the final form, the inertia force of reciprocating masses will be found by the formula:

$$F_м = (m_{мем} + m_c + \frac{1}{3} \cdot m_{con}) \cdot R \cdot \omega^2 \cdot (\cos\varphi + \lambda \cos 2\varphi), \tag{12}$$

Centrifugal force of inertia of rotating masses. It includes the mass of the axis of the crank and the mass of the connecting rod concentrated at the point of its connection with the crank is directed along the radius of the crank. We find its modulus by the formulas 1, 2, 4, 9, 10:

$$F_e = m_e \cdot a_{c.ac.}, \text{ N} \qquad (13)$$

where:

- m_e - mass of elements involved in rotational motion, kg;
- $a_{c.ac.}$ - centrifugal acceleration of rotating elements, m/s^2.

The power to drive the oil maker is the product of the torque, the angular velocity of the crank, and the safety factor:

$$N = \kappa_p \cdot F \cdot R \cdot \omega \cdot \frac{\sin(\varphi+\beta)}{\cos\beta}, \text{ W} \qquad (14)$$

where κ_p – power reserve factor, considering power costs for idling.

Considering the equations (13), (14) power to drive the oil maker with a power factor $\kappa_p = 1{,}2$ in final form could be found by the formula 15.

To determine the maximum power for the drive of the oil maker, we equate to zero the right side of the formula (15). Next, you need to determine the derivative of this function with respect to φ. Then you need to calculate the critical points. As a result, the resulting function after differentiation will be equal to zero or will not exist. Therefore, it is necessary to consider the range of real values.

$$N = \kappa_p \cdot \left(\frac{\pi \cdot g}{12} \cdot (D^2 + D \cdot d + d^2) \cdot (\rho_e \cdot R \cdot ((1-\cos\varphi) + \frac{\lambda}{4} \cdot (1-\cos 2\varphi)) - \rho \cdot H) + \right.$$
$$+ \frac{4 \cdot E_{мем} \cdot h_{мем} \cdot R \cdot ((1-\cos\varphi) + \frac{\lambda}{4} \cdot (1-\cos 2\varphi))}{3 \cdot (1-\mu_{мем}) \left(\frac{(D^2 - d^2)}{4 \cdot \pi} - \frac{D^2 \cdot \ln^2 \frac{D}{d}}{\pi \cdot \left(\frac{D^2}{d^2} - 1 \right)} \right)} +$$
$$+ \frac{\pi}{12} \cdot \rho \cdot H \cdot R \cdot \omega^2 \cdot (D^2 + D \cdot d + d^2) \cdot (\cos\varphi + \lambda \cdot \cos 2\varphi) +$$
$$\left. + (m_{мем} + m_c + \frac{1}{3} \cdot m_{con}) \cdot R\omega^2 \cdot (\cos\varphi + \lambda \cos 2\varphi) \right) \times$$
$$\times R \cdot \omega \cdot \left(\sin\varphi + \frac{\lambda \cdot \sin\varphi}{2 \cdot \sqrt{1 - \lambda^2 \cdot \sin^2\varphi}} \right), \text{ N} \qquad (15)$$

In order to identify the sign of the derivative of the function, it is necessary to study the intervals to the right and left of the obtained points. Since we are trying to get the maximum value, we need to investigate only intervals with a positive sign of the derivative of the function or with a value equal to $+\infty$. The found function is difficult to conduct research and determine the extremum.

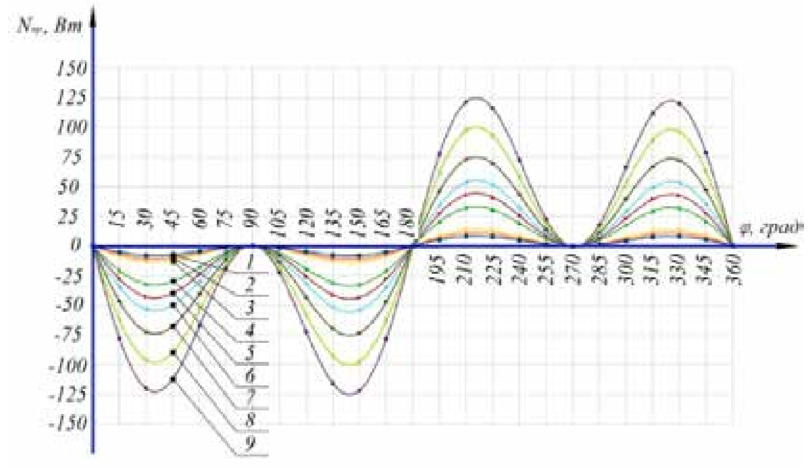


Figure 3. Graph drive power dependencies N from angular velocity ω and crank radius R at the angle of rotation crank φ

1 - at $R = 0{,}003$ m and $\omega = 30$ s–1; 2 - at $R = 0{,}003$ m and $\omega = 40$ s–1;3 - at $R = 0{,}003$ m and $\omega = 50$ s–1;
4 - at $R = 0{,}006$ m and $\omega = 30$ s–1; 5 - at $R = 0{,}006$ m and $\omega = 40$ s–1; 6 - at $R = 0{,}006$ m and $\omega = 50$ s–1;
7 - at $R = 0{,}009$ m and $\omega = 30$ s–1; 8 - at $R = 0{,}009$ m and $\omega = 40$ s–1; 9 - at $R = 0{,}009$ m and $\omega = 50$ s–1

Therefore, we set ourselves constant values and perform the calculation taking into account the change in the angle of rotation of the crank $\varphi = 0...360$ deg. We write the results obtained in the form of a graph $N = f(\varphi)$

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

(Figure 3). And then, when designing the drive, you can already determine the maximum value of the required power for the drive of the oil maker.

CONCLUSIONS

As a result of theoretical studies, a dependence was revealed to determine the power to drive an oil maker with a flexible vibration drive (15). The performed calculation made it possible to determine the values depending on the change in the design, kinematic and technological parameters. In the considered range of variation of factor values, the maximum (peak) value of power per drive is determined - 125 W.

Considering the results obtained, an AIRE 56V4 electric motor and a SG 62 gearbox were used to drive the oil maker with a flexible vibration drive.

REFERENCES

Melken, A.A. (1991) Kuhlenfuttementmistenaufstallen / AA Melken // *Alfa-Laval Komplett*. 36-46

Parfenov, V.S. (2014) Device for making butter / V.S., Parfenov, A.V. Yashin, Yu.V. Polyvyany // *XXI century: the results of the past and the problems of the present plus.* – Penza: Penz Publishing House. state technol. un-ta. 6 (22). - S. 177-180.

Patent 2491813 RF, IPC A 01J15/00. *Buttermaker of periodic action* / V.Parfenov, S. A.V. Yashin, Yu.V.Polyvyany, V.N. Strigin. - No. 2012129083/10; Claimed 07/10/2012; Published. 09/10/2013, Bull. No. 25.

Patent 2624925 RF, IPC A 01J15/00. *Butter manufacturer* / Yu.V.Polyvyany, V.S. Parfenov, V.A. Chugunov, A.V. Yashin. – No. 2016104701; Declared 02/11/2016; Published 07/11/2017, Bull.No. 20.

Shumaev V., Kulikova J., Kalabushev A., Gubanova A. (2021) Theoretical research on technological process of a stud seed with a furrow-forming working body.*Scientific paper Series A. Agronomy*. LXIV. 1. 154-160

Shumaev V., Kulikova J., Orekhov A., Polikanov A. (2020). Investigation of the grain seeder opener operation for environmental friendly technologies of crop production.*Scientific paper Series A. Agronomy*. 63. 1. 527-532.

Yashin, A. (2020) Results of research on justification of the device for producing ecologically pure butter / A. Yashin, Yu.Polyvyannii // *Scientific paper-Series A- Agronomy*. 63. 1. 632-636.

Yashin, A. (2021) Results of oil press studies for the production of ecologically clean butter / A. Yashin, Y. Polyvyanii, Ju. Kulikova*// Scientific paper-Series D- Animal sciences.* 64. 2. 404-408.

Yashin, A.V. (2017) Theoretical substantiation of the amplitude of oscillations of the membrane and the angular velocity of the crank of an oil maker with a flexible vibration drive / A.V. Yashin, Yu.V.Polyvyany // *NivaPovolzhya*. 4 (45).181-187.

Yashin, A.V. (2018) Determining the power to drive an oil maker with a flexible vibration drive / A.V. Yashin, Yu.V.Polyvyany, A.L. Mishanin, P.N. Khorev // *Proceedings of the Samara State Agricultural Academy*. 4. 92-101.

Yashin, A.V. (2019) Determination of the productivity of the oil press molding zone and the parameters of the molding nozzle /A.V. Yashin, Yu.V.Polyvyany, I.S. Ionov, M.A. Alderbegov // The contribution of young scientists to the innovative development of the agro-industrial complex of Russia. *Collection of articles of the All-Russian Scientific and Practical Conference of Young Scientists*. 216-219

Yashin, A.V. (2020) Batch oil maker with flexible vibration drive / A.V. Yashin, Yu.V.Polyvyany, M.A.Terekhin // The contribution of young scientists to the innovative development of the agro-industrial complex of Russia. *Collection of materials of the All-Russian (national) scientific and practical conference of young scientists*.116-120.

Yashin, A.V. (2020) Modeling of a vibrating oil maker with the required capacity / A.V. Yashin // Innovative achievements of science and technology of the agro-industrial complex. *Collection of scientific papers of the International Scientific and Practical Conference.*Kinel.440-444.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE CURRENT STATE OF THE ELECTRICITY MARKET AND SYSTEM SERVICES IN ROMANIA

Emil DIACONU

Valahia University of Targoviste, 13 Aleea Sinaia Street, 130004 Targoviste, Romania

Corresponding author email: emy_diaconu@yahoo.com

Abstract

The subject dealt with in this paper is a sensitive one due to the energy crisis whose presence is already felt and which will certainly deepen with the approach of the cold season. The current work represents only the first part of a study related to the analysis of the current state of the energy market and system services and will be continued with a second work that will propose a solution in cogeneration to counterbalance the system problems we are facing. Thus, the subject discussed is not that of energy production for domestic and industrial consumers, but that of the production necessary for the optimal functioning of the National Energy System (NES). Of course, from the point of view of the environmental protection all the electrical energy, even that required for system services, should be 100% produced from renewable energy.

Key words: *balancing market, environmental protection, National Energy System, renewable energy, sources system services.*

INTRODUCTION

The rapid pace of growth of the global economy, the technological advance and the demographic growth made the demand for energy to be higher and higher. This demand could be met by the use of fossil fuels which have come hand in hand with global warming, the greenhouse effect and climate change (Popescu et al., 2018). Also, the lack of these energy sources all over the world, the dependence on foreign resources and their fluctuating price lead to an ever-increasing interest in renewable energy resources and their study. (Kulcu & Cihanalp, 2017).

Almost 35% of electricity consumption in our country is provided by coal and gas plants (EGR, 2019). A considerable share of electricity production is achieved by production capacities that are nearing the end of their life. Some of these are already economically inefficient and too polluting, requiring renewal through retrofitting or replacement.

The lack of investment caused mainly by a deficient and unpredictable legislation has made Romania move from a traditional position of an exporting electricity producer to a position of an energy importer, reaching record imports of over 2000 MW per hour.

The increase in the production of energy from renewable sources, as a result of numerous wind and photovoltaic farms starting commercial operation, has led to the need to increase the amount of electricity for balancing, to cover the significant differences between the production and consumption of electricity.

THE CURRENT STATE OF THE NATIONAL ENERGY SECTOR

The main electricity production companies in Romania are owned by the state. These are the Cernavodă nuclear power plant, operated by Nuclearelectrica, hydroelectric plants operated by Hidroelectrica and around 20 thermal plants that use coal.

The structure of the energy sector and its expected evolution until 2030 indicate that the achievement of the strategic objectives defined by the Energy Strategy of Romania for the period 2019-2030 (EGR, 2019) depends on the success of strategic intervention in several key areas of the energy industry, especially in terms of renewal, retrofitting or replacing outdated electricity production capacities.

The main resources of electricity production from primary sources are coal and hydrological resources. Together they have a contribution of almost 50% in electricity generation. They are followed by nuclear, gas and wind power generation.

In the year 2021, the structure by types of resources of electricity delivered to the grid by producers with dispatchable units is presented in Figure 1 (ANRE, 2021).

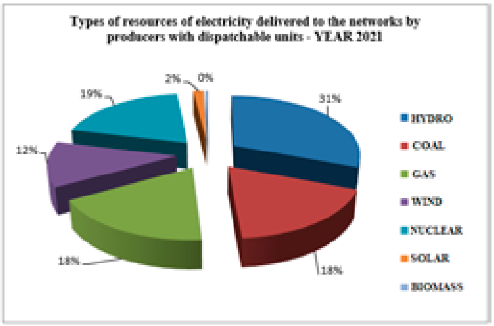


Figure 1. Production by types of resources in 2021

Currently, installed capacity by technology types and production structure by resource types are shown in Table 1 respectively Figure 2 (ANRE, 2021).

Table 1. Installed capacity by technology types

Present installed capacity	MWh
Hydro	6643
Coal	3092
Hydrocarbons	2623
Wind	3003
Nuclear	1413
Solar	1388
Biomass	107
Others	4
Total	**18273**

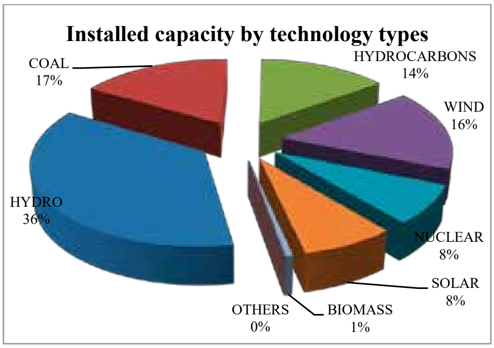


Figure 2. Production structure by types of resources

From the comparative analysis of the above data, a small variation of electricity production by types of resources can be observed. If 15 years ago Romania had a traditional position on the European energy market as an exporter of electricity, given the excellent hydrological conditions and the production of wind electricity, today Romania has reached record imports to cover a consumption of over 2000 MW per hour.

In 2019, 27.93% of the total energy was produced in hydropower plants, in 2020 was 29.01%, and in 2021, 30.85%. Moreover, hydropower capacities have had and still have a substantial contribution to the system services market. Equally important is the fact that large hydropower plants were built between 1960-1990, requiring investment in modernization and/or retrofitting.

It is expected that there will be restrictions and impositions on hydropower to protect the environment, which will lead to a decrease in hydropower production. Given that the most favourable locations in terms of hydropower have already been used, new projects will only be developed to provide benefits other than energy and will require state participation in securing financing.

Coal-fired power plants produced 22.77% in 2019, 16.55% in 2020 and 17.99% in 2021 of the total generated electrical energy. Currently, coal-based capacities play an important role in ensuring system stability (providing system services). By 2026, coal-fired power producers will have to retrofit or replace equipment or lose their environmental permits.

In the long term, the role of lignite (Matei et al., 2010) in the energy mix can be preserved by developing new capacities, which must be equipped with CO_2 capture, transport and storage technologies.

Pit coal reserves are impossible to exploit in terms of economic efficiency, which makes the construction of new groups based on coal unlikely.

Of the country's total electricity production, the nuclear power plant produced 19.29% in 2019 and 20.78% in 2020. The two reactors with a total installed capacity of 1413 MW (2x706.5 MW) require upgrades. The first reactor is expected to be shut down between 2026-2028.

Currently, Nuclearelectrica and the American company NuScal have announced the construction of the first small modular reactor (SMR) in Romania, which will be installed at the former thermal power plant in Doicești, in Dâmbovița County. The NuScale power plant is equipped with 6 modules, having an electric power of 462 MWe and will contribute to the reduction of CO_2 emissions by 4 million tons of CO_2 emissions/year.

Thus, Romania becomes one of the first countries in the world, and the first in Europe, to implement the innovative and safe technology of small modular reactors (SMR) - NuScale, which enable the supply of "clean" energy.

In 2019 gas plants provided 15.88%, in 2020, 18.17% and in 2021 17.99% of the total energy produced. By 2025, the old gas-fired power plants, with more than 2500 MW installed, will require replacement.

Romania has set a strategic objective to rely on the new gas cogeneration units (gas turbines and gas engines) which can balance the unpredictable SRE production. This fact is due to the flexibility of the new cogeneration technologies.

Exploitation of the gas resources found in the Black Sea will make a major contribution to ensuring Romania's energy security. Onshore and offshore natural gas production may have the potential to exceed the current estimated level of domestic demand.

In 2019 wind energy represented 12.44% and in 2020 represented 13.63% of the total energy produced. Romania aims to remain an attractive destination for new RES investments in the long term. A gradual increase in wind power capacity by 1300 MW and photovoltaic power by 1700 MW is estimated. However, the maximum installed power in wind energy has already been reached (3000 MW). For any additional 300 MW installed in wind power, 100 MW of storage capacity is required.

The wholesale electricity market represents the framework in which electricity is purchased by suppliers from producers or other suppliers for resale or own consumption, as well as by grid operators to cover their own technological consumption.

Transactions between participants in the wholesale electricity market must be concluded only by participating in one of the centralized markets organized by the electricity market operator, Opcom SA (OPCOM, 2022).

On the Next Day Market (NDM) (Transelectrica, 2022) there are firm electricity transactions made every day for each time interval for the next day delivery, based on the offers submitted by NDM participants. OPCOM S.A. is the counterparty for all executed purchase/sale transactions (Tabel 2).

Table 2. Average NDM prices

	Average NDM prices (Ron/MWh)		
Year	201	2020	2021
weighted average price	251.21	296.37	1173.64
arithmetic average price	238.80	284.32	1139.30
maximum peak price	272.87	354.82	1424.15
average price outside the peak	204.75	213.82	854.45

In the bilateral contract market (PCB) (OPCOM, 2022), contracts for the sale and purchase of electricity are concluded for a fixed period of time (Table 3).

Table 3. Average PCB prices

	Average PCB prices (Ron/MWh)		
Year	2019	2020	2021
PCCB-LE-FLEX	289.54	262.91	323.24
PCCB-NC	277.69	264.28	367.83
PC-OTC	269.41	265.61	434.45

The Intraday market (IM) (OPCOM, 2022) was created in order to adjust the portfolio of contracts to production possibilities, consumption needs and cross-border transactions and to reduce possible imbalances. Participants can send purchase/sale offers after the transactions on NDM have been carried out and they are carried out at the beginning of the electricity delivery time - during the day of delivery, no more than 1 hour before delivery. OPCOM is the counterparty for all executed purchase/sale transactions.

SYSTEM SERVICES (SS)

The system services market (Transelectrica, 2022) was organized to maintain the operational safety of the national energy system and the quality of the transported electricity (Andrei et al., 2019). System services are provided by producers or end customers (ANRE, 2021) who provide services at the request of the transport system operator (TSO) in order to maintain the level of safety in operation of the NES, as well as the quality of the electricity transported to the parameters provided for by the rules in force.

By procuring the balancing capacity, the TSO has the possibility to activate an electricity production facility, on demand, for balancing the SEN in real time (TEL 04.05, 2022; ANRE, 2007; ANRE, 2011) the following categories of auxiliary services:

- **Secondary reserve**: the required power reserve, when the frequency and/or NES balance deviates from a certain value, and production capacities can be mobilized (started), automatically in a maximum of 15 minutes - becoming Automatic Frequency Recovery Reserve (minimum 1 MW, start-up time up to 30 seconds and time to reach nominal power - 7.5 minutes);
- **Fast tertiary reserve**: the energy reserve provided by generation groups that are qualified to charge in a maximum of 15 minutes (power generating units that can be switched on / off) - becoming the manual frequency recovery reserve (minimum 1 MW, start-up time up to 2.5 minutes and time to reach rated power of 12.5 minutes). In 2019, the weighted average price for the fast tertiary reserve was - 48.47 Ron / MWh). In 2020 the weighted average price for the rapidly increasing tertiary reserve was - 45.21 Ron/MWh, and the weighted average price for the rapidly decreasing tertiary reserve was - 17.20 Ron/MWh).
- **Slow tertiary reserves:** energy reserve provided by generating groups that have start-up and load times of less than 7 hours (generation units that can be switched on / off) - becoming replacement reserve (minimum 1 MW, activation time /start up to 30 minutes and full activation time – 30 minutes).

The average amounts of energy contracted by Transelectrica for system services (hMW) in 2020 are presented in Figure 3 (Transelectrica, 2020).

To participate in the auctions, system service providers must operate dispatchable units technically qualified by CNTEE Transelectrica SA, register as market participants and register as part of a balancing responsible party (BRP). Registration as a participant in auctions is done immediately after signing the framework contract for the sale/purchase of system services.

Auctions for purchasing system services are held daily. The required quantities of system services will be auctioned for each reserve category and for each time slot of the respective period.

The closing price of the auction for each time interval of the purchase period is established by order of merit, registering all price-quantity pairs from the lowest price to the highest, until the required quantity is covered. The price of the last winning bid is the price at which all quantities in the winning bids are contracted. For each offer, an addendum is signed as part of the contract for the provided system services. System services are considered to be provided/performed if the system service providers offer the reserved energy on the Balancing Market.

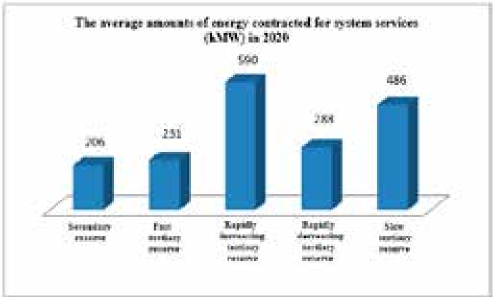


Figure 3. The average amounts of energy contracted for systems services (hMW) in 2020

THE BALANCING MARKET

The balancing market (BM) (Transelectrica, 2022) is the centralized market organized and managed by the transmission system operator (CNTEE Transelectrica SA) for the real-time balancing between electricity production and consumption and to ensure the safety and stability in operation of the National Energy System (NES) and to resolve grid congestions.

Bids in the balancing market are made several hours before the day the energy delivery starts, being the place of "last resort" where the final adjustment of the scheduled electricity deliveries could be made before the real-time delivery of the energy.

System service providers must offer on the balancing market:

- according to the regulations regarding the increase regulation - the available electrical power that can be increased/used to cover the production deficit/consumption surplus;

- according to the regulation on the downward adjustment - reduction of production to compensate for the production surplus/consumption deficit.

The winning price for each time slot is the price of the last winning bid (the highest price of the quantity-price bids, ordered in ascending order of merit) and is the price at which all quantities of the winning bids are contracted for upscaling and vice versa for downscaling .

Participants in the electricity markets must choose a BRP. It manages the imbalances of all participants and tries to reduce these imbalances, distributing to its own participants the amounts and financial costs of the imbalances within the BRP.

For negative imbalances (deficit), they have to pay the settlement price resulting from the increasing bids accepted on the Balancing Market (BM), while for positive (surplus) imbalances they realize and for which they pay the settlement price resulting from the bids discount accepted on the Balancing Market (BM).

From February 2021, balancing market settlements are made every 15 minutes, which impacts the amount of energy delivered by system service producers and the prices paid by BM participants. Positive and negative imbalances, according to the new regulations, can be settled either at a single price, or at a positive price for negative imbalances or at a negative price for positive imbalances, depending on the closing price of the BM on each interval. All these measures have been taken to better manage imbalances – reducing them and has substantial negative impact for those who do not manage imbalances effectively.

The integration of the Romanian electricity market into the European market is one of Romania's strategic objectives. Starting from 2014, the Romanian NDM operates in a coupled system with the NDM markets in the Czech Republic, Slovakia and Hungary.

Since the end of 2019, the romanian IDM has been operating together with 20 other EU member states.

All transmission operators in Europe, including Transelectrica (member of the European Network of Transmission System Operators for Electricity - ENTSO-E), are working to establish the European platform for balancing energy exchanges (PICASSO, MARI) (PICASSO, 2022; MARI, 2022) to be fully operational by the end of 2022.

CONCLUSIONS

This paper presents the current situation of the National Energy System (NES) and the current conditions on the energy market.

Considering the current situation of NES, the author will list on the one hand some of the problems it faces and on the other hand opportunities. The oportunities listed below favor the development of a cogeneration power plant project needed to provide system services, project that will be presented in a future paper which will constitute the continuation of this work and, at the same time, the end of the study.

Among the current problems faced by NES it can be mentioned:

- a considerable share of electricity production is made by production capacities that are nearing the end of their life;
- increase in the production of energy from renewable sources (Nedelcu et al., 2019; Dragomir et al., 2016), as a result of numerous wind and photovoltaic farms starting commercial operation, has led to the need to increase the amount of electricity for balancing, to cover the significant differences between the production and consumption of electricity;
- the lack of investments caused mainly by a deficient and unpredictable legislation, made Romania move from a traditional position of electricity producer that exports, to a position of energy importer, reaching record imports of over 2000 MW per hour.

To counterbalance the existence of the energy problems we are facing, it is also mentioned some opportunities that could solve some of them and that will be discussed in a feature paper:

- Expansion of electricity markets at European level;
- By the end of 2022, the European platform for balancing energy exchange (PICASSO, MARI) is expected to be fully operational; as a result, all existing manufacturers wishing to participate in the European

balancing market will go through a new qualification process.

- The European directions for the development of the energy markets - transposed in the Directives, provide for the expansion of the use of cogeneration, especially of capacities up to 20 MW as a measure to increase energy efficiency and promote the distributed production of electricity.

REFERENCES

Andrei, F.D., Dogaru Ulieru, V., Salisteanu, I.C., Nedelcu, O., Salisteanu, B., 2019. Medium voltage networks automation to improve the electrical energy distribution service, *19th International Multidisciplinary Scientific GeoConference* SGEM 2019.

ANRE Order no. 21/13.07.2007 regarding the approval of the "framework contract for the sale and purchase of system technological services between the Provider of system technological services and the transport and system operator" (ANRE, 2007).

ANRE Order no. 40/30.09.2011 for the amendment and completion of the framework contract for the sale and purchase of system technological services between the provider of system technological services and the transport and system operator, approved by the Order of the President of ANRE no. 21/2007 (ANRE, 2011).

Autoritatea Nationala de Reglemantare in domeniul Energiei (ANRE, 2021). Retrived from https://www.anre.ro /ro/energie-electrica/rapoarte

Dragomir, A., Dogaru, V., Salisteanu, C.I., Nedelcu, O., Issa, F., 2016. Analysis on islanding states using renewable energy systems, *16th International Multidisciplinary Scientific GeoConference SGEM 2016, Renewable Energy Sources and Clean Technologies*, Book 4, Volume 1 ISBN: 978-1-5108-2990-9 / ISSN 1314-2704.

EGR, 2019. Retrived from http://energie.gov.ro /transparenta-decizionala/strategia-energetica-a-romaniei-2019-2030-cu-perspectiva-anului-2050/

Kulcu, R., Cihanalp C., 2017. Evaluating of electric energy generating potential using biogas from animal biomasses in Burdur city, Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, Vol. V, Print ISSN 2285-6064, 17-22.

Manually Activated Reserves Initiative (MARI, 2022). Retrived from https://www.entsoe.eu/network_codes /eb/mari/

Matei, M., Matei, L., Soare, B., Nedelcu, O., Sălișteanu, C., Udroiu, I., 2010. Greenhouse gas emission reduction by biomass co-combustion with lignite, *9th Internațional Power & Energy Conference (IPEC, 2010)* ISSN: 1947-1262, pp. 515- 518.

Nedelcu, O., Salisteanu I. C., Ivanovici, T., Dogaru, V., 2019. Energy passivation of a building. The ICSTM building case study, *E3S Web of Conferences 112, 02003* (2019) TE-RE-RD 2019.

Operational Procedure "Purchase by auction of technological system services" code TEL 04.05 (TEL 04.05, 2022)

Operatorul pietei de energie electrica si de gaze naturale din Romania (OPCOM, 2022). Retrived from https://opcom.ro/pp/home.php

Operatorul pietei de energie electrica si de gaze naturale din Romania (OPCOM, 2022). Retrived from https://www.opcom.ro/tranzactii_produse/tranzactii_produse.php?lang=ro&id=74

Operatorul pietei de energie electrica si de gaze naturale din Romania (OPCOM, 2022). Retrived from https://www.opcom.ro/tranzactii_produse/tranzactii_produse.php?lang=ro&id=162

Popescu Luminita-Georgeta, Popa Roxana-Gabriela, Schiopu Emil-Catalin, 2018. The thermal power plant impact on the environment and some possibilities of reduce it by ash and slag recicling and reuse. Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, Vol. VII, Print ISSN 2285-6064, 10-15.

The Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation (PICASSO, 2022). Retrived from https://www.entsoe.eu/network_codes /eb/picasso/

The Romanian National Energy Regulatory Authority (ANRE) Order no. 89/2021 regarding the approval of the technical classification procedure for the provision of system services (ANRE, 2021).

Transelectrica, 2020. Retrived from https://www. transelectrica.ro/web/tel/rapoarte-lunare-echilibrare

Transelectrica, 2022. Retrived from https://www. transelectrica.ro/web/tel/piata-de-echilibrare

Transelectrica, 2022. Retrived from https://www.transelectrica.ro/web/tel/piata-serviciilor-tehnologice-de-sistem

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE DEVELOPMENT OF A COGENERATION POWER PLANT FOR SYSTEM SERVICES TAKING INTO CONSIDERATION ENVIROMENTAL PROTECTION

Emil DIACONU

Valahia University of Targoviste, 13 Aleea Sinaia Street, 130004 Targoviste, Romania

Corresponding author email: emy_diaconu@yahoo.com

Abstract

The current work represents the continuation of a two-part study regarding the analysis of the energy market and system services in Romanian environmental protection as well as the role of cogeneration in countering the problems in the national energy system. This article presents the solution of a cogeneration plant and its usefulness in the national energy grid. As it is expected, the solution has to be environmentally friendly and as efficient as possible, and at the same time, taking into consideration the area where it will be installed so that the thermal energy produced can be efficiently exploited.

Key words*: National Energy System, system services, balancing market, cogeneration power plant, environmental protection.*

INTRODUCTION

The expected evolution of the structure of the energy sector shows that in a few years Romania will base its electricity production mainly on hydropower capacities and wind and photovoltaic resources, which will put more pressure on the transport system operator (CNTEE Transelectrica SA) to ensure the safety and operational stability of the National Energy System (NES) (EGR, 2019; ANRE, 2021) - approximately 1900 MWh/h is the power reserve contracted by Transelectrica on the system services market (Transelectrica, 2022; ANRE, 2021; TEL 04.05, 2022; ANRE, 2007; ANRE 2011).
Currently, over 90% of system services are provided by state-owned companies, mainly Hidroelectrica and some coal-fired power plants. There are only a few private manufacturers who have technically qualified for such services.
The unpredictability of electricity production from renewable energy sources (RES) (Dragomir et al., 2016) has determined a change in the structure of energy delivered to the balancing market depending on the type of reserve that ensures balancing, thus increasing the need for fast tertiary reserve.
It is expected that the european balancing energy exchange platform (PICASSO, MARI) (PICASSO, 2022; MARI, 2022) to be fully operational by the end of 2022. As a result, all existing manufacturers wishing to participate in the European balancing market will go through a new qualification process.
Taking into account the technical requirements, it is unlikely that any manufacturer will be able to meet the qualification conditions for system services without additional investment to upgrade the equipment or even completely replace it.
Thus, the perfect conditions are created for the implementation of cogeneration solutions. The cogeneration process has become more and more used both for efficiency and for the footprint on the environment, polluting much less than solutions with fossil fuels. Of all the solutions in cogeneration, the one most desired by the European countries and not only is the one with biomass because it also allows a high degree of recycling. The study carried out in Turkey by Kulcu and Cihanalp in 2017 reinforces the idea (Kulcu & Cihanalp, 2017).
The presented project represents a new investment in a dispatchable unit with an installed electrical capacity of approximately 20 MW, using cogeneration engines that use natural gas and which will meet the new technical requirements and ensure the flexibility required by Transelectrica on the system services market.
The estimated cost of this investment is 13.9 million euros.

The average annual EBITDA (Earnings Before Interest, Taxes, Depreciation and Amortization) will be around 3.2 million euros/year and the average annual net profit will be around 1.7 million euros/year.
The investment recovery period will be around 5.6 years, project IRR (Internal Rate of Return) - 16.3%.
If the installation will also provide heating services in the winter season, provided that the specific regulations allow it and / or a new High Efficiency Cogeneration Support Scheme is implemented, the project could have an EBITDA and a period of similar or improved investment recovery.

The purpose of the project

The project consists in the construction and operation of a cogeneration power plant with a total installed capacity of 20 MWel.
The chosen technical solution consists in the installation of 6 natural gas engines manufactured by INNIO Jenbacher of 3.358 MWel each, with an electrical efficiency of 44.73%.
The estimated cost of the investment is 13.9 million euros, which can be further adjusted according to the company's final project. Of this value, 500 thousand euros was estimated for purchasing the necessary land. The specific investment (excluding land) is 665 thousand euros/MW.
The company will only provide system services and will record revenues from:

a) System Services – fast tertiary backup adjustment as follows:
   - 95% of the year, the plant will supply 18 MWh/h, tertiary regulation reserve;
   - 5% of the year, during the peak intervals when the prices will reach a certain level, the plant will sell the electricity on the Next-Day Market (NDM) (OPCOM 2022) also offering a fall adjustment reserve;
b) Balancing services - fast tertiary adjustment. At the request of Transelectrica, the plant will supply electricity:
   - 15% of the time when the upward adjustment reserve is contracted;
   - 30% of the time, energy is supplied for downward regulation – period in which the down regulation reserve is contracted;

The project can be implemented in 12-15 months. The life of the project is assumed to be 15 years, although the number of operating hours on each engine at the end of this period, when the overhaul would take place, is 36660 hours, since the average annual number of operating hours per engine is 1,556 hours. This number of hours corresponds to a demand of 15% for the increase adjustment from the total time slots and 5% electricity delivered at the peak on the NDM minus 30% demand for the tertiary decrease adjustment.
As an alternative to system services, the plant can also provide thermal energy to the local distribution operator in the winter season, if the specifics and/or conditions allow this and/or if the new support scheme for the cogeneration production of high-efficiency electricity will be approved.

Location

Constanta is one of Romania's cities with the highest price for thermal energy (331.84 Ron / MWh for consumers connected to the transport network and 482.73 Ron / MWh for consumers connected to the thermal energy distribution network) and the City Hall grants substantial subsidies for the population.
The main local producer - Electrocentrale Constanța produces inefficient and polluting thermal energy (Nedelcu et al., 2019) with hot water boilers that can only operate until the end of 2022, with a derogation for CO2 emissions.
One of the operating scenarios of the plant would be the delivery of system services, balancing services, the sale of electricity on NDM during the winter and the sale of thermal energy to the RADET thermal energy distributor.
In this scenario, the plant will operate and record revenues from:

a) System Services - fast tertiary regulatory reserve - during the summer season (6 months), as follows:
   - 95% of the period, the power plant will supply 18 MWh/h, the upward adjustment reserve;
   - 5% of the period, during the peak intervals when the prices will reach a certain level, the plant will sell the electricity on the NDM, also providing a fall adjustment reserve;
b) Balancing services - fast tertiary adjustment - at the request of Transelectrica, the plant will supply electricity:

- 15% of the time when the upward adjustment reserve is contracted, according to the upward adjustment request;
- 30% of the downward adjustment time, during the period in which the downward adjustment reserve is contracted;

c) Sale of electricity produced in cogeneration - during the winter season (6 months), on NDM or through bilateral electricity contracts;
d) Sale of thermal energy, heat and hot water - during the winter season (6 months), to the local thermal energy distributor (RADET).

During the winter season, the plant could choose to partially provide a secondary regulation reserve. If a new scheme to support high-efficiency cogeneration will be approved, the power plant will also request its qualification to benefit from the scheme.

Technical characteristics of cogeneration engines

The cogeneration plant is equipped with 6 INNIO-Jenbacher manufacturing cogeneration modules of the JMS 620 GS-N.LC type with an installed electrical power of 3358 kWel and an installed thermal power of 2101 kWth. The technical specification engine JMS 620 GS-N.LC – J02 are presentet in Table 1.

Table 1. Technical specification engine JMS 620 GS-N.LC – J02

Thermal engine type	JMS 620 GS-N.LC – J02	
Electric power	3.358	kWel
Recoverable thermal power (180°C at basket) - tolerance ± 8%	2.101	kWt
Hourly fuel flow at PCI = 9.5 kWh/Nm3 - tolerance + 5%	791	Nm3/h
Electrical efficiency - tolerance ± 8%	44.7	%
Thermal efficiency - tolerance ± 8%	28.0	%
Total yield - tolerance -13% - +3%	72.7	%
Generator voltage	10.5	kV
Frequency	50	Hz
Fuel gas pressure	22.01	bar
Engine cooling water circuit temperature	80	°C
Engine cooling water return temperature	44	°C
Engine noise level	65 dB at 10 m	

Investment

The main elements of the investment are: land, equipment - 6 cogeneration engines, construction and installation works, connection to electricity networks (including the power station), natural gas, water and thermal energy, obtaining approvals and authorizations and other expenses. The elements of the investment are presented in Table 2.

Table 2. Investment elements of the project

Investment		
Land acquisition	EUR	500,000
Cogeneration engine equipment	EUR	6,951,060
Construction and installation	EUR	3,223,680
Connection to the power grid	EUR	2,719,980
Authorizations, approvals, design	EUR	200,000
Other	EUR	302,220
Total	EUR	13,896,940

As it has been shown above, the main elements of the investment refer to:

- Land acquisition.
- Purchase of the main equipment – 6 cogeneration engines. They come equipped with all auxiliary installations and equipment - cooling, ventilation, heat exchangers on the burned gas circuit, the glycol circuit and the cooling water circuit. After their installation, only the connection to the energy utilities is made - electricity, natural gas, water.
- The construction works consist of the construction of the building where the cogeneration engines are located, the foundations on which the engines are installed (according to the technical specification of the equipment supplier, the creation of access roads, etc.).
- The works regarding the connection to the power grid refer to the construction of a connection station (in the case of energy capacities over 10 MW it is mandatory), the realization of the electricity network between the motors and the power station, and the connection works to the power lines of the distribution operator.
- Costs related to the preparation of technical documentation, approvals and authorizations necessary for the achievement of the objective and its operation, design, obtaining the cogeneration energy production license and registration in the energy markets.

HYPOTHESES FOR PROJECT OPERATION AND ANALYSIS

Technical data of the plant

As it was previously presented, the plant is equipped with 6 INNIO-Jenbacher cogeneration engines of the JGS 620 GS NLC J02 type.

Currently, the legislation does not mention the granting of the cogeneration bonus. For this reason, the operation of the plant premise started from delivering only electricity, with the aim that in the future, in the event of a change in legislation, thermal energy will also be delivered to the local thermal energy distribution operator. This pessimistic scenario of service provision can demonstrate the reliability of the project; the future delivery of thermal energy bringing even more feasibility.

Fuel consumption efficiency, electrical energy supply efficiency and thermal efficiency supply efficiency were determined. Thus, to establish the efficiency of fuel consumption, the transition from the lower calorific value of natural gas to the higher one (HCV/LCV=0.9) and the tolerance given by the equipment supplier regarding fuel consumption deviations of 2.5% were taken into account compared to the standard consumption given by the technical specification of the engine. As it is known, technical calculations are made taking into account the lower calorific value of the fuel (LCV), but the fuel costs are determined taking into account the higher calorific value of the fuel (HCV).

To determine the efficiency of electricity supply it had to be taken into account:

- the internal consumption of the plant -2.5% of the production.
- the losses in the transformer - 2.5%.
- the losses in the line (from the engine to the settlement point with the energy distribution operator electrical) of 2%.

According to the data provided by the supplier INNIO-Jenbacher, the lifetime of the engine is 60,000 hours of operation until the overhaul, and preventive maintenance is carried out every 2000 hours of operation. The technical operating data of an engine and power plant are presented in Table 3.

Table 3. Technical operating data of engines

Engine		
Type		JGS 620 GS NLC J02
Number of engines	No	6
Electric energy produced	kWel	3,358
Thermal energy produced	kWth	0
Fuel consumption	kW PCI	7,507
Fuel efficiency	%	87.75%
Efficiency of electricity supply	%	93.64%
Efficiency of thermal energy supply	%	95.00%
The electrical efficiency of the motor	%	44.73%
Thermal efficiency of the motor	%	0.00%
Number of hours of operation until the capital overhaul	Hours	60,000
Maintenance intervals	Hours	2,000
Annual average number of operating hours / engine	Hours/ year	1,648

Assumptions regarding the operation of the plant

In order to establish the operating forecasts of the plant, the structure of the energy market, the statistics of System Services offers, the activation of the tertiary reserve of increase or decrease and NDM were analysed (Andrei et al., 2019).

Thus, the plant will provide electricity for:

a) System Services – Fast Tertiary Backup Adjustment as follows:
   - 95% of the year, the plant will supply 18 MW, the tertiary regulation reserve.

b) Delivery of electricity on NDM for 5% of the time. In the peak intervals when the prices will reach a certain level, the plant will sell the electricity on the NDM, also providing fallback regulation reserve.

Electricity producers are obliged to offer electricity for Balancing Services - Fast Tertiary Regulation. The plant will supply electricity at the request of Transelectrica. It was considered that in this market the activation orders given by the National Energy Dispatcher for the activation of the rapid tertiary adjustment reserve will be:

- 15% of the time the growth adjustment reserve is activated;
- 30% of the time energy is supplied for down regulation.

The analysis of the project is done over a period of 15 years of operation (or 180 months) plus the implementation period which lasts approximately 1 year. To be on the safe side it was considered the starting point of operation is the second month of the third year.

The plant starts operating from year 2 – March until year 17, the tenth month.

Only the production of electricity was considered, although in the winter months, when the city needs larger amounts of thermal energy, both electricity in the NDM and thermal energy for heating in the centralized system could be delivered.

It was also considered that 2% of the bids submitted for system services are lost.

Offering system services through monthly and weekly auctions, it was estimated for each time interval the quantitative and financial offer submitted and how much of it is won. Also, when establishing the operating schedule, the availability of the engines, 92% (8200 hours/year), and their planned overhaul periods were taken into account.

Thus, the 6 engines, out of the total of 49200 hours available, will operate a total of 18048

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

hours delivering a total of 185231 MWh. The situation of operating hours and the amount of electricity delivered annually from the plant is presented in Table 4.

Table 4. Hours of operation and quantities of energy delivered from the plant annually

Typeof service provied	Functioning hours	Energy delivered
	h	MWh
Increase adjustment	7500	22,500
Decrease adjustment	131	2,477
NDM	1,836	5,778
Total	9,467	30,755

The annually amount of electricity delivered from the plant is presented in Figure 1. It is noted that 83% of the amount of electricity is delivered for System Services, 14% on the Balancing Market (BM) and 3% on NDM.
As shown, the revenues of this project are provided from the system services and implicitly from the Balancing Market.
Thus, the income will be from:

- System services – fast growing tertiary reserve.
- System services – fast growing tertiary reserve.
- Balancing market – increase adjustment.
- Balancing market – decrease adjustment.
- NDM – peak price (7.00-23.00).

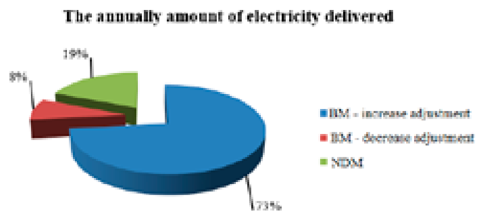


Figure 1. Share of the quantities of electricity delivered annually

Revenues from System Services represent revenues from contracting system services (the obligation to make available to National Energy System (NES) the quantities of electricity contracted for the rapidly increasing and decreasing Tertiary Reserve).
The revenues from the Balancing Market represent the revenues obtained from:

- the increase adjustment, at the National Energy Distributor (NED) order, when NES is in deficit.
- the decrease adjustment at the NED order, when NES is in surplus.
- from the NDM where it must deliver to secure itself on the market balancing decrease ordered by NED.

CONCLUSIONS

The plant implementation will increase the stability of the NES, while following and fulfilling the European and national environmental and energy efficiency legal provisions. This were stipulated in Romania's National Energy Strategy as well as in the legal measures established for its fulfilment.
In conclusion, the project of the cogeneration plant 20 MWel takes advantage of the existing opportunities by solving some of the current problems.
The plant is equipped with 6 cogeneration engines with an installed electrical power of 6x3358 =20148 MWel and an installed thermal power of 12606 MWth.
The electrical efficiency is 44.7% and the thermal efficiency is 28%.
Being specially designed to provide system services, The engines were chosen with a high electrical efficiency.
The plant can provide system services, electricity on the centralized market (bilateral contracts), NDM, Intraday Market (IM) and can provide thermal energy to the centralized thermal energy supply system of the city.

REFERENCES

Andrei, F.D., Dogaru Ulieru, V., Salisteanu, I.C., Nedelcu, O., Salisteanu, B., 2019. Medium voltage networks automation to improve the electrical energy distribution service, *19th International Multidisciplinary Scientific GeoConference* SGEM 2019.

ANRE Order no. 21/13.07.2007 regarding the approval of the "framework contract for the sale and purchase of system technological services between the Provider of system technological services and the transport and system operator" (ANRE, 2007).

ANRE Order no. 40/30.09.2011 for the amendment and completion of the framework contract for the sale and purchase of system technological services between the provider of system technological services and the transport and system operator, approved by the Order of the President of ANRE no. 21/2007 (ANRE, 2011).

Autoritatea Nationala de Reglementare in domeniul Energiei (ANRE, 2021). Retrived from https://www.anre.ro /ro/energie-electrica/rapoarte https://www.transelectrica.ro/web/tel/piata-serviciilor-tehnologice-de-sistem.

EGR, 2019. Retrived from http://energie.gov.ro /transparenta-decizionala/strategia-energetica-a-romaniei-2019-2030-cu-perspectiva-anului-2050/.

Dragomir, A., Dogaru, V., Salisteanu, C.I., Nedelcu, O., Issa, F., 2016. Analysis on islanding states using renewable energy systems, *16th International Multidisciplinary Scientific GeoConference SGEM 2016, Renewable Energy Sources and Clean Technologies*, Book 4, Volume 1 ISBN: 978-1-5108-2990-9 / ISSN 1314-2704.

Kulcu Recep, Cihanalp Cihannur, 2017. Evaluating of electric energy generating potential using biogas from animal biomasses in Burdur City. Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, Vol. V, Print ISSN 2285-6064, 17-22.

Manually Activated Reserves Initiative (MARI, 2022). Retrived from https://www.entsoe.eu/network_codes /eb/mari/.

Nedelcu, O., Salisteanu I. C., Ivanovici, T., Dogaru, V., 2019. Energy passivation of a building. The ICSTM building case study, *E3S Web of Conferences 112, 02003* (2019) TE-RE-RD 2019.

Operational Procedure "Purchase by auction of technological system services" code TEL 04.05 (TEL 04.05, 2022).

Operatorul pietei de energie electrica si de gaze naturale din Romania (OPCOM, 2022). Retrived from https://www.opcom.ro/tranzactii_produse/tranzactii_produse.php?lang=ro&id=74

Operatorul pietei de energie electrica si de gaze naturale din Romania (OPCOM, 2022). Retrived from https://www.opcom.ro/tranzactii_produse/tranzactii_produse.php?lang=ro&id=162

The Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation (PICASSO, 2022). Retrived from https://www.entsoe.eu/network_codes /eb/picasso/.

The Romanian National Energy Regulatory Authority (ANRE) Order no. 89/2021 regarding the approval of the technical classification procedure for the provision of system services (ANRE, 2021).

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE RISKS OF LAND FRAGMENTATION OVER THE QUALITY OF LIFE IN RURAL AREAS IN ROMANIA

Lucica DOBRE, Dorina Nicoleta MOCUȚA

University of Agronomic Sciences and Veterinary Medicine of Bucharest,
59 Marasti Blvd, District 1, Bucharest, Romania,

Corresponding author email: dorinamocuta@yahoo.com

Abstract

Agriculture, as the basic branch of the economy and as biological branch of the material production, is an economic sector of national priority. We aim to capture aspects related to risk management in agriculture, in the dynamics determined by the lack of coherent agrarian, economic, social, unitary policies, complementary to the reality on the spot, and to facilitate the merger of agricultural lands in Romania. Through a comparative analysis, we show the perspective of specific Romanian trends, leading to perpetuation and development of several major risks with a significant impact on the performance of Romanian agriculture, as well on the quality of life in rural areas. Is there a pattern that leads to an inertia of agricultural activities? How can the negative effects can be overcome? What needs to be changed in order to generate performance and economic progress in agriculture? The methodology used is based on NIS, Eurostat results, documenting broader perspectives described in specialized literature through which we illustrate the general picture of the quality of Romanian agriculture, namely the merging of agricultural lands.

Key words: *land merging, risk management, technology, agriculture, globalization.*

INTRODUCTION

In a broad sense, risk and its effects cover vast areas of action, with concrete, pragmatic manifestations at all levels of social, economic, political life, etc. The notion of risk refers to the existence of uncertainty, to a possible danger, to the possibility of occurring events, random, unforeseen events, even damages that have or may have the effect of disrupting the activity of the field in which it operates. It is a sure thing that the only thing we know is that we do not know for sure the subsequent evolution of the actions and events that take place.

From this perspective, it is wise to always act by taking precautionary measures for possible risks that may arise due to malfunctions or disturbances in the dynamics of things.

In terms of risk management - an area that includes all rigorously planned and organized activities, whose role is to manage and assess the dynamics of change and calculate the risks and margins between which they may occur - the notion of risk is integrated, as a central element, in the analysis of the probability of occurrence of possible changes often perceived as dangers, minor or major damage.

Effective risk management involves working as a working hypothesis in researching and calculating the risks of any type of activity, such as: "If the variable event, unforeseen X happens, then the results will generate possible damage Y". "If the results are Y, then the activity I carry out is a risky one in itself." Therefore, in order to validate one or more presumptions, as many working hypotheses as possible must be generated, including presumptions that are based on common sense arguments, but not exclusively on them, because the critical apparatus of thought leaves room for confusion. "Assuming X is true, and then Y happens." Effective thinking, thinking about consequences, i.e. that which takes place through a chain of reasoning that leads to predicting solutions, anticipating further effects, is considered by us, an essential part in assuming a management of calculated risks. Obviously, there will always be calculations that may escape us, the so-called human errors, and calculation errors. To a large extent (calculated) the possible risks, mistakes, and dangers, assumed or not, are really beneficial, they generate innovative effects throughout the field of activity. In fact, a responsible, responsible risk is a proactive behavior, it is, in fact, a plenary manifestation of courage. Extending, we can say that a risk taken is a natural act on: *What we must do?* - As an act transferred to the possible future.

Hence, a long-term, courageous, sustainable thinking about the effects that an assumed risk can generate. It is also a structural change of mentality, a revolution, a trial-and-error process, the removal of false security - a reality in which the Humankind (as humanity in itself) is an effect, an effect that generates innovation.

Through the analysis of risk factors and risk reduction strategies in agriculture, we try to obtain a broader understanding of them, an understanding that will lead us, on the one hand, to the correct identification and assessment of factors, risk-generating processes, and ameliorating the negative effects by adopting preventive measures by decision-makers at both the global, macroeconomic and social higher levels, as well as at the intermediate, microeconomic, local levels.

The calculation of the costs involved in a particular activity, specific to a wider field and how these costs are managed, so that the activity undertaken is sustainable, self-generating, largely depends on the environment, the context of socio-political and economic stability carried out by that activity. Every activity bears the imprint of the one who generated it, whether we are talking about the individual himself or a community or society as a whole. Agriculture, as the basic branch of the economy and the biological branch of material production, is an area of national priority.

Not a hundred years ago, the main occupation of the population, both in the western and in the eastern areas, was centered on agriculture, the way of life being organized in close connection with agriculture, with tillage work.

In the historical vein of the Romanian people, the occupations related to the work of the land have imprinted the essence of the Romanian psycho-social and cultural profile. In "*The Psychology of the Romanian People*" Rădulescu-Motru makes a fine analysis of the soul of the Romanian people to whom he finds a series of qualities and defects: *"The Romanian is persevering in something. At the agricultural work that if he starts, he never leaves. As a landowner he is able not to part with his lot even if he has a small gain, which does not even ensure his subsistence. The Romanian does not like company; he wants to be on his own, absolute master he at home, with a small part of the property, but his own. Because of this, he leans a little towards anarchy. The lack of commercial spirit among Romanians is also due to the ignorance of the exchange value of goods, which are known only by their subjective value of use, and free competition as it appears in the "bourgeois" states of the West and which considers man as an anonymous wage force - it is not yet assimilated by the morals of our people. For the Romanian, time does not mean money, he bargains for hours for nothing*" (Rădulescu-Motru, 1998).

MATERIALS AND METHODS

Our research has a transdisciplinary documentation base. From a transdisciplinary perspective, in addition to quantitative methods and statistical-mathematical techniques, we consider and pay more attention to the field of interdisciplinary, because it provides us with inclusive models that coherently bring together various theoretical models from various scientific fields. Research in the field of risk management, INS statistics, Eurostat reports as well as established economic and sociological theories (Bădescu et al., 2003) are the basis of analysis for the research we carry out and bring to light here (https://insse.ro/cms/ro; https://ec.europa.eu/eurostat/statistics-explained/; https://ec.europa.eu/eurostat/statisticsexplained/index.php?title=File:Key_indicators_%E2%80%94_share_in_EU-28_total,_2013_(%25)_YB16.png#file, https://ec.europa.eu/eurostat/statistics-explained/; https://ec.europa.eu/eurostat/statistics-explained/).

In a global context, the functioning of society is mainly determined by the way in which social changes act at the level of the social structure and the social system. "*Man's ability to participate intelligently in the evolution of his own system depends on his ability to perceive the whole*"(Wallerstein, 1974).

The dynamics of the social reality present in Romania, but also anywhere in the world,

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

presupposes equally both the knowledge and description of the components of the parts of the whole, as well as the understanding of the social reality itself, a reality that is always changing.
In this sense, the significant landmarks of the past can be reinterpretations of reality in the form of present perspectives that would constitute sketches for future projections. Overcoming an excessive descriptivism resulting from the meanings of theoretical-methodological technical analyzes, can also be done by moving to transdisciplinary, in-depth analyzes, in which the capital resource – *the Man* - is in its multidimensional relationship: with the group to which it belongs, with work in the community, in the region / area, with the environment in which they integrate, with the way they communicate and understand to set their priorities.

RESULTS AND DISCUSSIONS

The land is an invaluable asset, the main natural resource on which agriculture as a field of human activity depends.
Land - as the main element of agricultural capital, in complementarity with other natural resources that participate and facilitate human activity - water, climate, forests, plants, animals, soil and climate factors, etc. - unreproducible, indivisible resource whose complex role is economic, functional, material, is the main condition of human labor.
Not being a good directly produced by man or with similar characteristics of other goods, the land is defined according to the elements with which it enters into a relationship, elements which grants the character of a multidimensional good.
At the same time, the land is a living organism, which contains other resources, either on the surface or in the soil, which in turn are natural, depletable goods, and which are also not directly the product of human labor or activity.
Natural land resources, although vast, actually have a low potential for use in the cultivation and agricultural production of major crops. This is mainly due to natural factors - agriculture being the economic sector with high economic risk due to the fact that it depends to a large extent on naturally unpredictable conditions.

Political, economic and social factors, which are constantly changing, also contribute. Globally, of the world's agricultural area of about 4.152 billion hectares, arable land is between 1.524-1.804 million hectares (Figure 1).
An important indicator, not to be neglected in the overall picture, is the distribution of land location, with a stronger concentration in developing countries, and whose population is about three quarters of the world's population (Figure 2). Most of them are in India, China, Russia, which own more than half of the cultivated area - 723.5 million hectares. By 2050, amid global population growth of 7.5 billion to as much as 11 billion, statistical forecasts show that food demand will increase by 70%. This trend will be particularly accentuated by developing countries as the demand for food will double.

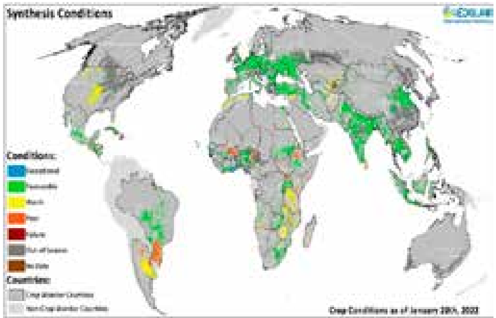


Figure 1. The map of global production/crops (https://cropmonitor.org/index.php/crop-conditions/classification-systems/)

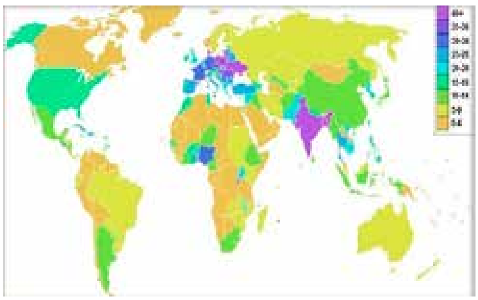


Figure 2. World map of arable land: agriculture land arable land, pastures/hayfields (https://www.everythingconnects.org/arable-land. html)

By comparison to the other nations, we can say that Romania occupies a relative favorable place, in terms of the ratio of the owned land and the number of citizens.

At European level (EU28), Romania occupying the 9th place, i.e. 5.33% as a surface The essential changes of the last five to six decades, which have taken place in social dynamics, in relationships and interactions between people, between communities, nations, but also mecha-nization, technology, increasing demand for agri-food products have led to the development of production methods in which , through an intensive, mechanized and chemicalized agricultural system, the main word is *overproduction*.

Ensuring global food production depends to a large extent on a rational, efficient and sustainable management of the land, and in general on everything involved in organizing and planning the economic system in which agriculture remains, not only in theory, an important field of economic activity and a primary sector of the economy.

Following the global trend and the shortcomings that endanger the existence and balance of the ecosystem itself, the aim is a reorientation of agricultural policies by implementing environmental policies that respect and protect the environment.

This involves not only what we cultivate but also, especially, how we cultivate, so that the crops are of quality, healthy and sustainable, without exhausting the natural resources at our disposal.

According to Eurostat statistics, Romania has a total area of rural areas of 207,522 km (20,752,200 ha), i.e. 87.1% of 238,398 km (23,839,700 ha) total area (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Main_Page).

Out of a population of 19,476,713 inhabitants in 2018, approximately 8,995,201 inhabitants, i.e. 46.18% is represented by the rural population.

Although it has significant development poten-tial, it is underused. At European level, the share of agricultural land shows a picture with significant differences between the number of agricultural holdings and the agricultural area actually used in agriculture (Figure 3).

According to NIS statistics, compared to 2010 when the agricultural area used was 13,306 million ha, it decreased to 12,502 million ha in 2016. Of this area, arable land is 63.47%, pastures and hayfields 33.44% and 2.34% permanent crops (Figure 4.) Compared to 2010, the total number of agricultural holdings decreased in 2016 by 11.3%, being 3,422,030, which represents 32.7% of the number of agricultural holdings in the EU.

72% of the total registered holdings, i.e. 2,480,770 holdings, fall into the segment of up to 2 ha.

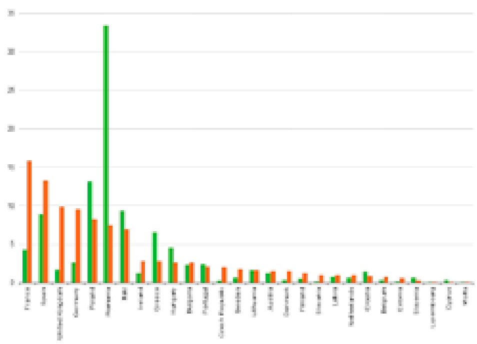


Figure 3. Number of agricultural holdings vs utilized agricultural area UAA

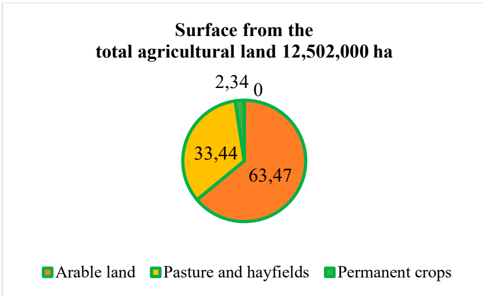


Figure 4. Agricultural land use by categories (https://data.consilium.europa.eu/doc/document/ST-14282-2020-ADD-21/ro/pdf)

On holdings of up to 2 ha, 12.24% of the total utilized agricultural area (*1.53 million ha*) of agricultural land owned is used to obtain goods for own consumption, without carrying out market-oriented economic activities. Also, of the agricultural area used, a percentage of 28.7% belongs to farms in the segment up to 5 ha in a total number of 3,420,030, of which farms smaller than 5 ha - 3.14 million (91.8%), respectively holdings on the segment 2-5 ha, numbering 660,000. On the segment of farms larger than 5 ha, the number of farms is decreasing, as follows: the number of farms between 5-50 ha is 262,930 (7.7%), the segment 50-100 ha, with a number of 6,010 (0.17%) and the segment of holdings over 100 ha with a number of 12,310 (Figure 5).

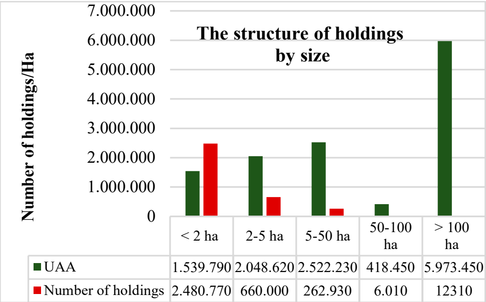


Figure 5. The structure of Romanian agricultural holdings

In 2019, SAPS payments were made for an area of 9,748,666 ha and a number of 796,021 farmers, compared to 2016 when the number of farmers was 901,507, SAPS payments being for an area of 9,177,354 ha agricultural units (Table 1).

Table 1. Number of farmers/areas SAPS/APIA 2016

Category of areas	Number of beneficiary	Precent	Areas	Precent
No SAPS areas	58.312	6.47%	-	-
< 5 ha	63.465	70.82%	1.491.648	16.25%
Between 5 și 50 ha	184.654	20.48%	2.205.069	24.03%
Between 50 și 100 ha	8.018	0.89%	569.856	6.21%
Between 100 și 300 ha	7.644	0.85%	1.292.933	14.09%
Between 300 și 500 ha	1.987	0.22%	766.333	8.35%
Between 500 și 1000 ha	1.559	0.17%	1.091.857	11.90%
Over 1.000 ha	868	0.10%	1.759.656	19.17%
Total	**901.507**	**100%**	**9.177.354**	**100%**

From the data analysis, the decrease in the number of farmers indicates that associative structures have been created; however, the inertia with which the land amalgamation process takes place is evident (Figure 6).

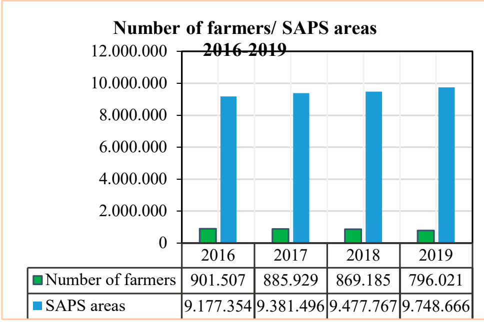


Figure 6. Number of farmers/SAPS areas 2016-2019

In the Romanian rural areas, after more than three decades since the removal of the communist regime, the peasants-farmers look with suspicion and reserve at the initiatives of organization by association that would favor and carry out the process of merging agricultural lands. As the data presented in this study show, the largest share of land is represented by small farms under 5 ha, 2-5 ha. (The few exceptions of land consolidation and the existence of associative structures of some agricultural producers, show the productive efficiency and the lucrative level of these structures). The fragmentation of land, the large number of small isolated lots, along with the land acquisitions made by foreign investors, made against the background of lack of legislative coherence, represent two major risks in agriculture.

The *2006 draft law* on the reorganization of agricultural land states that the purpose of merging agricultural land is to create operating structures that allow the formation of commercial production units, and in compliance with the rules on soil and environmental protection. The agrarian policy actions, after 1989, materialized by the ownership, the establishment of the property right - according to the *Law 18/1991* and 1/2000 - the non-restriction of the sale-purchase of agricultural lands, as well as the division of the land fund through donations, inheritances etc. are some of the causes fragmentation of the existing land fund, which affects not only the economic level of production, but also the property as such (https://agroromania.manager.ro/docs/lege-masuri-stimulare-comasare-terenuri-agricole.pdf).

Also, the temporary or permanent removal from the agricultural circuit of some lands, as a result of the demarcation of the demarcation lines, the boundaries between the plots, as well as the lack of a coherent and unitary cadastral policy to manifest in the sense of clarifying the location, destination use and sizing of plots, but also the decrease of the economic value, and of the patrimony of the properties with a high degree of scattering, are as many sources of deepening the confusion and the anomie of the agricultural policy.

The cadastral program 2015-2023 is realized, on 31.01.2022, as follows:

- out of the total of 9.54 million ha of agricultural lands that are the object of APIA subsidies, 6.27 million ha (66%) were registered in the integrated system of cadastre and land book.
- out of the total of 3,181 ATUs in Romania, systematic registration works were completed in 129 ATUs (of which in 122 ATUs in full and in 7 ATUs partially), as well as in cadastral sectors, with a total area of 3,566,059.11 ha.
- completed systematic registration works in 2 ATUs (of which one full ATU and one partial ATU), as well as in cadastral sectors, with a total related area of 19,836.64 ha
- systematic registration works are underway in 1,999 ATUs, with an estimated area of 4,909,347.62 ha (https://www.ancpi.ro/ pnccf/ documente/NOTA_privind_activitatea_ANCPI _la_data_de_31.01.2022.pdf).

In terms of risk management, the indicators listed above have effects and have a direct impact on the quality of life in both rural and national economies.

At the organizational level, on practical, concrete action, the land merger is not only a strict problem of agriculture or related to the countryside, because it involves, on the one hand the act of will and decision of the owner, and, on the other hand implies a more accentuated level of involvement of the State, through its mechanisms of stimulation, social action and control and the organization of agrarian policy measures.

It is unlikely that the land merger process could still have the collectivist character specific to the communist regime.

In a democratic society, with a free market economy, the need for merger is imposed as a condition and an action of the utmost importance without which economic progress is not possible, otherwise agriculture is permanently under the spectrum of precarious potential.

In a speech given at the Academy of Economic Studies on the topic of merging agricultural lands in Romania, prof. univ. dr. Constantin Anghelache claimed that, in fact, the Law 18/1991 was more a reclaiming of possession and less an agrarian reform, the fragmentation of the territory, agriculture as a whole, through its factors of progress - mechanization, chemicalization, irrigation - being far below the level since 1989.

The law had to ensure the possession of the old owners under certain conditions, for example, maintaining for 5 years the existing cooperative structures in order to facilitate the transition to individual farms, in conditions of sufficient productive potential, and not only to "check out an activity" or animated by the feeling of immediate justice (Istudor et al., 2017).

Legislative inconsistencies have an overwhelming impact on the reform process, which, of course, was well thought out by some ministerial teams, but which, out of a concrete desire for modernization and progress, did not fully align with EU requirements, nor with the reality on the ground, which had a relative impact on the quality of life in rural areas.

For example, through PNDR 2014-2020 out of a total of 6,202 contracted projects, amounting to EUR 355.1 million, payments of EUR 174.6 million were made (https://www.pndr.ro/ situatia-proiectelor-depuse-2014-2020.html).

30.9% represented investments to create, expand and the improve of local services as well as the necessary infrastructure, namely 23.6% were investments allocated to micro-enterprises with non-agricultural activity and 17.3% investments in the development and modernization of agricultural holdings. Although the support for young farmers had the purpose into attracting more active people in agriculture and encouraging the sustainable economic development of agricultural activities, on a small-scale, the level of depopulation has shown an upward trend, but overall, the progress of development is not yet being felt.

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

CONCLUSIONS

Contrary to optimistic expectations, Romania's integration into the EU has led to a slowdown in the land merger process, one of the reasons being the granting of direct payments to beneficiaries, which has led to higher land prices and rent, farmers of previous generations since 1989, not being interested in leasing or selling to young investors.

This attitude has directly affected the performance and development of a rational agriculture, planned and organized on a modern scientific basis.

The essential role of agriculture is to participate in economic development and growth, agriculture evolving in proportion to the specificities of economic and social structure, as well as the degree of industrialization of each nation.

Agriculture, as a specific socio-economic system, requires, unlike other fields, "an organic production process, while in industry the production process is mechanical. This implies another method of work and a special role of human labor - said V. Madgearu. *It is possible* to mechanize agriculture, but the conditions for evolution and growth change".

The new clothes of modernity do not always seem to be suitable for Romanian rurality. Even the continuity of rurality worldwide, in the current conditions of modernity, over-technology and globalism, can make the evolution one that leads to a differentiation even within the rurality, and, in some areas, even to a diminution of the borders between rural and urban.

Can the phenomenon of globalization transform the essence of the rural environment and diminish the specific Romanian ethos?

As a complex social structure, the village is (more) free from the constraints imposed on the structure and the specific urban organization.

The interdependence is one that comes from the city to the village and not the other way around. The modernization of the villages does not result from a relationship of dependence on the city, because the villages by their very structure and form can subsist by themselves.

The modernization of villages is reflected in a different level of organization through the emergence of economic, administrative and political mechanisms and levers that participate in the functioning of the system and structures of a state, of a nation, as a whole.

In one of our previous article (Dobre and Mocuta, 2021) we analyzed, from the perspective of the 17 objectives of sustainable development, some major problems existing in the Romanian rural environment and which affect the quality of life - such as poverty, marginalization and social exclusion, lack of infrastructure, population decline and aging in rural areas, as well as the human development index - HDI composed of three important indicators: life expectancy, education index (expressed by school employment rate) and GDP / capita.

To these we add the risk generated by the delay of the merging agricultural lands process and – as consequences- the unfavorable influence over the quality of life in rural areas.

"I have said it before and I repeat it: the only solution is to return to tradition and get out of this modern society, little by little, so easily. Let us return to the old habits of our ancestors, to cultivating a piece of land, because nature itself will come to our aid. The nature of the Romanian can only be falsified with great difficulty, because our man has a very healthy and strong fiber" said Father Iustin Pârvu in an interview (www.atitudini.com) about the current state of Romanian society.

The question is: do we, the Romanians, remain the eternal villagers of history? If we look not too far in recent history and in the very letter and spirit of the (agricultural) legislature, this attitude is preferred.

It seems that the mental structures that contribute to the overall modernization of the most important possible sector of a nation's economy, agriculture, do not yet have the unitary resources to complete a work of national importance.

Is this running around in circles in terms of land merging process a sign of the Romanian peasant's resistance to the modern and current changes of the globalized society, resistance which undoubtedly belongs to the historical and cultural profile given by the consciousness of "*eternity*", and of its permanence on the Romanian land?

"*The problem of merging, in our opinion, is much more difficult and will face a resistance that is difficult to defeat on the part of the* *peasants. The proof is the little we have achieved so far in this direction*" said the agricultural economist N.D. Cornățeanu, 70 years ago (Cornățeanu, 1943).

From the perspective of the objectives of the Europe 2020 Strategy and the analysis of the quality of life in rural areas, there is no doubt that a significant indicator is the level of poverty associated with a community.

An objective of the utmost importance is to reduce the number of people at risk of poverty or social exclusion, in this regard Romania aiming to reduce it from 4.99 million in 2008 to 4.41 million in 2020, a target yet unattainable (http://europedirectbucuresti.ier.ro/wp-content/uploads/brosura_europa_2020_8mb.pdf).

An important progress factor in increasing the quality of life, the Local Action Groups (LAGs) have helped to raise European quality standards by including measures to support the integration of minority communities, as well as measures - identified at the local level - to promote forms of economic association.

The phenomenon of poverty has a geographical distribution that requires careful management of resource allocation so as to reduce discrepancies between different areas, both in rural and urban areas, especially given that the socio-economic-cultural status of some villages changed and they received the status of city.

Practically, a risk added to the list of shortcomings faced by the rural population and which essentially creates social and economic distance in relation to developed areas.

Poverty is not just about the lack of financial resources to facilitate an easier way to live a decent life, such as, to have a decent home, clothing, to have enough food for a satisfactory, normal level of health.

The social phenomenon of poverty also involves aspects related to intellectual, moral, ethical health that can significantly contribute to increasing the quality of life in general.

For example, in order to attain the EU objectives, through the implementation of European programs, to access European funds, the use of modern, computerized, technological services, can be just as many obstacles in creating a sustainable infrastructure, due to in part to the high costs, but especially the biases and ignorance of their benefits and advantages (even if some services are free).

Continuing the implementation of European and local policies and intervention programs, as well as streamlining local strategic actions on both the merging of agricultural land for development and progress in agriculture, on the one hand, and the reduction of poverty, social inequality, integration of marginalized communities, on the other hand, build the premises of a more sustainable economic, social, cultural and moral perspectives that would lead to an increase in the quality of life in rural areas.

REFERENCES

Bădescu, Ilie, Claudia Buruiană (2003). *The peasants and the new Europe*, Bucharest, RO: Mica Valahie Publishing House, apud. Op.cit, pp. 349.

Cornățeanu, N.D., (1943), *Conditions for the intensification of Romanian agriculture*, Official Monitor and State Imprimery, Bucharest, pp.65.

Dobre Lucica, Mocuta Dorina Nicoleta (2021). Demographic aspects in Romania pointing out the problems of the rural population. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, Vol. 21, Issue 4, 2021, pp. 190.

http://europedirectbucuresti.ier.ro/wp-content/uploads/brosura_europa_2020_8mb.pdf

https://agroromania.manager.ro/docs/lege-masuri-stimulare-comasare-terenuri-agricole.pdf (accessed on 06.02.2022)

https://cropmonitor.org/index.php/cropconditions/classification-systems/ (accessed on 04.02.2022)

https://data.consilium.europa.eu/doc/document/ST-14282-2020-ADD-21/ro/pdf

https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Ferme_%C8%99i_terenuri_agricole_%C3%AEn_Uniunea_European%C4%83_-_statistici

https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Farms_and_farmland_highlight_FP19-RO.png https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Ferme_%C8%99i_terenuri_agricole_%C3%AEn_Uniunea_European%C4%83_-_statistici

https://ec.europa.eu/eurostat/statisticsexplained/index.php?title=File:Key_indicators_%E2%80%94_share_in_EU-28_total,_2013_(%25)_YB16.png#file (accessed on 04.02.2022)

https://www.ancpi.ro/pnccf/documente/NOTA_privind_activitatea_ANCPI_la_data_de_31.01.2022.pdf (accessed on 06.02.2022)

https://www.everythingconnects.org/arable-land. html (accessed on 04.02.2022)

https://www.everythingconnects.org/arable-land. html World map of arable land, percentage by country 2019

https://www.pndr.ro/situatia-proiectelor-depuse-2014-2020.html (accessed 28.02 2022)

Istudor, Nicolae Popescu, Gabriel, (2017). The merging of arable land, AES Publishing, pp. 10-31-58.

National Institute of Statistics, Statistical indicators of sustainable development, Data base of Sustainable Development Indicators in Romania - SDIR https://insse.ro/cms/ro Accessed on 31/01/2022

Rădulescu-Motru, Constantin (1998). *The psychology of Romanian people,* Paideia, Publishing House, pp. 15-18.

Wallerstein, Immanuel (1974). The Modern World-System, vol. I: Capitalist Agriculture and the Origins of the European World-Economy in the Sixteenth Century. New York/London: Academic Press

www.atitudini.com, Attitude magazine, no. 60/2012

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

MICROBIAL DIVERSITY IN SOILS FROM HIGH NATURAL VALUE AGRICULTURAL SYSTEMS WITH PASTURES AND NATURAL MEADOW IN SUCEAVA COUNTY

Gabi-Mirela MATEI, Sorin MATEI, Monica DUMITRAȘCU

National Research-Development Institute for Soil Science, Agrochemistry and Environment, Bucharest, 61 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: so_matei602003@yahoo.com

Abstract

Agriculture with High Natural Value (HNV) is a new concept, develped in the last two decades to describe those agricultural systems in Europa owing the widest biodiversity. Its main characteristics are the low intensity and the presence of semi-natural vegetation. Romania has one of the most important resource of areas classified as HNV due to the great variety of species associated to agricultural land utilised as permanent meadows, by traditional mowing and grazing activities. The aim of this paper is to present the results of research carried out to evaluate the biodiversity of microbial communities in three soils under traditional management of HNV pastures (Vicovu de Jos, Comănești) and natural meadow (Valea Moldovei), Suceava county. The total counts and species of bacteria and fungi (estimated by dilution plate), soil respiration (by substrate-induced respiration method), diversity index of Shannon (H) and similarity index between habitats were calculated and presented as Venn diagram. Biodiversity of microbial communities consists in 6 to 9 species with important roles in main processes in plant rhizosphere, soil organic matter recycling, cellulose decomposition, soil aggregation, biocontrol.

Key words: *HNV agricultural systems, biodiversity, microbial communities, pastures, natural meadow.*

INTRODUCTION

The concentration of CO_2 and other greenhouse gases (GHGs) in the atmosphere is increasing as a result of fossil-fuel combustion, industrial activities and land-use change, leading to climate change and global warming.
The process of soil C sequestration or flux of C into the soil is part of the global carbon balance (Blujdea et al., 2014). The factors affecting the flow of C into and out of the soil are affected by land-management practices (Oancea, 2003).
Kirschbaum, (1995) evidenced the temperature dependence of soil organic matter decomposition, and predicted that soil organic C stocks will decline as an effect of global warming. Land-management options that improve C sequestration, increasing plant productivity and simultaneously preventing soil erosion are of major interest in regions with desertification risk.
Recent studies reported the impact of agronomic practices on soil organic carbon dynamics by their influence on various labile/non-labile fractions equilibrium (Abril & Bucher, 2001; Jackson et al., 2002; Guo et al., 2014; Lalichetti & Sultan, 2020).
Studies on the ecology of grassroots underlined that complex plant-microbe-soil interactions proved to be important drivers of plant and microorganisms' community structure and dynamics (Reynolds et al., 2003; Prommer et al., 2020).
Organic amendments and land management affect soil microbial community composition, diversity and biomass (Gomez et al., 2006; Lejon et al., 2007; Bonilla et al., 2012; Eftene et al., 2014; Moreno et al., 2019; Bonanomi et al., 2020).
Soil microbiota has an important contribution to soil services (Aislabie & Deslippe, 2013; Dobrovol'skaya et al., 2015; Matei et al., 2020).
An important source of biodiversity for both plants and soil microorganisms is represented by HNV areas.
This paper presents the results of research carried out to evaluate the biodiversity of microbial communities in three soils under traditional management of high natural value (HNV) pastures (Vicovu de Jos, Comănești) and natural meadow (Valea Moldovei), Suceava county, North-East Romania.

MATERIALS AND METHODS

The period analysed in this study was autumn 2020-spring 2021.
Surface samples (0-20 cm) from soils under traditional management of HNV pastures (Vicovu de Jos, Comănești) and natural meadow (Valea Moldovei), Suceava county were analysed by using microbial indicators (microbiological activity from soil, number and micro-organisms types) to characterize the biodiversity of microbial communities.
Microbiological analyses were performed by soil dilution method on specific culture media with agar-agar: Nutrient agar (NA) for aerobic heterotrophic bacteria and potato-dextrose agar (PDA) for fungi. After 7 days incubation at dark, colonies were counted and microbial density (Total Number of Bacteria-TNB and Total Number of Fungi-TNF) was reported to gram of dry soil.
Taxonomic identification was done using morphologic criteria, according to the manual (Bergey & Holt, 1994) for heterotrophic bacteria and to Domsch & Gams (1970) and Watanabe (2002) determinative manuals for fungi. Morphological characteristics were measured and photographed under a MC 5.A optic microscope.
The total number of species (S) was recorded for each microbial community, as well as relative abundance and dominance of each species. The ratio between the number of species and microbial counts in communities expressed species richness (SR_2 index).
The Shannon index (H') that takes into account both the richness and evenness (ε) of a given ecosystem was used to evaluate the microbial biodiversity in soil samples (Mohan & Ardelean, 1993). Its value increases with the increased number of species and is also higher when the species are evenly distributed (Morris et al., 2014).
The index of Brillouin (1956) and Simpson (D) index (Stugren, 1982) were also used to calculate the diversity and "equitability" component of microbial species diversity (distribution of "individuals" on species). Similarity indices (SI) between habitats were calculated (Tiwari et al., 1994) and the results of comparative analysis of the microbiomes composition were presented as Venn diagrams (Gentlemen & Ihaka, 1994).
The global physiological activities of soil active microflora were determined by substrate induced respiration method (SIR) and results were expressed as mg CO_2x100 g^{-1} soil (Matei, 2011). Circular paper chromatograms were made by migration of soil extracts to obtain information on soil biological quality (Papacostea, 1976).
All assays were carried out in triplicate. Results were interpreted by one-way analysis of variance (ANOVA). The value $p<0.05$ was considered statistically significant (Student test).

RESULTS AND DISCUSSIONS

Data analysis revealed statistically significant differences between the three HNV areas concerning both total counts of bacteria, fungi and global physiological activities (Table 1).

Table 1. Total microbial counts and global physiological activity of soil bacterial and fungal microflora in HNV pastures and natural meadow

No crt.	Soil profile location (land use)	TNB (x 10^6 viable cells x g^{-1} d.s.)	TNF (x 10^3 cfus x g^{-1} d.s.)	Soil respiration (mg CO_2 x100^{g-1} soil)
1	Vicovu de Jos P1 (pasture)	7.669b[1]	125.798a	41.137a
2	Comănești P3 (pasture)	6.513c	101.394b	34.201b
3	Valea Moldovei P5 (natural meadow)	9.425a	125.613a	32.168c

[1]The values in a column followed by the same letter are not significantly different for P< 0.05 (Student test)

P1 - Soil from Vicovu de Jos P1 (pasture) presented low density of aerobic heterotrophic bacteria, high values for the representatives of fungal community and moderate values of soil respiration potențialului (41.137 mg CO_2 x 100 g^{-1} soil).
6 fungal species have been identified (Figure 1), two belonging to the group of Zygomycetes, developed on cattle excrements on the pasture, and actively involved in their decomposition, as well as in humification processes (*Zygorrhynchus moelleri, Mucor circinelloides)* and associated with species belonging to other genera with strong cellulolytic, pectinolytic or chitinolytic capacities (*Cladosporium, Penicillium, Paecilomyces, Mortierella*).

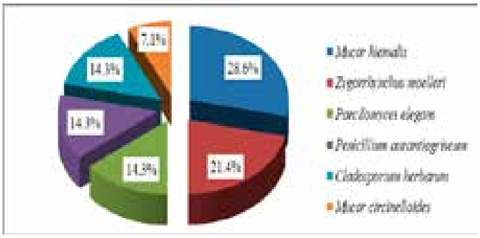


Figure 1. Percent mean relative abundance of fungal microflora composition in soil under pasture from Vicovu de Jos

Bacterial microflora, formed by representatives of 9 species (Figure 2), was dominated by fluorescent pseudomonads (well-known as microbial antagonists and implicated, along with fungal species identiffied, in the processes of humus formation), asssociated with bacillaceae, *Arthrobacter* and accompanied by actinomycetes with role in aggregation of soil particles. The role of pseudomonads in biological control of fusarium wilt was confirmed by *in vivo* experiments on tomato, carried out by Attitalla et al. (2001).

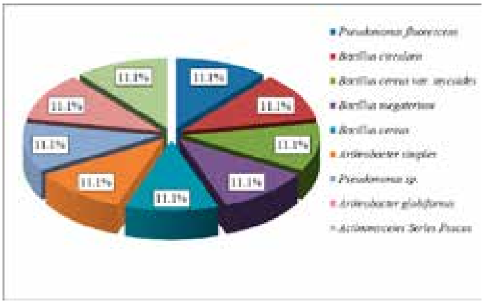


Figure 2. Percent mean relative abundance of bacterial microflora composition in soil under pasture from Vicovu de Jos

P3 – Soil from **Comănești P3 (pasture)**, presented a low density of bacteria (6.513 x10^6 viable cells x g^{-1} dry soil) and a relative high level of total counts of fungi (101.394 x10^3 cfu x g^{-1} dry soil).

A moderate microbial activity (34.201 mg CO_2 x 100 g^{-1} soil) was registered for this soil biota.

Fungal microflora (7 species) was dominated by species from the group of Zygomycetes (*Mucor, Actinomucor*) accompanied by less abundant ubiquitary, cellulolytic species from genera *Aspergillus, Penicillium*, *Acremonium, Cladosporium* and *Fusarium* (Figure 3).

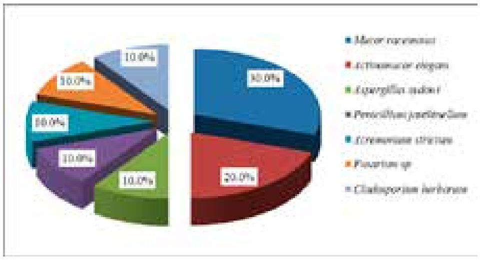


Figure 3. Percent mean relative abundance of fungal microflora composition in soil under pasture from Comănești

The group of heterotrophic bacteria consisted of 7 species belonging to bacillaceae, pseudomonadaceae (fluorescent, non-fluorescent) and arthrobacteriaceae (Figure 4).

The presence of species *Bacillus subtilis* indicate an environment higher humidity conditions and an easily degradable organic material (possibly excrements from animals grazing on the pasture).

Pseudomonas aeruginosa is known as saprophyte and parasite of animal and vegetal organisms (Papacostea, 1976).

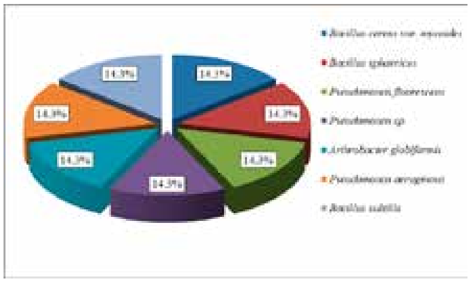


Figure 4. Percent mean relative abundance of bacterial microflora composition in soil under pasture from Comănești

P5 - Soil from **Valea Moldovei P5 (natural meadow)** presented a low to moderate level of total counts of bacteria (9.425 x 10^6 viable cells x g^{-1} dry soil) and a high level of total counts of fungi (125.613 x 10^3 cfu x g^{-1} dry soil). The global physiological activities of soil active microflora were moderate as intensity (32.168 mg CO_2 x 100 g^{-1} soil) but significantly lower than in soils under pastures. Fungal microflora consists of 8 species. It was identified the species *Zygorrhynchus moelleri*, (Figure 5), dominant în community, frequently isolated from rhizosphere and especially from acid debasified soils, with important role in degradation of organic matter.

Figure 5. *Zygorrhynchus moelleri* dominant in soil under natural meadow from Valea Moldovei (x200)

Termophilic species (*Fusarium pallidoroseum*, two species of the genus *Aspergillus*) were accompanied by other strong cellulolytic species of genera *Penicillium*, *Verticillium* and *Paecilomyces* (Figure 6).

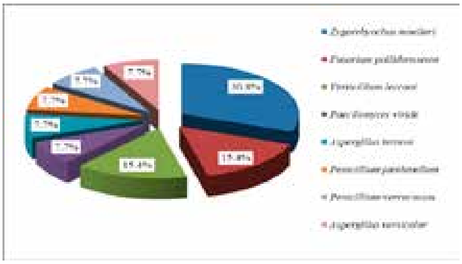


Figure 6. Percent mean relative abundance of fungal microflora composition in soil under natural meadow from Valea Moldovei

Bacterial microflora, consisting of 6 species was characterized by the co-dominance of bacillaceae with pseudomonads, each represented by 3 species (Figure 7).

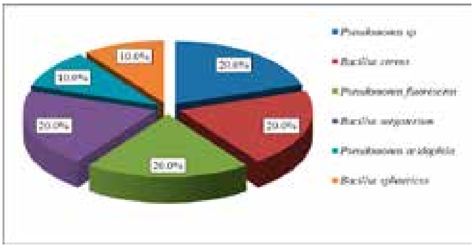


Figure 7. Percent mean relative abundance of bacterial microflora composition in soil under natural meadow from Valea Moldovei

Bacillus species are considered beneficial in soil communities and pseudomonads contribute to the biocontrol of plant pathogens, as well as to C sequestration in stable forms (humus), as reported in literature (Kucuc & Kivanc, 2003; Matei et al., 2018; Dumitrașcu et al., 2019).

Ecologic spectra of fungal and bacterial groups in each soil profile evidenced the percent relative abundance of a species in the structure of microbial cenosis and revealed species status (e.g., as dominant species).

Analysis of bacterial species composition lists and the logic diagram (Venn) from Figure 8a showed that two species representing fluorescent pseudomonads and non-fluorescent pseudomonads were shared between the three lists. Our results are in concordance with other studies (Weller et al., 2002), that attribute the suppressiveness character of the soil to the pseudomonads, able to control plant pathogens.

In fungal communities, no species was shared by all the three lists (Figure 8b).

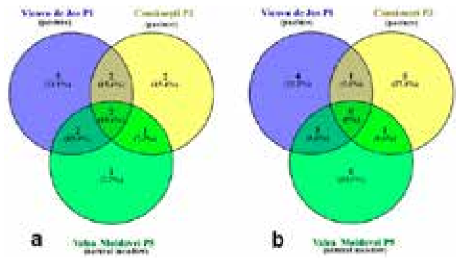


Figure 8. The Venn diagram denoting the unique and shared number and proportion of bacteria (a) and fungal (b) species in the communities from HNV soils

Biodiversity (S) of edaphic microbial communities consisted in 6 to 9 species. The highest value of diversity index of Shannon for bacterial community was found in soil under pasture from Vicovu de Jos (H'=2.364 bits and evenness ε=0.864). The communities from the two pasture soils were characterized by high homogeneity, as calculated by Brillouin formula (value E=1).

For the group of fungi, the highest diversity was found in soil under the natural meadow from Valea Moldovei (diversity index of Shannon H'=1.925 bits and evenness ε=0.796). The homogeneity, as calculated by Brillouin formula, reflected that the mycocenoses were formed by few dominant species, with higer abundance and more species with homogen distribution of less abundant individuals (see Table 2 for the values of all diversity indices).

Table 2. Taxonomic composition and biodiversity indices of bacterial and fungal microflora in HNV soils under pastures and natural meadow

Soil profile location (land use)	Fungal species	Bacterial species
Vicovu de Jos P1 (pasture)	*Mucor hiemalis* *Zygorrhynchus moelleri* *Paecilomyces elegans* *Penicillium aurantiogriseum* *Cladosporium herbarum* *Mucor circinelloides*	*Pseudomonas fluorescens* *Bacillus circulans* *Bacillus cereus* var. *mycoides* *Bacillus megaterium* *Bacillus cereus* *Arthrobacter simplex* *Pseudomonas* sp. *Arthrobacter globiformis* Actinomycetes Series Fuscus
	S=6 SR_2=0.476 Shannon H'=1.710 ε=0.855 Brillouin H=0.563 B= 7.879 E=0.902 Simpson Index D=0.806	S=9 SR_2=1.173 Shannon H'=2.364 ε=0.874 Brillouin H=0.618 B=5.560 E=1 Simpson Index D=0.889
Comănești P3 (pasture)	*Mucor racemosus* *Actinomucor elegans* *Aspergillus sydowi* *Penicillium janthinellum* *Acremonium strictum* *Fusarium* sp. *Cladosporium herbarum*	*Bacillus cereus* var. *mycoides* *Bacillus sphaericus* *Pseudomonas fluorescens* *Pseudomonas* sp. *Arthrobacter globiformis* *Pseudomonas aeruginosa* *Bacillus subtilis*
	S=7 SR_2=0.690 Shannon H'=1.834 ε=0.789 Brillouin H=0.498 B=4.481 E=0.934 Simpson Index D=0.820	S=7 SR_2=1.074 Shannon H'=1.946 ε=0.780 Brillouin H=0.529 B=3.702 E=1 Simpson Index D=0.875
Valea Moldovei P5 (natural meadow)	*Zygorrhynchus moelleri* *Fusarium pallidoroseum* *Verticillium leccani* *Paecilomyces viride* *Aspergillus terreus* *Penicillium janthinellum* *Penicillium verrucosum* *Aspergillus versicolor*	*Pseudomonas* sp. *Bacillus cereus* *Pseudomonas fluorescens* *Bacillus megaterium* *Pseudomonas acidophila* *Bacillus sphaericus*
	S=8 SR_2=0.636 Shannon H'=1.925 ε=0.796 Brillouin H=0.601 B= 7.812 E=0.964 Simpson Index D=0.828	S=6 SR_2=0.636 Shannon H'=1.748 ε=0.836 Brillouin H=0.536 B=5.356 E=0.871 Simpson Index D=0.820

Circular paper chromatograms were used to obtain information on soil biological quality, by image analysis, that allow the evaluation of features such as soil vitality, fertility, the intensity of biotic activity, the degree of complexity of organic matter and the presence of stable humus (Figure 9).

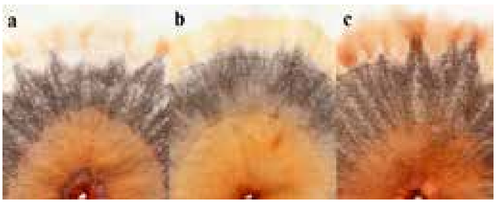


Figure 9. Sections of circular chromatograms of soils under pastures from Vicovu de Jos (a), Comănești (b)and natural meadow from Valea Moldovei (c)

The sections of circular chromatograms highlight the qualitative differences between the soils under the influence of land use as pastures and natural meadow.

Analysis of the chromatograms revealed different capacities of humus formation, reflected in reduced content in labile organic carbon, increased content in nitrogen and in the dynamics of organic carbon decomposition. Processes of intermediary development with row organic matter, accumulated but also with tendency of integration in soil were evidenced.

There are not evidences of unfavorable conditions in soil.

Mineral diversity was observed especially in chromathgrams from P1 (pasture) and P5 (natural meadow).

The qualitative/quantitative content in accesible minerals appeared very well evidenced at P5, with intense mineralization and reduced at P3.

Protein content was high and very well structured, as evidenced by specific features, especially for chromatograms of P5 and P1, excepting P3 chromatogram, where no tendency of structuration of protein material was registered.

P3 chromatogram revealed formation of acid humic substances with low stability and in P1, P5, the formation of brown colloidal humus with high stability. The most intense processes of mineralization with reduction of organic matter reservoir were evidenced in soil under pasture from Comănești.

Chromatograms revealed the presence of aggregates in solution, as well as elements for construction of soil. Microbial activity was very well evidenced on chromatogram of P1. The lowest level of microbial activity and functional diversity appeared for P3.

Functional diversity was well outlined by specific aspect of characteristic zone on chromatograms P1, and P5. Conditions relatively favorable for organic aggregation and floculation appeared mainly in P5, followed by those from P1.

Nutritional potential and carbon sources were represented by fragmented chemical compounds, enreached in nitrogen and with a relatively equal distribution (excepting P3).

Generally, the chromatograms revealed a moderate to low level of enzymatic activity.

P3 presented the lowest level of enzymatic activity and P1 the highest.

Our results on microbial bio diversity in soils from HNV areas are in concordance with other studies from literature (Grayston et al., 2001; Singh et al., 2007; Liu et al, 2012).

Zhao et al. (2018) found that relative abundance of individual bacterial taxa varied distinctly among different samples (by over several ranges of magnitude) as a result of the differences in soil properties and conditions.

Parton et al. (1995) presented the impact of climate change on grassland production and soil carbon worldwide and Reeder & Schuman (2002) underlined the influence of livestock grazing on C sequestration in semi-arid mixed-grass and short-grass rangelands.

Present research findings are in concordance with previous results (Eftene et al., 2014) on the influence of 4 land use types (cultivated land, vineyard, *Acacia* forest and pasture) on microbiological activity of sandy soils from Băilești Plain (southwest of Romanian Plain), in climatic conditions with hot dry summers and low precipitations. The most intense global microbial activity, measured as soil respiration, was in soil under pasture and the lowest values of total counts of bacteria and fungi were recorded under vineyard, as response of edaphic microbiota to anthropic interventions.

Further research results application are necessary for introduction of sustainable pasture management practices among farmers/ shepherds, aiming biodiversity conservation, combating of desertification/land degradation and avoidance of climate changes.

CONCLUSIONS

Natural meadow soil from Valea Moldovei presented significantly higher density of both bacteria and fungi and lower levels of CO_2 released by global physiological activities as compared with the two pastures.

Biodiversity of edaphic microbial communities consisted in 6 to 9 species.

The highest value of diversity index for bacterial community was found in soil under pasture from Vicovu de Jos (H'=2.364 bits and evenness ε=0.864).

For the group of fungi, the highest diversity was found in soil under the natural meadow from Valea Moldovei (H'=1.925 bits and evenness ε=0.796).

Edaphic microorganisms identified contribute to important soil services in HNV pastures and natural meadow by recycling of nutrients and formation of soil, cellulose decomposition, C sequestration and synthesis of stable organic matter (humic acids), improving soil structure by aggregation of soil particles and biological control of pathogens by production of active metabolites with inhibitory role.

Specific paper chromatograms revealed good conditions in all HNV soils but higher enzyme activity, functional diversity, higher level of nutritional reserve, more intense humification processes (with colloidal substances and mineral compounds well integrated in the organic material) for land use as natural

meadow, followed by pasture from Vicovu de Jos than for the pasture from Comănești.
Protection and conservation of microbiological diversity in soils from HNV areas contributes to sustainable use of biodiversity components and is imperative for the preservation of important functions, structures and processes of natural, as well as agro-ecosystems.

ACKNOWLEDGEMENTS

This work was supported by two grants of the Romanian Ministry of Research, Innovation and Digitization by Research Programme NUCLEU, the project PN 19 34 03 02/2019 and project number 44 PFE /2021, Program 1 – Development of national research-development system, Subprogramme 1.2 – Institutional performance – RDI Excellence Financing Projects.

REFERENCES

Abril, A. & Bucher, E.H. (2001). Overgrazing and soil carbon dynamics in the western Chaco of Argentina. *Applied Soil Ecology, 16*, 243 – 249.

Aislabie, J., Deslippe, J. (2013). Soil microbes and their contribution to soil services. In: Dymond JR (Ed.), *Ecosystem services in New Zeeland–conditions and trends*. Lincoln, New Zeeland: Manaaki Whenua Press.

Attitalla I., Johanson, P.M., Brishammar, S., Gerhardsson, B. (2001). *Pseudomonas* sp., strain MF30 suppresses fusarium wilt of tomato in vivo. *Phytopathologia Mediterranea, 40*, 234–239.

Bergey, D. H., & Holt, J. G. (1994). *Bergey's manual of determinative bacteriology* 9, vol.2. Baltimore, US: Williams & Wilkins (Eds.).

Blujdea, V.N.B., Marin, Gh., Stoichițescu, M. (2014). Land dataset uncertainty: effect on Romanian National Greenhouse Gas Inventory. *Annals of Forest Research, 57*(2), 299-317.

Bonanomi, G., Alioto, D., Minutolo, M., Marra, R., Cesarano, G., Vinale, F. (2020, May 14). Organic amendments modulate soil microbiota and reduce virus incidence in the TSWV-tomato pathosystem. *Pathogens*, 9(5), 379. Retrieved February 24, 2021, from https://doi.org/10.3390/pathogens9050379.

Bonilla, N., Cazorla, F.M., Martinez-Alonso, M., Hermoso, J.M., Gonzales-Fernandez, J., Gaju, N., Landa, B.B., de Vicente, A. (2012). Organic amendments and land management affect bacterial community composition, diversity and biomass in avocado crop soils. *Plant and Soil, 357*, 215–226.

Brillouin, L. (1956). *Science and information theory*. New York, USA: Academic Press.

Dobrovol'skaya, T.G., Zvyagintsev, D.G., Cernov, I.Y., Golovkenko, A.V., Zenova, G.M., Lysak, L.V., Manucharova, N.A., Marfenina, O.E., Polyanskaya, L.M., Stepanov, A.L., Umarov, M.M. (2015). The role of microorganisms in the ecological functions of soils: evolution of approaches and methods. *Eurasian Soil Science, 48*(9), 959–967.

Domsch, K. H., & Gams, W. (1970). *Fungi in agricultural soils*, Edinburg, London, GB: T&A Constable Ltd. Publishing House.

Dumitrașcu, M., Lungu, M., Ștefănescu, S.L., Mocanu, V., Matei, G.M., Lazăr, R. (2019). Soil fertility assessment of an high natural value eligible area in South-Eastern Transylvania. *Journal of Present and Sustainable Development*, *13*(1), 57–67.

Eftene A., Matei G.M., Matei S., Răducu D. 2014 – Influence of land use on microbiological activity of sandy soils. *Proceedings of 5th International Conference on Advanced Materials and Systems ICAMS 2014*, 427-432.

Gentleman, R. & Ihaka, R. (1996). The R Language. *Journal of East China Geology Institute,15*, 693–704.

Gomez, E., Ferreras, L., Toresani, S. (2006). Soil bacterial functional diversity as influenced by organic amendment application. *Bioresources Technology, 97*, 1484–1489.

Grayston, S., Griffith, G., Mawdsley, J., Campbell, C., Bardgett, R.D. (2001). Accounting for variability in soil microbial communities of temperate upland grassland ecosystems. *Soil Biology and Biochemistry, 33*, 533–551.

Guo, L.J., Zhang, Z.S., Wang, D.D., Fang, C.L., Cao, C.G. (2014). Effects of short-term conservation management practices on soil organic carbon fractions and microbial community composition under a rice-wheat rotation system. *Biology and Fertility of Soils*, *51* (1), 65–75.

Jackson, R.B., Banner, J.L., Jobbagy, E.G., Pockman, W.T., Wall, D.H. (2002). Ecosystem carbon loss with woody plant invasion of grasslands. *Nature*, *418*, 623 – 626.

Kirschbaum, M.U.F. (1995). The temperature dependence of soil organic matter decomposition, and the effect of global warming on soil organic storage. *Soil Biology and Biochemistry*, *27*, 753–760.

Kucuc, C. & Kivanc, M. (2003). Isolation of *Trichoderma* spp. and determination of their antifungal, biochemical and physiological features. *Turkish Journal of Biology, 27*, 247–253.

Lalichetti, S. & Sultan, S. (2020). Impact of agronomic practices on soil organic carbon dynamics: A review. *International Journal of Chemical Studies, 8*(4), 2173–2178.

Lejon, D.P., Sebastia, J., Lamy, I., Chaussod, R., Ranjard, L. (2007). Relationships between soil organic status and microbial community density and genetic structure in two agricultural soils submitted to various types of organic management. *Microbial Ecology, 53*, 650–663.

Liu, N., Zang, Y., Chang, S., Kan, H., Lin, L. (2012). Impact of grazing on soil carbon and microbial biomass in typical steppe and typical desert steppe of inner Mongolia. *PLOS ONE, 7*(5), 1–9.

Lloyd, M. & Ghelardi, R.J. (1964). A table for calculating the "equitability" component of species diversity. *Journal of Animal Ecology, 33*, 217–225.

Matei, G.M., Matei, S., Mocanu, V. (2020). Assessing the role of soil microbial communities of natural forest ecosystem. *The EuroBiotech Journal, 4*(1), 1–7.

Matei, S. (2011). Determination of soil respiration and microbial biomass. In: Dumitru, M. & Manea, A.(coord.). *Methods of chemical and microbiological analysis (utilized in soil monitoring system)*, (in Romanian) (pp. 283–288). Craiova, RO: SITECH Publishing House.

Matei, S., Matei, G.M., Dumitrașcu, M. (2018). Soils from HNV Agriculture Systems as Source of Microorganisms with Antifungal Activity. *The EuroBiotech Journal, 2*(4), 196–199.

Mohan, G. & Ardelean, I. (1993). *Ecology and environment protection* (in Romanian). Bucharest, RO: Scaiul Publishing House.

Moreno, J.L., Torres, I.F., Garcia, C., Lopez-Mondejar, R., Bastida, F. (2019). Land use shapes the resistance of the soil microbial community and the C cycling response to drought in a semi-arid area. *Science of the Total Environment, 648*, 1018–1030.

Morris, E.K., Caruso, T., Buscot, F., Fischer, M., Hancock, C., Maier, T.S., Meiners, T., Müller, C., Obermaier, E., Prati, D., Socher, S.A., Sonnemann, I., Wäschke, N., Wubet, T., Wurst, S., Rillig, M.C. (2014). Choosing and using diversity indices: insights for ecological applications from the German Biodiversity exploratories. *Ecology and Evolution, 4*(18), 3514–3524.

Oancea, M. (2003). *Modern management of agricultural holdings*. Bucharest, RO: Ceres Publishing House.

Papacostea, P. (1976). *Soil biology*. (in Romanian). Bucharest, RO: Scientific and Encyclopedic Publishing House.

Parton, W.J., Scurlock, J.M.O., Ojima, D.S., Schimel, D.S., Hall, D.O. 1995. Impact of climate change on grassland production and soil carbon worldwide. *Global Change Biology*, *1*, 133 – 220.

Prommer, J., Walker, T.W.N., Wanek, W., Braun, J., Zezula, D., Hu, Y. *et al*. (2020). Increased microbial growth, biomass, and turnover drive soil organic carbon accumulation at higher plant diversity. *Global Change Biology, 26*, 669–6681.

Reeder, J.D. & Schuman, G.E. (2002). Influence of livestock grazing on C sequestration in semi-arid mixed-grass and short-grass rangelands. *Environment Pollution*, *116*, 457–463.

Reynolds, H.L., Packer, A., Bever, J.D., Clay, K. (2003). Grassroots ecology: plant-microbe-soil interactions as drivers of plant community structure and dynamics. *Ecology, 84*, 2281–2291.

Singh, B.K., Munro, S., Potts, J.M., Millard, P. (2007). Influence of grass species and soil type on rhizosphere microbial community structure in grassland soils. *Applied Soil Ecology, 36*, 147–155.

Stugren, B. (1982). *Bases of general ecology* (in Romanian). Bucharest, RO: Scientific and Encyclopedic Publishing House.

Tiwari, S.C., Tiwari, B.K., Mishra, R.R. (1994) Succession of microfungi associated with the decomposing litters of pineapple (*Ananas comosus*). *Pedobiologia, 38*, 185–192.

Watanabe, T. (2002). *Pictorial Atlas of Soil and Seed Fungi: Morphologies of Cultured Fungi and Key to Species* 2nd ed. London, New York, Washington D.C., USA: CRC PRESS, Boca Raton Publishing House.

Weller, D.M., Raaijmakers, J.M., McSpadden Gardener, B.B., & Thomashow, L.S. (2002). Microbial populations responsible for specific soil suppressiveness to plant pathogens. *Annual Review of Phytopathology, 40*, 309-348.

Zhao, X., Fan, F., Zhu, H., Zhang, P., Zhao, G. (2018). Microbial diversity and activity of an aged soil contaminated by polycyclic aromatic hydrocarbons. *Bioprocess and Biosystems Engineering, 41*, 871–883.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

REASONS FOR MAINTAINING AND/OR INTRODUCING TREES ON GRASSLANDS

Elena MIHĂILĂ[1], Elena TĂULESCU[2], Adrian TUDORA[1], Mihăiță BÎTCĂ[1]

[1]National Institute for Research and Development in Forestry "Marin Drăcea", 128 Eroilor Blvd, Voluntari, Ilfov, Romania
[2]Transilvania University of Brasov, 1 Sirul Beethoven Street (S-building), Brasov, Romania

Corresponding author email: lilianmihaila@gmail.com

Abstract

Grasslands with sparse trees are a high biological and cultural value agroforestry system, which are not enough promoted in Romania. In this article, a grassland with sessile oak and pedunculate oak and one without trees were studied. Data were collected from a number of 7 sample areas distributed randomly with an area of 100 m². In these surfaces were taken soil samples from the layer 0 - 10 cm deep and samples of grassy species, about 200 grams. Also, in the grassland with sparse trees all the trees were inventoried and were measured the diameter of the trunk at 1.30 m, the height of the trees and the projection of their crown.
From the analysis of the data, the grassland with trees is superior to the tree-less grassland, from all points of view: productive, protective and aesthetic, which is why this agroforestry system in the temperate zone of our country plays a very important role in maintaining a balance between the quality of the pastures and the quantity and quality of the animal products obtained.

***Key words**: agroforestry system, grasslands with sparse trees, grassy species, trees, protective.*

INTRODUCTION

For more than four decades, agroforestry, along with agriculture and forestry, have contributed to ensuring sustainable land management and have studied all land use systems in which agricultural and forestry species combine on the same land area in order to increase ecological, economic and social benefits (Bene et al., 1977 cited by MacDicken and Vergara, 1990; Leakey, 1996).
Grassland with trees (along with forest shelterbelts) are the most representative agroforestry systems in our country, in terms of occupied areas and the ecological, economic and social benefits they provide (Costăchescu et al., 2010; Marușca, 2017).
There is no rigorous country-wide statistics on the area occupied by grassland with tree, but following the research undertaken, they are found in large areas in the Transylvania area, but also in the Dobrogea Tableland. Grassland located in the lowland area and low hills not comprise significant forest vegetation, although in these areas the impact of climate change on grass vegetation and animals is greater. It is the area where forest deforestation in the last two centuries has been massive, inclusive in grasslands, where there is no longer tree forest vegetation but only shrubs or no forest vegetation. In relation to the total area of the country, grassland (with and without trees) occupies 14.11%, which represents approximately 3,36 million hectares (www.insse.ro). Grasslands belong to communities, are managed at the level of the Hall and are usually grazed by cattle, sheep and goats. The scattered trees on grassland, referred to in this paper as grassland with trees, mainly come from oaks forests which have been gradually cut over the last 100 to 200 years, where a small number of oaks, wild pear and other species remained. The main problem of grassland with trees is that the few old trees present on grassland will gradually disappear and, given the impossibility of natural regeneration (due to constant grazing), the continuity of these species can be much more difficult. In addition, grassland mainly existing in the lowland and hill areas does not have trees but only shrubs in isolation. Under these circumstances it is necessary to plant trees on pasture, with all the difficulties that this process raises.

The present paper presents the research carried out in two pastures, with trees and without trees, located in the locality of Herculian, the commune of Bățani, the county of Covasna.

MATERIALS AND METHODS

In order to study the influence of trees on grass vegetation and both directly and indirectly on animals, a comparative analysis of one permanent grassland with oak trees (*Quercus robur* L. and *Quercus petraea*, Liebl) and one no-tree grassland was carried out. Both analysed grasslands have approximately equal areas (Figure 1).

Figure 1. The outline of the grassland with and without trees and the location of the floristic surveys (Google Earth Pro, 2019)

The latter category of land was delimited and taken in the study as a comparative area (control) with the grassland with trees. Both areas under study are part of much larger grasslands, these portions being representative of the two types of grassland selected. Permanent grassland with oak and sessile oak is part of a tree pasture located west, north-west of Herculian, with an area of about 82 ha and bordering on the west a forest body of about 95 ha, from which it is likely to have broken off. The contour of the two areas taken in the study and the position of the floristic surveys within them were determined using GPS technology (Figure 1).
The trees in the area under study were fully counted, measuring the diameter of the trunk at 1.30 m with dendrometer, the height of trees and the pruned stem with caliper and the diameter of their crown projection in two directions with tape measure (Figure 2).

Figure 2. Tree inventory within the grassland with trees

The density of trees within the perimeter of the grassland with trees was determined as the ratio of the number of trees identified during the field work to the area of land studied. All trees counted from the survey area were numbered. The graphic representation of the spatial structure of the tree-pasture profiles was done using the PROARB software (Popa, 1999).
The records of the forestry works carried out in grassland with trees have been taken from the data centralized in the silvopastoral management plan in force.
In both categories of grassland, 7 floristic surveys were made on 100 sqm (Figure 1) areas. The distribution of the test surfaces has been randomized to comprise approximately the entire area of the perimeter being studied.
The floristic surveys within grassland with trees, having circular shape, were carried out under the tree canopy, being located midway between the crown edge and the tree trunk. In the grassland without trees, the floristic surveys had the shape of square.
Soil samples were taken at a depth of 0 to 10 cm with an pedological auger and analyzed in the laboratory and the results obtained were interpreted according to the methodology developed by the National Institute for Research and Development for Pedology and Agrochemistry (Stoica et al., 1986; Florea et al., 1987).

For the determination of the quality of the feed consumed by the grazing animals, approximately 200 g of green grass was taken from each sample area, which was analyzed in the quality laboratory of the Research-Development Institute for Grassland Brașov using the NIRS (Near Infrared Reflectance Spectroscopy) method. The results obtained were interpreted by the standard feed quality classes and summarized in a table of optimal values (Table 1).

Table 1. Optimum values of the nutritional parameters of the feed

Nutritional parameters	Optimal contents
Crude protein	16-18%
Neutral detergent fiber	45-50%
Acid detergent fiber	28-32%
Crude fiber	20-30%
Lignine detergent acid	< 6%
Digestibility	≥ 65%

The yield (qualitative and quantitative) of the two types of grassland has been determined by a new method (Marușca, 2019), the basis of which is the study of the plant cover (Marusca et al., 2020 a, b).

In this respect, floristic surveys were achieved by directly assessing the percentage share of species (P, %) in the grass cover in order to be able to continue to perform calculations on pastoral value, production index and useful green mass production (t/ha).

The pastoral value (VP) has been calculated according to the following formula:

$$PV = \Sigma P\ (\%) \times F/9, \quad (1)$$

where F is the feed quality index (Kovacs, 1979, Păcurar & Rotar, 2014, Marușca, 2019).

The assessment of PV is as follows:

- 0-5 degraded grassland;
- 5-15 very weak;
- 15-25 week;
- 25-40 mediocre;
- 40-60 medium;
- 60-80 good;
- 80-100 very good.

The production of useful Phytomass or green feed mass was then calculated, establishing a weighted production index (Marușca, 2019). The final assessment of the production of green fodder mass was made by multiplying the production index by other indicators established in the grassland experiences. In order to determine whether there is statistical assurance for the production of green feed mass, variance analysis was performed using standard techniques and differences between the media were compared with the Duncan test.

RESULTS AND DISCUSSIONS

The areas under study, situated on slopes of low to medium slope (5-25%), at altitudes of 500 to 650 m, are in the basin of the stream Baraolt, a right-hand tributary of Olt (Posea & Badea, 1984). The watercourse**,** which delimits the grassland with trees and the one without trees, is the stream of Fruntea Popii, often without the water, which after winter with abundant snow or rich rain, when the flow of the stream increases, flows into the stream Baraolt.

From a climate point of view, the surveyed area is characterized by the following parameters:

(i) annual average temperature of 7.6ºC;

(ii) average growing season of 170 days;

(iii) annual average precipitation of 584.1 mm;

(iv) annual potential evapotranspiration of 599 mm;

(v) percentage of windy days of 72%, and calm days of 28%;

(vi) annual De Martonne index of 33.1 (http://www.meteoromania.ro).

The soil types identified in the analyzed territory are of the cambisols class, namely eutricambisol and districambisol (***, 2017).

The soil supply of nutrients directly influences the flower composition of the grassland, thus the results of the soil samples analysed reveal relatively large differences in trophicity, which is higher in the grassland with trees than in the one without trees (Table 2).

According to the classification of indicators for the assessment of the nutrient supply of soils, the amount of nitrogen contained in tree-free grassland is at an approximately normal level (0.21%), compared to that in grassland with trees where it is very high (3.78%), (Lixandru et al., 1986). For the areas under study and in view of the acid reaction of the soils and the high erosion of the grassland without trees, the amount of phosphorus contained in the soil is very low (4.4 ppm), as opposed to that in grassland with trees where it is very good (78.4

ppm), the phosphorus deficiency of the soil affecting the content of plants in nutrients. The provision of potassium soil for tree-free grassland is good (181.0 ppm) and for tree grassland very good (308.0 ppm). The plants absorb all these nutrients contained in the soil throughout the growing season with different intensities depending on the phenophase. Therefore, the deficiency of any nutrient in the soil has the effect of slowing down or stopping plants growth, which leads to insufficiency or lack of feed to the grazing animals.

Table 2. Agrochemical values of the soil in the grassland with trees and in those without trees

Specification	U	1.Grassland without trees	2. Grassland with trees	Dif. 2-1 +, -	%
pH	ind.	5.70	5.20	-0.50	91
Humus	%	4.19	6.20	+2.01	148
Nitrogen index (N)	%	0.21	3.78	+3.58	1809
Mobile Phosphorus (P)	ppm	4.40	78.40	+74.00	1781
Mobile potassium (K)	ppm	181.00	308.00	+127.00	170
Amount of exchangeable bases (SB)	me/100 g	18.00	13.60	-4.40	76
Hydrolytic acidity (Ah)	me/100 g	6.00	8.70	+2.70	145
Cation exchange capacity (CEC)	me/100 g	19.90	22.30	+2.40	112
Base saturation degree (BS)	%	75.00	61.00	-14.00	81
Interchangeable aluminum	me/100 g	0.26	0.12	-0.14	45

The forest species component of the grassland with trees consists of large oak and sessile oak aged between 80 and 120 years. They mainly play a balancing role, stabilizing the ecosystem, bringing the following benefits to grassland: improve microclimate conditions, prevent erosion, facilitate the flow of water and nutrients, provide shelter and protection for animals, fix carbon, and beautify the landscape (Olea & San Miguel-Ayanz, 2006; Ficut et al., 2018).

With the optimum density of trees on grassland, their shadow and the moisture that they can hold in the soil thanks to the root system and wide crowns, contribute to the development of a diverse, rich plant cover, while also contributing to the production of high-quality feed (López-Carrasco et al., 2015; López-Sánchez et al., 2016).

In the grassland with trees 171 trees were counted, which means a density of 14 trees per hectare. That value is at the lower limit of the density of pastures with oaks in countries with tradition in development of pasture with tree, such as Spain, Portugal, Italy and Greece. Here the number of trees per hectare varies from 10 to 40 for the first countries and from 10 to 100 for the last two countries (Eichorn et al., 2006).

The average diameter of the trunk at 1.30 m, the average height of the trees and the average surface of the crown projection are important both for their influence on the crop mat and for the function of production of the tree component of the agroforestry system, even if the latter is secondary. The values of these biometrics are given in Table 4.

The diameter of the trunk at 1.30 m, the height of the trees and the surface of the crown projection are characteristics which influence the rich of the plant cover or the wooden production on the pasture, even if the last one is secondary. The average values of these parameters are given in Table 3.

The sum of tree crown projections has also been calculated, and the 171 trees from the area under analysis are estimated to cover grassland at 22%.

This percentage may in fact be lower, since it has been found that, although most trees are sparse, there are also grouped trees whose crowns projections are partially overlapping (Figure 3).

Table 3. Biometric characteristics of forest species in grassland with trees

Feature analysed	Sessile oak	Oak	Total
Number of trees / % of total	132/ 77%	39/ 23%	171/ 100%
Medium diameter (cm)	67	75	69
Medium height (m)	18	20	19
Medium surface of the crowns projection (sqm)	145	186	154
The sum of the crown projections (sqm)	19182	7252	26434

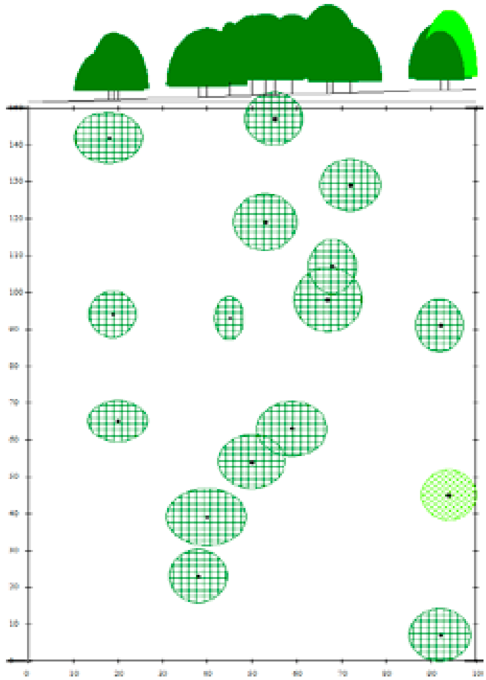


Figure 3. Vertical and horizontal graphic expression of a portion from the Herculian grassland

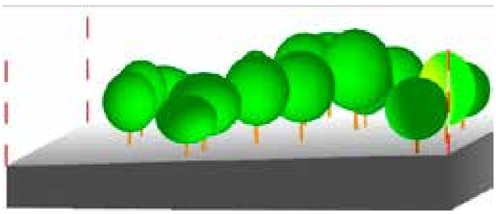


Figure 4. 3D profile of a portion from the Herculian sessile and pedunculate oak grassland

The diameter of trees has been found to vary, with values ranging from 47 cm to 114 cm. This variation is explained by the fact that the cutting of trees was not carried out taking into account the provisions of forest management projects, but that trees with high economic value were mainly extracted. Variations are also recorded in the case of crowns projections related to the diameter classes, which shows the way the trees are grouped on the pasture, some grouped (they have diameters and crowns projections small), some scattered (they have diameters and crowns projections bigger) (Figure 5). The higher value of the recorded parameters (diameter, height, surface of crown projection) at pedunculate oak in relation to the sessile oak, recommend that oak to be used when trees are introduced on grassland, the last one proven to be a more productive species. In addition, it will provide shelter and shade to animals grazing during the growing season on a larger area.

The phytosanitary status of the trees in grassland with trees is generally good and, where appropriate, it is proposed that the whole area be covered by hygienic work.

According to the data extracted from the silvopastoral management project, about 16m^3 of firewood were harvested in five years. In the autumn of 2021, approximately 13 tons of acorn were harvested from the tree pasture, which was exported to Hungary for the production of seedlings in nurseries. Both aspects also demonstrate the social functions that the grassland with trees perform.

The presence of trees on grassland causes changes in the flower composition of the herbaceous cover, in the spatial structure and distribution of herbaceous communities, leading to the emergence of micro-ecosystems of different species not found on sunlit grassland (López-Sánchez et al., 2016).

Trees, as well as the level of loading of grassland with animals for grazing, are very important factors in maintaining the diversity of grassland. Exceeding the optimal of cattle and/or sheep on grazing may lead to the creation of predominantly nitrophilous micro-ecosystems, which is undesirable for the production of high-quality feed (Moreno et al., 2016).

As regards the grass cover, the floral composition and productivity (qualitative and quantitative) in the grassland with and without trees are shown in Figure 6 and Table 4.

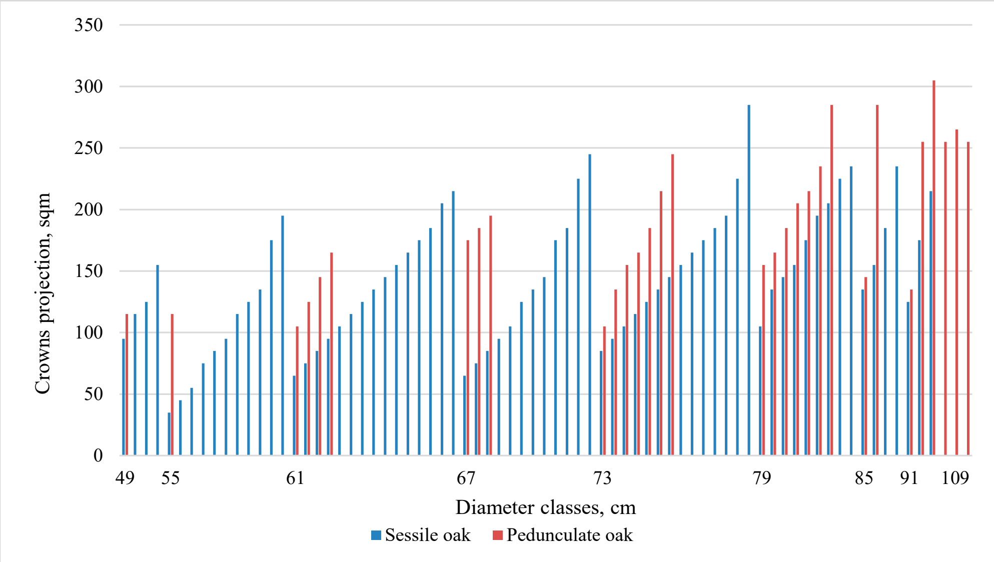


Figure 5. Variance of the crowns projection according to the diameter of the trees

Table 4. Floristic composition and productivity of grass from the no-tree grasslands and with trees

Species	Presence (class)		Participation %				Indices	
	Grassland without trees	Grassland with trees	Grassland without trees	Grassland with trees	Dif. + -	%	F	M
Cover	X	X	97.8	95.1	-3.5	96	X	X
Poacee								
Agrostis capillaris	V	V	10.7	12.3	1.6	115	7	6
Anthoxanthum odoratum	IV		2.7	0.0	-2.7		7	5
Cynosurus cristatus		IV	0.0	1.4	1.4		5	3
Danthonia (Syeglingia) decumbens		I	0.0	0.1	0.1		7	4
Deschampsia caespitosa		II	0.0	1.1	1.1		4	3
Festuca pratensis		I	0.0	0.3	0.3		3	0
Festuca rubra	V	V	29.0	44.0	15.0	152	9	8
Festuca valesiaca	III		2.0	0.0	-2.0		5	3
Lolium perene		IV	0.0	5.1	5.1		9	8
Nardus stricta	V		14.1	0.0	-14.1		3	0
Poa pratensis	III		1.0	0.0	-1.0		8	6
Total			59.5	64.4				
Fabaceae								
Genista sagittalis	III		1.3	0.0	-1.3		3	0
Genista tinctoria	III		0.9	0.0	-0.9		3	0
Lotus corniculatus	V	III	2.6	0.6	-2.0	22	8	6
Trifolium pratense	V	V	2.0	1.7	-0.3	86	8	7
Trifolium repens	V	V	10.7	11.1	0.4	104	8	5
Total			17.4	13.4				
Other families								
Achillea millefolium	IV	III	2.1	0.9	-1.3	40	6	4
Agrimonia eupatoria	I	III	0.1	0.6	0.4	400	3	0
Alchemilla vulgaris	III		0.6	0.0	-0.6		6	4
Carduus achantoides		III	0.0	0.7	0.7		3	0
Carlina vulgaris	I	III	0.3	0.4	0.1	150	3	0
Centaurea phrygia		III	0.0	0.4	0.4		4	6
Centaurium umbelatum		II	0.0	0.3	0.3		3	0

Species	Presence (class)		Participation %				Indices	
	Grassland without trees	Grassland with trees	Grassland without trees	Grassland with trees	Dif. + -	%	F	M
Cichorium intybus		II	0.0	0.4	0.4		5	6
Crataegus monogyna	III	I	0.4	0.1	-0.3	33	3	0
Daucus carota	III		0.4	0.0	-0.4		6	5
Euphorbia cyparisias	III		1.6	0.0	-1.6		1	0
Fragaria viridis	III	III	1.1	0.6	-0.6	50	4	1
Galium cruciata	I	I	0.1	0.1	0.0	100	3	0
Juncus conglomeratus	I		0.1	0.0	-0.1		3	0
Leontodon autumnalis	I	V	0.1	2.1	2.0	1500	5	3
Luzula campestris	III		0.6	0.0	-0.6		4	2
Plantago lanceolata	V	V	2.9	2.1	-0.7	75	6	1
Plantago major		V	0.0	1.7	1.7		5	3
Plantago media	V		1.7	0.0	-1.7		6	2
Polygala vulgaris	II		0.3	0.0	-0.3		4	1
Potentilla reptans	II	II	0.3	0.3	0.0	100	3	0
Prunella vulgaris		IV	0.0	1.4	1.4		4	2
Pteridium aquilinum		I	0.0	0.7	0.7		3	0
Pyrus piraster	I	I	0.1	0.1	0.0	100	3	0
Ranunculus repens		I	0.0	0.1	0.1		1	0
Rosa canina	III	IV	0.6	1.0	0.4	175	3	0
Taraxacum officinale	V	III	3.6	1.1	-2.4	32	7	3
Thymus montanum	III		1.9	0.0	-1.9		4	2
Urtica dioica		II	0.0	1.9	1.9		3	0
Veronica chamaedrys	III		0.4	0.0	-0.4		4	2
Viola canina	V		1.1	0.0	-1.1		4	1
Total			20.9	17.3				
Total species (no.)			34	31	-3	91	X	X
From which: - fodder			21	18	-3	86	X	X
- not fodder			13	13	0	100	X	X
Participation of fodder species			77.6	87.6	+10	113	X	X
Participation of harmful species			20.3	7.5	-12.8	37	X	X
Vegetation gaps (bare soil)			2.1	4.9	+2.8	233	X	X
Pastoral Value			58.4	68.7	+10.3	118	X	X
Phytomass index			3.69	4.75	1.06	130	X	X
Fodder production (t/ha)			9.14	12.83	+3.69	140	X	X

Figure 6. Herbaceous cover in grassland without trees

The indices of presence I, II, III, IV, V indicate the existence of a certain species, in a certain number, in the analysed floristic surveys.
The non-valuable (pastoral) species *Nardus stricta* which is present in all the test areas from trees-free grassland, is 14.1% absent in the grassland with trees. Instead of this weed, *Lolium perenne* develops with more than 5%, the *Festuca rubra* is extended from 29.0 to 44.0%. *Agrostis capillaris* has a 15% higher participation rate in the grassland with trees than in the tree-less grassland and in the shadow areas there is also *Cynosurus crystatus*, which is quite well consumed by the animals. As regards legumes, the percentage of participation in the grass cover in the tree-free grassland is higher than in the grassland with trees, but the difference is given by two species harmful to the grass, not consumed by the animals, namely the *Genista sagittalis* and the *Genista tinctoria*. *Lotus corniculatus* has a relatively small percentage in the grassland with trees, which prefer to the more acidic and

poorer soils as those in the sun-filled in the tree-less grassland (Ciocârlan, 2009).

In general, the valuable feed species on the fields benefiting from the shadow of the oaks exceed 13% of the grass cover participation compared to those existing on open land, and the harmful ones are 63% less in the tree-grassland than in the trees-less pasture. Of course, all these values influence the quality of the plant material consumed by the grazing animals.

The quality index as the feed value, assessed according to the floristic indices in the grassland with trees reaches 68.7, 10.3 higher than in the enlightened grasslands. Indeed, the difference is not very large, the appreciation for the pastoral value of the pasture without trees being medium, and for grassland with trees good, but it gives us the information that the quality chemical parameters of the forage have much higher nutritional value in the silvopastoral system than in the control surface (without forest vegetation).

The production of green fodder mass amounts to almost 13 t/ha on the shaded land compared to 9.14 t/ha on the sunlit grassland, i.e., 40% more under the protection of tree shadows.

The amount of green fodder mass per variant and each floristic survey, together with the mean of the variance, is given in Table 5.

Table 5. Production of fodder from floristic surveys made in grassland with trees and no-trees grassland

Green mass production (t/ha)								
Variants	Repetitions (Floristic surveys)							Mean of variance
	1	2	3	4	5	6	7	
No trees grassland	9.53	10.92	8.35	5.43	8.02	11.83	10.03	9.14
Grassland with trees	14.28	10.79	13.58	11.57	14.56	11.34	13.45	12.83

The quality of feed species refers to how well the feed produced on grassland is consumed by the animals and how efficient the feed nutrients are to be transformed into high-quality animal products (Fulgueira et al., 2007). There are six biological and technological factors that influence the nutritional quality of feed: type of grassland (with woody vegetation and without), soil fertility, grassland composition (percentage of grasses and legumes), optimal loading with animals, exploitation and maintenance of the grassland. The first three factors have been analysed above and the last three, as a result of the findings at the time of the field works, are respected according to the provisions of the silvopastoral management in force.

For green mass samples collected from the oaks silvopastoral system and the no-tree grassland, the following chemical quality parameters of the feed have been analysed: crude protein; crude fibre; ash; fibre fractions: acid detergent fibre, lignin detergent acid and neutral fibre; digestibility of dry matter; digestibility of organic matter. Table 6 contains information on each chemical component contained in the feed, analysed independently.

The average of each variable, the minimum and maximum limit of each parameter analysed and the level of data scatter (standard deviation) is given. In this way, from the table we note that for the raw protein variable, the maximum value is 17.2, the minimum value 11.1, and the average value is 14.0, from which we can conclude that the raw protein has a quite high value, the feed quality class is excellent.

Analysed separately for each variant, crude protein of the tree-less grassland reaches almost 13% and increases to over 15% in grassland with trees. Similarly, the digestibility of dry matter and organic matter grow on the tree grassland from 18 to 21% due to the superior quality of the fodder obtained on these surfaces (Table 6).

Table 6. General data and differences in chemical quality parameters of forage, from grassland with trees and grassland without trees

Chemical parameters for forage quality	Minimum value	Maximum value	The average of the 14 cases analyzed	Standard deviation	Content %			%
					Grassland without trees	Grassland with trees	Dif. + -	
Crude protein	11.1	17.2	14.0	1.89	12.59	15.43	2.84	123
Ash (ASH)	8.2	11.8	9.8	0.81	9.39	10.30	0.91	110
Crude fiber (CF)	28.8	36.4	32.6	2.17	33.80	31.54	- 2.26	93
Acid detergent fiber (ADF)	33.2	41.4	37.1	2.22	38.37	35.74	- 2.63	93
Lignin detergent acid (LDA)	3.2	5.6	3.8	0.60	4.09	3.51	- 0.57	86
Neutral detergent fiber (NDF)	56.7	68.4	62.3	3.31	64.36	60.19	- 4.17	94
Digestibility of the dry matter (DMD)	44.5	64.9	55.0	6.27	50.41	59.51	9.10	118
Digestibility of the organic matter (DMD)	40.9	61.8	52.3	6.47	47.31	57.23	9.91	121

The feed quality indexes of the grassland with oaks are clearly better than those of grassland without forest vegetation. Given that there is a balance between the values of the nutrients contained in the grassland with trees, the production and the quality of the livestock is certain.

CONCLUSIONS

The forest vegetation in the pastures with trees consists of sessile oak and pedunculate oak, the sessile oak being the predominant species. From the analysis of the forest component of the silvopastoral system found that the trees are not evenly distributed, so that the pasture does not benefit from shade evenly. It should be noted that pedunculate oak has developed trunk sizes and crowns larger than sessile oak, compensating in a certain proportion for the smaller number of specimens than the sessile oak. The density of 14 trees per hectare provides optimal conditions for the development of grassy cover and shade for animals that graze during the growing season.

The comparative study between the pastures with trees and the pastures without trees showed that in the pasture with trees the values of the three most important nutrients in the soil composition, namely: nitrogen, phosphorus and potassium, are much higher than the grassland without trees, but without exceeding the maximum limit necessary for the development of herbaceous vegetation. The presence of trees and manure left by animals in their shade during the rest periods, increase the amount of nitrogen and phosphorus in the soil compared to the forest-free grassland. The vegetal cover is 13% richer in forage species than the tree-less pastures. Also, the production of green fodder mass is 40% higher and the pastoral value 13% higher in the wood pasture compared to the tree-less pasture. From the quality analyses of the fodder grassy species, it results that the high values of the fibre concentration (33.8%) of the pasture without trees give a low nutritional value to the fodder obtained on this pasture, which is why the digestibility value is also lower by about 82% in the pasture without trees compared to the pasture with trees.

The grassland with trees were maintained in a pretty good condition compared to the grassland without trees where, due to the practice in time of the unreasonable grazing and the non-application of some agrotechnical works absolutely necessary to improve the floristic composition, they led to the decrease of the quantities of mineral substances on the profile and to the accentuation of the soil acidity, conditions in which *Nardus stricta* (species without pastoral value) extended over the entire surface, slowly removing the valuable species. Also, through unrationed grazing, anthills of vegetal origin are formed, on the dense bushes of some grasses, such as *Deschampsia caespitosa*, understood after their trampling by animals and which lead the grassland to a state of degradation by reducing to the point of elimination the valuable herbaceous species. The data presented are arguments for maintaining and caring for trees on pasture. In order to ensure the continuity of trees on pastures, given that existing trees are not evenly distributed over their stretch, it is necessary to plant new specimens in the open spaces and to gradually replace the dried trees.

ACKNOWLEDGEMENTS

This research work was carried out by the project PN 19070403 "Establishment of new agroforestry systems in Romania", financed by the Ministry of Research, Innovation and Digitization through the Nucleus Program

REFERENCES

Ciocârlan, V. (2009). *Ilustrated flora of Romania*, Ceres Publishing House, Bucharest.

Costăchescu, C, Dănescu, F, Mihăilă, E. (2010). *Protective forest shelterbelts*. Forestry Publishing House (in romanian with summary in english), Bucharest, pp. 262.

Eichorn, M.P., Paris., P., Herzog, F., Incoll, L.D., Liagre, F., Mantzanas, K., Mayus, M., Moreno, G., Papanastasis, V.P., Pilbeam, D.J., Pisanelli, A., Dupraz, C. (2006). Silvoarable systems in Europe – past, present and future prospect. *Agroforestry system*, 67.

Ficuț, C.A., Măcicășan, V., Maloș C.V., Muntean O.L., Roșian, G., Hartel, T. (2018). Soil erosion assessment in wood pastures and tree-less pastures (a case study: Hârtibaciului Tableland). Retrieved February 23, 2022, DOI:10.2478/pesd-2018-0004.

Florea, N., Bălăceanu, V., Răuţă, C., Canarache, Al. (1987). Methodology of pedological studies elaboration, CMDPA - ASAS, Bucharest.

Fulgueira, C.L., Amigot, S.L., Gaggiotti M., Romero L.A., Basílico J.C. (2007). Forage quality: Techniques for testing. *Fresh Prod*, 1(2), 121-131.

ICDP Brasov (2021). Report on the implementation of research and development services within the PN 19070403 project, Establishment of new agroforestry systems in Romania. INCDS manuscript.

Leakey, R. (1996). Definition of agroforestry revisited. Agroforestry today 8 (I): 5 – 7. Nairobi: ICRAF

Kovacs, A.J. (1979). Biological, ecological and economic indicators of grassland flora, Agricultural technical propaganda editorial board Bucharest, 50.

Lixandru, G., Alexandrescu, I., Tarnauceanu, E. (1986). Application of fertilizers to the vine. *Scientific papers: Horticulture Series*, 89.

López-Carrasco, C., López-Sánchez, A., San Miguel, A., Roig S. (2015). The effect of tree cover on the biomass and diversity of the herbaceous layer in a Mediterranean dehesa. *Grass and Forage Science*, 70(4), pp. 639-650.

López-Sánchez, A., San Miguel, A., López-Carrasco, C., Huntsinger, L., Roig, S. (2016). The important role of scattered trees on the herbaceous diversity of a grazed Mediterranean dehesa. *Acta Oecologica*, 76, pp. 31-38.

MacDicken, K.G., Vergara, N.T. (1990). Agroforestry: classification and management. *A Wiley – Interscience Publication*. New York, Toronto.

Marușca, T. (2017). *Gradient elements and mountain ecology*. Second edition, Ed. "Transilvania" University of Brasov.

Marușca, T. (2019). Contributions to the evaluation of pasture productivity using the floristic releve. *Romanian Journal of grassland and forage crops*, 19, 33-47.

Marușca, T., Taulescu, E., Zevedei, P.M., Andreoiu, A.C., Comșia, C.C. (2020a). Study on the agroforestry system with oak trees (Quercus robur L.) in the context of changing climate. *Annals of the Academy of Romanian Scientists, Series on Agriculture, Silviculture and Veterinary Medicine Sciences*, 9(2), pp. 47-54, Bucharest.

Marușca, T., Taulescu, E., Memedemin, D. (2020b). Preliminary study of agrosilvopastoral systems from Romania. *Romanian Journal of Grassland and Forage Crops*, 20(20), pp. 22-30.

Moreno, G., Gonzalez-Bornay, G., Pulido, F., Lopez-Diaz, M.L., Bertomeu, M., Juárez, E., Diaz, M. (2016). Exploring the causes of high biodiversity of Iberian dehesas: the import ance of wood pastures and marginal habitats. *Agroforestry Systems*, 90(1), pp. 87-105.

Olea, L., San Miguel-Ayanz, A. (2006). The Spanish dehesa. A traditional Mediterranean silvopastoral system linking production and nature conservatio. *21st General Meeting of the European Grassland Federation, Badajoz (Spain). Opening Paper*.

Păcurar, F., Rotar, I. (2014). Methods of study and interpretation of grassland vegetation. Risoprint.

Popa, I., (1999). Silvicultural research: CAROTA and PROARB programs, *Forestry Magazine*, 114 (2), pp. 41-43.

Posea, G., Badea, L. (1984). *Romania, Map of relief units (geomorphologic regionalization).* Scientific and Encyclopedic Publishing House, Bucharest.

Stoica, E., Răuţă, C., Florea, N. (1986). Methods of chemical analysis of the soil ICPA (ASAS), Bucharest.

***, 2017. Silvopastoral, Composesorat Herculian, Covasna County.

***, Google Earth Pro, 2019.

https://www.google.com/earth/download/gep/agree.html?hl=en-GB.

http://www.meteoromania.ro/anm2/wp-content/uploads/centre/descriereCMR.pdf.

www.insse.ro

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ELABORATION THE SUBSTANTIATING STUDIES FOR THE NECESSITY OF FOREST SHELTERBELTS TO PROTECT THE FIELD, PREMISE FOR OBTAINING FUNDS FOR THEIR REALIZATION

Elena MIHĂILĂ, DORINA DRĂGAN, CRISTIANA MARCU, CORNEL COSTĂCHESCU, FLORIN DĂNESCU, FLORIN DORIAN COJOACĂ

National Institute for Research and Development in Forestry "Marin Drăcea", 128 Eroilor Blvd, Voluntari, Ilfov, Romania

Corresponding author email: lilianmihaila@gmail.com

Abstract

Forest shelterbelts are the most widespread and efficient type of agroforestry system in Romania used for the crops protection. Following the contracts signed with the Ministry of Agriculture between 2005-2006, substantiation studies for the establishment of forest shelterbelts were carried out for seven counties from Romanian Plain and Dobrogea. At different stages of the Nucleus Program, funded by the Ministry of Research, in the period 2011-2021 studies were conducted to substantiate the need of realisation of forest shelterbelts to protect the field in other nine counties located in the mentioned area. The aim of these studies was to establish: the land areas occupied by the forest shelterbelts; the network of forest shelterbelts using GIS techniques, current rectified aerial images and detailed pedological maps; the afforestation compositions; the number of forest seedlings and to estimate the costs necessary for their installation and maintenance, until the canopy is close. For practical reasons, it was established that the width of the curtains should be 10 m, thus resulting in a percentage of occupation of the agricultural land with forest vegetation of approximately 2%.

Key words: *agroforestry system, forest shelterbelts, GIS techniques, the afforestation compositions, forest seedlings.*

INTRODUCTION

The aridity process is directly generated by the oscillations of climatic factors, but also indirectly by human activity, resulting in the degradation of land, soil, vegetation and water resources. For this reason, many countries have environmental concerns, the agroforestry systems, which involve combining agricultural and forestry crops, being successfully used to protect agricultural land, its crops, communication routes, socio-economic objectives and human settlements. The forest shelterbelts are considered the most efficient types of agroforestry systems used in this respect, having a rich tradition in our country (Popov et al., 2017; Costăchescu et al., 2018).
As a signatory to the Convention on combating Desertification (1994), due to the fact that areas potentially affected by desertification are registered in Romania, our country must contribute to achieving its main objective, therefore, to combat desertification and reduce the effects of drought in countries with serious drought and/or desertification problems through effective measures at all levels to help achieve sustainable development in the affected areas. Droughts are caused both by climate imbalances and by the sharp reduction in the area of forest vegetation in the lowland and low-hill regions. Priority must therefore be given to building forest shelterbelts networks in areas affected by frequent, long periods of drought. The introduction of forest vegetation into agricultural land has consequences not only in terms of protecting and preserving environmental conditions, but also in terms of increasing agricultural production or at least maintaining it at a relatively constant level, even in the context of significant climatic oscillations (Giurgiu, 2012).
As regards the studies on the basis of the need for the establishment of forest shelterbelts, these were carried out, in accordance with the provisions of the law (laws 289/2002 and 213/2011), by the Institute for Forestry Research and facilities (ICAS - through the Technological Development Department), in the first stage at the level of Olt, Dolj, Mehedinți and Teleorman counties, and in the second stage at the level of Ilfov, Tulcea and Constanţa counties (Adam et al., 2012;

Costăchescu & Dănescu, 2005; Costăchescu & Dănescu, 2006; Mihăilă, 2006; Greavu et al., 2012; ICAS - through the research compartment). As a result, during the period 2004-2007, studies were carried out to establish the necessity for 7 counties in the Romanian plain and in the Dobrogea Podișul, therefore for about 37% of the total surface on which the establishement of the forest shelterbelts network is required in the first emergency. For the localities in Olt, Dolj, Mehedinti and Teleorman counties, the technical and economic documents (feasibility studies and technical projects) were drawn up in accordance with the provisions of Law 289/2002.

Since 2015, in the framework of projects included in the National Nucleus Program, studies have been carried out on the basis of the necessity for the establishment of forest shelterbelts for field protection and for the counties of Buzau, Ialomița, Calarasi, Giurgiu, Brăila, Galaţi, Dâmboviţa, Vrancea, Prahova, currently the study for Arges County (Danescu, 2015; Comaster chescu, 2018; Danescu & Coplay, 2019), work carried out by National Institute for Research and Development in Forestry (INCDS) - through the Research Department.

MATERIALS AND METHODS

For the establishment of the network of forest shelterbelts for protection of crops at the level of the counties exposed to the aridity in the Romanian Plain, only arable land and pastures were taken into account, by means of vectorization to the orthorectified plans scale 1: 5000, the orchards, vineyards, the intravillan of localities and, of course, the land occupied by forest vegetation were excluded from the beginning. The river's waterside areas which run through the area under consideration, delimited and addressed in this respect in previous projects, have been excluded, only the possibility of connecting forest shelterbelts networks located in the river's waterside areas with the county forest shelterbelts networks for the protection of the field itself will be considered. This resulted in the total area of agricultural land analyzed for the location of the forest shelterbelts network.

In order to establish technical solutions for the development of forest shelterbelts, it was necessary to define the territory from ecological site conditions point of view. The dominant soil types were thus established at the level of all municipalities, with the indication that the preliminary classification was made on the basis of the information provided by the scale 1: 200000 pedological map, drawn up by ICPA (Institute for Pedology and Agrochemistry Research), over which the administrative boundaries of the localities overlap. For this purpose, the pedological map was georeferenced, using the orthorectified aerial images.

Afforestation solutions have been established by soil types and groups of soil types close to the environment, linking the ecological requirements of the species to the ecological characteristics of the soil. The transposition of afforestation solutions into plans has therefore been achieved by linking them to the soils already highlighted on the work maps.

Over these successive layers of information (geographical, hydrographic, pedological, afforestation, administrative, infrastructure, etc.) the network of forest shelterbelts for field protection has been located, using GIS techniques (Figure 1). The network was performed by vectorization on the orthorectified plans 1:5000 scale, and the GIS database was completed.

RESULTS AND DISCUSSIONS

In our country the activity of studying and installing forest shelterbelts has a rich tradition, the development of these agroforestry system beginning in the early years of the 20th century, this issue having both periods of boost and decline (Lupe, 1952; Neșu, 1999).

Summing up the evolution of their development it can be said that there was a first phase that started with the early years of the 20th century and lasted until the years 1960 when forest shelterbelts were installed on about 10,000 ha (Popov et al., 2017).

The second phase lasted from 1960 to 2000 and is characterized by deterioration, destruction, regression in terms of forest shelterbelts, and a return in the last years of the period through studies that reassessed their importance.

Finally, the period from 2000 to the present date, which is marked by the promulgation of the law on forest protection curtains in 2002 and characterized by the carrying out of many studies and projects to install forest protection curtains and to a lesser extent by their establishment.

Using the way of working presented in chapter Material and methods, within the Research Department of INCDS, the forest shelterbelts networks for all counties of the Romanian Plain and Dobrogea were vector-based on the orthorectified plans (not previously covered with such works) (Figure 2).

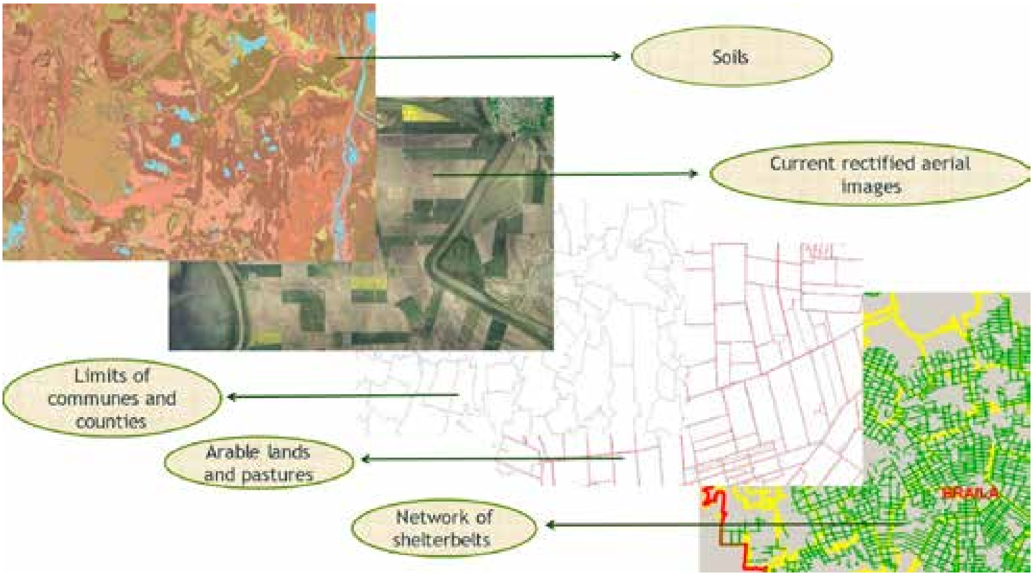


Figure 1. The successive layers of diverse information (geographical, hydrographical, pedological, administrative) over which the network of forest shelterbelts was placed

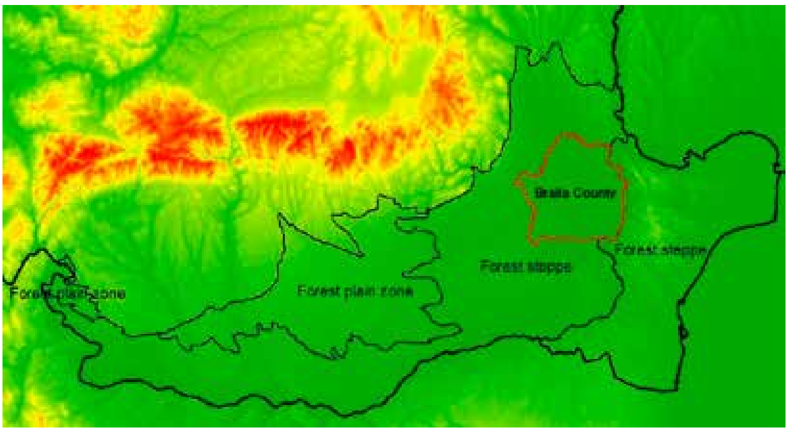


Figure 2. Romanian Plain and Dobrogea Tableland

The diversity of the stational conditions and the combination of the ecological site condition factors within the Romanian Plain and Dobrogea also determines the diversity of the forest solutions recommended for the achievement of forest shelterbelts for protection of field. In order to choose the species indicated for the development of the forest shelterbelts network, a detailed analysis of the natural environment within the geographical unit,

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

including a description of the ecological site conditions factors, which by variation, their distribution and mode of association determine the composition and the diversity of afforestation solutions to be adopted in order to achieve the objective (Costăchescu et al., 2010). In particular, the resistance to unfavourable stational conditions in which such protective forest crops are to be developed, the longevity of the species and the value of their products have been taken into account (Stănescu et al., 1997; Dănescu et al., 2010).

As regards the actual installation of forest shelterbelts for protection of crops, the tree and shrubs species were established and the main characteristics of forest shelterbelts (location in the field, orientation, width, distances and planting schemes).

The implementation by means of a vectorization approach on the orthorectified plans of the forest shelterbelts network for the protection of crop in the Romanian Plain and Dobrogea, allowed us to accurately determine the area to be occupied by it, the requirements of the seedlings and the costs of the actual realization of the forest shelterbelts networks, both at the local level, and at the county level.

Maps of the distribution of the forest shelterbelts network and of afforestation solutions for territorial and administrative units and at county level were drawn up for better illustration (Figure 3).

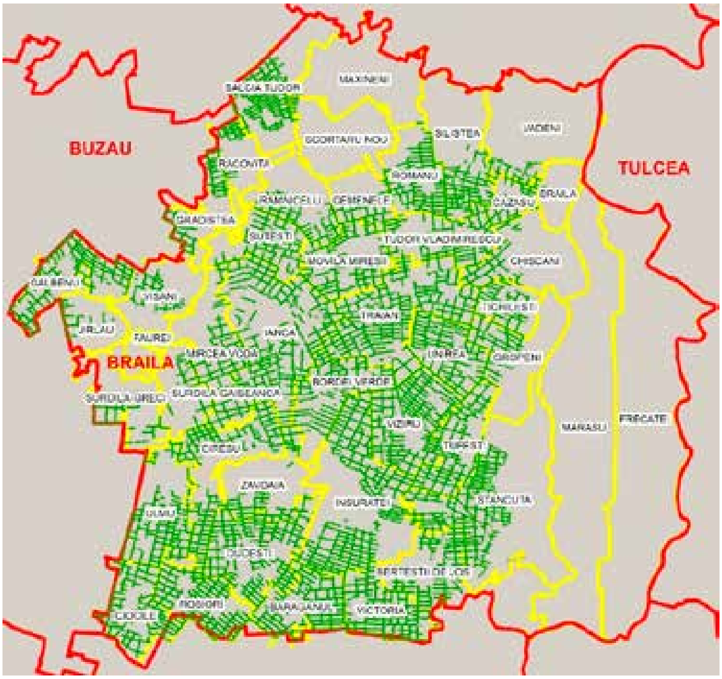


Figure 3. Location of the forest shelterbelts network for field protection in the localities within a county (Braila)

The main factors that were considered for the location of forest shelterbelts on the administrative surface of the locaties in the project were: microrelief, the form of agricultural land units, soil, local hydrographic conditions, spontaneous and cultivated woody vegetation, as well as the network of irrigation or drainage channels, railways, roads and roads of general interest.

Forest shelterbelts for protection of field have generally been placed on the edge of agricultural land in the immediate vicinity of their boundaries.

The principle was that the network should consist of main forest shelterbelts spaced at 600 m (or 500 m) and secondary forest shelterbelts, which intersect the main forest shelterbelts at a distance of 1200 m (or 1000 m), the dimensions 600 x 1200 m (or 500 x 1000 m) being the most common dimensions of agricultural land.

For practical reasons relating in particular to the need to simplify the design and subsequent execution of the forest shelterbelts network, a single forestry shelterbelts width of 10 m has been adopted, leading to a theoretical percentage of agricultural land occupancy of around 2%.

The location of forest shelterbelts has taken account of the fact that they fragment agricultural areas as little as possible and that existing wood vegetation is integrated into the created network.

The forest shelterbelts network was interrupted at the points of intersection with major communication routes (railways, highways, national roads and county roads), with water (rivers, lakes, pools) or with high-voltage power lines.

The area of the network of forest shelterbelts on localities, categories of use and afforestation solutions resulted from the overlap of the network over the above mentioned information layers, on this basis being determined the need for afforestation material (Figure 1).

Taking into account the large area on which the afforestation works are to be carried out and the high degree of spread of the works, the amount of afforestation material to be produced and the nursery area required for the production of the seedlings were also determined.

It was estimated the financial effort necessary for the realization of the network of forest shelterbelts for the protection of the crops at the county level, taking into account the cost of the actual execution of the work from the installation to the dense stand, the cost of the technical and economic documentations on the localities, the cost of obtaining the necessary legal approvals and the cost of the documentations regarding the application of the procedure for the award of the execution contracts.

For each county, the areas that will be occupied by the forest shelterbelts for crop protection (at the level of localities and at the county level), the composition of the forest shelterbelts according to the identified ecological site conditions, the need for seedlings by species have been determined and the costs of actually achieving the forest shelterbelts for crop protection have been estimated. The results obtained shall be summarised in Table 1.

Table 1. The compositions of forest protection curtains for the counties of Campia Romana, the area occupied by them, the needs of juveniles and the estimated cost of producing them

Nr. crt.	County	The surface of forest shelterbelts network (ha)/ number of localities	The composition of the forest shelterbelts	The area occupied by the composition (ha)	Total need for seedlings (thousands of seedlings)	Estimated cost for actual achievement (thousand €)
1	Braila	3,830 / 40	40Stb 20Ult 20Sl 20arb	3,830	19,150	38,300
2	Buzau	4,376 / 54	40Stb 20Ult 20Sl 20arb	1,587	7,935	43,760
			40Stb 20Ult(Tea) 20Pă 20arb	2,688	13,440	
			40Stb20Tea(Ju) 20Pă 20arb	101	505	
3	Calarasi	6,405 / 55	40Stb 20Ult 20Sl 20arb	2,588	12,940	64,050
			40Stb 20Ult(Tea) 20Pă 20arb	3,273	16,365	
			40Stb20Tea(Ju) 20Pă 20arb	544	2,720	
4	Constanța	3,800 / 52	20Stb 20Stp 20Ult 20Sl	2,390	19,000	38,000
			40Stp 20Ult 20Sl 20arb	590	2,950	
			40Stb 20Mj(Pă) 20Sl 20arb	820	4,100	
5	Dambovita	2,053 / 53	40Stb(St) 20Pa(Tea) 20Cd 20arb	2,053	10,265	20,530
6	Galati	2,124 / 40	40Stb 20Ult 20Sl 20arb	1,020	5,100	21,240
			40Stb 20Ult(Tea) 20Pă 20arb	1,104	5,520	
7	Giurgiu	3,509 / 53	40Stb 20Ult 20Sl 20arb	384	1,920	35,090
			40Stb 20Ult(Tea) 20Pă 20arb	683	3,415	
			40Stb20Tea(Ju) 20Pă 20arb	706	3,530	
			40Stb(St) 20Pa(Tea) 20Cd 20arb	1,721	8,605	
			40Ce(Gi) 30Pe 30arb	15	75	
8	Ialomita	5,466 / 63	40Stb 20Ult 20Sl 20arb	2,896	14,480	54,660
			40Stb 20Ult(Tea) 20Pă 20arb	2,417	12,085	
			40Stb20Tea(Ju) 20Pă 20arb	153	765	

9	Ilfov	241 / 7	20St20Tep20Ju40Arb	113	565	2,410
			20St20Tep20Ju40Arb	128	640	
10	Prahova	2,288 / 42	40Stb 20Ult 20Sl 20arb	284	1,420	22,880
			40Stb 20Ult(Tea) 20Pă 20arb	740	3,700	
			40Stb20Tea(Ju) 20Pă 20arb	81	405	
			40Stb(St) 20Pa(Tea) 20Cd 20arb	642	3,210	
			40Stb 20Ult(Mj) 20Ju 20arb	541	2,705	
11	Tulcea	1,157 / 35	20Stb 20Stp 20Ult 20Sl	500	5,785	11,570
			40Stp 20Ult 20Sl 20arb	457	2,285	
			40Stb 20Mj(Pă) 20Sl 20arb	200	1,000	
12	Vrancea	2,608/33	40Stb 20Ult 20Sl 20arb	698	3,490	26,080
			40Stb 20Ult(Tea) 20Pă 20arb	466	2,330	
			40Stb20Tea(Ju) 20Pă 20arb	149	745	
			40Stb 20Ult(Mj) 20Ju 20arb	1,295	6,475	
Total		**37,857 / 527**		**37,857**	**189,285**	**378,570**

Note:
Stp = *Quercus pubescens*, pubescent oak;
Stb = *Quercus pedunculiflora,* greyish oak;
St = *Quercus robur*, pedunculate oak;
EC = *Quercus cerris,* Turkey oak;
Gâ = *Quercus frainetto,* Hungarian oak;
Ult = *Ulmus pumila*, Siberian elm;
Mj = *Fraxinus ornus,* flowering ash;
Pă = *Pyrus pyraster*, wild pear;
Tea = Tilia *tomentosa,* silver lime;
Sl = *Eleagnus angustifolia,* oleaster;
Pa = *Acer platanoides,* Norway maple;
Ju = *Acer campestre*, Field maple
CD = *Prunus cerasifera*, cherry – plum;
arb= shrubs.

It is found that in the case of the 12 counties for which the substantiation studies of the necessity of achievement the forest shelterbelts for the protection of field have been carried out, the area occupied by them is 38,000 ha that will be carried out on the lands of 527 territorial - administrative units (localities). At the level of a locality, the average area occupied by forest shelterbelts is 72 ha, the need for seedlings is about 360,000 copies, and the cost of actually achivement forest shelterbelts is 720,000 euros.
The presented values are useful for sizing and distributing the production capacity of the afforestation material.
Considering the very large area on which the afforestation works are to be carried out, the high degree of spread of the works, as well as the very large amount of afforestation material to be produced, it is estimated that such a work must be distribute over a period of at least 5 years.
Taking into account the above values regarding the area of the network of forest shelterbelts, the total number of seedlings required and this minimum period of production of afforestation material and the execution of the work, it follows that the production of the necessary seedlings can be carried out on an area of approximately 125 ha of nursery, which must be available at least one year before the start of the installation works and must be distributed relatively uniformly at the level of the counties concerned, proportionally to the area of forest shelterbelts for each county.
Therefore, for the production of afforestation material involved in the creation of the network of forest shelterbelts for crop protection, the area of nurseries required at county level is on average about 10.5 ha.

CONCLUSIONS

Currently, specialists in agronomy, hydrology, climatology, environment and, of course, forestry are in full consensus on the need to move as urgently as possible to the establishment of the national system of forest shelterbelts for field protection, as a basic measure in preventing and combating the drought and aridity phenomena that affect especially the south and east of Romania, but also to protect the environment, to increase agricultural production and save water resources, which is, however, a very important step forward.
As regards the technical way of approaching it, the establishment of the national system of forest shelterbelts for crop protection must be carried out in stages and in a succession that takes into account the urgency of implementation, the existing technical and financial possibilities and other practical aspects involved in an action of this magnitude

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

and the aim pursued (maximum protective effect in the shortest possible time).

To achieve the forest shelterbelts network at the level of the two main geographical units, which amounts to about 38,000 ha (5,000 ha in Dobrogea and 33,000 in Romanian Plain) the necessary amount is 380,000,000 euros.

Whereas it is clear that the expenditure involved in setting up forest shelterbelts at national level is high, preceded by the expenditure required for the technical and economic documentation (which is in addition to the costs of implementation), the entire financial effort should be made, the technical and execution shall be phased over a period of at least 5 years as part of a national plan for the implementation of the national system of forest shelterbelts for crop protection.

Since, in the current economic context, funding from the national budget for this large-scale plan is unlikely, we believe that there is sufficient information and arguments to request funding from one of the programs carried out within the European Union.

ACKNOWLEDGEMENTS

This research work was carried out by the project PN 19070401 “Fighting the aridity process and protecting the agricultural lands in the plain area from the south of the country by setting up some county networks of forest shelterbelts”, financed by the Ministry of Research, Innovation and Digitization through the Nucleus Program.

REFERENCES

Adam, I., Ivanschi, T., Merce, O., Turcu, D., Cadar, N., Cântar, I. (2012). Establishment of forest shelterbelts for crop protection in the plain area of Mehedinți County. *Journal of Forestry and Hunting,* 30, 23-26.

Costăchescu, C., Dănescu, F. (2005). Establishment of forest shelterbelts for crop protection in the plain area of Teleorman County (SF and PT). Manuscript I.C.A.S.

Costăchescu, C., Dănescu, F. (2006). The substantiating study for necessity to install forest shelterbelts for field protection in Constanţa County. Manuscript I.C.A.S.

Costăchescu, C. (2018). PN 18040301 Substantiation of the need for the establishment of forest shelterbelts networks for the protection of agricultural lands, in counties in the south of the country affected by aridity and other harmful factors. Manuscript I.N.C.D.S.

Costăchescu C., Dănescu F., Mihăilă E. (2010). Forest shelterbelts. Forestry Publishing House.

Costăchescu C., Dănescu, F., Drăgan, D. (2018). Substantiation of the need to establish forest shelterbelts to protect the field in Giurgiu County. *Journal of Forestry and Hunting*, 42, 51 – 58.

Dănescu, F., Costăchescu, C., Mihăilă, E. (2010). Systematics of forest ecological site conditions. Forestry Publishing House.

Dănescu, F., Costăchescu C. (2015). PN 09460214 Protecting the agricultural lands in the Romanian Plain exposed to aridity by creating county networks of forest shelterbelts. Manuscript I.C.A.S.

Dănescu, F., Cojoacă D.F. (2019). PN 19070401 Fighting the aridity process and protecting the agricultural lands in the plain area from the south of the country by setting up some county networks of forest shelterbelts. Manuscript I.N.C.D.S.

Giurgiu, V. (2012). Forest shelterbelts for protection of field in the context of ensuring ecological and food security. Constraints and perspectives. *Forest magazine*, 6: 7-18.

Greavu, M., Mănescu, M., Vals, S., Vildan, F., Dogaru, M. (2012). Considerations regarding the design of forest shelterbelts for the protection of the field and of the communication roads in Dobrogea and east of Bărăgan. *Journal of Forestry and Hunting,* 30, 27-29.

Lupe, I. (1952). Forest shelterbelts for protection of field and their cultivation in the Plains of the Romanian People's Republic. Publishing House of the Academy of the Romanian People's Republic.

Mihăilă, E. (2006). The substantiating study for necessity to install forest shelterbelts for field protection in Ilfov County. Manuscript I.C.A.S.

Neșu, I. (1999). Forest shelterbelts for field protection. STAR TIPP Publishing House, Slobozia.

Popov, E., Hinkov G., Kachova V., Constandache C., Dincă L. (2017). A brief review of forest shelter belt establishments in Bulgaria and Romania. *Journal of Forestry and Hunting*, 41, 16 – 23.

Stănescu, V., Şofletea, N., Popescu, O. (1997). Romania's wood forest flora. Ceres Publishing House, Bucharest.

*** (1963 – 1986). Map of soils in Romania, scale 1:200000 și 1:1000000. ICPA

*** (1994). United Nations Convention to Combat Desertification in Severe Drought-Affected Countries Retrieved February 25, 2022, from http://publications.europa.eu/

*** (2002a). Law no. 289 on forest shelterbelts. Official Monitor, part I, no. 338.

*** (2002b). Anexa la Ord. MAAP nr. 636 privind aprobarea îndrumărilor tehnice silvice pentru înfiinţarea, îngrijirea şi conducerea vegetaţiei forestiere din perdelele forestiere de protecţie.

*** (2011). Law no. 213/2011 for the amendment and completion of Law no. 289/2002 regarding the forest shelterbelts. Official Monitor, Part I, no. 825.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

LOCAL BASED SOLUTIONS EDAPHIC-BLOOM DANUBE - CONSIDERATIONS ON THE ROLE OF ORGANIC CARBON IN REDUCING GREENHOUSE GASES IN AGRICULTURE

Iulian NICHERSU[1], Costel NEGREI[2], Oliver LIVANOV[1], Edward BRATFANOF[1], Dragoș BALAICAN[1]

[1]Danube Delta National Institute for R & D, 165 Babadag Street, Tulcea, Romania
[2]Bucharest Academy of Economic Studies, 6 Piata Romana, Bucharest, Romania

Corresponding author email: nichersu_iulian.nichersu@ddni.ro

Abstract

Following Parliament's call in January 2020 to set binding targets for saving biodiversity, in May 2020 the European Commission presented the new 2030 Biodiversity Strategy. At its June 2021 plenary session, Parliament adopted a position on the EU's 2030 Biodiversity Strategy: Bringing Nature back into our lives to ensure that the world's ecosystems are protected, restored, and resilient by 2050. Parliament wants the EU to become a leader, guaranteeing that 30% of its territory will be in natural areas by 2030 and taking biodiversity into account in all its policies. Climate change is one of the most important threats to humanity and it will increasingly matter how we manage our existence and development. Climate stabilization, as provided for in the Paris Agreement, requires mitigation and adaptation measures to reduce the impact of climate change and increase the resilience of essential ecosystem services. In the wetland environment, the degradation and loss of wet habitats, especially carbon-capturing ecosystems, results in an unprecedented loss of biodiversity and ecosystem services. Blue carbon is the carbon stored in wetlands, coastal and marine ecosystems, which represent significant carbon sinks. Indeed, they sequester carbon in its organic form and store it for thousands of years. Moreover, "blue carbon" ecosystems provide a wide range of ecosystem services that underpin livelihoods and support adaptation to climate change. However, despite the importance of the ecosystem services provided, these habitats are disappearing at an alarming rate.

Key words: *sustainable-biodynamic-regenerative agriculture, permaculture, paludiculture.*

INTRODUCTION

"Edaphic-Bloom Danube - Ecological resizing through urban and rural actions & dialogues for GHG mitigation in the Lower Danube Floodplains & Danube Delta" is an ambitious project in the frame of EUKI Programme, that aims to develop actions and dialogues both on the conservation of organic soils that have the ability to fix and store Carbon, one of the most harmful greenhouse gases, but also the energy efficiency of buildings in urban areas, thus contributing to reducing the carbon footprint and its impact.

The project addresses the reduction of the ecological footprint and the importance of organic soils in GHG mitigation, through 4 steps: a DPSIR analysis, an Artificial Neural Networks type process, an Agent-Based Modeling control function, and planning solutions for Ecosystem-Based Management.

Moreover, the most important challenge is to get out of the Citadel of Science and Innovation in the Living Lab, just implementing the knowledge of collaborators from KIT, Karlsruhe University, Steinbeiss, Institute of Pedology, URBAN INCERC, ASE, City Halls, and County Councils from Danube Floodplain and Delta geographical area, an area that has undergone major changes in the last hundred years and which through adaptive and ecosystem management will contribute to the reduction of greenhouse gases and the reduction of the ecological footprint.

In the first stage, the analysis of carbon reserves and flows from the Danube area soils will be performed, their mapping and scenarios of conservation, soil restoration, modification of the type of activities through Land-Based Management (e.g. modernization of agriculture through methodologies of agri-environment) or changing the utility of land with organic soils to improve carbon sequestration and storage.

In the second stage, a Master Plan for GHG reduction in the Floodplain and the Danube Delta and guides for good practices in land management with organic soils will be elaborated. These steps will be followed by the creation of a WEB Platform and the organization of exchanges of experience between administrators who manage regions rich in organic soils, knowledge transfer, demonstration farms, publications of scientific articles, and promotion of sustainable land use, etc.

In the third stage, the involvement of the Ministry of Environment and the Department of Sustainable Development is opportune and desired, which will consist of actions for the application of these scenarios, for example, the creation of regulations (legislation, application norms) regarding the audit and monitoring of greenhouse gas emissions. greenhouse gases (GHGs), incentives for activities (e.g. environmentally friendly agriculture) that preserve its organic soils.

It is also desirable to create a Networking with all stakeholders: the Ministry of Environment, County and local councils, NGOs, and private companies that manage the lands in the Meadow and Danube Delta for the implementation of the Master Plan to reduce GHGs in this area.

In the last stage, the good practices resulting from this Networking will be promoted at the national and European levels, correlated with the results of other complementary projects, contributing to the EU's goal of reducing the effects of climate change by reducing global warming by 1.5 - 2 degrees Celsius and become climate neutral by 2050.

We try to highlight the importance of carbon sequestration by protecting organic soils in the Danube Floodplain/Delta, GHG policy guidelines for achieving the goals of reducing the carbon footprint with benefits for farmers, the economy, society, and the environment.

Organic soils have formed under conditions of permanent humidity, which prevents the complete decomposition of dead biomass, which leads to the rich accumulation of carbon in organic matter. When the soil is no longer saturated with water, this organic matter decomposes quickly, causing huge GHG emissions. By draining organic soils for agriculture, pastures or forestry on about 70%, being responsible for a huge amount of anthropogenic GHGs that influence global warming in the Romanian Plain and Dobrogea.

This requires the protection of existing organic soils if we are to achieve the goal of the Paris Agreement - zero GHG emissions by 2050.

Unfortunately, there will be some impacts of climate change that we will not be able to avoid and that we will have to adapt to, but it is important to limit the magnitude of future impacts. The good news is that we can do a lot. Not only politicians can take action. We can all contribute by making smart choices - such as storing C.

Many believe that the soil is just dust, but it plays a key role in regulating the planet's climate. The soil stores carbon mainly in the form of organic matter and is the second-largest carbon deposit in the Earth, after the oceans. The capacity of the soil to hold huge amounts of stored carbon has declined in recent decades, largely due to unsustainable land management practices and changes in land use. Sustainable agriculture, good forestry practices, and good land management can help maintain or even increase the amount of carbon stored in the soil. The importance of carbon sequestration by protecting organic soils in the Danube Floodplain and Delta, and GHG policy guidelines for achieving carbon footprint reduction benefits for farmers, the economy, society, and the environment, and by promoting environmentally friendly methods such as biodynamic agriculture regenerative, paludiculture and permaculture is the main focus of Edaphic-Bloom Danube.

It is well known that carbon dioxide accounts for 80% of GHG greenhouse gases and 5% of methane, according to the United Nations Framework Convention on Climate Change UNFCCC Data Interface, 2019. Agriculture accounts for 9.27% of total GHGs, according to the same report - Figure 1. Moreover, the price of fertilizers has increased by about 3 times.

What can we do about climate change?

Carbon sequestration on agricultural land is possible through several soil management strategies and could be substantial with widespread implementation. Sequencing historical carbon from emissions is now essential, as it is unlikely that mitigation alone will stabilize our atmosphere. There are many management strategies for extracting carbon from the atmosphere and retaining it in the soil. These strategies vary in efficiency depending on different climates, soil types, and geographical areas.

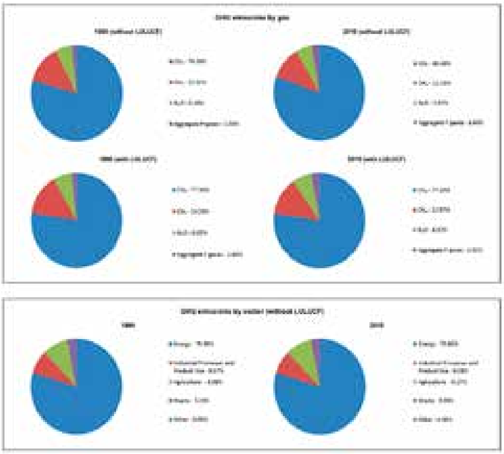


Figure 1. UNFCCC Data Interface, 2019 compared to 1990 as a Base Year
(Summary of GHG Emissions for Annex I. Base Year (Convention) = 1990, UNFCCC. Retrieved from https://di.unfccc.int/ghg_profiles/annexOne/ANI/ANI_ghg_profile.pdf)

MATERIALS AND METHODS

Land characterization is done according to ART - the average residence time of C.
There is an increase in the net carbon balance that enters the soil each year in relation to what is lost.
Also, assessing soil respiration as an indicator for carbon emissions from organic soils.
To assess soil respiration, it is mandatory to determine the total porosity of the soils (**n**).
The porosity of the soil (**n**) represents its pores volume (**V_p**) reported to its total volume (**V**), in percents:

$$n = \frac{V_p}{V} \qquad [\%] \tag{1}$$

In practice, the total porosity (**n**) is calculated with more practical formulas derived from equation 1 such as:

$$n = 1 - \frac{\gamma}{\gamma_s(1+w)} \qquad [\%] \tag{2}$$

where:
- γ is the probe's specific weight in its natural state;
- **γ_s** is the probe's specific weight of its mineral part;
- w is the moisture content.
Each of these three parameters can be determined in a testing laboratory.

The evaluation of the γ parameter in the laboratory

It is the easiest parameter to evaluate. By following the specifications from STAS 1913/3-76, the **γ** parameter can be assessed. The soil samples must be taken using a matrix of known volume. It is recommended to weigh these samples in the field, immediately after the sampling. In this mode, the total mass of the sample (in its natural state) is determined. For a known volume, the density of the sample it's easy to be estimated by applying this simple formula:

$$\rho = \frac{m_1 - m_0}{V} \qquad [\mathrm{g/m^3}] \tag{3}$$

where:
- ρ is the density of the probe in its natural state;
- m_1 is the total weight of the probe;
- m_0 is the weight of the matrix (in which the probe was contained);
- V is the volume of the matrix.
By knowing **ρ**, **γ** can be written as follows:

$$\gamma = \rho g \qquad [\mathrm{KN/m^3}] \tag{4}$$

where **g** is a constant (gravitational acceleration, **g** = 9.81 m/s^2)

The evaluation of the γ_s parameter in the laboratory

As with **γ**, to calculate **γ_s** - probe's specific weight of its mineral part, the probe's density of its mineral part (**ρ_s**) must be determined. This parameter represents the volume unit mass from the solid phase. **ρ_s** can be computed by applying the specifications mentioned in STAS 1913/2-76.
In the laboratory, to determine the density of the mineral part, the pycnometer method is used. This is a glass flask of precisely determined volume (50, 100, 150 cm^3), provided with an overflow valve and a thermometer.
Methodology: For each pycnometer (of known tare weight **m_0**), one must proceed as follows:

Insert the soil sample into the flask and weigh it (**m_1**). Add the immersion liquid (distilled water or benzene for soils with organic compounds) so that the sample is completely covered. Gradually bring to the boil (15 minutes at most). This is done to eliminate the cohesion between the particles and thus release air from the pores. Then return to a temperature of 15-30°C and add liquid until the known volume is reached, then weigh it (**m_3**). Read the exact temperature of the water/sample mixture. Finally, weigh the pycnometer filled with water to the mark (**m_2**).
With these data, the density of the mineral part can be calculated with the formula:

$$\rho_{s_{20^\circ C}} = \frac{m_s}{V_s} = \frac{m_1}{\frac{m_1+m_2-m_3}{\rho_{w_{t^\circ}}}}\Psi \quad [\text{g/m}^3] \tag{5}$$

where:
- **$\rho s_{20^\circ C}$** is the density of the mineral part of the probe;
- **m_s** is the mass of the mineral part of the probe;
- **V_s** is the volume of the mineral part of the probe;
- **m_1** is the mass of the probe in the desiccated state;
- **m_2** is the pycnometer mass filled with fluid to the mark;
- **m_3** is the pycnometer mass that contains the probe (after boiling) and filled with fluid to the mark;
- **$\rho w_t o$** is the water density at room temperature t°C, before the boiling;
- **Ψ** is a water density correction factor depending on temperature:

$$\Psi = \frac{\rho_{w_{t^\circ C}}}{\rho_{w_{20^\circ C}}} \quad [\text{dimensionless}] \tag{6}$$

where:
$\rho w_{20^\circ C}$ is the water density at 20°C.
Similarly, to the equation 4, **γ_s** can be written as follows:

$$\gamma_s = \rho_s g \quad [\text{KN/m}^3] \tag{7}$$

The evaluation of the w parameter in the laboratory

The evaluation of the moisture content of a probe (**w**) is done according to the STAS 1913/1-82 specifications.

Moisture content is the water mass lost by a soil sample by drying at 105 ± 2°C per its dry mass. It is expressed as a percentage.
In the laboratory, the moisture content is determined by the oven-drying method. As laboratory equipment, the following can be used: containers with lids, glass ampoules, clamped glass bottles, thin chromed brass capsules, technical balance, shelf dryer with adjustable temperature, desiccator containing dehydrating substances (anhydrous $CaCl_2$ or anhydrous granular microporous silica gel).
Methodology: The containers with lids are dried at 105 ± 2°C, cooled, then dried. Their tara weight, **m_c**, must be checked periodically.
The container with the testing material is closed immediately after harvesting it from the field. The next step is to weigh the container to determine its mass (**m_u**). The sample container is then opened and dried in a shelf dryer at 105°C. This temperature must be kept constant with a maximum deviation of ± 2°C. During drying, the vent of the shelf dryer must be kept open.
After drying, the test sample container must be left open in the desiccator to cool for one hour. After cooling, the dried sample container is weighted - **m_d**.
Finally, the moisture content **w** is calculated based on the values of **m_u**, **m_d**, **m_c**, with the following relation:

$$w = \frac{m_u - m_d}{m_d - m_c} 100 \quad [\%] \tag{8}$$

where:
- **m_u** is the wet mass of the sample + tare weight;
- **m_d** is the dry mass of the sample + tare weight;
- **m_c** is the tare weight.

In our tasks, we propose also an assessment of sequestered organic carbon under different agricultural land uses versus wetlands, by using the dry combustion method - after SR ISO 10694:1998 Soil quality - Determination of organic and total carbon after dry combustion (elementary analysis), a precise determination of the organic carbon content will be obtained. The amount of organic carbon (**OC**) from the soil will be estimated by extrapolating the **OC** content per soil mass to the **OC** reserve per soil volume, which was obtained by multiplying the

OC by the apparent soil density (**D$_a$**) and the depth of the horizon layer (**d**) at which the determination is made. As this approach does not take **D$_a$** into account on the soil profile (because errors may occur), **D$_a$** values will be used to take into account the standard soil depth. To determine the amount of **OC** accumulated at different standard depths the following formula will be used:

$$OC = OC\% \cdot D_a \cdot d \cdot CF_{st} \tag{9}$$

where:
- **OC** is the amount of organic carbon from the soil;
- **OC%** is the amount of organic carbon in percent from the laboratory analyses;
- **D$_a$** is the apparent density of the soil;
- **d** is the depth or the thickness of the analyzed soil layer;
- **CF$_{st}$** is the correction factor for the skeletal material.

The obtained database was structured for the identified types of soils per corresponding sampling depths.

RESULTS AND DISCUSSIONS

Soil organic matter represents a key indicator of soil quality, both for agricultural functions (i.e. production and economy) and environmental functions (e.g., C sequestration and air quality). Soil organic matter is the main determinant of biological activity. The amount, diversity, and activity of soil fauna and microorganisms are directly related to organic matter. Organic matter, and the biological activity that it generates, have a major influence on the physical and chemical properties of soils. Aggregation and stability of soil structure increase with organic matter content. These in turn increase the infiltration rate and available water capacity of the soil, as well as resistance against erosion by water and wind. Soil organic matter also improves the dynamics and bioavailability of main plant nutrient elements (Robert, 2001).

Most agricultural soils (both mineral and organic) are depleted in C relative to the native ecosystems from which they were derived, due to reduced net primary production and export of harvested biomass-which reduce C inputs to soil; nutrient depletion, intensive soil disturbance, and soil erosion are other contributing factors to soil C depletion. Most cropland mineral soils have lost 30-50% of the C stocks in topsoil layers (0-30 cm) relative to their native condition (Paustian et al., 2019).

The concentration of SOC in agricultural soils

It has been suggested that a critical level of SOC is 2% (SOM 3.4%), below which soil structural stability will suffer a significant decline (Spink et al., 2010)

However, direct measurements of SOC content taken from the continuous corn treatment in the Morrow Plots, which is the oldest agronomic trial in North America, indicate that despite an over 300% increase in grain yield achieved due to crop improvement and agronomic inputs since 1923, SOC contents have not increased in response (Figure 2). Measured trends in SOC in the fertilized soils suggest soils will not even recover 50% of the SOC contained in the soils in 1880 if current practices are maintained (Wander Nissen, 2004).

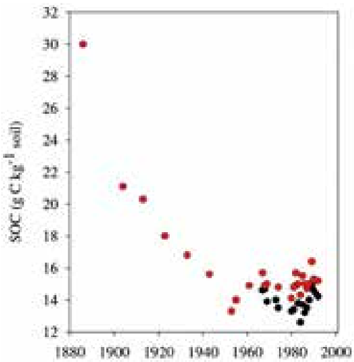


Figure 2. Trends in soil organic carbon contents and corn grain yield in the continuous corn treatment of the Morrow Plots (USA). Red circles - fertilized plots, black circles - non-fertilized plots (Wander, Nissen, 2004)

Clay content correlated to SOC

Most soil structure-related physical properties are correlated to soil organic carbon (SOC) content. Texture, mineralogy, and SOC: clay ratio is also acknowledged to affect physical properties. SOM content is correlated to several soil physical properties, like soil bulk volume, moisture retention curve, fluid transfer properties, and mechanical resistance of the soil to stresses. This can be quantified via numerous parameters, most of which are largely correlated to SOM. This is true for soil aggregate stability, mechanical properties, or penetration resistance. The most documented is probably the relationship between SOM, or soil organic carbon (SOC), and soil bulk density. A continuous increase in soil porosity with SOC was reported in many cases. Studies that included a broad range of SOC values (from 0 to> 50%) usually found a semi-logarithmic relationship, thus decreasing the effect of SOC on porosity or bulk density (BD) at large SOC content. Studies based on a limited range of low SOC contents even found a linear relation, thus proportional increase, between porosity and SOC.

Because in many soils, a significant portion of the SOC is bound to clay minerals, it is considered clay or clay + fine silt content as covariables when analysing the effect of soil constituents on soil physical properties. Together with SOC, the texture is generally assumed to influence the physical properties. By increasing clay content, a larger SOC content is necessary to achieve the same level of aggregate stability.

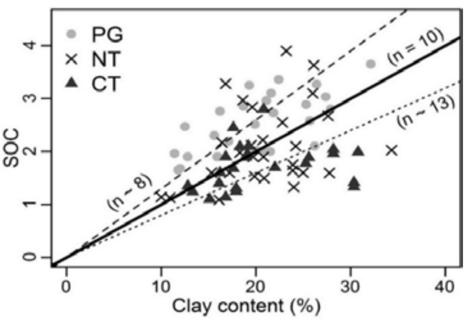


Figure 3. Soil organic carbon content (SOC) as a function of clay content for different soil management practices (PG: permanent grass, NT: no-till, CT: conventional tillage) within soils of good structural state. The dashed line indicates a SOC: clay ratio of 1: 8, the full line a SOC: clay ratio of 1: 10, and the dotted line a SOC: clay ratio of 1: 13 (Johannes et al., 2017)

By analysing the role of the clay: SOC ratio in the relation between bulk density (BD) and SOC using different soil databases that included soils of several taxonomic orders, the concept of “Complexed Organic Carbon” (COC) was introduced as the fraction of the SOC bound to clay. It was determined that the highest coefficient of determination of the linear relation between COC and soil volume (1/BD) for clay: COC = 10, thus interpreted as the saturation of the clay surface by SOC. The same optimum ratio for clay dispersibility was obtained and the fraction of SOC corresponding to a tenth of the clay content was considered to be the maximum COC controlling the structure-related physical properties of soils. In particular, it was concluded that structural porosity was no longer increasing with SOC above 10% of clay content and that the optimum SOC content of soil would thus be 10% of the clay content (Johannes et al., 2017).

For soils showing no evidence of physical stress or structure degradation, the linear relation between SOC and soil pore volume (or 1/BD) means that a SOC increase will result in a proportional increase of soil porosity regardless of how much SOC is complexed to clay. There is no optimum correlation between the physical properties and a COC fraction of the SOC proportional to the clay content. The largest correlations were observed when the SOC content was fully taken into account indicating that total SOC controls physical properties rather than COC.

The SOC: clay ratio, however, appears to be a relevant criterion when considering soil structure quality. Soils with visually evaluated good structure quality have higher SOC: clay ratios than soils of poor structural quality, and the different structure quality scores correspond on average to different SOC: clay ratios. This allows the establishment of criteria for SOC management. A ratio of 1:8 is optimum for good structure quality, and 1:10 is a reasonable goal for farmers, reachable even with tillage. Finally, 1:13 is a ratio below which the structure quality is most likely unacceptable and needs improvement. Nevertheless, the 1: 8 and 1: 10 SOC: clay ratios do not guarantee a good soil structure, since mechanical damage may occur regardless of SOC content (Figure 3). The complexed organic carbon is a relevant concept for soil structural quality, and that clay content has to be taken into account in the definition of objectives for SOC content (Johannes et al., 2017).

Organic Soils (Histosols)

Histosols are the main component of the soil cover of the DDBR. According to RSSC, under this name have been classified all soils with a histic horizon of more than 50 cm thickness with its upper boundary within 25 cm of the soil surface. These soils are formed there as a result of very wet and reducing conditions prevailing in the low-lying areas (<0.5 m above MBSL) of the DDBR which retard the decomposition of the remnants of very rich climax vegetation. This vegetation consists of mostly reed, sedge, and reedmace, with minor participation of some woody species, i.e. *Salix cineraea*. Besides the excess water and reducing environment, one of the main conditions for the occurrence of these soils is the reduced (or at least discontinuous) rate of the mineral sedimentation in the area where they develop.

The organic matter content of these soils ranges from 20% in the case of organo-mineral materials and up to 95% in purely organic materials (Munteanu, 1996).

Land-use

In the natural state, Histosols function as basic pedological support for wetland ecosystems. Their ecological value is given by their high-water storage capacity and mechanical filtering capacity.

Apart from their bio function in natural ecosystems, Histosols are very fragile soils. If drained, besides the abovementioned acidification, in the Danube Delta under warm and dry climatic conditions, Histosols lose about 5 cm of the top a year due to mineralization and wind erosion. If the groundwater is mineralized, the salinization process also develops more rapidly. Experience has shown that Histosols in the DDBR are almost completely unsuitable for arable land use. Besides the toxicity which develops following acidification, the relatively coarse Histosols offer unfavourable ploughing and rooting conditions and have low water availability. The bearing capacity is low, the tilth is poor, the production of weeds is very high, and the macronutrient supply is extremely unbalanced especially due to excess amounts of nitrogen. More than 10 000 ha of the Histosols in the DDBR have already been lost by burning to obtain arable land in the Pardina and other agricultural polders of the delta (Munteanu, 1996).

Agricultural Soils

About 45% of global soils are under some form of agricultural use. In most soils, organic matter makes up a small fraction (~1-10%) of the total soil mass which is dominated by mineral matter (i.e., sand, silt, and clay particles); these are so-called "mineral soils". It is worth mentioning that the mass of organic matter contains nearly 50% carbon.

Most agricultural soils (both mineral and organic) are depleted in C relative to the native ecosystems from which they were derived, due to reduced net primary production and export of harvested biomass - which reduces C inputs to soil; nutrient depletion, intensive soil disturbance, and soil erosion are other contributing factors to soil C depletion. Most cropland mineral soils have lost 30-50% of the C stocks in topsoil layers (0-30 cm) relative to their native condition (Paustian et al., 2019).

It is not a consensus regarding agricultural soils in Danube Delta. Agriculture, as mentioned above, can use mineral and organic soils such as gleysol, kastanozem, histosol, and to some extent, alluvial soil, psammosol, and even sandy soil.

Carbon sequestration in soils

Soil Organic Matter stores a huge amount of atmospheric carbon. Carbon, in the form of carbon dioxide, is a greenhouse gas associated with global warming. So, by increasing soil organic matter, more carbon can be stored in soils, reducing the potential for climate change (Magdoff, van Es, 2021).

The Soil Organic Carbon represents the largest reservoir in interaction with the atmosphere and is estimated at 1500 Pg C to 1m depth. Vegetation (650 Pg) and the atmosphere (750 Pg) store considerably less C than soils do (Robert, 2001).

Fluxes between terrestrial or soil organic carbon and the atmosphere are important and can be positive (sequestration) or negative (emission of CO_2) (Robert, 2001).

Organic Matter in Soils

The organic matter content of agricultural topsoil is usually in the range of 1-6%. A study of soils in Michigan demonstrated potential crop-yield increases of about 12% for every 1% increase in organic matter. During an experiment, researchers saw an increase of approximately 80 bushels of corn per acre when organic matter increased from 0.8% to 2%. The enormous influence of organic matter on so many of the soil's properties - biological, chemical, and physical - makes it of critical importance to healthy soils (Figure 4). Part of the explanation for this influence is the small particle size of the well-decomposed portion of organic matter, the humus. Its large surface-area-to-volume ratio means that humus is in contact with a considerable portion of the soil. The intimate contact of humus with the rest of the soil allows many reactions, such as the release of available nutrients into the soil water, to occur rapidly. However, the many roles of living organisms make soil life an essential part of the organic matter story (Magdoff, Van Es, 2021).

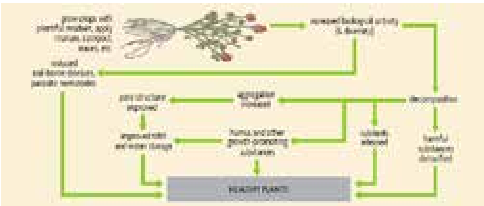


Figure 4. The Organic Matter and its benefits (Magdoff, Van Es, 2021)

The historical conversion of forests and grasslands to farming was responsible for a large transfer of carbon (from accelerated soil organic matter decomposition) into the atmosphere as CO_2. This agricultural conversion is second to the burning of fossil fuels as the largest contributor to increasing atmospheric CO_2 concentrations. As forests are burned and soils are plowed to grow crops (enhancing the use of organic matter by soil organisms), CO_2 is emitted into the atmosphere. But soils managed in ways that build up organic matter can become net sinks for carbon storage and can enhance their health at the same time. Increasing soil organic matter is no silver bullet for combating climate change, but it can help to slow the increase in CO_2 for a while if done on a massive scale all over the world.

If organic matter decreases from 3% (as it is nowadays) to 2%, the amount of carbon dioxide in the atmosphere could double.

Soil organic matter is the key to building and maintaining healthy soils because it has such great positive influences on essentially all soil properties - aggregation, nutrient availability, soil tilth and water availability, biological diversity, and so on - helping to grow healthier plants. Soil organic matter transformations are a key part of plant nutrition and the ability to achieve good crop yields. Soil organic matter is also an integral part of local and global cycles of carbon, nitrogen, and water, impacting many aspects that define the sustainability and future survival of life on earth (Magdoff, van Es, 2021).

Increased SOC through improved management practices is likely to add substantial resilience to croplands and farming systems, particularly during drought years or increased seasonal variability, helping to avoid edaphic (soil-related) droughts that result from land degradation. Given that hundreds of millions of small farmers for their subsistence depend upon croplands around the world, mitigation benefits of enhanced SOC storage must be recognized as only one significant component of an array of multiple benefits to achieve (Zomer et al., 2017).

In the past, the development of agriculture was the main cause of the increasing CO_2 concentration in the atmosphere, but now the combustion of fossil carbon by industry and transport (6.5 Pg yr^{-1}) represents the main contribution. An important point is that, at present, while deforestation in many tropical areas produces C emissions estimated at 1.5 Pg C per year, elsewhere around 1.8 to 2 Pg C per year is accumulating in terrestrial ecosystems. This represents what is called the "missing carbon" in the cycle: a sink that may be mainly situated in the northern part of the northern hemisphere. The main factors acting on organic matter evolution concern the vegetation (residue input, plant composition), then climatic factors (temperature/moisture conditions), and soil properties (texture, clay content, and mineralogy, acidity) (Robert, 2001).

Other factors, relating to soil fertilisation (N, P, or S), or irrigation, have an effect on plant production and hence on organic matter content. The rate of SOM mineralization depends mainly on temperature and oxygen availability (drainage), land use, cropping system, soil, and crop management. In a given soil type exposed to constant practice, a near-equilibrium (steady-state) SOM content is normally reached after 30 to 50 years (Robert, 2001).

Erosion

Soil erosion is one aspect of soil physical behaviour in which SOC content is regarded as a factor. Being a selective process, soil erosion preferentially transfers fine and light materials, which are typically enriched in SOC relative to the bulk soil. This process can lead to carbon loss in the eroding profiles and enrichment of the labile C fraction in the depositional profiles (Li et al., 2019).

Soil erosion by wind and water and subsequent sediment transport and depositional processes may lead to soil organic carbon (SOC) loss, especially from a sloping agricultural land unit. The erosion processes change land unit SOC stock by transporting SOC-rich sediment off an agricultural land unit, oxidizing SOC stocks, and releasing carbon dioxide (CO_2) into the atmosphere, as well as causing loss of SOC through surface runoff. Thus, erosion, transport, and depositional processes redistribute landscape SOC, enhance oxidation, and create a SOC source and a sink. However, redistributed SOC to bottomland soils is not sequestered SOC if it originates outside the borders of the measured land unit (Olson et al., 2016).

In Figure 5, the relationship for soils under cereals is, effectively, non-existent, whilst that for soils under pasture is more definite. From the graph, it would seem that soil loss decreases markedly above a SOC content of about 3% (Loveland, Webb, 2003). It is noted that in the case of cereal crops, even if there is no obvious relationship between SOC and Soil Loss, it is observed that the latter is more pronounced in the case of a lower percentage of OC.

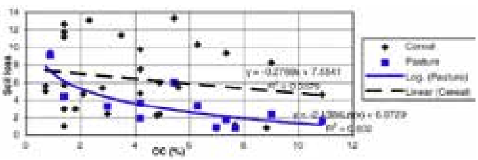


Figure 5. Relationship between SOC content (%) and soil loss (g/m^2 per month) under different land uses (Loveland, Webb, 2003)

In poorly drained soils and soils of the wetlands, decomposition reactions of humic matter occur at a greatly reduced rate. These soils support a different population of microorganisms that produce different types of end products, although CO_2 is included for the continuation of the carbon cycle. An incomplete decomposition under anaerobic conditions generally yields fermentation products, e.g., methane, mercaptans, nitrosamines, and the like, some of which are foul-smelling whereas others are believed to be carcinogenic. The main decomposition processes in such environments are expected to be hydrolysis and reductive cleavage. A schematic representation of the formation of methane through hydrolysis of humic substances by methanogenic bacteria is given below as an example:

$$(C_6H_5) - COOH + 6H_2O \leftrightarrow 3HCOOH + CO_2 + 3CH_4 \quad (10)$$

where:
- (C_6H_5)-COOH is part of the humic molecule;
- HCOOH is Formic Acid.

In summary, it can be stated that humic matter is an active constituent of the organic cycle in the soil ecosystem. Utilizing organic carbon for the formation of humic substances means preserving it for the benefit of the physicochemical condition of the soil ecosystem. It is a form of soil carbon sequestration, a process considered of vital importance for the environment. Although relatively stable, the stored carbon remains a formidable energy source for many microorganisms. The microbial population is often noted to thrive prolifically in soils rich in humus. By way of enzymatic decomposition and mineralization, the humic substances are eventually broken down into H_2O and CO_2, which completes the cycle.

Researches in Danube Delta

DDNI Tulcea within the Edaphic Bloom Project (***European Climate Initiative, 2020), analysed soil samples collected from the Danube Delta. In addition to the soil samples of organic origin specific to the Danube Delta, samples from agricultural soils were also collected. Sampling was realized in two field expeditions, in the summer (July) and autumn (September-October) of 2021 (Table 1). The target parameter was the percentage of organic carbon - OC in soils. The results on the soils of agricultural origin showed that Organic Carbon - OC on the first 10 cm of soil falls in the range of 2.4-6.7%, corresponding to a normal concentration found worldwide (1-6%) (Magdoff, Van Es, 2021). There is also a seasonal variation in the concentration of Organic Carbon, which can be explained by the fact that the summer sampling was carried out on cultivated land and in autumn on the already plowed land.

Table 1. Agricultural soils - The Organic Carbon content. From summer and autumn 2021 field expeditions data results (***European Climate Initiative, 2020)

Area	Depth [cm]	Organic Carbon [%] july. 2021	Organic Carbon [%] sept. 2021	Difference	Crop	Soil
Nufăru-Rusca	0-10	6.7	2.4	-4.3	wheat	Grey-black loose clayey silty gleyed alluvial soil
Pardina	0-10	4.7	2.7	-2	two rowed barley	Brown-olive silty clayey alluvial soil
Tatanir	0-10	4.7	3.4	-1.3	sunflower	Dark-brown micaceous silty clayey alluvial soil

DDNI Tulcea made a series of measurements aimed at recording CO_2 emissions from the Danube Delta soils in September 2021. Three locations, two natural areas, and an agricultural area were chosen as testing sites.

The CO_2 emissions were recorded continuously for two weeks, and the results are shown in Table 2. It was found that natural soils emit less CO_2 than agricultural soils because the percentage of Organic Carbon accumulated in agricultural soils is lower. In terms of numbers, CO_2 emissions exceed the global value of 412.5 ppm (2020) (***Global Methane Initiative, 2020) and 418 ppm (2022) (*CO_2 Earth. Numbers for living on Earth. Retrieved from https://www.co2.earth/*) for the first two locations. At Matița-Roșca, CO_2 emissions are below global value.

Table 2. CO_2 emissions recorded in the Danube Delta - September 2021 (***Beia Consult International, 2021)

Location	**Medium value [ppm]**	**Minimum value [ppm]**	**Maximum value [ppm]**	**Remarks**
Nufăru-Rusca	428	353	728	Agricultural area
Candura Channel	423	386	627	Natural area
Matița-Roșca	336	203	579	Natural area

Farm managers can strongly influence this dynamic in four ways:

1) Decreasing the level of soil disturbance (i.e. soil agriculture process) to increase the physical protection of soil carbon.
2) Increasing the mass and quality of plant and animal inputs to the soil.
3) Improving soil diversity and microbial abundance.
4) Maintaining the cover of continuous living plants on the ground throughout the year.

Managing these processes can quickly lead to increases in soil carbon sequestration, which can be extremely helpful in lowering atmospheric CO_2 content. Regenerative and therefore biodynamic agriculture goes beyond organic or sustainable agriculture, which only supports the way food is produced but does not reverse the damage ratio.

What is unique about Sustainable-Biodynamic-Regenerative Agriculture?

The concept of Biodynamic Agriculture includes the term Regenerative Agriculture and aspires to be transformative, aiming to maximize the health and vitality of the soil, ecosystem, and crops.

Practices include:

- Replacing chemical herbicides with farm-based herbal products to improve and revitalize crops;
- Replacing chemical pesticides with agricultural practices that promote a healthy balance between predators and prey with appropriate planting techniques;
- Replacement of chemical fertilizers with natural compost produced by the farm for soil fertilization.

Planting cover crops out of season, draws carbon back from the atmosphere and improves soil vitality and nutrient content.

- Disposal of chemicals

Industrialized agriculture is largely based on chemicals that kill important insects and pollute the water and the environment. Replacing toxic chemicals with natural alternatives so that no chemicals with negative effects on human health end up in food!

- Regular crop rotation increases soil vitality and helps retain water.

Unlike organic farming, which focuses mainly on crops, the biodynamic certification certifies the entire farm and all aspects of the farm.

- Sustainable-Biodynamic-Regenerative Agriculture sets higher standards for environmental sustainability and ecology, as it requires that agricultural practices not only refrain from plant damage but also improve it in the process;
- Zero tolerance for GMOs;

Sustainable-Biodynamic-Regenerative Agriculture can contribute to reducing the impact of climate change - by acting on the weaknesses of current practices:

- Current agricultural practices are based only on economic and not ecological grounds. People have manipulated the way we grow and harvest food in an effort to produce in bulk at a cheaper price. These agricultural practices have led to:
    - development of GMO crops;
    - the destruction of healthy soil;
    - animal cruelty;
    - water pollution.
- Excessive use of toxic chemicals such as glyphosate, a cancer-causing chemical found in popular baby foods such as cereals;
- These destructive agricultural practices also play an important role in the loss of biodiversity, pollinators and play an important role in climate change.

Fortunately for us (and for the little ones), there is a better way to cultivate, which could even reverse global warming: Sustainable-Biodynamic-Regenerative Agriculture that seeks to heal the Earth by working with nature to improve and "repair" the earth and farms, rather than harming them. Scientists say that this type of agriculture can even help fight climate change. Globally, in the world, this type of agriculture is more developed in the United States of America, and in Romania, there is no such farm (Figure 6).

Because our study area, the Danube Floodplain, and the Delta, includes peatlands where agriculture is practiced, paludiculture is good to apply. In conventional agriculture, many peatlands are drained to allow intensive farming. Unfortunately, drainage causes a multitude of problems, such as landslides and an increased risk of flooding. By increasing groundwater, these problems can be avoided. After re-humidification, the cultivation of flood-tolerant plant species can prevent eutrophication and provide an alternative product for farmers. Thus, *the main purpose of paludiculture cultivation is the conservation and restoration of peatlands, simultaneously using the biomass produced.* Paludiculture cultivation combines the reduction of greenhouse gas emissions from peatlands drained by re-wetting with continuous land use and wet biomass production.

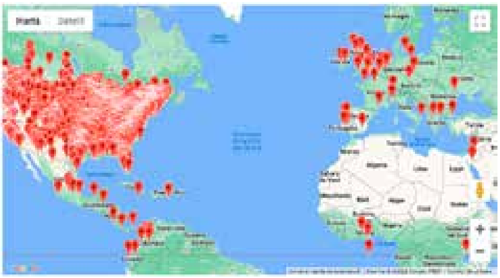


Figure 6. Regenerative Farms în the world
(Regenerative Farm Map. Retrieved from https://regenerationinternational.org/regenerative-farm-map)

With paludicuture cultivation, peatlands are kept productive in permanently humid conditions, preserving peat and potential for peat formation. Thus, it is a model for storing carbon in peatlands, while producing food, feed, and energy. The corresponding benefits of paludiculture cultivation could contribute to the objectives of the *EU Green Deal policy* (*European Commision. European Green Deal. Retrieved from https://ec.europa.eu/clima/eu-action/european-green-deal_en*) by maintaining and restoring more ecosystem services, such as maintaining water, retaining nutrients, cooling the local climate, and providing habitat for rare species, while allowing agricultural production. Paludiculture includes a variety of agricultural production systems that aim to produce plant-based or animal-based commodities - from harvesting vegetation on semi-natural sites to establishing specific permanent crops.

Paludiculture uses above-ground biomass, while underground biomass, i.e. a major part of the net primary production, remains for peat formation. After the establishment of high groundwater near the surface of the soil throughout the year, wet meadows can be developed by a succession of vegetation or permanent crops with specific peat species that can be cultivated. The harvested biomass can be used as food, feed, and fibber for industrial biochemistry, for the production of building materials, high-quality liquid or gaseous biofuels, for the production of heat by direct combustion, or other purposes such as extraction and synthesis of pharmaceuticals and cosmetics. These diverse options for paludiculture biomass show its great potential for future applications of the circular bioeconomy.

Paludicultural plants and utilization options include:

- Isolation material;
- Filling material (fibbers);
- Building Materials;
- Packaging and disposable tableware;
- Horticultural crops that replace peat;
- Pollen for feeding predatory mites (pest control in greenhouses);
- Straw;
- Combustion;
- BIOGAS;
- Protein extraction;
- Paper;
- Liquid fue;l
- Silicone from reed leaves;
- High-performance energy storage devices.

These proposed practices must be supplemented with permaculture. In their book *Permaculture One* (1978), Bill Mollison and David Holmgren outlined the three ethical directions of permaculture:

- *Caring for the Earth: making sure that living systems can continue to survive and proliferate;*
- *Caring for humanity: making sure that people have access to all the resources they need to live;*
- *Ethical distribution and limiting the consumption of resources: by setting limits for our needs, we can obtain resources to support the two previous directions. We will share the surplus with others.*

Permaculture deals with the design of the environment so that it is self-sustaining, on ecological and biological principles, often using patterns that occur in nature. The aim is to optimize the effect and minimize the work. The purpose of permaculture is to create stable, productive systems that meet human needs and harmoniously integrate the environment with its inhabitants. To achieve its goal, permaculture takes into account the ecological processes of plants and animals, their feeding cycles, climatic factors, and weather cycles.

In the last instance, agricultural exploitation is defined by the economic parameters, within which, after the realization of the input-output balance, either a surplus or a steady-state or losses is realized, but also by ecological indicators.

The optimum is defined in a field of action of concrete factors, in which the total cost of production (TCP) per unit of output is the lowest, but with ecological effects beneficial to the environment.

CONCLUSIONS

- Greenhouse gases are a phenomenon with long-term global implications. The alarming rise in GHG concentrations in the atmosphere determined scientists to search for effective methods to reduce emissions of these gases. The main gases that are considered dangerous in this context are carbon dioxide and methane. Even though methane is found in very low concentrations in the atmosphere, it is much more potent than carbon dioxide and can be a real danger in the event of a substantial increase.
- Carbon sequestration in the soil is seen as the main mean of reducing GHG emissions. As agriculture is highly dependent on soil quality, a supply of organic matter is needed to improve soil quality and is, therefore, an effective method of reducing GHG and secondly, it can

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

visibly improve the quality and quantity of agricultural production.

• Danube Floodplain and Delta Soils, although the monitored properties present non-significant improvements because their evaluation remains in the ranks characterized by the agriculture of subsistence. It is important to note that the decrease of organic content in the soil, understood as organic carbon, favoured the chemicals nutrients input, and degraded physical and biological properties evaluated in the demonstration area.

• Carbon sequestration on agricultural land is possible through several soil management strategies and could be substantial with wide-spread implementation. Sequencing historical carbon from emissions is now essential, as it is unlikely that mitigation alone will stabilize our atmosphere. Farm managers can strongly influence this dynamic in four ways:

1) Decreasing the level of soil disturbance (i.e. soil agriculture process) to increase the physical protection of soil carbon;
2) Increasing the mass and quality of plant and animal inputs to the soil;
3) Improving soil diversity and microbial abundance;
4) Maintaining the cover of continuous living plants on the ground throughout the year.

• Soil quality is constantly deteriorating, either due to natural phenomena (eg soil erosion) or anthropogenic intervention due to the use of destructive practices (eg use of harmful substances to eliminate pests or increase agricultural production). For the soils to be of agricultural and ecological quality, an optimal percentage of Carbon Organic (> 2% SOC) must be maintained. By increasing SOM (SOC) in soils, one can obtain important benefits like detoxification of harmful substances, increasing the growth of the plants, improving pore structure, tilth, and water storage, and releasing vital nutrients for plant health.

• There are many management strategies for extracting carbon from the atmosphere and retaining it in the soil. These strategies vary in efficiency depending on different climates, soil types, and geographical areas.

• The proposals for the Danube Floodplain and Delta Agriculture there are:

- Sustainable-Biodynamic-Regenerative Agriculture;
- Paludiculture;
- Permaculture.

ACKNOWLEDGEMENTS

This study was carried out within Edaphic-Bloom Project (Ecological resizing through urban and rural actions & dialogues for GHG mitigation in the Lower Danube Floodplains & Danube Delta) under European Climate Initiative ("Euki").

REFERENCES

Johannes A., Matter A., Schulin R., Weisskopf P., Baveye P., Boivin P. (2017). Optimal organic carbon values for soil structure quality of arable soils. Does clay content matter? *Geoderma 302, 14-21.*

Li T., Zhang H., Wang X., Cheng S., Fang H., Liu G., Yuan W. (2019). Soil erosion affects variations of soil organic carbon and soil respiration along a slope in Northeast China. *Ecological processes 8, 28.*

Loveland P., Webb J. (2003). Is there a critical level of organic matter in the agricultural soils of temperate regions: a review. *Soil & Tillage Research 70, 1-18.*

Magdoff F., Van Es H. (2021). Building soils for better crops. Ecological management for healthy soils. Fourth Edition. *Sustainable Agriculture Research and Education (SARE) program.*

Mollison B., Holmgren D. (1978). Permaculture One: A Perennial Agriculture For Human Settlements. Tagari Publications, Australia.

Munteanu I. (1996). Soils of the Romanian Danube Delta Biosphere Reserve. *Research Institute for Soil Science and Agrochemistry, Bucharest.*

Olson K., Al-Kaisi M., Lal R., Cihacek L. (2016). Impact of soil erosion on soil organic carbon stocks. *Journal of Soil and Water Conservation, 71(3), 61A-67A.*

Paustian K., Larson E., Kent J., Marx E., Swan A., Soil C. (2019). Sequestration as a Biological Negative Emission Strategy. *Frontiers in climate, volume 1.*

Robert M. (2001). Soil carbon sequestration for improved land management. *Food and agriculture organization of the United Nations, Rome.*

Spink J., Hackett R., Forristal D., Creamer R. (2010). Soil Organic Carbon: A review of critical levels and practices to increase levels in tillage land in Ireland. *Teagasc, Oak Park Crops Research Centre, Carlow.*

Wander M., Nissen T. (2004). Value of Soil Organic Carbon in Agricultural Lands. *Mitigation and Adaptation Strategies for Global Change 9: 417-431.*

Zomer R., Bossio D., Sommer R., Verchot L. (2017). Global Sequestration Potential of Increased Organic Carbon in Cropland Soils. *Scientific Reports, Springer Nature.*

***Ecological resizing through urban and rural actions & dialogues for GHG mitigation in the Lower Danube Floodplain & Danube Delta (Edaphic-Bloom Project). *European Climate Initiative ("EUKI")* 2020.

***Global methane emissions and mitigation opportunities. *Global Methane Initiative,* 2020.

***Monitoring of some environmental parameters associated with the soil types in the Danube Delta. Final Report. *Beia Consult International, Bucharest,* 2021, in Romanian, not published.

***SR ISO 10694:1998 Soil quality. Determination of organic and total carbon after dry combustion (elementary analysis). *Romanian Standard. Date of approval* 28.10.1997, in Romanian.

***STAS 1913/1-82 Foundation Ground. Determination of Moisture Content. *National Standard. Official Edition. Date of approval* 01.08.1982, in Romanian.

***STAS 1913/2-76 Foundation Ground. Determination of Soil Skeletal Density. *National Standard. Official Edition. Date of approval* 01.02.1976, in Romanian.

***STAS 1913/3-76 Foundation Ground. Determination of the Soil Density. *National Standard. Official Edition. Date of approval* 01.02.1976, in Romanian.

CO_2 Earth. Numbers for living on Earth. Retrieved from https://www.co2.earth/

European Commission. European Green Deal. Retrieved from https://ec.europa.eu/clima/eu-action/european-green-deal_en

Regenerative Farm Map. Retrieved from https://regenerationinternational.org/regenerative-farm-map

Summary of GHG Emissions for Annex I. Base Year (Convention) = 1990, UNFCCC. Retrieved from https://di.unfccc.int/ghg_profiles/annexOne/ANI/ANI_ghg_profile.pdf

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

A ROADMAP FOR A SUSTAINABLE ENVIRONMENT OF DANUBE DELTA - A 3D INITIATIVE

Iulian NICHERSU[1], Delia DIMITRIU[2], Iuliana I. NICHERSU[3], Dragoș BALAICAN[1], Edward BRATFANOF[1], Alexandru NICHERSU[4], Oliver LIVANOV[1]

[1]Danube Delta National Institute for R & D, 165 Babadag Street, Tulcea, Romania
[2]Manchester Metropolitan University, All Saints Building, All Saints, Manchester M15 6BH, United Kingdom
[3]Steinbeis-Europa-Zentrum, 12 Steinhäuserstraße, 76135 Karlsruhe, Germany
[4]Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

Corresponding author email: nichersu_iulian.nichersu@ddni.ro

Abstract

3D - Danube Delta Decarbonising is an essential concept that promotes the maintenance of swamps and wetlands of the Danube and the adaptation of their socio-economic system to climate change. The relationship between climate change, atmospheric structure and greenhouse gases (GHGs) and other critical factors for the global environment, such as alteration of the water cycle, changes in biogeochemical cycles, erosion of soils and coastal areas, reduction of sea salinity, loss biodiversity, is a complex of specificities for the Danube Delta, given the duration of processes, diversity, and causality, both endogenous and exogenous system, and requires analysis of different variants and intensities of manifestation as an objective need for the functioning of the hydro-geo- morphological (HGM) and socio-ecological (SSE) of the Danube Delta. Wetlands such as the Danube Delta are a major source of methane (CH_4) and contribute between 30 and 40% to total CH_4 emissions. CH_4 emissions from wetlands depend on temperature, groundwater depth, and the quantity and quality of organic matter. Global warming will affect these three factors of methanogenesis, raising questions about the feedback between natural methane production and climate change. Forecasts show that by the end of this century, natural methane (CH_4) emissions from wetlands are expected to increase by up to 80% by the turn of the century if no concrete measures are taken to reduce greenhouse gas emissions and especially those generated by the anthropogenic factor, a better understanding of the situation is needed for future rebalancing. The scientific community agrees that an economic system based on fossil fuels, intensive agriculture, and the unsustainable exploitation of global natural resources have irreversible effects on the environment. The effects of the current economic system have detrimental effects on the Danube Delta, such as climate change, air and ocean pollution, and ecological decline, causing material and human damage to the local population. Thus, there is a real risk of catastrophic damage to our economies and societies over the next few decades, if the prevailing forms of production and consumption are not radically changed.

Key words: *Danube Delta, decarbonization, Greenhouse Gas emissions, climate change.*

INTRODUCTION

Any human approach in terms of practice is a form of manifestation of the relationship between the level of knowledge and understanding of the surrounding reality, on the one hand, and the value system assumed at different spatial-temporal scales.

The Danube Delta, the youngest and most dynamic geographical unit in Romania, is, in terms of systemic methodology, the expression of the legal interaction between natural components, matter, and energy flows (mainly climatic and hydrological), on the one hand, and human intervention in intensity and consequences more and more in the last decades), on the other hand (Niculescu, Lardeux, & Hanganu, 2017).

The transformations to which the Wetland System of the Lower Danube Floodplain and Delta has been subjected, given the spatial scale of manifestation, are relevant for the current context, marked by the absence of decision-making support tools that capitalize on decision-making power, scientific knowledge, experiences, and information.

We must recognize, at the same time, that the present provides us with much more scientific and factual evidence of the limited capacity of natural capital to provide goods and services (energy and raw material crises, climate change, and pollution of the planet) and yet the readiness to improve the ecological performance of socio-economic systems, as a reflection of an intra- and inter-generational solidarity, it is maintained at levels that feed the state of pessimism rather than optimism.

The effects of the current economic system such as climate change, air and ocean pollution, and ecological decline are *causing material and human damage to tens of millions of people globally, thus, there is a real risk of catastrophic damage to our economies and societies over the next few decades if the forms that currently are dominated by production and consumption are not radically changed* (IPCC, 2022)**.**

Mainly, the main objective, will be focused on the development of proposals for Carbon Neutral and scientific development in ecological restoration and rescaling in the conditions of Climate Change and scientific support for Adaptive and Ecosystem Management in the Danube Delta Biosphere Reserve, as a separate research-innovation direction of administrative operational projects, but at the same time excellent research, such as complex theories of entropy and aggregation.

At present, there are many arguments which convincingly demonstrate that sufficient time has elapsed to accumulate the data and facts strictly necessary to conclude, whether or not only preliminary, concerning what is, conceptually, merging, overlapping, in an unprecedented way, of the crisis of biodiversity loss and coastal erosion due to rising sea levels and decarbonisation:

- Construction of Lake Complexes in the Black Sea according to the natural model of the genesis of the Danube Delta, complexes located at the mouths of the outflow, where the accumulation phenomenon is more developed (Panin, Tiron, & Dutu, 2016).
- Increasing the sequestration time of C, by mineralizing of organic carbon. As the mineralization of the residual material is performed, the nutrients associated with dissolved organic C (DOC) and organic C particles (POC) can be released and transported to surface waters. Depending on abiotic and biotic processes, sequestration or C emission from a wetland may vary, biotic processes may include vegetation uptake by assimilation by planktonic communities, while abiotic processes may include adsorption, precipitation, and soil balance. and water columns.

It can be said that concrete measures are required, first of all (which is perfectly true), but we must not forget that nothing has a greater practical value than a good theory. **Without solid theoretical support**, even the most basic control measures do not have the consistency necessary to give the expected results.

From a scientific perspective, it is necessary to assume a realistic assessment of the limits of economic systems, where only the role of natural capital as a vital factor of production is reflected, to a very small extent; the exclusivity of private profit as a performance indicator must be abandoned, to make possible a multicriteria approach, in a holistic, integrative context.

Economic and environmental criteria must be complemented by socio-political criteria. It should be noted, in this context, that the multifunctional spatial planning of the Lower Danube Meadow / Romanian Sector is partially or totally replaced by advantages appropriate to the individual time scale (generated by agrosystems) with advantages appropriate to the social time scale (generated by wetlands); therefore, the socio-political criteria can significantly correct the result of the analysis of the economic-ecological efficiency.

3D – DANUBE DELTA DECARBONIZATION STRATEGY

The main objective is to develop proposals for Biodiversity Conservation and Sustainable Development in the context of Climate Change and scientific support for Adaptive and Ecosystem Management in the Danube Delta Biosphere Reserve. They represent a distinct direction of research innovation providing support in administrative operational projects, but at the same time research with a high degree of excellence, such as molecular genetics studies, not addressed at the institutional level so far (INCDDD Tulcea, 2022).

This complex, inter-, multi-, and trans-disciplinary approach can be implemented by the specialists of several disciplines, grouped in research nuclei correlated with the directions and priorities defined by the 3D Strategy.

The scientific community agrees that an economic system based on fossil fuels, intensive agriculture, and the unsustainable exploitation of global natural resources have irreversible effects on the environment. The effects of the current economic system such as climate change, air and ocean pollution, and ecological decline are causing material and human damage to tens of millions of people globally. Thus, there is a real risk of catastrophic damage to our economies and societies over the next few decades if the forms that currently dominate production and consumption are not radically changed.

Under the Paris Agreement, many countries have agreed to set a target to reduce greenhouse gas emissions sufficiently to keep the average global temperature rise below 2°C above pre-industrial levels. Keeping global temperatures above 2°C requires limiting greenhouse gas concentrations in the Earth's atmosphere to about 450 ppm of CO_2 equivalent emissions. As we can see from Figure 1, the time left to complete this change is very short. A massive effort to decarbonise is absolutely necessary over the next three decades. Forecasts show that in order to achieve reductions in line with the proposed 2°C target, CO_2 emissions from the electricity sectors of OECD countries, for example, should be reduced by 90% by the middle of the century (Volintiru et al, 2019).

Among the issues addressed at the 3D strategic level:

1. Issues specific to greenhouse gas emissions:

• Restoration of wetlands to offset carbon emissions. Wetlands have been systematically destroyed throughout Europe over the past century. Restoration of these areas is gaining importance in the carbon sequestration process due to a large number of scientific papers showing their ability to capture carbon emissions.

• Monitoring land-use change and specifically forestry, including deforestation and the need for sustainable practice through satellite monitoring techniques. The development of carbon sequestration "industries" and organic farming is an opportunity with great potential to accelerate the transition to a carbon-neutral economy. Vulnerability of the natural environment, forests, compact reed areas to climate change, the need for more innovations in the value chain of natural resources, and the difficulty of integrating biodiversity conservation and various landscaping in agriculture, fisheries, and forestry make land-use an important subject for storage and carbon sequestration through proper land and forest management (as well as ecosystem-based approaches) (Tognetti, Smith, & Panzacchi, 2021).

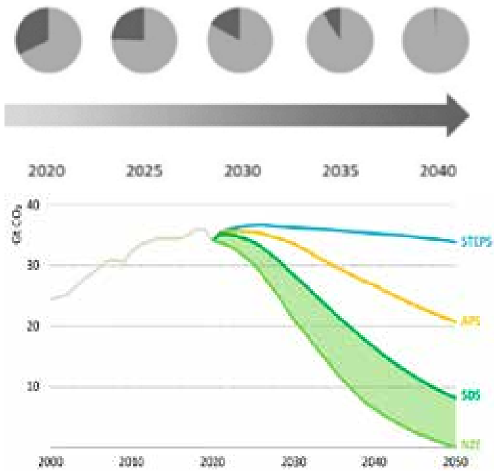


Figure 1. (top) Carbon Budget Evolution - Source IEA 2015 (bottom) CO_2 emissions in the WEO-2021 scenarios over time (IEA, 2021)

• Carbon capture, storage, use, and/or disposal. These "new industries" in which researchers, either by chemical processes or by facilitating natural processes, obtain new fuels and industrial products require investment in research and development. These processes support the capture, storage, use, and/or disposal of carbon with effects in decarbonising the economy.

• Industrial (process) emissions have been identified as a major problem for the carbon transition, with untapped potential for improving industrial efficiency (for example, through the use of alternative energy sources or the recovery of waste heat).

2. Specific economic sectors:

• Agriculture is a major emitter of greenhouse gases (especially animal husbandry), with significant opportunities at the local level to improve production cycles and reduce carbon emissions.

• Sustainable industrial production. The need to support sustainable production systems based on green energy and to encourage the use of new technologies and circular business models leads to the establishment of sustainable production standards.

• Waste management, recycling, reuse, and circularity in practice - have been identified each year as an important issue for communities, as well as the need for integration into policies to reduce pollution and change the culture of consumers.

3. Economic, legal and social models

• Economic models - including sustainable consumption and production, circular and life cycle rethinking. They need to be focused on resource efficiency, resilience, and conscious consumption or production based on the search for plans, strategies, and investments.

• Reducing the Carbon Footprint by Changing Consumer Behavior - there is a need for a cultural shift towards lower consumption, less waste, and more conscious decisions. These fundamental changes in behavior can only be implemented through the use of mixed economic, social, financial, and legislative policies (BIO Intelligence Service, 2012).

• The need for a regulatory system with an intersectoral approach.

• Fairness and fairness - these are linked to a transition that requires major socio-economic changes and the active involvement and participation of citizens and communities. Dealing with the effects of the transition on employment is often seen as a challenge, but many changes are expected to have a positive impact on employment, through proper training and education opportunities.

4. Public policy issues

• Public investment - including research and development - is seen as an opportunity to support clean technologies and administrative solutions that are needed to accelerate the low-carbon transition. Public transport, renewable energy sources, and electric vehicles are some of the areas that need public support (Gielen, et al., 2019).

• Taxes and fiscal policy are framed in both opportunities and challenges. In general, taxes reflect more on the behavior that needs to be encouraged or discouraged.

• Spatial Policy and Planning - an important issue includes creating synergies between urban and rural areas. The future of spatial policy and planning also faces challenges in developing suburban areas and the availability of workspaces in a way that does not promote road travel. Moreover, such a policy must take into account the regions and areas that will suffer from the energy transition.

• Carbon budgets - policies need to set ambitious but realistic decarbonisation targets that are seen as an opportunity in general. However, there are uncertainties, including scientific ones, which is why assessing the feasibility of these ambitious targets is very important. It is important to set carbon budgets and five-year targets for each administrative entity. The EU's overall goal is currently a challenge for all levels of society, as the 2050 zero emissions target is very difficult to achieve (Matthews, et al., 2020).

5. Multi-disciplinary studies on environmental issues

• Co-benefits, opportunities for improved air quality, improved health, reduced pollution, reduced biodiversity loss, economic development around regional supply chains, new industries, and job creation, energy security, and other environmental benefits.

6. Energy policies

• Renewable energy (as part of a clean or green energy system), emphasizing the need to develop renewable energy sources and technologies that inject more renewable energy into the grid. Several opportunities are emerging in this direction and include improving synergies between territories - given the Biosphere Reserve, decentralization of the energy system, research and development to improve existing technologies, and harnessing the potential. Rural areas can be a hub for solar energy and have the potential to produce renewable energy to provide for urban areas as well.

Considered a challenge between green restoration projects and the energy sources on which urban industries depend, as well as the need for energy storage (Bergmann, Colombo, & Hanley, 2008).

• Energy efficiency in buildings, especially for renovations, but also new buildings, identified as an important issue representing both an opportunity and a challenge. In general, new buildings have the potential to become carbon neutral as well as renovating their existing building stock. This requires investment in improving heating and cooling technologies but also in building materials. Improving the energy efficiency of homes also requires trained professionals and has the potential to create jobs (Khan, 2013).

• Fossil fuels are an important issue. Banning the use, import, and production of fossil fuels can be seen as an opportunity for the green and renewable energy market, but it is more of a challenge. Transport, infrastructure, and production in shipping are geared towards fossil fuels. Another challenge is the difficulty of removing hazardous pollutants from fossil fuels from the atmosphere.

• The use and efficiency of the energy industry are seen as a challenge in terms of the need for significant innovation and investment to further reduce energy consumption.

• Emissions from mobility and transport activities:

i. Cars and road transport and ships, shipping have been identified as opportunities, such as the development of biofuels and environmentally friendly modes of transport (eg cycling, car/ship exchange, or the use of electric vehicles).

ii. Public transport - development of the public transport network.

We consider that this 3D concept is itself a "challenge" for its authors, not only at the technical level, for analysis and elaboration of considerations, but also at the professional level. The opportunity to design this strategy allowed us to carry out an extensive, current, and objective analysis of the state of play of the EU Neutral Carbon policy. The current context inextricably links us to the environment in the conduct of daily activities, but also to the transfer of information between all entities, from companies, organizations, and government agencies to end-users. Also evolving, the virtual environment also generates opportunities for the development of the information society and can make a decisive contribution to the implementation of 3D.

The **general objective** of this desideratum is the analysis of the current challenges present in the field of Neutral Carbon, identifying the development paths but also the threats, vulnerabilities, and risks. The implementation capacity is studied, both at the national and European, and regional levels. The specific objectives of the project are to identify and classify resources but also vulnerabilities and risks present, analyze the evolution and structure of the ecosystem and adaptive management, identify good practices on Neutral Carbon, prevent and limit the effects of climate change, research preparedness to counter risks and challenges, the analysis of the cooperation between the public and the private sector in the field of Neutral Carbon and the proposal of some policies to harmonize the normative framework in Romania with the European recommendations in the field.

The development of a strategy to fulfill the mission for which it was designed includes the consideration of a long-term vision, as well as a risk assessment, precisely so that the design of the systems can answer the questions "what", "how", “who” and “how much”.

3D vision has 3 axes:

• 3D Initiative proposes a vision of the Danube Delta transformations, related to all economic and societal components, towards a well-preserved biodiverse region with net-zero greenhouse gas emissions by 2050 (with significantly reduced carbon footprint by 2030), in a social innovative context, enriching local economy and capitalising the local opportunities for job creation and local population benefits.

• This systematic multidisciplinary initiative proposes a complete innovation management process (supported by innovation agencies and companies in the group) in order to bring the region to the decarbonisation goal.

• In this scope, there will be projects on all levels, from Research to Innovations, Scaling Up actions, towards Business and Industry, targeting as an important milestone Social Innovation with Job Creation.

Looking ahead, it is assumed that system performance challenges will take place and new ways of implementing are actively being sought (Figure 2).

Starting from the fact that the *relationship between climate change, atmospheric structure, respectively greenhouse gases (GHG), and other critical factors for the environment, globally, which can interact with climate change, such as alteration of the water cycle, changes in biogeochemical cycles, soil and coastal erosion, reduction of sea salinity, loss of biodiversity,* is a complex of specificities, given by the duration of processes, diversity, and causality, both endogenous and exogenous system, analysis of various variants and intensities of manifestation is required as an objective need for the functioning of the hydro-geo-morphological (HGM) and socio-ecological (SSE) systems. The strategy has 5 Pillars and 6 Interdisciplinary domains. Figure 3 emphasizes the schedule of the actual stage with stakeholders involved in 3D.

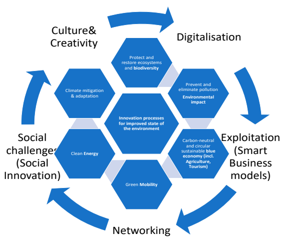


Figure 2. 3D Inter-relationship

Considering the current state of floodplain and deltaic ecosystems, their spatial distribution and major biometric characteristics, permanent climate change, accelerating regimes of warping of canal and lake clogging, and dramatic increases in anthropogenic pressure with a particularly negative impact on deltaic ecosystems, future climates of the region can lead to substantial drying up in large areas, damage to ecosystems and their services and, above all, to global warming.

Figure 3. Pillars of 3D Strategy

ARGUMENTS FOR 3D

1. **Climate change** is the notion that acts on the system, which consists of the two major subsystems in constant transformation: man, with his activities (SES) and nature (HGM) but the content of this notion is huge, consisting of many features on which have the elements included in the scope of this notion.

Any change in the elements of the system, in their interactions, in the external vectors, can lead to climatic variations, and the statistically significant variations in the climate characteristics are called climate changes.

We presented the atmospheric structure, because in this notion GHG acts, as follows:

The dry atmosphere contains:

■ gases that are not influenced by the infrared rays emitted by the Earth and are weakly influenced by solar radiation: (by volume) nitrogen (N_2) 78.08%, oxygen (O_2) 20.95%, argon (Ar) 0.934%;

■ gases that absorb and emit infrared radiation: carbon dioxide (CO_2) 0.04%, methane (CH_4) 0.0017‰, nitrous oxide (N_2O) 0.00003‰, ozone (O_3), these are called "Greenhouse gases" (GHG) and play a key role in the Earth's energy balance. But the normal atmosphere contains approx. 1% water vapor (H_2O), and this is the strongest natural GHG and the most variable component of the atmosphere.

Because water vapor only stays in the atmosphere for a few days or weeks before the rain, hence the water vapor inventory can change very quickly. In most general models for water vapor circulation, vapor parameters depend on the temperature at the surface of the oceans (e.g.: 8% per degree Celsius), and the relative humidity remains almost constant. Therefore, the changes that occur in the value of water vapor parameters will amplify the primary phenomena. For example, in the case of an excess of anthropogenic CO_2, in most models, the water vapor feedback amplifies the primary forcing of greenhouse gases 2-3 times.

There is a global consensus, most recently expressed in the Paris Agreement, that the change in global average temperature must remain well below 2°C. In this way, it is hoped to avoid the most severe effects of global warming on human societies, which include rising sea levels, increased frequency, and intensity of droughts, floods, and other extreme weather events, resulting in reduced food production, threatening the livelihood of millions of people and adding to existing migration pressures.

If the EU, GHG emissions budget were based only on cost considerations as low as possible, it would vary between 50 Gt (in the 1.5°C scenarios) and 90 Gt (in the 2°C scenarios), for the period 2020-2100. With current annual emissions at around 4 Gt, the EU would use its budget for 1.5°C by 2032. In scenarios for 2°C, the EU budget could be depleted by 2042, concludes the 2018 study (Ohlendorf, Vob, Velten, & Benjamin, 2018).

2. Biosphere

Earth Planet is a closed system for matter (except for small amounts of cosmic debris that enter the atmosphere), in other words, all the elements necessary for the structural and chemical processes of life have existed in the Earth's crust since it was formed. The ecosystem works by entraining solar energy and nutrients in the biological circuit where, by transformation into organic substances, it enters the structure of populations in the biocenosis.

The U.N.O. report "Millennium Ecosystem Assessment", in 2004, defines the ecosystem as "a dynamic complex composed of plants, animals, microorganisms and the surrounding still life, interacting as a functional unit."On a global scale, this movement forms geo-biochemical cycles, and the chemical elements and substances involved in the construction of the living world, called bioelements, go through these cycles in nature, with their own speeds and durations (Council Directive 92/43/EEC) (e.g. water circuit, carbon, nitrogen, phosphorus, organic matter circuit).

Geo-biochemical cycles are disrupted by extreme natural events and anthropogenic interventions. Many biogeochemical processes due to these interventions radically change the speed, intensity, and balance of some cycles, and we refer here, especially to the water circuit - which is responsible for carrying out metabolic processes in cells, maintaining the flow of nutrients through ecosystems, heat and energy distribution. - and the very long carbon cycle, geologists estimate that each carbon atom on Earth has made approx. 30 cycles in the 4 billion years since life is thought to exist here. In nature, carbon is found in oxidized form (CO and CO_2) or reduced form (methane and organic matter).

Some bacteria participate in carbon sequestration, and others produce methane from H_2 and CO_2. Carbon is also stored in the $CaCO_3$ of shells and the skeleton of organisms. In the last century, large amounts of carbon generated by human society have entered the environment, half of them remaining in the atmosphere. Mainly, global warming is a natural process: the sun's rays enter the atmosphere and reach the Earth's surface, where about half of the sun's heat is stored by the earth's crust and oceans, the rest being reflected back into space. The biosphere directly influences global warming, leading to cyclical global warming/cooling processes that take place over millions of years. Increasing the concentration of greenhouse gases in the atmosphere acts as a shield that prevents some of the infrared radiation reflected from the Earth's surface from reaching space. So we are witnessing an increase in global temperature as more and more heat is stored in the atmosphere, in the earth's crust, and the ocean water. And the most important greenhouse gas is carbon dioxide (CO_2), resulting from both natural processes and human industrial activity, based primarily on burning fossil fuels.

3. Carbon budget

The "carbon budget" shows us how much longer we can afford to pollute (how much CO_2 we can emit into the atmosphere) so as not to exceed a certain limit of global average temperature rise. The first annual "Global Carbon Budget" report have been published since 2005 by the organization Global Carbon Project (which was set up in 2001 to quantify carbon emissions and identify their sources), but only recently since 2013, they have become official reports of the IPCC (Intergovernmental Panel on Climate Change, a body set up by the United Nations to study climate change) (Figure 4).

Specialists' calculations show that in order to eliminate the pollution produced in the last 150 years, we would need to remove about 1,200 gigatonnes of CO_2 from the atmosphere. We do not discuss how long it would take for such a thing (if we assume, by absurdity, that we can decarbonize about 40 gigatonnes of CO_2 annually, so the pollution we produce in a year, we would need about 30 years) (Figure 5).

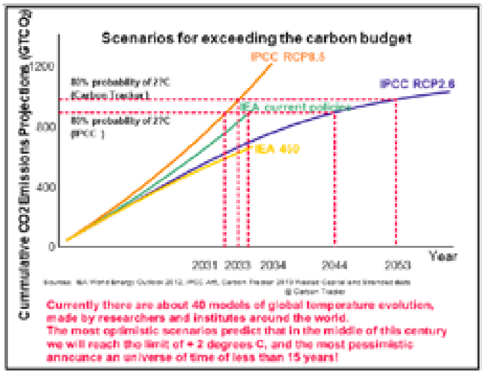


Figure 4. C Budget Scenarios (https://stiintasitehnica.com/carbon-budget-carbon-bubble-carbon-capture-groparii-economiei-fossil-fuels/)

The associated cost of capturing and sequestrating this impressive amount of carbon (1.2 billion tonnes of CO_2) would amount to about $ 150 trillion.

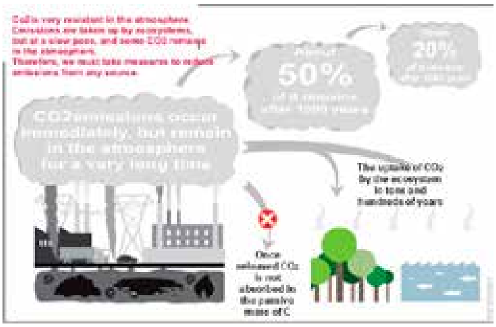


Figure 5. Carbon dioxide has long-term effects. The "recycling" of CO_2 emissions is the responsibility of plants in the ecosystem and the oceans. Human industrial activity and the intensive burning of fossil fuels (coal, oil, natural gas) have led to the accumulation in a very short time of a very large amount of CO_2 which adds to the carbon dioxide that already exists in the planet's cycle - so the biosphere and oceans need to process more CO_2, but this takes decades or centuries. Therefore, carbon dioxide accumulates massively in the atmosphere, directly contributing to the greenhouse effect. Experts estimate that in a century, only half of the anthropogenic carbon dioxide (emitted by humans) could be eliminated naturally, and after 1,000 years about 20% of this CO_2 would still remain in the atmosphere. (https://stiintasitehnica.com/decarbonizarea-atmosferei-noua-provocare-tehnologica-secolului)

4. Terrestrial/Wetland Ratio

In recent years, the expression "carbon sequestration" has become more and more common. It all started with an interesting hypothesis: if the surplus of carbon emitted into the atmosphere (due to human pollution) accelerates the phenomenon of global warming, could the extraction of this carbon not slow down climate change so that we have time to find solutions to understand them and adapt to new conditions.

Photosynthesis is the natural process by which plants absorb CO_2 from the atmosphere, which they separate, under the action of the sun's rays, into carbon (which they use as "food") and oxygen (which they emit back into the atmosphere as "residue"). Once the plants finish their life cycle, they begin to decompose. However, if there are certain conservation conditions (as in swamps, for example), plants are transformed, over millions of years, into what we now call fossil fuels: coal, oil, and natural gas.

In this context, maintaining swamps and wetlands is essential for adapting to climate change. Also, in the European context to meet the GHG reduction targets proposed by the European Commission for 2030 (40% at the EU level), Romania can no longer rely on "economic shocks" as it did in the first commitment period. (2008-2012 compared to 1990). Additional investment will be needed to achieve the required reductions while maintaining an acceptable level of economic growth - World Bank (2014) - Romania, Climate Change Program and Low Carbon Green Growth, Synthesis Report of Component B, Summary of Rapid Sector Assessments and Recommendations for Incorporating Climate Actions into Romania's Sectoral Operational Programs 2014-2020, January 2014. Meeting the 2030 target on reducing GHG emissions could have an impact on Romania's economy as GHG emissions today are rising again, having reached the lowest level (in 2012) compared to the levels of 1989. Therefore, when considering the potential effects of the 40% target, it will be important to pay attention to the aspects regarding the inclusion of the land use and forestry sector, not included in the previous commitments of the EU (LULUCF).

Wetlands are among the most important ecosystems in the carbon sequestration (CS) response strategy. However, their current CS potential is declining due to human disturbances, with a further decrease expected in the context of global population growth and climate change. Various measures are mentioned in the literature that seeks to improve CS through wetlands and therefore allow these ecosystems to remain vital in the global carbon (C) balance and climate change mitigation.

"A critical analysis of these measures, regarding their feasibility and impact on the functioning of wetlands, both ecologically and socio-economically indicates that the CS can be improved both by non-imposed measures and by a manipulative impulse. Non-manipulative measures aim at improving CS by spatially expanding wetlands, while manipulative measures aim at changing the characteristics of certain characteristic wetland components that influence CS.

Their overall objective is to increase the intake of organic matter, the allocation of C in the pools with longer life, and the increase of sequestration time. Based on the identified research knowledge, we recommend that CS actions for wetlands be addressed as a matter of priority in order to conserve existing natural wetlands.

Additional measures should take into account the associated risks, such as those on wetland flora and fauna, soil and hydrological regimes, and ecosystem services. In addition, we believe that the successful implementation of the measures that are imposed on the CS will require the attachment of economic incentives that are not only predictable but also adequate to meet the yields of competing land uses" (https://link.springer.com/article/10.1007/s41748-019-00094-0).

CONCLUSIONS

The impact of the current economic system on climate change, air and ocean pollution, and ecological decline are causing material and human damage to tens of millions of people globally. Thus, there is a real risk of catastrophic damage to our economies and societies over the next few decades if the forms that currently are dominated by production and consumption are not radically changed.

Considering the current state of floodplain and deltaic ecosystems, their spatial distribution and major biometric characteristics, permanent climate change, accelerating regimes of warping of canal and lake clogging, and dramatic increases in anthropogenic pressure with a particularly negative impact on deltaic ecosystems, future climates of the region can lead to substantial drying up in large areas, damage to ecosystems and their services and, above all, to global warming, the 3D Strategy is an indispensable instrument to adapt and mitigate the negative consequences of climate change.

3D Strategy is essential to ensure climate resilience and more sustainable and resilient development, Romania participates in global efforts to reduce greenhouse gas emissions, aiming to reduce its emissions by 20% by 2020, by 40% by 2030, and by 80-95% by 2050.

It can be said that, above all, concrete measures are required (which is perfectly true), but we must not forget that nothing has a greater practical value than a good theory. Without solid theoretical support, even the most basic control measures do not have the consistency necessary to give the expected results.

From now on, there are many fundamental changes in a multitude of connections, between the economic strength of a country and public health in the same territory, between labor and capital, between the market and public policies, between internal and external factors, between the individual and the communities to which he belongs, between the local communities and all the inhabitants of a state. For these reasons, an unprecedented mobilization and reallocation of resources has been and is needed, because only in this way can the battles for survival be won in the face of radical changes in the entire dominant social system in the world today.

REFERENCES

Bergmann, A., Colombo, S., & Hanley, N. (2008). Rural versus urban preferences for renewable energy developments. *Ecological Economics* , 616-625.

BIO Intelligence Service. (2012). *Policies to encourage sustainable consumption, Final report prepared for.*

European Commission (DG ENV). BIO Intelligence Service.

Gielen, D., Boshell, F., Saygin, D., Bazilian, M., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energy Strategy Reviews*, 38-50.

INCDDD Tulcea. (2022). *Decarbonazing Danube Delta*. Retrieved from 3d.ddni.ro

IPCC. (2022). *AR6 Synthesis Report: Climate Change 2022.* The Intergovernmental Panel on Climate Change.

Khan, M. A. (2013). Performance-Based Design and Retrofit Methods for Buildings. *Earthquake-Resistant Structures*.

Matthews, H. D., Tolarska, K. B., Nicholls, Z. R., Rogelj, J., Canadell, J. G., Friedlingstein, P., . . . Zickfeld, K. (2020). Opportunities and challenges in using remaining carbon budgets to guide climate policy. *Nature Geoscience*, 769-779.

Niculescu, S., Lardeux, C., & Hanganu, J. (2017). Alteration and Remediation of Coastal Wetland Ecosystems in the Danube Delta: A Remote-Sensing Approach. *Coastal Wetlands: Alteration and Remediation.*, 41.

Ohlendorf, N. M., Vob, P., Velten, E., & Benjamin, G. (2018). *EU Greenhouse Gas Emission Budget: Implications for EU Climate Policies.* Berlin: the Ecologic Institute.

Panin, N., Tiron, L., & Dutu, F. (2016). The Danube Delta. *Journal of Mediterranean geography*, 37-54.

Tognetti, R., Smith, M., & Panzacchi, P. (2021). An Introduction to Climate-Smart Forestry in Mountain Regions. *Climate-Smart Forestry in Mountain Regions*, 1-33.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

CONSEQUENCES OF FRAGMENTATION OF AGRICULTURAL LAND ARRANGEMENT WITH DRYING-DRAINAGE WORKS

Radu OPREA

"Ion Ionescu de la Brad" Iasi University of Life Sciences, 3 Mihail Sadoveanu Alley, Iasi, Romania

Corresponding author email: opricaradu@yahoo.com

Abstract

Agriculture plays a strategic role in all countries, as it is the main sector responsible for food security of the population, while also making a special contribution to the overall process of sustainable economic development and environmental protection. Land improvement works, in all the states of the world, have a very important contribution in the food supply of the population. Despite the special agricultural potential of the lands in the meadow and terraces of the River Moldova, arranged with surface and subsurface drainage works, the deficient organization of this sector, after 1991, by the increased fragmentation of the agricultural lands, the exploitation on small plots located improperly compared to the network of absorbent channels and drains, the lack of advanced agricultural technologies, led to the practice of a subsistence agriculture, depending on the weather conditions. The modeling of the land inconsistent with the position of the absorbent drains and the network of canals favoured the stagnation of water in ditches and micro-depressions, the prolongation of excess moisture, which led to delays and improper performance of soil works and, implicitly, to low yields.

Key words*: surface and subsurface drainage, excess moisture, shaping in ridges and furrows, canal network.*

INTRODUCTION

Agricultural land and agricultural production are threatened by climate change mainly due to extreme variability in rainfall and temperature. Water shortages as well as stagnant water on the land surface have a negative impact on agricultural production, impact that can be reduced with the help of land improvement works (irrigation, surface drainage, deep drainage, combating soil erosion, etc.).

If properly operated, surface and subsurface drainage systems can serve as ample reservoirs to retain or release water and dissolved substances. Controlled drainage systems can be used to reduce agrochemical runoff from agricultural land and are valuable tools for flood prevention control (Bohne et al., 2012).

The drainage channels are ubiquitous features in the agricultural landscape. The design of two-stage canals demonstrates an increase in river stability, facilitates sediment deposition and creates important habitat characteristics. This management practice may be a viable option for addressing erosion issues, sediment imbalance and poor habitat in surface and subsurface drainage systems (Kalcic et al., 2018; Hodaj et al., 2017; Krider et al., 2017; Dunn et al., 2016; D'Ambrosio et al., 2015).

MATERIALS AND METHODS

The surface and subsurface drainage arrangements under study are located on the middle course of the Moldova river basin, belonging entirely to the extra-Carpathian region. The Moldova River Basin is located in the NE part of the Eastern Carpathians and in the NW of the Moldavian Plateau, being framed by the meridians 25º08'37″ - 26º58'35″ east longitude and by the parallels 46º55'37″ - 47º43'38″ north latitude.

The landscaped lands are part of the Falticeni Plateau (Somuzurilor Plateau), between the rivers Moldova, Somuzul Mare and Siret, which is a separate subunit of the Suceava Plateau. According to many authors, the area is included in the Subcarpathians, as an external unit of hilly piedmont. Some authors include this area on the Moldavian Plateau under the name of the Piedmont Plateau, which also includes the wide meadow of Moldova between Paltinoasa and up to Roman, called the Baia-Moldova-Roman Piedmont Plain.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

From a climatic point of view, the river basin is part of the temperate continental continent of Eastern Europe, which also has some transitional features from some humid, oceanic and sub-Baltic shades in the upper course, to others more excessive in the lower course, to which is added the föehnization of the air masses descending on the eastern slopes of the Eastern Carpathians.

In order to eliminate excess water, improve the aerohydric regime of the soil and introduce these lands into the normal circuit of agricultural production, in order to capitalize on their full fertility potential, four surface and subsurface drainage systems were arranged in the meadow and terraces of the Moldova River, Suceava County, in the period 1978-1985 (Figure 1).

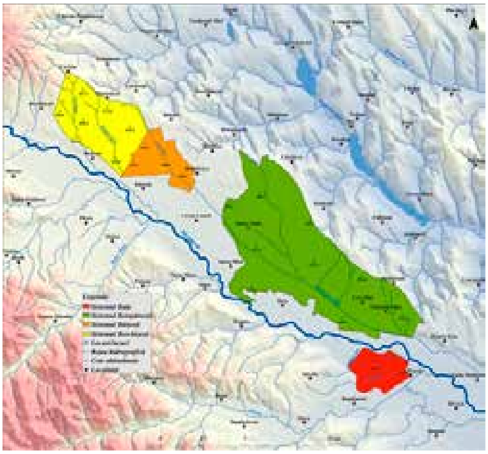


Figure 1. Surface and subsurface drainage arrangements in the Moldova river basin

The surface and subsurface drainage systems facilities cover a total area of 8761 ha, of which, on an area of 3059 ha, underground drainage works with pipes were carried out. The network of drainage canals with a total length of 126.85 km consists of collecting, evacuation, intercepting and other canals. In order to evacuate the excess water from the soil profile, according to the nature and intensity of the excess humidity, and the underground drainage network consisting of absorbent drains and collector drains, with a total length of 1575.12 km.

In order to highlight the behavior of surface and subsurface drainage systems following land fragmentation and exploitation on individual plots, field observations and topographic measurements were performed with the ROVER STONEX S7-G GPS, and the Auto-CAD Map 3D 2014 program was used for data processing.

The cartographic materials were obtained using TNTmips v.6.9 and QGIS. An important step in spatial modeling was the realization of the Numerical Terrain Model (MNT) by vectorizing contours and elevations on topographic maps at a scale of 1:25 000.

RESULTS AND DISCUSSIONS

The technical and improvement efficiency of the surface and subsurface drainage systems depends on the mode of exploitation of the arranged surfaces, the rigorous application of maintenance work and the rhythmicity and correctness of the work to accelerate the removal of excess moisture.

Surface and subsurface drainage systems have been designed to be operated on drainage sectors.

Hydro-improvement works, regardless of their complexity and intensity, cannot act directly on the entire surface in the sense of modifying or improving some physical properties, unfavorable chemical and biological conditions of the soils, in relation to the requirements of growth and development of agricultural crops. In this regard, in order to raise their production capacity to the optimum level needed productively, on the lands arranged from the Moldova river meadow, the hydro-amelioration works were applied in complex with the agro-amelioration works (leveling, modeling, deep loosening, calcium fine, etc.).

By applying the Land Fund Law no. 18/1991, for the constitution and reconstitution of the property right, the conditions for the exploitation of the drained surfaces have changed. The reconstitution of the property right, as a rule, on the old site determined the different orientation of the plots towards the network of canals and / or the absorbent drain lines (Figure 2).

The individual exploitation of the plots of land and, in particular, the mouldboard ploughing determined, over time, modeling the land in ridge strips, with widths, level differences and transverse slopes varying depending on the width of the plots, the way of use and the equipment used for the application of agricultural works.

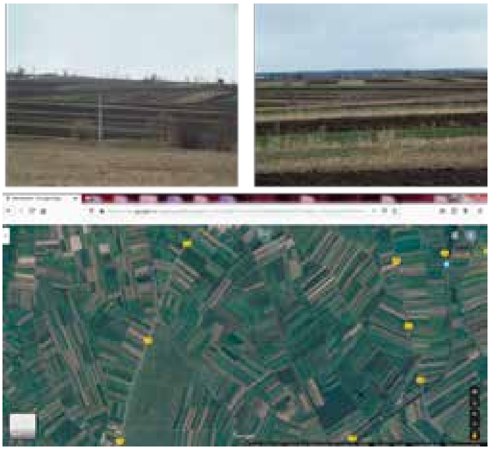


Figure 2. Individual exploitation of plots of land

The land shaping in ridges and furrows was provided in the projects for the execution of surface and subsurface drainage systems as a measure to accelerate the elimination of excess water. For the effectiveness of this measure, in the case of the drained surface, the gutters must be located above the absorbent drain lines, and in the case of the drainage surface they must be oriented on the line of the highest slope and perpendicular to the network of channels.

In order to highlight the influence of the orientation of the plots and, implicitly, of the land shaping in ridges and furrows, as a result of the individual performance of the soil works, on the elimination of the excess water, an area of 62 700 m^2 was studied, from the surface and subsurface drainage system Dragoiesti-Berchisesti, arranged only with drainage works. Topographic measurements were performed on several alignments, transversely on the plots, the topographic points being established at the boundary between the plots (gutters) and on the formed ridges. Figure 3 shows the position of the topographic points on the transverse profiles made on the plots and their elevations, determined in the Black Sea-1975 reference system.

In order to highlight the orientation of the plots on the surface arranged only with drainage works, in Figure 4 and 5 the level curves with the natural equidistance of 0.5 m and the 3D model of the land surface are shown. The analysis of the figure shows that the 15 plots on the NW side are oriented on the line of the highest slope and the 14 plots on the SE side are oriented approximately along the level curves.

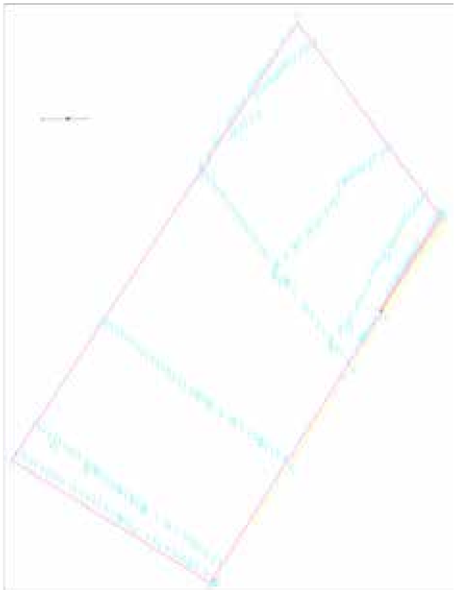


Figure 3. Topographic plan with dimensioned points

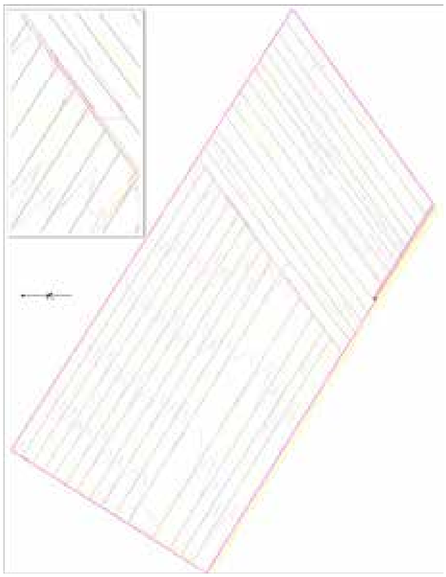


Figure 4. Topo-cadastral plan with level curves

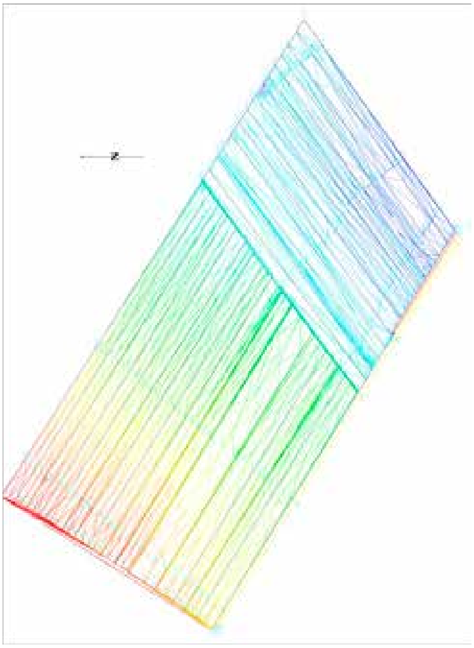


Figure 5. Topo-cadastral plan in the 3D representation system

The analysis of the size of the plots in Figure 6 reflects their relatively small dimensions, both in terms of area and especially width. For plots oriented perpendicular to the level curves, the smallest has an area of 1867.340 m^2 and an average width of 9.50 m, and the largest has 4927.315 m^2 and a width of about 23.00 m. At the plots oriented approximately parallel to the level curves, the smallest has 1071.412 m^2 and an average width of 6.00 m, and the largest has 2104.938 m^2 and an average width of 12.00 m. From the route of the level curves presented in figure 4 results the land shaping in ridges and furrows on the individual plots of land, the ditches being located at the boundary between the properties. This modeling is the result of the individual performance of the soil works, in particular, the mouldboard ploughing, which is generalized in this area, through the gutters being materialized the boundary between the properties. The formation of ridge-shaped modeling as a result, mainly, of the execution of plowing on the ridge also results from the transversal profile made on 5 plots oriented on the line of the highest slope, exploited as arable, with widths between 10.54 m an 23.34 m (Figure 7).

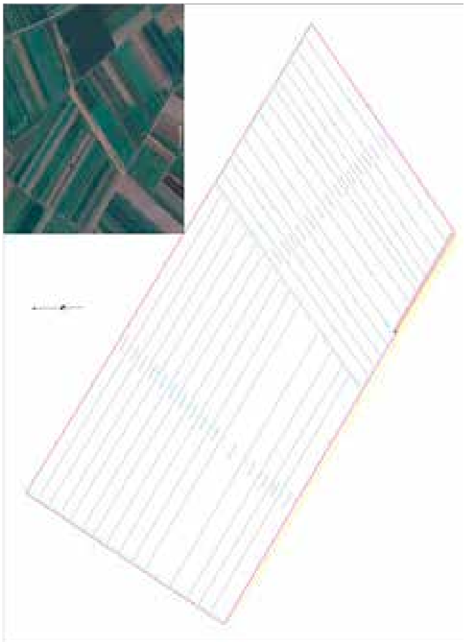


Figure 6. Dimensions of individual plots of land

Level differences between ditches and ridges resulting from soil work, determined at the time of measurements, they have values between 0.24 and 0.67 m, with an average of 0.48 m. At the limit between the first four plots, the formation of ditches is observed, with a triangular section, formed after plowing, with variable dimensions depending on the agricultural equipment used and the working depth. The opening of the gutters between the first three plots is about 2.00 m and have depths between 0.30-0.45 m.

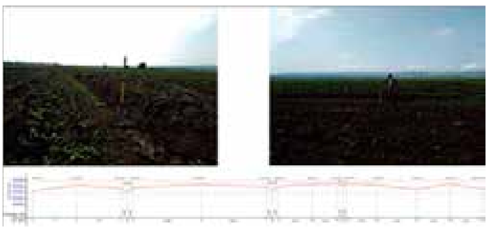


Figure 7. Transverse profile through the plots oriented on the line of the highest slope

The gutter formed between plot three and four has smaller dimensions, the opening is about 1.40 m and the depth is 0.24 m. From the form of modeling plots three and four, it can be deduced that on these two plots, in the previous years, the basic works of the soil were carried out in combination, by plowing the mouldboard. From this it can be concluded that the geometric elements of the land modeling in ridge strips depend on the width of the plots, the agricultural machinery used to perform the basic work of the soil, the direction of return of the furrow and the number of years used. The land shaping in ridges and furrows, on the plots oriented perpendicular to the level curves, favors the drainage of the excess water in the periods with abundant precipitations. However, these leaks are obstructed, downstream, by the modeling of the plots oriented approximately parallel to the level curves and remain confined in their gutters (Figure 8).

Figure 8. Drainage and cantonment of water caused by shaping in ridges and furrows

The evacuation of the excess water, coming from precipitations, towards the collector channel of the bordering sector, in the SW part of the plots oriented along the level curves, is also hindered by the higher elevation of the land at the end of the plots towards their middle. The prolongation of the excess humidity in this area is also due to the fact that some of the canals have been blocked and introduced in the agricultural circuit, and the sector collector channel adjacent to the plots has a high degree of clogging, accelerated by facilitating owners' access to plots and vegetation wood intensely developed on some sections. Stagnation of water and prolongation of excess moisture for a long period of time, especially in spring, delay the spring work and the establishment of crops, as well as the delay and improper performance of maintenance work (Figure 9).

The prolongation of the excess water, the delay and the improper performance of the soil works, implicitly the obtaining of small productions, determined the landowners to give up, year by year, on a part of the surfaces where the excess is manifested, using as arable only the higher areas from where the excess water is removed in a shorter interval.

Figure 9. Clogging of ducts and prolongation of excess moisture

Thus, most of the individual plots oriented approximately parallel to the level curves, with arable use, are no longer capitalized on their entire productive capacity, they have passed, one by one, to the hay exploitation mode (Figure 10).

Figure 10. Changing the exploitation of the arranged lands

On these lands exploited as hay, due to the reappearance of excess moisture, the floristic composition is inferior, the hygrophilous vegetation predominates and the fodder productions obtained are of poor quality, with low nutritional value.

In recent years, the increase in interest in agricultural land, with the granting of subsidies and verification through the Integrated Administration and Control System carried out by APIA, it was found that the landowners tried to reinsertion these areas into the arable circuit. However, in the absence of canal network rehabilitation works and works to accelerate the removal of excess water, especially leveling, reintroduction to arable land is not completed, agricultural works being limited by the same restrictive factor, namely excess moisture (Figure 11).

Figure 11. Arable reintroduction attempt

Although the soils in the surface and subsurface drainage systems have a high productive potential, the agricultural production is significantly diminished by the exploitation of the lands on the individual plots. Production losses are directly correlated with the prolongation of excess water, the delay in the application of agricultural works and the impossibility of applying agricultural technologies due to the small width of individual plots of land.

CONCLUSIONS

The excess moisture lands have been arranged with surface and subsurface drainage works to be exploited on drainage sectors.
The capitalization of the entire productive potential of these lands is ensured by the rigorous and rhythmic application of the works of acceleration of the elimination of the excess of water and of the maintenance ones.
Reconstitution of the property right as a result of the application of the Land Fund Law no. 18/1991 and the subsequent laws, as a rule, on the old sites, determined a strong fragmentation of the arranged lands.
The individual exploitation of the plots of land and, in particular, the performance of the basic work, determined the land shaping in ridges and furrows, with widths, level differences and variable transverse slopes, depending on the width of the plots, how to use and the equipment used for the application of agricultural works.
Landscaping inconsistent with the canal network favours stagnant water on the gutters between plots of land and prolonging excess moisture.
The prolongation of the excess water, the delay and the improper performance of the soil works, implicitly, the obtaining of small productions, led to the renunciation of the exploitation as arable of these plots of land and the gradual transition to the use of hay.
The excess of humidity determined a lower floristic composition of the hayfields, the hygrophilous vegetation predominating and the obtained fodder productions are of poor quality, with low nutritional value.
The production losses are in direct correlation with the width of the plots, the duration of the stagnant water in the gutters, implicitly, the delay in the application of agricultural works and the impossibility of applying modern technologies due to the small width of the individual plots of land.

REFERENCES

Bohne B., Storchenegger I. J., Widmoser P. (2012). An easy to use calculation method for weir operations in controlled drainage systems. *Agricultural water management*, Volume: 109, 46-53. doi: 10.1016/j.agwat.2012.02.005

D'Ambrosio J. L., Ward A. D., Witter J. D. (2015). Evaluating geomorphic change in constructed two-stage ditches. *Journal of the American Water Resources Association* 51(4), 910-922.

Dunn M., Mullendore N., Jalon S. G., Prokopy L. S. (2016). The Role of County Surveyors and County Drainage Boards in Addressing Water Quality. *Environmental management*, Volume: 57, Issue: 6, 1217-1229. doi: 10.1007/s00267-016-0689-z

Hodaj A., Bowling L. C., Frankenberger J. R., Chaubey I. (2017). Impact of a two-stage ditch on channel water quality. *Agricultural water management*, Volume: 192, 126-137. doi:10.1016/j.agwat.2017.07.006

Kalcic M., W. Crumpton W., Liu X., D'Ambrosio J., Ward A., Witter J. (2018). Assessment of beyond-the-field nutrient management practices for agricultural crop systems with subsurface drainage. *Journal of Soil and Water Conservation* 73(1), 62-74. doi:10.2489/jswc.73.1.62

Krider L., Magner J., Hansen B., Wilson B., Kramer G., Peterson J., Nieber J. (2017). Improvements in Fluvial Stability Associated with Two-Stage Ditch Construction in Mower County, Minnesota. *Journal of the American water resources association*, Volume: 53, Issue: 4, 886-902. doi: 10.1111/1752-1688.12541

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

A NEW STRATEGIC APPROACH USED FOR THE REGENERATION OF SOIL FERTILITY, IN ORDER TO IMPROVE THE PRODUCTIVITY IN ECOLOGICAL SYSTEMS

Eugen POPESCU, Florin NENCIU, Valentin VLADUT

INMA Bucharest, 6 Ion Ionescu de la Brad Blvd, Sector 1, Bucharest, Romania

Corresponding author email: florin.nenciu@inma.ro

Abstract

The constant pressure to increase food, fiber, and fuel production in order to meet the increasing global demand and prevent malnutrition has put significant pressure on soil resources. Minimal attention to soil protection and conservation, inadequately aggressive management, as well as climate change have resulted in abandoned, degraded, and the expansion of agricultural marginal areas with major agricultural limitations. Agricultural production on degrading land necessitates increasing amounts of chemicals such as fertilizers and pesticides with a negative long-term effect. In recent years, many activities have been proposed to improve soil characteristics starting with the change of cultivation methods, grazing, mulching, composting, soil conservation, green manuring, soil remineralization, however no clear strategies are known to integrate all these measures in a unitary way. which helps farmers to restore degraded soils, while obtaining high yields in organic farming. To reverse these trends, fundamental adjustments in productive systems are required, including the implementation of sustainable natural resource management. Our study proposes a strategy that successfully integrates several soil regeneration techniques, as well as design new planning that allow farmers to benefit from the services offered by agroecosystems.

Key words: *soil regeneration, strategies for organic farming, healthy ecosystems.*

INTRODUCTION

Agro-systems that are not sustainable and resilient are deteriorating the environment by reducing soil productive capacity, degreasing biodiversity, and causing damage to water availability and quality. Food production is currently one of the most pressing global concerns, posing numerous challenges that require a multidisciplinary investigation into climate change, agricultural production limitations caused by soil and water resource degradation, as well as into social issues such as food security, and social justice in the provision and distribution of food.
Soil is composed of organic matter, minerals, living organisms, air and liquids all together supporting plants grow. Soil fertility is one of the most important factors that influence grains yields and the crop quality. Nowadays, soil degradation is a global phenomenon caused by natural land erosion, human activities and climate change. In Europe large fields from Spain, Portugal, Italy, Greece, Bulgaria and Romania are in process to desertification. (European Court of Auditors, 2018). Conventional Agriculture, based on synthetic fertilizers, monocultures and excess of tillage increase the speed of soil degradation (Lal, 1993; Mircea C., 2020). The impact strongly influences the soil biology, land health, plants health, as well as animals and human health. Soil biology is the key to an agricultural ecosystem that influence the physical properties and in the same time is an instrument of natural bioremediation and biocontrol (Shah, 2016; Nenciu F., 2022). Nature manages its own soil fertility without external inputs, but relay on microbial activity to recycle nutrients and slowly release them, in available forms, to the plant roots (Osman, 2012; Nenciu F., 2021). The use of chemical fertilizers improves soil chemistry, in the short term, but negatively affects the structure and soil biology. A mechanical aeration improves soil physics, but also creates better conditions for soil biology, and helps plants to better absorb nutrients. Soil structure depends on the balance between calcium, magnesium and sodium. Calcium is opening the soil, makes it more friable, while magnesium and sodium close it, creating hardness that restricts, water, air and roots

penetration, prone to erosion. Carbon is also a very important element for soil structure and soil fertility. Carbon and nitrogen are the basic elements that provide food source for soil life. Soil biology refers to life in soil, bacteria, fungi and larger critters that break down dead matter, release nutrients and create soil organic matter.

Following intensive agricultural practices, many soils contain less than 5% soil organic matter, and have an important negative impact for plants grow (Osman, 2012). Natural soil regeneration takes place over long periods of time, usually 100 years (Petit, 2004), however farmers working with nature can rebuild soil fertility in few years.

Healthy plants thrive in fertile soil that contain humic substances like humin, humic acid and fulvic acid. Plants are less subject of stress, have high yields, high quality, full of nutrients. To increase soil organic matter recommend-dation is in changing the methods used in Conventional Agriculture to methods and principals used in Regenerative Agriculture (Nenciu F., 2022).

The present paper aims to briefly describe a regenerative technology used in Romania for a corn crop and quantifying the results obtained for a period of 6 years.

MATERIALS AND METHODS

The concept Regenerative Organic Agriculture was first adopted by Rodale Institute from USA. The idea starts from using the farm internal resources to increase soil fertility and yields, avoiding chemical inputs.

Starting 2017 Regenerative Agriculture is certified under the name Regenerative Organic Agriculture (ROC).

Regenerative agriculture main goal is to regenerate the soil fertility, due to soil health that can sustain healthy plants. To solve this issue Regenerative Agriculture, have 5 main principals and materials like instruments, amendments and biological solutions.

Methods like soil protection, minimum tillage, living roots and biodiversity are accepted by all farmers and scientific workers inside Regenerative Agriculture.

The last principals, but not the least, integrated animals, is used in present in few farms, but trend is coming back in more and more farms.

Soil disturbance. Minimization or tillage going to elimination is one of the most important principals to achieve the main goal. Tillage in excess, synthetic inputs application disrupts physical soil structure and fungi hyphae and provide oxygen to soil microbes to star break down soil organic matter. Tillage to improve soil aeration, break hardpan, open pores for water flow and drill the seeds is allowed as long as soil structure is not affected.

Topsoil is always an issue of erosion. To protect the topsoil, in a cereal growing crops the principals of Regenerative Agriculture recommend using cover crops. This method reduce erosion, maintains moisture, keep temperature constant, increase microorganism population. Providing a natural shield, soil is protected from erosion caused by wind, heavy rains, while providing foods and habitat for macro and microorganisms. Soil food web starts to be active. Soil food web create tunnels and decompose organic matter in a form that plants can absorb nutrients.

In Regenerative Agriculture biodiversity has an important role in soil regeneration. Monoculture is a human practice, nature always for diversity plants and animals. Biodiversity is critical for ecosystem stability, productivity and nutrients plants absorption.

Living roots. Living roots keep the engine running during the whole agricultural year. During the photosynthesis process plants eliminate exudates through the roots. Carbohydrates inside exudates is food for bacteria and fungi. Fungi and bacteria, basement for soil food web, in return provides water and food to plants. Living roots continue growing into early winter and break biology dormancy in the spring. Plants exudates feeding soil biology keep the soil population at a high rate. This incredible soil food web creates porous soil that retains and provide water and nutrients to plants.

Integrated animals. Grazing animals helps farmers in improving soil fertility, nutrients recycle through animal manure. Applying all principals increase natural biodiversity, soil fertility while controlling weeds. It is an exact copy of nature cycle. Holistic Agriculture methods based on integrated livestock restored millions of hectares, especially in Africa. Plants and animals have a symbiotic relation and

improve ecosystem helping each other in recycle nutrients.
Growing plants inside this technology need specific implements and machineries completed by organic, mineral and biological fertilizers. No herbicides, insecticides or pesticides are allowed to be applied.
Nowadays, the main issue in soil regeneration is soil compaction. Soil compaction reduced rainfall water infiltration, increase evaporation and water runoff and reduce microbial population activity. Mould board plough, used in Conventional Agriculture, results in hardpan, being one of the most disturbance tillage used in agriculture that destroy soil structure and soil food web (Alvaro-Fuentes, 2008). Mould board ploughs aerate the soil, but soil from 25-30 cm deep is overturned and loose moisture. Intensive conventional tillage and several crossings due to compaction. In draught condition with less moisture and fungi hyphae disrupt, by intensive tillage, plants will not thrive. To solve the situation, research workers develop, in the last decades, specific implements and machineries. A special subsoil (Figure 1) is cutting and aerating the soil, break the hardpan but not rising the soil (Figure 2) and that do not result in hardpan. Deep subsoils and minimum tillage do not compact soil, but create favorable condition for root plants to grow (Bennie, 1986).

Figure 1. John Deere Subsoil SR 1203

Figure 2. Image of field after a subsoil pass

To keep living roots alive all year long Regenerative Agriculture is using a large biodiversity of cover crops like rye, oats, vetch, mustard, radish, etc. These plants keep the soil covered until spring. In spring, before flowering cover crop is mow and row crops are seeded. Cover crops will be decomposed slowly and provide nutrients to row crop. Research workers from Rodale Institute, developed a roller crimper (Figures 3 and 4), used to drives over cover crops, mows the plants down and cutting them every 7 inches. Cover crops protect the soil from erosion, keep the moisture and temperature constant and suppress weeds. Fungi and bacteria decompose the cover crops and provide plants with nutrients. Long term benefits include minimization compaction, soil structure improvement. To avoid compaction, attach on the rear tractor a no-till drill. No-till drill (Figures 5 and 6) are used for a long period of time in No-Till technology. No-Till technology is part of Regenerative Agriculture, but is not a must because a deep subsoil to break the hardpan is sometimes necessary.

Figure 3. Tractor with roller grimper and no-till drill- in progress-

Figure 4. Roller grimper mounted in front of the tractor-in progress-

Figure 5. John Deere 7000 planter lateral equipped with granular and liquid fertilizer- lateral view

Figure 6. John Deere 7000 planter 4 rows in progress- rear view

In order to keep living roots alive all year long, Regenerative Agriculture is using a large biodiversity of cover crops like rye, oats, vetch, mustard, radish, etc. These plants keep the soil covered until spring. In spring, before flowering cover crop is mow and row crops are seeded. Cover crops will be decomposed slowly keep the soil temperature and moisture constant while providing nutrients to row crop. A large pallet of cover crop is used to attract a large number of microorganisms.

Microorganisms like bacteria and fungi are the basement for restoring soil food web. An active soil food web is improving soil fertility, crate healthy plants due to animal and human health.
Regenerative agriculture is based on fertilizers like organic fertilizers, amendments and biofertilizers applied on soil or on leaf that increase plant immunity due to pests and diseases resistant. Synthetic inputs suppress soil biology that create compaction and decrease soil fertility. Organic fertilizers like compost, manure, vermicompost

RESULTS AND DISCUSSIONS

Management inside Conservative Agriculture is focus on quantity. Conservative Agriculture methods include monoculture, synthetic inputs, bare soil, excess of tillage, due to soil degraded, unhealthy plants, animals and humans. All these methods have a negative impact on soil properties, compaction, crusted, hardpan, excess of synthetic inputs leaching in ground water, rivers and lakes, beneficial fungi and bacteria are suppressed (Hirt, 2020).
Inside INMA, few years ago, started a new strategy in developing new tillage implements and drilling machinery that are doing more operation on one pass to reduce fuel consumption, soil compaction and increase soil fertility (Bularda, 2020). The goal of this new strategy is to grow healthy plants and regenerate degraded soils.
To achieve the goal first change is in management. Growing healthy plants with high immune system will increase the quantity. Healthy plants create healthy soil and increase yields. Regenerative Organic Agriculture is based on increasing photosynthesis process which is the engine that never should be stopped. Regenerative Agriculture management is focus on balance nutrients and soil biology. Increasing photosynthetic process results in a larger quantity of exudate that increase the microorganism population and rebuild soil food web (Ingham, 2014).
Firs step was to do a logical scheme based on Regenerative Agriculture principals and our local farm renewable materials (Figure 7).
In red is the decision center. In yellow measurement for hardpan, soil and sap analysis. Information, from soil analysis and plant sap are processed and a decision is taken to fertilize with the needed minerals and biological solution. In green the growing crops during one year. Cover crop is growing as a main crop to get a maximum mulch and nutrients for main crop. In blue are the mechanical operation to achieve the goal. Subsoil is used only when hardpan is present. In grey are minerals and organic fertilizers for soil and leaf.

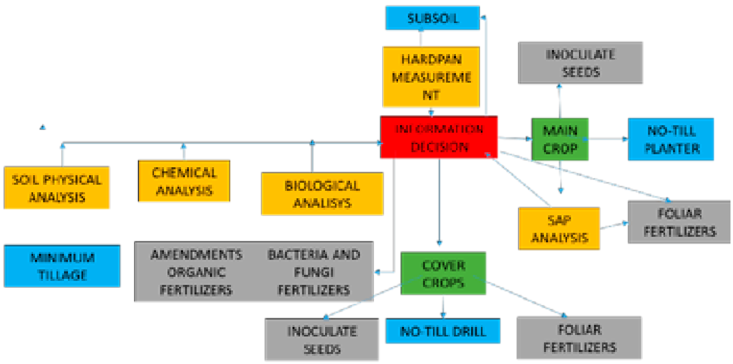


Figure 7. Regenerative Agriculture Technology

We developed a subsoil equipment (Figure 8) that is cutting the soil, breaking the hardpan and inoculate the soil with microorganisms and enzymes at one pass. Inoculation solution contain aerobic bacteria and fungi to decompose organic waste. Our expectation is that microorganism population increase, crate pores and tunnels and soil layers will not create hardpan again. Organic wastes decompose by microorganisms, and create long term nutrients for plants. Compared with a mould board plough, the new type of subsoil reduces the fuel

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

consumption, break hardpan, aerates the soil and do not overturn the furrow. On the contrary, a mould board plough overturns the furrow, create hardpan, disrupt fungi hyphae. Soil chemical analysis was performed to determine humus, pH, organic carbon, N, P, K, as seen in Table 1.

Table 1. Centralizing table of soil characteristics, before the implementation of Regenerative Agriculture technology

No. crt.	Samples	Tests performed					
		pH	Corg.	Humus	N	PAL	KAL
			%	%	%	mg/L	mg/L
1	P1	6.43	1.84	3.17	0.118	45	302
2	P2	6.42	1.28	2.20	0.101	32	244
3	P3	5.02	1.26	2.17	0.108	63	244
4	P4	6.33	1.13	1.94	0.120	38	232
5	P5	6.06	1.28	2.20	0.117	31	228
6	P6	5.65	1.23	2.12	0.107	33	206
7	P7	6.03	1.30	2.24	0.126	35	226
8	P8	6.41	1.70	2.18	0.100	35	216
9	P9	5.95	1.15	1.98	0.104	59	262
10	P10	7.64	1.66	2.86	0.129	101	356

Based on soil analysis, decision was to apply 200 calcium carbonate, 100 soft rock phosphate and organic fertilizers to be applied in rows when planting. Amendments are applying every spring and summer in small quantities that are not affected microorganisms and not leaching.

Biological analysis done visual, no worms, or tunnels was notice. Soil was sprayed with microorganisms to restore soil food web. Expectation is to restore soil food web in 2-3 years, then production will increase significantly.

Figure 8. Activities associated with the integration of the vegetal mass in the soil, in order to increase the fertilization

A combination of cover crops has been selected to increase biodiversity, control weeds, pests, diseases, erosion and improve soil fertility. We selected rye, oats, vetch, mustard, phacelia and Daikon radish seeds to accomplish these tasks. Seeds were previously inoculated with nitrogen fixing bacteria and phosphorus solubilizing bacteria. Cover crops are growing as a normal crop and fertilize with foliar applications (Figure 9). Minerals from foliar application will not be remove because in spring when plants start to bloom cover crop will be cut and left on soil as a mulch. We expect to control weeds, soil temperature and moisture. In time cover crop is decomposed by microorganisms and provide nutrients to main crop.

Maize is the main crop that will be seeded in this spring. Maize seeds will be inoculated with arbuscular mycorrhizae that will create a symbiotic relation between maize and mycorrhizae fungi. During the photosynthetic process maize eliminate exudates through the roots. Carbohydrates, part of exudates, represents food for fungi and in return fungi provide nutrients to plants.

To maize seeding have been used a No-Till Planter. A No-Till Planter (Figure 10) was designed and manufacture in our institute few years ago. In a conventional technology the fuel consumption for plowing, disking and planting is 48.35 l/ha while the new planter consumption is 30.6 liters/ha. It was using a Romanian tractor 65Cp equipped with mould board plough PPM, disk harrow GDU 3.4 and planter SPC 6 compared with new No-Till Planter SDB6.

Maize seeds will be inoculated with arbuscular mycorrhizae, this will create a symbiotic relation between plant and fungi they will feed each other.

Figure 9. In first plan soil is tillage with new subsoil breaking the hardpan and inoculate microorganisms, in second plan soil was plowed with a mould board plough

Figure 10. Establishment cover crops using no-till planting technology

A sap analyze will be done before and after foliar applications. Based on sap analyze and crop stage of growing a different mixture solution will be applied. A sap analyze is similar with a blood sap. The parameters values are measure in hours; decision is taken immediately.

Main crop will be fertilized foliar with vermicompost solution in which minerals will be added. In Institute we developed a vermicomposting system to produce vermicompost in a continuous flow. Vegetal waste like leaf, chopped branches and manure are transported, separated and feeding the continuous flow vermicompostor (Figure 11). The vermicompost obtained is used, as solid, in our green houses to fertilize the soil, 200 grams on a tomato seedling when planting. A small quantity, 2 kilo per hectares is used to manufacture vermicompost liquid solution for foliar applications. We develop a bioreactor (Figure 12) to manufacture a liquid vermicompost solution. A foliar vermicompost solution contain clean water, vermicompost, biostimulants for plants, biostimulants for microorgansms and minerals.

Bacteria and fungi are the basement for soil food web. When web food store is restored, foliar fertilization is less needed. First year expenditure is similar with Conventional Agriculture, but in second year they are at 75% and starting third year at 50% while soil fertility is improved and yields increases. Our expectation is to regenerate the tested soil in 2-3 years.

Figure 11. Vermicompost production using innovative equipment, developed by INMA Bucharest

In terms of cost reductions, the most important improvements take place in the crop establishment and maintenance works.

Regarding the costs of establishing crops, they can be reduced compared to conventional technology by eliminating the plowing and disking processes. Instead of these works, a scarify equipment will be used in the first year (and probably in the second year, only if the hardpan strengthens again), then the high level of loosening will no longer require mechanical activities.

The loosening occurs due to the inoculated microorganisms, the cover crops and due to the minimal processing technique.

In terms of maintenance works, no synthetic fertilizers, insecticides or herbicides are being used, which would also lead to a decrease in soil fertilization. Vermicompost amendments (which are much cheaper than chemical fertilizers) are used when needed. The technology uses only foliar fertilizers, and their costs will decrease over time (the reduction only for this component being 30-40%), and with the evolution of technology over time the required amount decreases. The costs of hoeing (neither mechanical nor chemical) are also reducing the total cost. Regenerative technology, however, has additional costs for establishing cover crops and their mechanical processing.

The total reduction has an increasingly importance over time, as can be seen in Figure 12.

Although regenerative agriculture could lead to small decreases in production in the first two years, the income is higher than that in conventional agriculture by up to 80% (after 3-6 years).

Figure 13 shows the increase in the total amount of humus in the soil during the analyzed period, as well as the improvement in the amount of maize obtained per hectare.

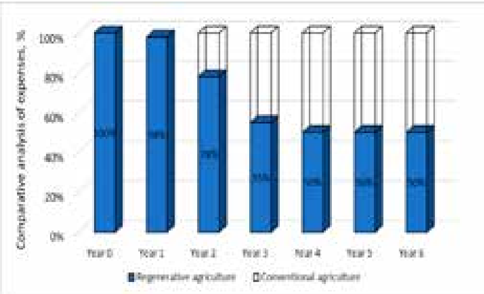


Figure 12. Comparative analysis of expenditures made in conventional versus regenerative agriculture

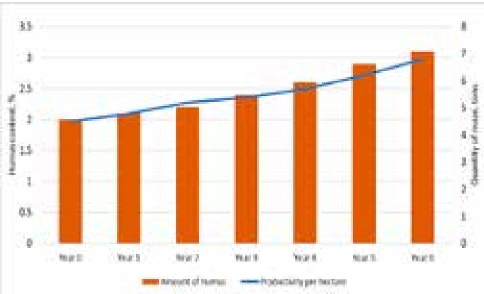


Figure 13. Increasing the total amount of humus and productivity per hectare in 6 years from the establishment of the technology

CONCLUSIONS

The regenerative technology used has shown to be effective in reducing the costs of setting up and managing maze crops. Even if in the first two years the expenses are similar or even higher than those associated with traditional agriculture, in longer periods of time the costs decrease significantly.

The effect must be analyzed integrated in the context of the rapid soil degradation in Romania and Europe and considering the effects of climate change on different crops.

One of the major improvements is that crop rotation is no longer required, so corn can be planted for 5-6 consecutive years without affecting production. This gives some management and prediction benefits to farmers and local authorities.

Depending on the quality of the soil (from year zero), regenerative technologies may have lower yields at first, but if farmers opt for conversion to organic products, then the financial benefit will be up to 4 times higher.

The equipment designed and executed by INMA has been shown to be effective, but for a more accurate analysis the experimental study must be extended to production farms, in order to identify the problems of farmers.

ACKNOWLEDGEMENTS

This paper was supported by a grant offered by the Romanian Minister of Research as Intermediate Body for the Competitiveness Operational Program 2014-2020, call POC/78/1/2/, project number SMIS2014 + 136213, acronym METROFOOD-RO.

REFERENCES

Álvaro-Fuentes J., López M.V., Cantero-Martínez C, J.L. Arrúe (2008). Tillage Effects on Soil Organic Carbon Fractions in Mediterranean Dryland Agroecosystems. *Soil Science Society of America Journal*, 72, 541-547.

Balesdent J. Chenu C. Balabane M. (2000). Relationship of soil organic matter dynamics to physical protection and tillage. *Soil and Tillage Research*, 53, 215-230.

Bennie A. T.P. Botha F.J.P. (1986). Effect of deep tillage and controlled traffic on root growth, water-use efficiency and yield of irrigated maize and wheat. *Soil and Tillage Research*, 7, 85-95.

Bougherra H., Bedini S. Flamini G., Cosci F., Belhamel K., Conti B, (2015). Pistacia lentiscus essential oil has repellent effect against three major insect pests of pasta. *Industrial Crops and Products*, 63, 249-255.

Dayakar V. Badri, Jorge M. Vivanco M. (2009). Regulation and function of root exudates. *Plant cell & Environment.*

Hirt H. (2020) How beneficial microbes in the soil, food and gut are interconnected and how agriculture can contribute to human health. *Science & Society*.

Lal R. (1993). Tillage effects on soil degradation, soil resilience, soil quality, and sustainability. *Soil and Tillage Research*. 27, 1-8.

Mircea C., Nenciu F., Vlăduț V., Voicu G., Gageanu I., Cujbescu D. (2020). Increasing the performance of cylindrical separators for cereal cleaning, by using an inner helical coil, *INMATEH - Agricultural Engineering*, vol. 62, No. 3, pp. 249-258.

Nenciu F., Paraschiv M., Kuncser R., Stan C., Cocarta D., Vladut V.N. (2022). High-Grade Chemicals and Biofuels Produced from Marginal Lands Using an Integrated Approach of Alcoholic Fermentation and Pyrolysis of Sweet Sorghum Biomass Residues. *Sustainability*. 14(1):402. https://doi.org/10.3390/su14010402

Nenciu F., Stanciulescu I., Vlad H., Gabur A., Turcu O.L., Apostol T., Vladut V.N., Cocarta D.M., Stan C. (2022). Decentralized Processing Performance of Fruit and Vegetable Waste Discarded from Retail, Using an Automated Thermophilic Composting Technology. *Sustainability*. 14(5):2835. https://doi.org/10.3390/su14052835

Nenciu F., Voicea I., Vladut V., (2021). Developing an operation strategy for a hybrid diesel-wind-photovoltaic system used to power an autonomous and remote fishing pond, Rural Development, DOI: http://doi.org/10.15544/RD.2021.020

Osman K.T. (2012). Soil Organic Matter. Soils, 89-96.

Petit R. E. (2004). Organic matter, humus, humate, humic acid, fulvic acid and humin: their importance in soil fertility and plant health. Harvestgrow.

Shah S. Prashar P. (2016). Impact of Fertilizers and Pesticides on Soil Microflora in Agriculture. Sustainable Agriculture Reviews, 331-361.

Van H.Es. (2017). A new definition of soil. Csa News, European court of auditors (2018). Combating desertification in the EU: a growing threat in need of more action. Special report 33. European Court of auditors, 2018.

Vladut V. Cujbescu D. (2020) THE effect of conservative agricultural works on soil and field plants and optimized mechanization technologies. *INMATEH - Agricultural Engineering*, 61, 35.

Yong R.N. Warkentin B.P. (2021). Soil properties and behaviour. *Developments in Geotechnical Engineering*, 5.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE TOURISM DEVELOPMENT OF THE SUREANU MASSIF BY VALORISATION OF THE NATURAL POTENTIAL

Florina VOICU, George Emanuel VOICU

"1st Decembrie 1918" University of Alba Iulia, 5 Gabriel Bethlen Street, Alba Iulia, Romania

Corresponding author email: florina.voicu@uab.ro

Abstract

The extraordinary complexity of the natural setting, the excellent geographical position, the diversity of landforms, the multitude of tourist resources resulting from human creations (cultural, historical, technical, economic, etc.) within the Șureanu Massif are favorable conditions for tourism development. The uneven distribution of the elements of the tourist potential has determined the creation of tourist concentrations with an easily observable territorial distribution: the natural tourist potential is found mainly in the central, less anthropized part of the massif, where it abounds in various tourist objectives. As we move away from the high central area and approach the hearth of the meadow settlements, the spectacular relief decreases, the natural tourist elements being replaced by the anthropic tourist potential, consisting of unique anthropic buildings, of a special beauty. The diversity of resources with tourist attractiveness was the basis for the development of a varied mountain tourism (winter sports, speotourism, weekend tourism, adventure tourism, integrated tourism, cultural tourism, etc.).

Key words**:** *GIS, development, natural potential, tourism planning, valorisation.*

INTRODUCTION

The Șureanu massif presents a generous natural setting and has constantly attracted the attention of many geographers who have crossed these mountains and tried to mark these things through their writings. The natural resources with tourist attractiveness are numerous and can be found on the whole surface of the massif. The natural tourist potential is thus distinguished by its diversity, being determined by the morphological stratification from the periphery to the interior of all the components of the natural environment which in turn determined a certain type of habitation and natural valorisation (Voicu, 2019).

On the territory of the Șureanu Massif, the morpho-touristic potential "is established in the richest and most varied tourist resource and constitutes the backbone of any landscape", being involved in drawing the attractive features of the other elements of the natural environment, such as hydrographic, climatic or biotic (Cocean, 1996).

The tourist development of the massif can be materialized with the help of the diversified and complex natural environment, the existence of the areas declared as protected areas to which is added the influence of some physical-geographical factors (climate, hydrography, vegetation, etc.). The different valorisation, in the past, of the elements of attractiveness was mainly due to the degree of accessibility compared to the main centers of tourist interest.

MATERIALS AND METHODS

In the achievement of the desideratum of tourism development of the Șureanu Massif were accomplished using different methodological tools, methods, techniques and means, treated separately in the following.

a. *The creation of the database:* it was the first stage of work for the realization of this study. Starting from the choice of the research topic, the study area and its current limits were individualized, seen through the prism of several applied criteria (geology, geomorphology, etc.). In the case of cartographic representation, for a better accuracy of the already existing digital models, the main elements found in most of the drawings (hydrography, access infrastructure, built perimeter, etc.) were vectorized and the primary or secondary data were entered in ArcGIS 10.1. The documentation stage for the cartographic representation of the main phenomena or elements studied and not only was completed by accessing current or older cartographic materials and collecting data from specialized institutions or by accessing public databases.

b. *The on-site documentation* included discussions with representatives of public and/or private authorities to identify the views, visions and issues facing the community or existing local/regional socio-economic initiatives. Some hypotheses regarding the territorial reality were verified, certain information from the field was collected and updated, eliminating certain data recorded incorrectly or that no longer correspond to reality. The objectives, buildings and phenomena of interest identified in the field were also photographed.

c. *The data processing* was performed using various programs and software of a general nature (Microsoft Office) or specific (AutoCAD, ArcGIS 10.1 etc.).

d. *The interpretation of the results* and the elaboration of the maps had as first step the consultation of the specialized literature, which consisted in works that can be found in profile libraries, scientific articles dealing with the studied subject, national and international databases, cartographic documents that served capturing some evolutionary territorial analyzes (orthophotoplanes). Based on this information, we made maps for each type of analysis at the level of the components of the Șureanu Massif territorial system, being analyzed at local level and synthesized at regional level. The last step consisted in writing the study.

RESULTS AND DISCUSSIONS

A first step for achieving the desideratum of development and valorisation of tourism of the natural morphotourism potential of the Șureanu Massif is its correct spatial delimitation (Figure 1). The boundaries of the region have been drawn and treated in various specialized studies, each of the authors having his own opinion on this issue (Voicu & Voicu, 2018).

In this case, the delimitation offered by Trufaș V. and Trufaș C. (1986), Velcea V., Savu Al. (1982) and the Romanian Carpathians, 1987, was taken into account, being considered adequate for the development and valorisation of tourism because of it supports maintaining the unity of geomorphological individuals. It was followed by inventory of the morpho-touristic potential, which is being found on the entire surface of the Sureanu Massif and determined by the morphological stratification from the periphery to the interior of all the components of the natural framework and which in turn determined a certain type of living and natural valorization.

Within the Sureanu Massif we find a varied number of morpho-touristic elements that will be treated separately during this paper.

The tourist potential of the High Mountains in the Şureanu Massif is noticeable at the level of four peaks that exceed 2000 m altitude: Pătru's Peak - 2130 m, Şureanu Peak - 2059 m, Cârpa Peak - 2012 m and Auşel Peak - 2009 m.

The relief modeled on crystalline shales impresses the Șureanu massif with contrasting physiognomies, essential elements for the development of tourism, consisting of strong orographic nodes, gentle or tiered peaks and systems of narrow and deep valleys, with frequent slope breaks. The main ridge of the massif, located in the southeast, is established in a real orographic node, with a length of 50 km and an east-west orientation (between Vârful lui Pătru and Mr. Taia). The high altitudes, with the appearance of domes, which consist of several heights (Taia - 1702 m, Ștevia - 1763 m, Comărnicel - 1894 m, Gropșoarele, Pârva - 1901 m, Șureanu - 2059 m and Vârful lui Pătru - 2130 m), are sweetened by their integration within a structural surface, the Borăscu platform - which presents an overall aspect of a true “suspended plain”, whose unit is relatively destroyed by the Gura Potecului and Șureanu curbs.

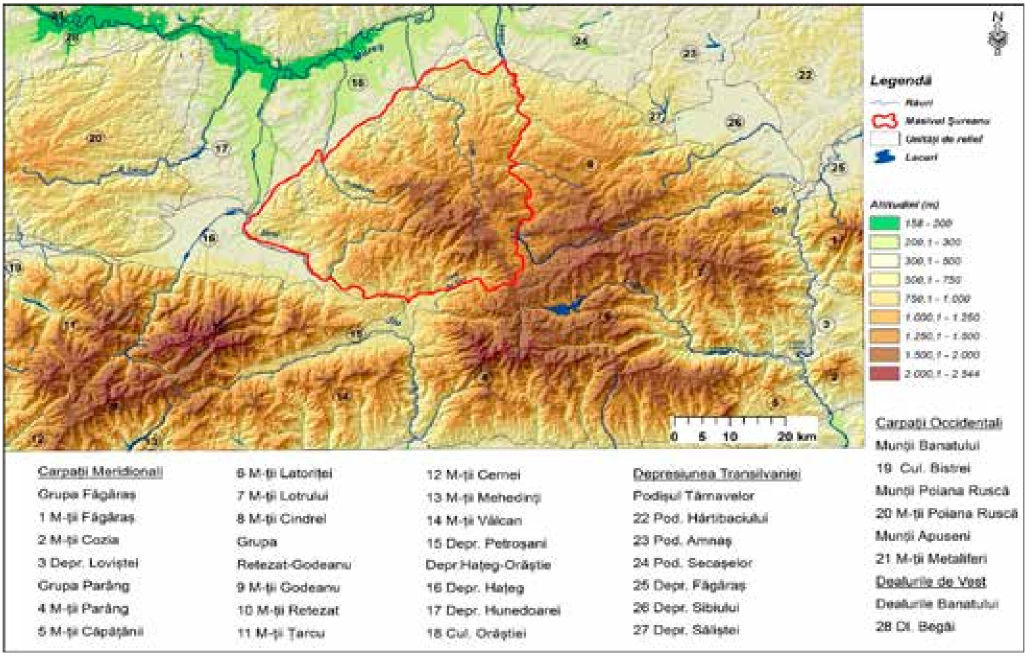


Figure 1. Șureanu Massif. Geographic location

The Borăscu, Râu-Șes and Luncani erosion platforms, through the gentle physiognomies of suspended plains, wide interfluvial bridges, steps and shoulders present within them, are established in morphometric elements favorable to hiking, by ensuring special visibility on the surrounding geographical landscapes. The presence of marginal glacial circuses, generated by quaternary plateau glaciers, enhances the charm of the Borăscu platform.
Crystalline shales thus develop unique and particularly interesting geological structures, confirmed by Law no. 5 of March 6, 2000 on the approval of the National Spatial Planning Plan - Section III - Protected Areas, where we find in the category of monuments and nature reserves the following geological reserves: "Oul Arșiței", "Masa Jidovului", "Stânca Grunzii" and "La Grumaji".
In the upper part of the mountain region, the glacial relief is developed, which has associated forms characterized by specific physiognomies, obviously increasing, through charm and variations introduced in the geographical landscape, the degree of attractiveness of the Șureanu Massif. Thus, simple glacial circuses appear, with the appearance of nests, except for the Cârpa circus, which shows a complex development. Their association with the forms of the cyclical relief imprints on the high floor a "Borăscu-type" physiognomy (Cocean, 1996). The areas on which the glacial relief is developed are less typical and appear on small surfaces, at altitudes over 1650 m., Cârpa, Pârva and Gropșoara, as well as those in the upper basins of some tributaries of Sebeș and Jiu de Est. It is represented by simple glacial circuses of the Pyrenean type, the most outlined being those with a northern exposure from Pătru, Șureanu, Cârpa and Pîrva. Thresholds, ram's backs and moraines are recognized in them.
The most important morphotourism differentiation, even if manifested on a relatively small territory in relation to the surface of the massif (4.5%), is induced by the appearance of limestones. "The presence of limestones in the southwestern part of the massif has determined the appearance of karst forms of surface and depth, particularly spectacular, but little known to hiking lovers" (Trufaș & Trufaș, 1986).
The speoturistic potential within these areas is a special one, expressed by the diversity of the forms of the calcareous and karstic relief. It is illustrated especially by caves, deep karst

forms, which were systematically studied by the members of the Speleology Club "Emil Racoviță". Their number is difficult to determine and differs depending on the authors due to the definition criteria used. Their most representative inventory was made by Trufaș and Trufaș (1986), authors who considered a number of 46 caves and avenues as the most representative, caves that are numbered in the text and represented cartographically in Figure 4. Of these, two are over 2000 m long: Ponorici-Cioclovina karst system (7890 m), (Figure 2) and Șura Mare Cave (3143 m) (Figure 3) and three have elevation differences of over 100 m: The Oat from Dosul Lăcșorului (268 m), Ponorici karst system -Cioclovina (174 m) and the oat from Tăul Negru (Bâtan) (101 m). The tourist and environmental value of some of them (Ponorici-Cioclovina Karst Complex (1.5 ha), Șura Mare Cave and Tecuri Cave) is confirmed by Law no. 5/2000, where they are classified as nature reserves and monuments. Tourists eager to practice speotourism look for them especially because of the attractiveness resulting from the special shape of the underground void, the size and manner of formation, the richness and diversity of stalagmite forms and fossil ice deposits, the difficulty of exploration and traces of primitive man.

On the surface of the massif, we find four areas with different extensions in which this type of relief is spread: Vârtoapele Massif, Cioclovina - Baru Mare Area, Crivadia Area - Disease Cave and Piatra Leșului Area (Drăguț, 2003)

The Vârtoapele Massif Karst Area is developed in the form of a limestone plateau with an area of approximately 2.5 km^2 and an average altitude of 900-950 m (the maximum being 1004 m), being delimited by Valea Rea (west), Valea Anineșului and Valea Mică (south) and Culmea Comărnicel (northeast). The exocarstic relief forms found on its surface are represented by sinkholes and lapies, the most widespread being sinkholes, with a diameter ranging from 2-3 m to 60 m (with an average value of 40 m), and the depth between 1-25 m (the most common having depths of 10-15 m), (Trufaș & Trufaș, 1986). The genesis of sinkholes can be explained by the corrosion process, which is suggested by the funnel shape of most sinkholes.

Figure 2. Cioclovina with Water Cave

Figure 3. Șura Mare Cave

The endocarst forms are smaller in number and size and consist of small caves clogged with detritus, Piatra Bodii cave, La Izvoare cave or Capul Pietrii avenue.

The Cioclovina-Baru Mare area is located between Bârnei, north-west and Petrosului, south-east. In the northern part of the border, the contact with the Christian Cistern is in the south, forming a sedimentary sediment of the superior Cretaceous. It includes a karstic plateau, Ponorici-Cioclovina, dominated by hills, which appear as witnesses of erosion: Mr. Arsului, Mr. Robului, Mr. Padeș, Mr. Mocșoarei, Mr. Law, Bl. Blidaru, Mr. Mătușanului etc (Voicu, 2019).

The exocarst is varied and well represented, here we find clints, which appear everywhere, in free or buried form. The most numerous are the sinkholes, which are grouped in the form of fields (Ponorici plateau, where they form an uvalas depression) or rows of sinkholes, forming valleys (Albii valley, Lunca Priporului, etc.). The valleys of this land appear as relic valleys, completely devoid of water, during which numerous antithetical steps can be observed, developed downstream by the successive water losses. The steep slopes appear to the northwest and have a diverse limestone relief (needles, towers, spurs and overhangs), to which are added caves and oats. The contact karst depressions Ponorici and Fundatura Ponorului, appear at the contact of the limestones with the impermeable rocks in the vicinity, in this case crystalline schists. Considered by some authors to be polished, it beautifies the landscape offered by the karst relief. The Ponor Foundation is the largest and most complex depression in the Șureanului Mountains, with a length of 1200-1300 m (Voicu, 2019).

The endocarst is also well represented by numerous caves and oats, there are several categories of caves depending on the formation: active caves - located at the end of the blind valleys (Ponorici Cave, Ponor Foundry), cavities through which the waters infiltrated in plateau (Cocolbea Cave, Valea Cheii Cave) and the third category, fossil cavities, witnesses of the old drains that remained at the upper levels of the current active networks (Cioclovina Uscată Cave, Avenul Ciobanului, etc.). Șura Mare Cave is distinguished by several rooms of impressive size, with a special acoustics (Table 1), (Voicu, 2019).

Table 1. Caves and oats in the Cioclovina-Baru Mare karst area

Crt. no.	Naming	Development (m)	Level difference	
			(-)	(+)
1.	Ponorici-Cioclovina with Water Cave	7890	174	-
2.	Șura Mare Cave	3143	-	50
3.	Dosul Lăcșorului Oat	796	268	-
4.	Cioclovina Uscată Cave	763	-	-
5.	Fundătura Hobenilor Oat	295	78	7
6.	Plăișorului Cave	239	-	28
7.	From Valea Cheii Cave	230	-	16
8.	Gavrilaș Vulcu's Cave	161	8	-
9.	Ponorici Oat	150	20	-
10.	Tău Negru (Bâtan) Oat	150	101	-
11.	Șura de Jos from Federi Cave	130	15	-
12.	Cocolbea's Cave	125	-	-
13.	Balaj Oat	92	46	-
14.	Scoaba Trăiștiorului Cave	85	-	3
15.	Potecă Cave	72	9	-
16.	Gaura Frânțoanei Cave	67	-	2
17.	Fața Comarnicelor Cave	51	9	-
18.	Cascadă Cave	47	-	13
19.	Balcan Oat	45	43	-
20.	Lăzuiu Oat	29	29	-
21.	Șesul Leordei Oat	27	16	-

Source: Trufaș V., Trufaș C., 1986

The Crivadia-Peştera Bolii karst area is delimited by the Petrosului and Jgheabului valleys (west), the narrow strip in which the Peştera Bolii (east) is shaped and different lithological formations to the north and south. The plateau is strongly karstified, higher than the Cioclovina-Baru Mare area (1100-1200 m), being rich in karst forms such as clints, sinkholes and dry valleys (Table 2). The very representative sinkholes are grouped in sinkhole fields (Comărnicel) (Voicu, 2019).

At the contact of the limestones with the neighboring lithological formations, complex forms are individualized: karst contact depressions, sinkholes, antithetical valleys (Clenjii valley), gorges (Crivadia gorges) or waterfalls.

Table 2. Caves and oats in the karst area Crivadia-Peștera Bolii

Crt. no.	Naming	Development (m)	Level difference	
			(-)	(+)
1.	Valea Clenjii Cave	1467	103	-
2.	Gaura Oanei Cave	577	-	-
3.	Under Cetate (Șarpelui) Cave	510	12	31
4.	Tecuri Cave	458	49	-
5.	Cetatea Bolii Cave	455	2	-
6.	Mare Cave from Piatra Peretelui Urzicari	427	15	4
7.	Ulciorului Cave	420	12	17
8.	Malul Roșu Cave	343	-	-
9.	Next to Pod Cave	281	-	-
10.	Perete Cave	273	14	-
11.	Țepoasă Cave	166	10	-
12.	Cezar Manea's Cave	150	5	-
13.	Gaura Boului Cave	122	15	-
14.	Urșilor Cave	120	-	12
15.	Izvoreni Cave	100	-	5
16.	Capul Stâncii's Cave	79	-	-
17.	Teiul Lung Cave	61	3	7
18.	Tecanul Rotund Oat	20	17	2

Source: Trufaș V., Trufaș C., 1986

Regarding the endocarst, limestone relief forms such as caves, oats and ponoare are highlighted. A particular case of caves is the Bolii Cave, which is actually a meandering tunnel about 450 m long, created by the Jupâneasa River.

The Piatra Leșului karst area is a limestone bar pierced at the ends of the Roșia and Taia valleys. The limestone relief is highlighted by various shapes (needles, spurs, towers, fangs, etc.) and the endocarst is represented by several small caves, developed especially in the Rosiei Gorges (Table 3).

The fluvial relief, made on the main valleys belonging to the Mureș and Jiu River basins, delimited by the main peak of the Șureanu Mountains, canton special landscape elements. The current network of valleys was finalized following the movements in the Wallachian and Pasadena phases. The overall appearance of the valley network is divergent, the rivers starting from the high peak of the massif to the north (Mureș Corridor), west (Hațeg Depression), east (Sebeș Valley) and south (Eastern Jiu Valley). The hydrographic network generates complex and spectacular forms of relief, such as: gorges and quays (Voicu, 2019).

The gorges represent the first and wildest stage of the valleys, formed by the actual sculpting of the morpho-hydrographic narrowing, when the stream of water overlaps a permanently flooded valley. Some representative examples of gorges found on the massif, some included in the list of nature reserves and monuments under Law no. 5/2000 would be Crivadiei Gorges, Taiei Gorges (Figure 5), Roșiei Gorges, Râului Mic (Cugirului) Gorges and Băniței Gorges. The Sebeș Valley, characterized by a succession of wide and narrow sectors, develops a spectacular physiognomy, especially in the gorge sector between Tău and Șugag.

Table 3. Caves and oats in the Piatra Leșului karst area

Crt. no.	Naming	Development (m)	Level difference	
			(-)	(+)
1.	Urșilor Cave from Valea Roșia	189	8	6
2.	Cave with Patru Intrări	145	7	6
3.	No. 7 Cave from Valea Roșia	92	2	4
4.	No. 4 Cave from Cheia Taia	76	-	-
5.	Două Etaje Cave	52	3	-
6.	Under Fag Cave	45	-	-
7.	No. 5 Cave from Valea Roșia	34	3	2

Source: Trufaș V., Trufaș C., 1986

"The ridges and peaks the result of the intersection of strongly sloping slopes, are established in real viewpoints above the surrounding regions" (Candea et al., 2012). Pătru Peak, Șureanu Peak, Clabucet, Jigoru Mare Peak, Negru Peak or Comărnicel are just a few examples of peaks that offer spectacular scenery for hiking lovers.

The bare mountainsides are attractive due to their permissiveness to capitalize by the location of the ski areas, allowing the arrangement of slopes located at altitudes between 1600 m and over 2100 m. The ski area Șureanu is the second in the country, after Sinaia, in terms of altitude located.

The steps and passes in the geographical area analyzed are distinguished not so much by the landscape or attractive value as by the functionality it confers. They play "a decisive role in concentrating tourist flows, in certain preferential directions" (Cocean, 1996).

Following the decantation of the tourist qualities of each of the components of the morphotourism potential of the Sureanu Massif and by analysing the attractiveness of the natural setting of the mountain area, the following aspects stand out:

- As a whole, the natural tourist potential of the Sureanu Massif presents diversity and an appreciable number of forms, but its components lack the spectacular element;
- The situation is saved by the morphostructure of the natural environment and the presence of relief types that provide important landscape differentiations (karst relief, glacial relief, fluvial relief, relief developed on crystalline schists), the presence of the ski area and the high number of protected natural areas;
- The areas that have on their territory the ski area (Șugag, Cugir, Petrila), the areas with a high number of protected natural areas, the areas that have very well-developed karst relief, with numerous caves, keys stand out in the top of the value of the natural tourist potential and gorges (Orăștioara de Sus, Pui, Boșorod, Baru, Bănița, Șugag) and ATUs that have unique and spectacular objectives on their territory, such as those developed on crystalline shales - the rocks: Spurs from Jina Coast, Jidov's Mass, Stânca Grunzii or Oul Arșiței;
- At the opposite pole, the areas with reduced natural tourist potential can be noticed, such as the Romoș, Bretea Română and Săliștea areas, where we find only a few elements of the fluvial relief.

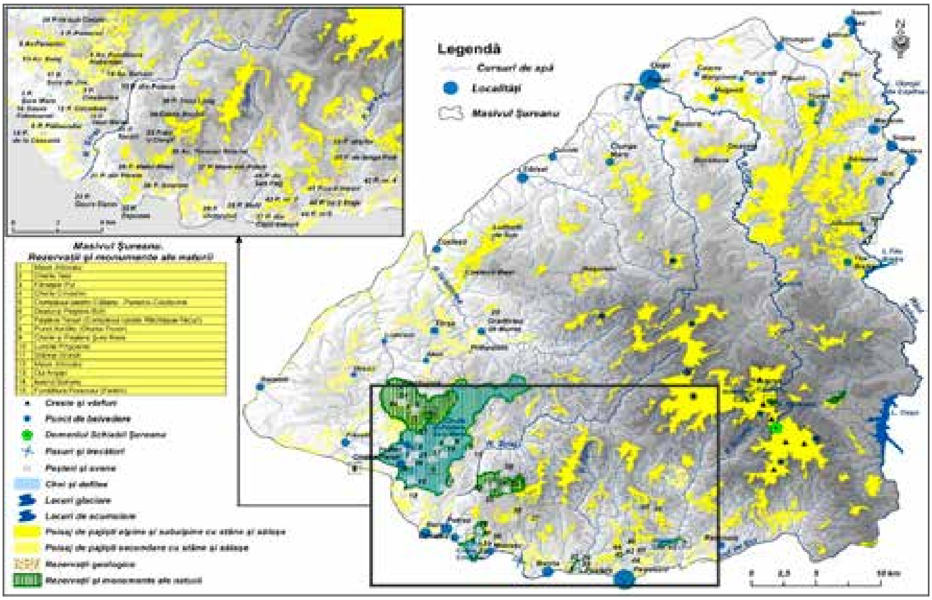


Figure 4. Şureanu Massif. Morphotourism potential

Figure 5. Taia Gorges (left) and Crivadia Gorge (right)

CONCLUSIONS

The tourist development of the Şureanu massif is supported by the richness of the morphotourism resources, which are presented, at individual level or of the landscape association, under an appreciable number of forms with a special morphopeisagistic attractiveness: steep, ridges, steps and passes, gorges, gorges and canyons, valleys, shores, fields with dunes or sinkholes, ponoare, ravines, caves, meanders, etc. From this point of view, tourism knows favorable conditions for development, benefiting from an extraordinary complexity and richness of the attractive elements offered by the natural environment.

The confirmation of the existence of this potential is given by the Law 190/2009 regarding the approval of the National Spatial

Planning Plan, Section VI, Tourist Areas, which mentions the territorial administrative units Mun. Petroșani Or. Petrila, Băița, Baru, Beriu, Bretea Română, Pui, Romoș, Sălașu de Sus and Sântămăria Orlea as having a high concentration of natural resources. A favorable aspect is the fact that many of these objectives are part of the category of protected areas, thus ensuring a high degree of conservation and protection.

The relief is also assigned the support function for the tourist infrastructure, from the accommodation and food bases, to the communication routes, the leisure infrastructure and the different tourist arrangements. Although the researched area has a generous tourist potential, it is very poorly exploited. The state of the tourist infrastructure is a possible cause of the low valorisation of the tourist potential, along with which there are certainly other conjunctural aspects that have contributed over the years to a low valorisation of tourism.

The tourist development of the mountain area of the Șureanu Massif, of the valleys that cross it, through the existence of the protected natural areas or the ones with a high tourist attractiveness, in correlation with some ethnographic, sociological or cultural heritage aspects, etc. provides all the conditions for practicing organized tourism.

REFERENCES

Cândea Melinda, Simon Tamara, Bogdan Elena (2012). *Romania's tourist heritage*, University Publishing House, Bucharest.

Cocean, P. (1996). *Tourism Geography*, Carro Publishing House, Bucharest.

Drăguț, L. (2003). Șureanu Mountains. Geomorphological study, Babeș-Bolyai University, Cluj-Napoca, *Doctoral thesis*.

Trufaș, Constanța, Trufaș, V. (1986). *Șureanu Mountains. Tourist guide*, Sport-Tourism Publishing House, Bucharest.

Voicu, Florina (2019). *Territorial planning and regional development of the Sureanu Massif*, Risoprint Publishing House, Cluj-Napoca.

Voicu, Florina (2018). Arrangement and tourist development of the Sureanu Massif, Babeș-Bolyai University, Cluj-Napoca, *Doctoral thesis*.

Velcea, Vleria., Savu, Al. (1982). *Geography of the Romanian Carpathians and Subcarpathians*, Didactic and Pedagogical Publishing House, Bucharest.

***(1987), Geography of Romania, III, Romanian Carpathians and the Transylvanian Depression, R.S.R. Academy Publishing House, Bucharest.

***(2000), Law no. 5 of March 6, 2000 on the approval of the National Spatial Planning Plan, Section III, Protected Areas, in the Official Gazette, Part I. Laws and decrees, no. 152/12 April 2000.

***(2009), Law no. 190 of May 26, 2009 on the approval of the National Spatial Planning Plan, Section VI, Tourist Areas, in the Official Gazette, Part I. Laws and decrees, no. 387/9 June 2009.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE IMPACT OF TURNkey SEISMIC MONITORING NETWORK IN BUCHAREST

Ștefan Florin BĂLAN, Bogdan Felix APOSTOL, Alexandru ȚIGĂNESCU

National Institute of R-D for Earth Physics, 12 Calugareni Street, Magurele, Romania

Corresponding author email: sbalan@infp.ro

Abstract

The paper presents the seismic monitoring network of the TURNKey Project (Towards more Earthquake-resilient Urban Societies through a Multi-sensor-based Information System enabling Earthquake Forecasting, Early Warning and Rapid Response Actions) in Bucharest. TURNkey aims to contribute to the mitigation of earthquake risks through European and global scientific collaborations. To reach its objectives the project brings together a strong multi-disciplinary team of experts (geophysicists/seismologists, geologists, engineers, disaster risk managers and sociologists) from 21 partner institutions covering 10 European countries. "Testbed 1" (Bucharest) is described in the paper, with its five monitored locations and the deployed seismic sensors and GNSS. The choice of monitored buildings is based upon the characteristics of the design code used in their construction. The paper considers the possible influence of local conditions at the sites of the monitored buildings.

***Key words**: GNSS, seismic sensor, seismic network, testbed, TURNkey.*

INTRODUCTION

TURNkey is a European project under development over a three-year period being part of the Horizon 2020 programme. Through its general objective, that is to contribute to earthquake risk mitigation, the project will have an important application in reducing future economic and social losses in Europe.
TURNkey has brought together a strong multi-disciplinary team of experts (geophysicists/ seismologists, geologists, engineers, disaster risk managers and sociologists) from 21 partner institutions covering 10 European countries.
The focus of the project is to close the gap between the theoretical systems and their practical applications in Europe and to assist stakeholders in different risk mitigation actions before, during, and after a damaging earthquake.
An operational earthquake appraisal is accomplished by using available earthquake-hazard data and information for the regions of interest under continuously monitoring process with appropriate instrumentation. Rapid response to earthquakes is pursued by informing relevant stakeholders about the most probable damage scenarios in near-real time and by estimating direct and indirect losses, i.e. generated by main shock or aftershocks. An extended and near future high potential for implementing applications pertain to an earthquake near-real time damage warning-related procedure that an earthquake happened, establishing its ground motion levels and buildings response characteristics of spectral or dynamical-type.
Therefore, one of the main outputs of the project is a versatile and cost-efficient TURNkey multi-sensor unit consisting of seismic (vibration) sensors optimized for easy-data access and processing. The technology is implemented and under testing in six earthquake-prone areas in Europe, collectively referred to as the European Testbeds (TBs). The new low-cost multi-sensor units are installed in six physical TBs with the following aims: to densify/enhance existing sensor networks; to build-up new permanent sensor networks; to establish a mobile temporary sensor network (in disaster situations, for aftershock monitoring).
In the paper is described the impact of these procedures in Bucharest city, named as Testbed 1 (TB1). Another output is the TURNkey platform itself consisting in a multi-sensor-based earthquake information system, facilitating Rapid Response actions and enabling Early Warning. Two-way communication allows the platform to be more effective. Persons receiving the warnings will be able to provide immediate feedback to the platform.

TURNkey NETWORK

The TURNkey network in Bucharest (TB1) consists of 15 seismic sensors and 5 GNSS (Global Navigation Satellite Systems) installed on 5 (initial no. of constructions to be monitored) +1(only with GNSS) buildings. The seismic sensors are Raspberry Shake RS4D, (Figure 1), a 3 component orthogonally placed sensor accelerometer and 1 vertical geophone, and multi-sensor connectivity in the project. Basically, the sensors are small (100x120x50 mm), light (0.35 kg) and easy to install (plug-and-go installation), (Specifications for: Raspberry Shake RS4D, 2018). The TURNkey GNSS sensors (Figures 2 and 3), are connected to the RS4Ds and transmit raw GNSS and telemetry data in real-time to the server through the RS4D (Prototype dual-frequency GNSS receivers, 2019). The multi-sensor unit is a connection hub for other instruments and uses a single communication module that compresses the data and transmits in a consistent data format. Every sensor is connected to the internet where it sends signals in a continuous mode to the TURNkey Platform.

Figure 1. Photo of an installed RS4D sensor setup

The GNSS data are processed in order to compute almost-real time estimations of the 3D displacements of the sensors and to provide long-term displacements measures with up to 1 mm repeatability (RMS), using a cost-effective multi-frequency calibrated GNSS antenna. The location of the sites with short description of the buildings and position of instruments are described in Table 1 and shown in Figure 4.

Figure 2. Photo of a GNSS antenna on a roof

Figure 3. Multi-frequency GNSS receiver fixed on the wall

The seismic sensors are deployed in 5 buildings in Bucharest city in the locations S1-S5, whereas 4 GNSS sensors are in S1-S4 locations and the fifth's is placed on a tower building (IFA building roof, S6) in Magurele, a locality in the near vicinity of Bucharest, considered as belonging to the metropolitan area of the capital.
All GNSS are connected to the Raspberry Shake RS4D and from here to the internet where they send signals in a continuous mode.
Next we will discuss the reasons and criterion for choosing these buildings. Bucharest is the capital of Romania and considered as the second-most earthquake-endangered metropolis in Europe.

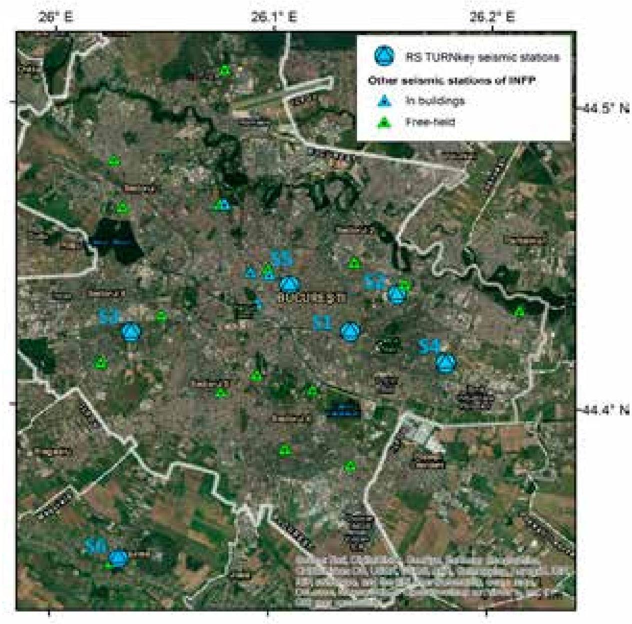


Figure 4. Location of TURNkey stations in Bucharest

Table 1. Description of the monitored buildings and position of instruments

No. site/ location	No. of floors	No. of instruments TURNkey	Location of instruments	Structure	Year of construction	Observation
S1/ near Baba Novac Blvd.	B[1] + GF[2] + 1F[3]	2	1) basement 2) attic	masonry with wooden floors	<1940	1 GNSS on the roof
S2/near National Arena	B+GF+8F	3	1) 1th floor 2) 5th floor 3) 8th floor	reinforced concrete and panels.	1982	1 GNSS on the roof
S3/ Drumul Taberei (near the park)	B + GF + 10F	3	1) G floor 2) 5-th floor 3) 9-th floor	reinforced concrete; frame and panels	1964-1965	1 GNSS on the roof
S4/Titan	B + GF +10F	3	1) G floor 2) 5th floor 3) 10th floor	reinforced concrete, large panels;	1972	1 GNSS on the roof
S5/ near Biserica Armenească	-3B + GF +11F	4	1) 3th floor 2) G floor 3) 5th floor 4) 11th floor	reinforced concrete - frames	2008	
S6/ IFA Tower building	B+GF+M[4]+10F		1) *B floor 2) *6 floor 3) *10 floor	reinforced concrete – shear walls	1974, retrofitted after 1990	1 GNSS on the roof

Legend: B[1]- Basement; GF[2] - Ground Floor; F[3] - Floor; M[4] - Entresol; * - recordings with professional seismic sensors from INCDFP.

Vrancea intermediate - earthquakes, characterized by focal depth between 90—200 km, are affecting large areas. Magnitude and local site (amplification) characteristics are decisive factors of how earthquakes are affecting the constructions in seismic areas.

The largest recent destructive earthquake recorded from the Vrancea region was on March 4, 1977, with a moment magnitude M_w=7.4, at 94 km focal depth. The epicentre was located at a distance of around 160 km from Bucharest area and significant structural damage were produced to the building stock of the city and its surroundings (Berg et al., 1980; Sandi et al., 2007). The loss assessment initiatives such as HAZUS-MH (USA, FEMA 2015) and RISK-UE (Milutinovic and Trendafiloski, 2003; Lungu et al., 2007) that considered the possible (earthquake) scenarios had to include the size and location of earthquakes together with the specificity of the local geology. Bucharest's building stock significantly changed after 1977 year (and certainly after 1989 as well). There is a wide distribution of buildings on various seismic design codes. Though there were accomplished activities in instrumenting and collecting data for the most representative buildings typologies, still it is very difficult to provide a damage or loss model for Bucharest and to derive earthquake scenarios likely to be generated by the Vrancea earthquake zone.

The variations of the ground motion parameters, the large variety of constructions materials, and high vulnerability buildings make seismic risk mitigation a difficult task. Thus, disaster prevention and mitigation of earthquake effects is an issue of highest priority for Bucharest and its population. Under these circumstances a program of monitoring some representative buildings was carried out during last years (Balan et al., 2019). The aim was to evaluate and analyse the response of the specific structures located in the Bucharest area.

Several buildings are monitored by National Institute of Research-Development for Earth Physics, and the TURNkey project added six instrumented buildings with a total of 15 multi-sensor units and 5 GNSS. The selected buildings are typical representatives of structures build under different seismic codes from 1930's to 1990's and for which the seismic vulnerability is different.

One first criterion for choosing buildings are the similarity in type (geometric conformation) and design, therefore outputs about their behaviour could be used for many others. The second criterion is based on the lessons that have to be learnt from the last century when strong earthquakes destroyed many buildings because there were not appropriate seismic codes in force in Romania at that time. The earthquake of 1940 (November 10, M_w = 7.7) led to the collapse of Carlton apartment block in Bucharest (the tallest reinforced building at that time in Bucharest) and almost entire cities (e.g., Panciu city near the source) were destroyed in a large proportion in the Vrancea epicentral region, with hundreds of people dead in the whole country. After this strong seismic movement of 1940 and after World War II ended, begun a constant preoccupation, among designers, about seismic codes which went through different stages of improvements along the years.

Thus, the following normative acts were elaborated in Romania:

- 1952 - STAS 2923-1952 comprising a seismic zoning map;
- P13-63, "Condition for the design of civil and industrial constructions in seismic regions" came into force on July 18, 1963, being carried out in accordance with the "Basic rules for the design of constructions in seismic regions" drawn up under CAER; - P13-70, "Norm for the design of civil and industrial constructions in the seismic regions", December 1970; Seismic zonation map STAS 2923-1963;
- P100-78, "Normative for the antiseismic design of social, cultural, agro-zootechnical and industrial buildings" with experimental application;
- P100-81, the above normative with seismic zoning map STAS 11100 / 1-77; map with 7 areas of different degrees of seismic zonation are specified;
- P100-91 and P100-92 with their own seismic zoning maps; there are 6 degrees of zonation;
- P100-1/2006, "Design provisions for buildings – Part I" in Seismic Design Code with its own zoning map;
- P100-1/2013, "Design provisions for buildings – Part I" in Seismic Design Code with an improved zoning map.

Therefore, the buildings were chosen to fit a certain specific code in force at the time of design and to analyse their behaviour for at least a medium seismic movement in the period of monitoring, started at August 2020. For the time being there was no seismic movement with M_w > 5.5 generated by the Vrancea seismic source to be recorded. However, the instruments and workflow can be implemented and tested in advance and the approach already demonstrated its readiness and functionality. The additional data from the RS4D sensors and from the TURNkey project in overall, will contribute to the studies of building structural (dynamic) response with application in risk estimation.

The strongest earthquakes the TURNkey network experienced during monitored time period were of medium intensity with the following characteristics: 1) April 9, 2021 M_w=4.2, time: 21:36:47 (local time), 78 km

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

focal depth, 156 km epicentral distance in Bucharest, maximum recorded PGA by Romanian Seismic Network 4.4 cm/s^2 and 2) May 25, 2021, M_w= 4.3, time: 00:30:37 (May 26 local time), 131 km focal depth, 126 km epicentral distance in Bucharest, maximum recorded PGA by Romanian Seismic Network 6.6 cm/s^2.

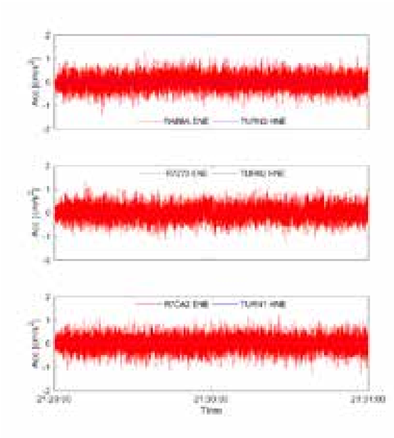


Figure 4. Pre-earthquake May 25, 2021 ambient noise on TURNKey sites S4 and S6.

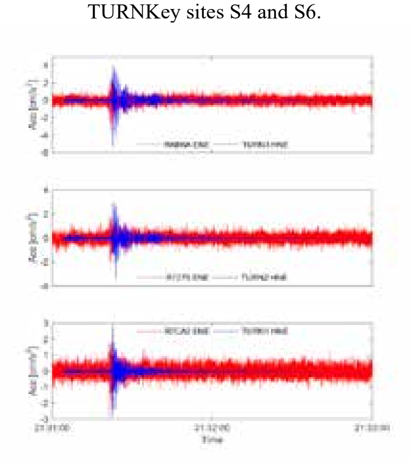


Figure 5. Recordings of earthquake of May 25, 2021 on TURNkey sites S4 and S6

In the following it will be presented some recordings from the TURNkey seismic sensors in the buildings from Table 1.
In Figure 4 can be seen a comparison of the pre-earthquake ambient noise level of the May 25, 2021 earthquake for the professional sensors mounted in S6 (in blue) and RS4D acceleration channels on East-West direction (in red) in S4, for the basement (TURN 1-B/S6, GF/S4), intermediate floor (TURN 2- 6 floor/S6, 5 floor/S4), and top floor (TURN 3 – 10 floor/S6, 10 floor/S4).
In Figure 5 is acceleration recordings channels (red) for earthquake of May 25, 2021 at site S4, compared with S6 building professional sensors (blue) on E-W direction. Displayed sensors are placed at basement (TURN 1- B/S6, GF/S4), intermediate floor (TURN 2-6 floor/S6, 5 floor/S4), and top floor (TURN 3-10 floor/S6, 10 floor/S4).

CHARACTERISTICS OF THE NETWORK SITES

The influence of the local soil geological conditions manifests itself in amplification for certain spots of the ground motion amplitude. Many urban areas hit by strong earthquakes that suffered considerable damage have certain specificity in local soil conditions, as Michoacan in 1985, Loma Prieta in 1989, Northridge in 1994 and Kobe in 1995 (Anderson et al., 1986; Bard et al., 1988; Beresnev et al., 1998; Celebi et al., 2017; Aguirre and Irikura, 1997; Boore, 1989). In the case of Bucharest city this specificity consists in the cohesion less Pleistocene-Holocene geological complex. The Romanian capital is built on alluvial soil underlain by soft weak consolidated rocks of Quaternary deposits. The proximity between the vibration period that characterizes the sedimentary layers and the building fundamental period may have an important role in endangering the safety of buildings during strong seismic movements. Obviously one may take into account the old buildings designed without any antiseismic norms and those with construction errors. For these the highest damages were recorded and almost all of collapses were due to their lack in design regulations or cumulative damage due to earthquakes / WWII bombing.
In the aftermath of the strong 1977 Vrancea event a campaign was launched for computing the particular period of oscillation for different sites in Bucharest area. The results show values between 0.9 s and 1.6 s (Mandrescu, 1978). In the next decade the studies have continued making use of the increasing number of geotechnical projects, several tens of deep

geological boreholes allowing to interpolate predominant period results covering the entire area of the city, the values varying between 0.9s and 1.9s, from south to north (Mandrescu et al., 2004). Similar results were obtained by applying the H/V ratio technique for ambient noise and small and moderate earthquakes (Bonjer et al., 1999).

Other information offered by geotechnical experiments or geophysical procedures were the shear soil velocity that allowed to apply the well-known formula $T_S = 4H/V_S$ (where T_S is the period, H is the depth, and Vs is the shear wave velocity) in delivering results about fundamental period. The shear wave velocity of 650 m/s is roughly chosen for the seismological (or geophysical) bedrock limit, where its value exhibits a jump toward higher values (Mandrescu, 2007). Other authors, applying different methods, recently, assign ~544 m/s (Bala et al., 2009), or between 477-628 m/s (Marmureanu et al., 2013 and references therein, Manea et al., 2016).

The five sites of the considered structures with seismic sensors are disposed from the west of Dambovita river (one) toward eastern part of the city (four). According to Mandrescu et al., 2004, the fundamental period encountered in these areas are roughly between 1.4 s and 1.5 s from South to North.

The local conditions in terms of V_{S30} for all five sites are in the range of 280-310 m/s which are specific for these layers of soft alluvial soils. Even the values for V_{S50} do not exceed values of ~320 m/s. According to EURCODE 8 this range implies a C-type soil for the considered areas. In fact the whole town has this soil conditions, these characteristics being withdrawn from all the studies and experiments carried out over time.

The average value for the shear-wave velocity considered as representative for the first seven layers of Quaternary sediments deposit for the seismological studies can be taken about 400 m/s. This information is used also for nonlinear behaviour studies which are suitable in the Bucharest subsoil context for intermediate-strong Vrancea earthquakes.

During the 1977 earthquake the majority of the collapsed buildings were in the centre of the city, where the considered intensity on MSK scale was VII-VIII. Almost all of these buildings were erected between the two world wars without adequate seismic design protection.

New empirical relationships were developed, between observed macroseismic intensity and strong ground motion parameters (e.g., peak ground acceleration and velocity) for the Vrancea subcrustal earthquakes (Constantin et al., 2021a). This approach can be used for the rapid assessment of ground motion level and damages in the interest areas. For this, different types of data were employed; including macroseismic database resulted after the re-evaluation of the effects produced by the strong Vrancea earthquakes (e.g., 1977 seismic event) (Constantin et al., 2021b). For example, in order to determine the seismic intensities, besides observation originated from the field surveys made immediately after the earthquake of 1977, macroseismic questionnaires were distributed in the damaged area, including city of Bucharest (2000 questionnaires only there). This way, information were gathered, regarding the effects on structures and on the environment. The outcome of the re-evaluation process consists in assigning the maximum observed intensity as IX-X (on MSK scale) and the final intensity for Bucharest being VIII-IX on the same scale at this earthquake (Pantea and Constantin, 2013).

RESULTS AND DISCUSSIONS

The entire ground motion types of displacements, from slow movements (with GNSS sensors) to earthquakes (with seismic sensors), including noise are measured by this network, closing data gaps with the other networks in Bucharest.

The recorded data (seismic sensors and GNSS) on every testbed in the project is transmitted to TURNkey - FWCR (Forecasting - Early Warning - Consequence Prediction - Response) platform, a multi-sensor-based earthquake information system, facilitating Earthquake Forecasting, enabling Early Warning and Rapid Response actions. It has a two-way communication that will allow the platform to be more effective; persons receiving the warnings will be able to provide immediate feedback to the platform. The platform is analysing in real time all

data from the 6 testbeds, fulfilling the targets mentioned above.
The TURNkey platform is using data from all testbeds for further testing, development and evaluation by researchers and stakeholders. One important accomplishment of the central system consists in an increased flexibility and applicability.
The activities involved in this project give the possibility to assess the buildings behaviour during and immediately after an earthquake. Therefore a rapid response is evaluated and the output can be implemented in general procedures that can be applied within and in conjunction with the project. The characteristics of each testbed (in terms of seismicity, sensor locations and locations of the elements at risk) were considered in the developed procedures so that they will be as useful as possible for the project. The wide range of characteristics of the TBs (Bucharest/Romania; Pyrenees mountain range/France; Municipality of Hveragerði, Municipality of Norðurþing, Húsavík/ Iceland; Patras and Aegio/Greece; Maritime ports in Gioia Tauro/Italy; Groningen province/ Netherlands) will also mean that the developments will be applicable widely beyond the project.
During the monitoring period (August 2020 - present), the TURNkey network recorded medium-low earthquakes (crustal and intermediate-depth), with local-magnitudes from 3.7 to 4.7. As can be seen in Figure 5 the sensors RS4D needs stronger seismic movements to get out of the sensor self-noise and the signal to be better observed.
For the selected recordings it cannot be distinguished a specific influence of local conditions, although for higher level of seismic movement over the city area or stronger magnitudes the site response can be affected by these features (Cioflan et al., 2004).

CONCLUSIONS

The testbeds including TB1 (Bucharest) manage to develop and validate a robust multi-disciplinary research methodology for guiding impact analysis of the involved systems (EEW etc.) toward improvement of the community resilience to earthquakes across Europe. In this endeavour the application is implemented and proved for Bucharest city area.
The TURNkey network undergoes an appropriate integration of its data in the national seismic network thus improving local and regional seismic monitoring. It secures and demonstrates the real-time streaming of various geophysical markers in a consistent data format to the central (SeisComP) server through continuously feed parametric data from the testbeds to the TURNkey (FWCR) platform that enables a consistent approach to improved Earthquake Early Warning and Rapid Response to Earthquakes.
The infrastructure development facilitates future integration of multiple other geophysical markers, thus contributing towards Operational Earthquake Forecasting advances in the European testbeds.
The aims that had to be achieved through the project activities were the coordination and management of deploying instruments in a consistent and coordinated manner in the geographically-based European testbeds (TBs) and real-time data provisions for the development of the TURNkey Forecasting - Early Warning - Consequence Prediction - Response (FWCR) Platform.
In the case of an absence of strong-earthquake data it will be completed a virtual implementation of the TURNkey platform at testbeds for monitoring, processing, analysis and visualization purposes - for the platform development.
With the data from the network, in the near future will be achieved:

- Performance evaluation and validation of the TURNkey platform against end-user use-cases;
- Ensuring a sustained flow of information to other TBs as needed.

ACKNOWLEDGEMENTS

This work was supported through the European Union's Horizon 2020 - TURNkey Project (821046).

REFERENCES

Aguirre, J. & Irikura, K. (1997). Nonlinearity, liquefaction, and velocity variation of soft soil layers in Port Island, Kobe, during the Hyogo-ken Nanbu earthquake, *Bulletin of the Seismological Society of America*, 87(5):1244-1258.

Anderson, J. G., Bodin, P., Brunbe, J. N., Prince, J., Singh, S. K., Quaas, R., & Onate, M. (1986). Strong ground motion from the Michoacan, Mexico earthquake. *Science*, 1043-1049.

Balan, S.F., Apostol, B.F. & Tiganescu, A. (2019). A Short Survey on the Buildings Behaviour under Strong Seismic Movements, Case Study for Bucharest City Area. *19th International Multidisciplinary Scientific GeoConferenc,* SGEM 2019.

Bala, A., Aldea A, Hannich, D., Ehret, D. & Raileanu, V. (2009). Methods to assess the site effects based on in situ measurements in Bucharest City, Romania. *Romanian Reports in Physics,* 61(2):335–346.

Bard, P.-Y., EERI, M., Campillo, M., Chávez-Garcia, F.J. & Sánchez-Sesma, F. (1988). The Mexico Earthquake of September 19, 1985 - A Theoretical Investigation of Large- and Small- Scale Amplification Effects in the Mexico City Valley, *Earthquake Spectra*, 4, 609-633.

Beresnev, I., Field, E., Abeele, K.V. & Johnson, P. (1998). Magnitude of Nonlinear Sediment Response in Los Angeles Basin during the 1994 Northridge, California, Earthquake. *Bulletin of the Seismological Society of America*, 1079-1084.

Berg, G. V., Bolt, B. A., Sozen, M. A. & Rojahn, C. (1980). Earthquake in Romania, March 4, 1977: An engineering report. National Academy Press, Washington D.C.

Bonjer, K-P., Oncescu, M.-C., Driad, L. & Rizescu, M. (1999). A Note on Empirical Site Response in Bucharest, Romania. In *Vrancea Earthquakes: Tectonics, Hazard, and Risk Mitigation*, Editors: Wenzel, F., Lungu, D., Kluwer Academic Publishers, 149-162.

Boore, D.M., Seekins L. & Joyner, W.B. (1989). Peak acceleration from the 17 October 1989 Loma Prieta earthquake, (1989). *Seismological Research Letters*, 60, 151-166.

Çelebi, M., Sahakian, V. J., Melgar, D., & Quintanar, L. (2018). The 19 September 2017 M=7.1 Puebla-Morelos earthquake: spectral ratios confirm Mexico City zoning. *Bulletin of the Seismological Society of America*, 3289–3299.

Constantin, A. P., Moldovan, I. A., Partheniu, R., Grecu, B. & Ionescu, C. (2021a). Relationships between macroseismic intensity and peak ground acceleration and velocity for the Vrancea (Romania) subcrustal earthquakes, *Annals of Geophysics,* 64(4).

Constantin, A. P., Moldovan, I. A., Partheniu, R., Grecu, B., & Ionescu, C. (2021b). Correlations between Macroseismic Intensity Values and Ground Motion Measures of Vrancea (Romania) Subcrustal Earthquakes. *Romanian Journal of Physics*, 66(5-6).

Cioflan, C. O., Apostol, B. F., Moldoveanu, C. L., Panza, G. F. & Marmureanu, G. (2004). Deterministic approach for the seismic microzonation of Bucharest. *PAGEOPH*, 161:(5-6), 1149-1164, March 2004, special issue: Seismic ground motion in large urban areas; Main results of the UNESCO-IUGS-IGCP Project; Panza G.F., Nunziata C., Paskaleva I. (Eds); Birkhauser Verlag, Basel, Switzerland, ISSN 0033-4553.

Eurocode 8 (2004). Design of Structures for Earthquake Resistance, Part 1: General Rules, Seismic Actions and Rules for Buildings, EN 1998-1, European Committee for Standardization (CEN), Brussels, Belgium

FEMA, NEHRP Recommended Seismic Provisions for New Buildings and Other Structures Report FEMA P-1050-1/2015 Edition (2015).

Lungu, D., Arion, C., Aldea, A., & Vacareanu, R. (2007). Seismic hazard, vulnerability and risk for Vrancea events. In *International Symposium on Strong Vrancea Earthquakes and Risk Mitigation* (pp. 291-306).

Milutinovic, Z. V. & Trendafiloski, G. S. (2003). advanced approach to earthquake risk scenarios with applications to different European towns, WP4: Vulnerability of current buildings, European Commission, p. 110.

Manea, E. F., Michel C., Poggi, V., Fäh, D., Radulian M. & Balan S. F. (2016). Improving the shear wave velocity structure beneath Bucharest (Romania) using ambient vibrations, *Geophysical Journal International*, 207(2):848-86.

Marmureanu, G. (2013). Geological Database GDB for Romania, BIGSEES yearly report.

Mândrescu, N. (1978). The Vrancea Earthquake of March 4, 1977 and the Seismic Microzonation of Bucharest, *Proc. 2nd Int. Conf. Microzonation*, San Francisco, 1, 399-411.

Mândrescu, N, Radulian, M & Marmureanu, G. (2007). Geological, geophysical and seismological criteria for local response evaluation in Bucharest urban area, *Soil Dynamics and Earthquake Engineering* 27(2997):367–393.

Mândrescu, N., Radulian, M. & Marmureanu, G. (2004). Microzonation of Bucharest: Geology of the Deep Cohesionless Deposits and Predominant Period of Motion, *Revue Roumain de Geophysique,* 48, 120-130.

Pantea, A. & Constantin, A. P. (2013). Re-evaluation of the macroseismic effects produced by the March 4, 1977, strong Vrancea earthquake in Romanian territory. *Annals of Geophysics*, 56(1), R0104; doi:10.4401/ag-5641.

Prototype dual-frequency GNSS receivers: technical note about device characteristics and installation constraints (TURNkey project), 2020.

Sandi, H., Pomonis, A., Francis, S., Georgescu, E. S., Mohindra, R. & Borcia, I. S. (2007). Seismic vulnerability assessment. Methodological elements and applications to the case of Romania. In *International Symposium on Strong Vrancea Earthquakes and Risk Mitigation*, Oct. 4–6, 2007, Bucharest, Romania.

Specifications for: Raspberry Shake RS4D, Last updated: 28-january-2019.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

SUSTAINABLE SOLUTIONS IN BUILT ENVIRONMENT SAFETY

Claudiu-Sorin DRAGOMIR[1, 3], Daniela DOBRE[2, 3], Iolanda-Gabriela CRAIFALEANU[2, 3], Emil-Sever GEORGESCU[3]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania; National Institute of Research and Development URBAN-INCERC, 266 Pantelimon Street, District 2, Bucharest, Romania
[2]Technical University of Civil Engineering Bucharest, 122-124 Lacul Tei Avenue, District 2, Bucharest, Romania
[3]National Institute of Research and Development URBAN-INCERC, 266 Pantelimon Street, District 2, Bucharest, Romania

Corresponding author email: dragomirclaudiusorin@yahoo.com

Abstract

The paper presents the current level in the development of an integrated system to ensure the security of the built space, with semi-automatic generation of PGA maps from seismic actions or other vibrating sources and rapid assessment of the vulnerability of instrumented/monitored buildings. The integrated and automated system is an essential step for the early detection of damage to future earthquakes. As performance benchmarks are listed: identification and acquisition of specialized software, an instrumentation campaign of public utility buildings belonging to NIRDs at national level, some case studies. The obtained results are transferable and of special technical and legal importance, the elaborated documents representing the basis for the Technical Book, and the archived data constituting initial records for the future data obtained after a major earthquake. Finding a reliable solution for a quick analysis after an earthquake, by generating a report with the dynamic parameters of the monitored buildings behaviour, is a challenge of a strategic and logistical nature, of acquisition, storage and continuous processing of data, elaboration of analytical models for validation, in context of digital approach for structural engineering.

***Key words**: built environment, digitalization, integrated system, security, structural dynamic parameters.*

INTRODUCTION

Laborious research at present is being undertaken to determine sustainable and ecologically integrated solutions in the spatial development and safety of the built environment, with the advanced potential of open innovation (Figure 1).
Thus, a national project seeks a reliable solution for performing a semi-automatic rapid analysis after a moderate/severe earthquake (M > 5) (PN 19-33.01.01).
In this context, the digitization process is based on a network of sensors for monitoring the structural health of buildings, and seismic instrumentation/ monitoring offers the opportunity to generate digital maps, which centralize all technical data of a building, in addition to information on the evolution dynamic defining characteristics, for the elements of resistance, or non-structural, the directions of propagation of the effects of an earthquake, or referring to the nature of the registered damages (visible or not). These sensor assemblies include electrical, optical, mechanical, photometric, photogrammetric or geodetic technologies - in conjunction with the cost-benefit function, being necessary to be controlled remotely and the evolutions in their operation to be stored automatically.
The allowed digitization optimization allows the authorities and the owners to monitor not only the equipment for utilities, but also the overall behaviour of the building (Dragomir et al., 2017; 2018; 2020; Dobre et al., 2019).
Some activities involved in structural health monitoring-SHM are:

- permanent seismic monitoring of some special public buildings, belonging to importance classes I and II, in accordance with the current Romanian seismic design code, indicative P100-1/ 2013;
- seismic instrumentation (temporary) of special public buildings, of class II importance

(according to the current seismic design code, P100-1: 2013);

- identification and acquisition of software dedicated to monitoring, as well as the acquisition of new seismic stations etc.

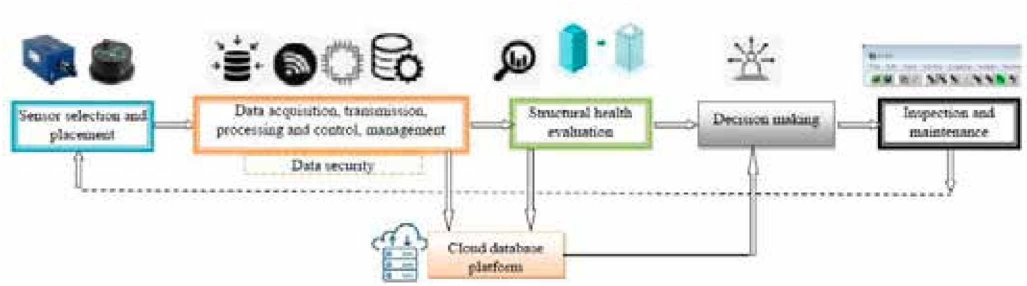


Figure 1. Logical scheme in the context of structural health monitoring and digitization

METHODOLOGY FOR DATA ACQUISITION AND PROCESSING

It is strongly related to the steps taken in order to obtain "zero" data records for the structural dynamic characteristics are the following:

- establishing the locations of the seismic stations according to the objectives, the structural configuration and the access mode; the layout schemes (on the vertical / horizontal direction of the building) of the sensors will be established;
- the effective location of the seismic stations according to the pre-established schemes; their connection with the equipment and with the laptop;
- starting the multichannel recording stations and the laptop and, respectively, launching the communication application with the equipment; setting how the recording is triggered (manually or automatically by defining a trigger threshold);
- determining how to recover / transfer the recorded data, stating that some types of transfer;
- making recordings/verification/calibration tests according to the procedures required by the equipment supplier;
- triggering recordings and recording structural vibrations due to vibration sources (ambient, seismic vibrations); at least five sets of recordings (2 minutes per recording) will be made in the same location;
- verification of each record after its completion with the available monitoring possibilities;
- completing the record form with the parameters of each location and the operating conditions of the vibration source;
- transfer of recordings on the HDD of the laptop/PC on which the recorded data processing software is installed;
- data processing in order to obtain graphic images regarding the time histories of accelerations, velocities and displacements; for each time history, the maximum amplitude obtained in that record will be specified etc.

The specific items of the methodology for data acquisition and processing are presented below (Figure 2).

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

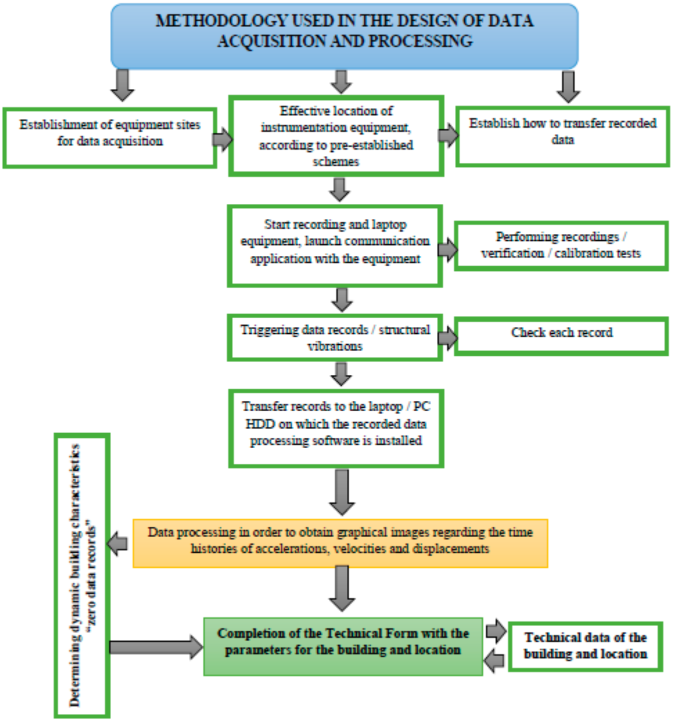


Figure 2. Steps of the Methodology for data acquisition and processing

SEISMIC INSTRUMENTATION/ MONITORING

Regardless of the studies on the identification and acquisition of monitoring software, are necessary activities referred to:

- documentation, identification and description of advanced software used in seismic monitoring of buildings (SeisComP - GFZ and Gempa, OASIS Plus and AUTOPRO (Kinemetrics), GEOSMART (GEOSIG), ARTEMIS Modal Pro, ANTELOPE (Kinemetrics) (Figures 3 and 4);
- identifying the software applications that will be purchased and installed in the data center; For example, Seiscomp, GeoSIG, ARTeMIS software are installed for the seismic monitoring of buildings to the data centre of NIRD URBAN-INECRC.
- temporary seismic instrumentation of some public buildings - elaboration of the technical files of the instrumented buildings, basic data obtained, analysis of the registered data;
- documentation and identification of software dedicated to the study of the structure-field interaction;
- activities carried out within the national seismic network in order to maintain the general functionality throughout the territory etc.

Regardless of the analysed building, the frequency ranges in which the spectral amplifications and the PGA level from ambient vibrations take place are highlighted in extensive technical reports.

From the point of view of the natural vibration periods of the instrumented building (ambient vibrations), based on the results obtained from the analysis of the response spectra it is found that, for the two orthogonal directions in the plane, the spectral amplifications are included in some domains of frequencies and the maximum accelerations do not exceed a limit value (Figure 5).

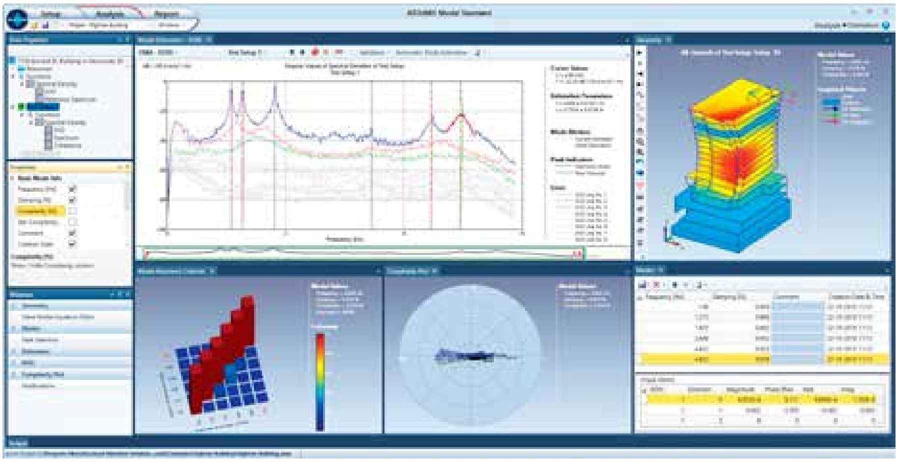


Figure 3. Results of seismic instrumentation/monitoring of buildings (Artemis)

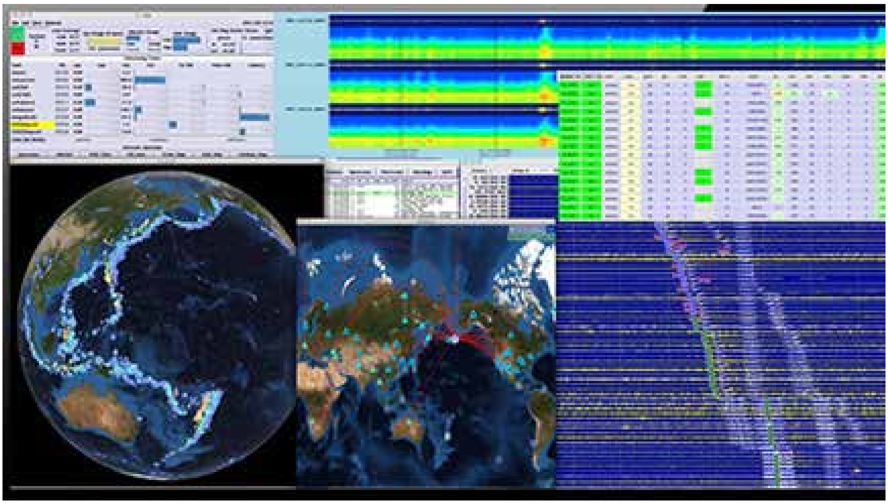


Figure 4. Data organizer, records and processing (Antelope)

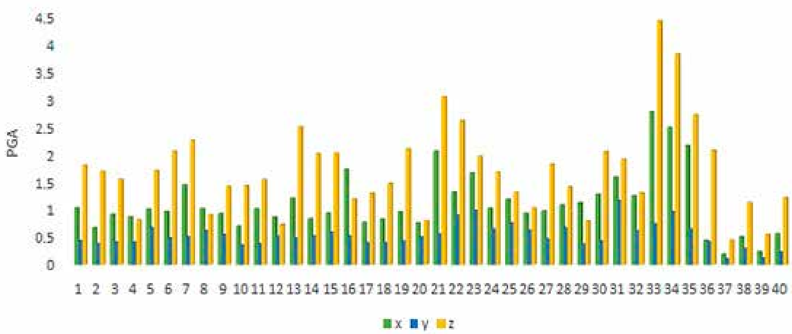


Figure 5. Example of PGA level from ambient vibrations

CONCEPTUAL FLOW OF APPROACHES TO SEISMIC VULNERABILITY ASSESSMENT. DIGITIZATION AND AUTOMATION

The usefulness of digitization is also reflected in the ability to collect and compare data obtained in real time from sensors located in a building (on different floors), or in collecting and comparing data received from an area for which certain value judgments are required. on the level of the dynamic parameters of the recorded movement/vibration, resulting in a large volume of data, which requires archiving and management to support immediate or subsequent analysis.
The following figure shows the conceptual flow of approaches for assessing seismic vulnerability, based on digitization and automation (Figure 6).

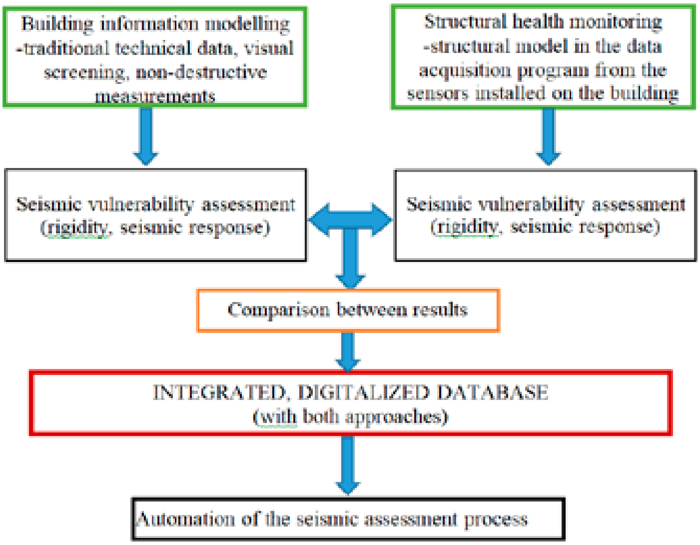


Figure 6. Building information modelling and Structural health monitoring

RESULTS OF THE INSTRUMENTATION/ MONITORING

The obtained results are transferable and of special technical and legal importance, the elaborated documents representing the basis for the Technical Book, and the archived data constituting initial records for the future data obtained after a major earthquake.
Finding a reliable solution for a quick analysis after an earthquake by generating a report with the dynamic parameters of the monitored buildings behaviour, is a challenge of a strategic and logistical nature, of acquisition, storage and continuous processing of data, elaboration of analytical models for validation, in context of digital approach for structural engineering.
The prepared technical data sheets include (variably, depending on the possibility of collecting data from existing plans/reports/ works) some details represented in (Figure 7).

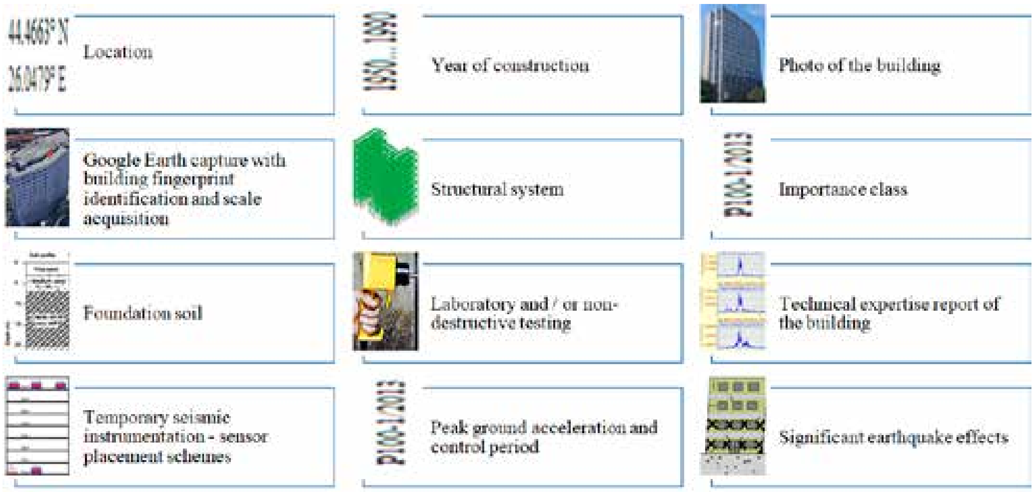


Figure 7. Block scheme with technical data

CONCLUSIONS

Monitoring seismic vibrations or from other sources, both on the ground and on buildings, has many applications in maintaining the safety and normal functionality of the built fund. Internationally, many integrated hardware and software solutions have been developed recently, which ensure the acquisition, processing and analysis of recorded data, quickly or in real time. They are an essential element in preventing the effects of earthquakes or dangerous vibrations on buildings and infrastructure, in early warning and in substantiating rapid post-earthquake response strategies.

Based on the synthesized information, we proceeded to identify software solutions for real-time data transmission, acquisition and processing, which will be installed in the Data Center of the seismic network of INCD URBAN INCERC, infrastructure operating within the Department "National Monitoring Network and Seismic Protection of Built Heritage (IOSIN)". The most appropriate solutions have been identified, both in terms of functionality and the necessary investment, respectively available. An important criterion in the selection was the modular structure of the platform used, so that the gradual expansion and completion of the system can be considered, through successive endowments, but acquiring, from the very beginning, one or more basic functionalities, so that the system can be installed in a pilot, preliminary form.

ACKNOWLEDGEMENTS

Results are part of the project "Research on the implementation of an integrated system for ensuring the security of the constructed space, with semi-automatic generation of PGA maps provided by seismic actions or other vibratory sources and quick evaluation of vulnerability of instrumented buildings" (PN19 33.01.01).

REFERENCES

Dragomir C.S. & Dobre D., (2017). "Selection criteria for investigation of microseismic and ambient vibrations. Case studies", 17th International Multidisciplinary Scientific Geoconference & Expo SGEM, Albena, Bulgaria, doi: 10.5593/sgem2017/14/S05.049.

Dragomir C.S., Craifaleanu I.G., Dobre D. & Georgescu E.S., (2018). "Prospective studies for the implemen tation of a remote access earthquake damage detection system for high-rise buildings in Romania", Proceedings of the The World Multidisciplinary Earth Sciences Symposium/WMESS, Prague, Czech Republic, doi:10.1088/1755-1315/221/1/012036.

Dobre D., Dragomir C.S. & Georgescu E.S., (2019). "Experiential learning for seismic protection using living lab approach in Romania", Proceedings of the World Multidisciplinary Civil Engineering-Architecture- Urban Planning Symposium World Multidisciplinary Civil Engineering - Architecture-Urban Planning Symposium/WMCAUS, Prague, Czech Republic, DOI:10.1088/1757-899X/603/2/022020.

Dragomir C.S. & Dobre D., (2020). “Improvements in a smart monitoring system for buildings”, XXth International Multidisciplinary Scientific GeoConference Surveying, Geology and Mining, Ecology and Management - SGEM 2020, doi: 10.5593/sgem2020/1.2/s05.075, 2020.

Dragomir C.S., Dobre D. & Iliescu V., (2020). “A comprehensive approach for the seismic vulnerability of a building of public utility”, The 5th World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium WMCAUS, doi:10.1088/1757-899X/960/4/042073.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ANALYSIS OF THE EFFECT OF DEFORESTATION ON LAND STABILITY BY GEOMATIC METHODS - CASE STUDY ANALYZED IN THE GeoSES PROJECT

Tiberiu Mihai KALMAR[1], Marcel DÎRJA[1], Adrian Traian Gh.M. RĂDULESCU[2], Petru Daniel MĂRAN[2], Virgil Mihai Gh.M. RĂDULESCU[2], Corina M. RĂDULESCU[2], Gheorghe M.T. RĂDULESCU[2]

[1]University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Manastur, Cluj-Napoca, Romania
[2]Technical University of Cluj-Napoca, 15 Constantin Daicoviciu Street, Cluj-Napoca, Romania

Corresponding author email: mdirja@usamvcluj.ro

Abstract

From 2005 to 2009, in Maramureş, over 1,000 hectares of forest area were cleared, although the entire area is part of the integral protection area of the Maramureş Mountains Natural Park. Although, worldwide, the main cause of deforestation is the development of land for agricultural purposes, in Romania, from the beginning, the main purpose has been to obtain timber. Thus, in Maramureş, and in the year of the 2020 pandemic, more than 104,000 cubic meters of illegally cut wood were reported in a communiqué of the Ministry of Environment, practically 340 hectares of forest being severely affected. The effect of deforestation on land stability can be viewed from at least two points of view: 1. Deforestation causes climate change that in turn causes landslides, 2. Deforestation causes land instability by eliminating stabilizing roots leading directly to landslides.
The analysis of these effects, directly on the case studies made in the field is currently carried out by means of Geomatics. The paper analyses the techniques and tools that can be used, the technological flow and the results, using one of the case studies analysed in the GeoSES Project, located in Sighetu Marmației, the most affected by the more or less legal deforestation practices taking place in Romania.

Key words*: deforestation, geomatics, landslides, 3D Model, orthophotoplan.*

INTRODUCTION

Regardless of the causes of deforestation, the main effects are climate change and, as a cumulative effect, landslides. The Romanian Parliament, through an Information Sheet entitled Deforestation and forest degradation, a document drafted on September 7, 2009, does not make a correlation between deforestation and landslides. Instead, the parliamentary question of September 27, 2017, addressed to the European Parliament by a Romanian member of Parliament states that the negative consequences of excessive deforestation include an environmental component: increased risk of floods, and slides and other natural disasters.
In a report prepared by the World Bank at the request of the Government of Romania, as a result of the World Bank's Climate Change Advisory Services program, in Chapter 2. Dangers and effects of climate change in Romania, paragraph 2.5 Landslides, confirms the above by stating: “Landslides are caused by gravitational forces, but are triggered by a variety of processes. Deforestation can increase the likelihood of landslides. As a result, the frequency of landslides may increase because of climate change”. Globally, from 57% 10,000 years ago, only 38% of the total land area is now covered by forests.
Following a continental distribution of the percentage of forest-covered area of the total mentioned above, Europe represents 25.07%, South America 20.8%, Africa 15.68%, Asia 15.34%, Oceania 4.56%, the rest of the territories not mentioned above representing the difference of 18.55% (https://ourworldindata.org/forest-area).
The view shown in Figure 1 shows the breakdown of the global forest area by world region. In the case of Romania, the forested area decreased from 7.048 million hectares in 2016 to 6.929 million hectares in 2020, according to Eurostat estimates.

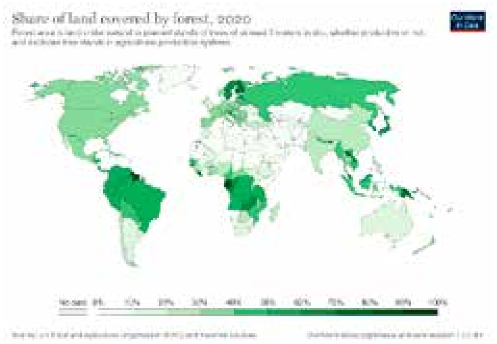


Figure 1. The degree of afforestation of land surfaces worldwide
(Source: https://ourworldindata.org/)

The national forest accounting plan for Romania, for the first commitment period (2021-2025) identifies that among the most important measures that are included in the objective regarding the sustainable management of the National Forest Fund are the following:

- Harmonization of the national system of indicators for sustainable forest management with the European one;
- Continuous adaptation of forests to climate change;
- Development of the integrated information system for forestry; (http://www.mmediu.ro/app/). Rhett Ayers Butler, American author, and founder of the Mongabay platform, considers in his paper Consequences of Deforestation (Butler, 2019) that "the local level is where deforestation has the most immediate effect. The forest acts as a kind of sponge, absorbing the precipitation brought by the storms, while anchoring the soils and releasing water at regular intervals". The same author identifies as the main effects of deforestation: soil erosion and its effects, respectively landslides.

According to Tariq M., deforestation has caused environmental hazards in Pakistan, and he found that as the deforestation rate increases, floods have also increased and deforestation has caused landslides in Dir Kohistan, Pakistan (Tariq et al., 2014). Khan, (Khan, 1994) also mentioned in his papers that deforestation causes landslides and stated that, in the last three decades, the magnitude and severity of the adverse effects of landslides have increased enormously.

Forest cutting, especially deforestation, affects the various hydro geomorphological processes of forest land and has negative effects on improving surface erosion (Roberts and Church, 1986; Edeso et al., 1999). There are also changes in the slope of the hill or the hydrology of the basin (Keim and Skaugset, 2003; Dhakal and Sidle, 2004) and the intensification of landslides (Brardinoni et al., 2002; Jakob et al., 2005; Sidle and Ochiai, 2006).

Immediately after initiation, landslides attributed to deforestation exert significant destructive forces and provide large volumes of sediment to river courses, thereby increasing catchment sediment (Gomi and Sidle, 2003; Constantine et al., 2005), changing the structure of the watercourse and creating ecosystems of water currents (Gomi et al., 2004; Gomi and Sidle, 2003).

Thus, the influence of forest management, including logging and/or forest regeneration, on landslides needs to be assessed to maintain the integrity of river ecosystems, as well as to create better conditions for disaster reduction and prevention.

The presence of vegetation on steep slopes contributes to the mechanical stability of the soil roof primarily by strengthening the roots which improves soil resistance (Schmaltz et al., 2017) and by reducing moisture conditions by evaporation and interception of precipitation. Studies suggest that deforestation favors landslides (Schmaltz et al., 2017). For example, cutting forests in areas with steep slopes has been reported to generate 2 to 10 times more landslides than on sloping lands with vegetation (Brardinoni et al., 2002; Dhakal and Sidle, 2003).

After deforestation, as the young forest slowly recovers, the soil mantle regains strength (Imaizumi et al., 2008), reducing the vulnerability to landslides within 3-15 years after harvesting the wood.

MATERIALS AND METHODS

On June 16, 2009, the Hungarian National Development Agency, in cooperation with the Slovak Ministry of Construction and Regional

Development, the Romanian Ministry of Regional Development and Housing and the Ministry of Economy of Ukraine, opened a call for proposals within the Hungary -Slovakia - Romania - Ukraine Cross-Border Cooperation Program.

All calls organized within the programs 2007-2013, 2014-2020 for the Hungary-Slovakia-Romania-Ukraine Cross-Border Cooperation Program and it seems that also those for the next period, 2021-2027, had themes, objectives, priorities, and measures related to Disaster management. The extension of the operational "Space Emergency System" to the monitoring of dangerous natural and artificial geo-processes in the HU-SK-RO-UA cross-border region was the title of the Project in which TUCN is a partner in the Cooperation Program, 2014-2020, Call 2, HUSKROUA/1702. The project is under Thematic Objectives, TO8 Common Safety and Security Challenges, Priority 1: Support for joint activities to prevent natural and man-made disasters, as well as joint actions in emergencies.

The leader of the project is Uzhhorod National University, Ukraine and the applicants are groups from the Pavol Jozef Šafárik University in Košice, Slovakia, Technical University of Cluj-Napoca, Romania, Budapest University of Technology and Ecomomics, Hungary and Self Government of Szabolcs-Szatmár-Bereg County, Hungary.

Within the GeoSES Project, the role of the Technical University of Cluj-Napoca is to monitor, in terms of vulnerability to disasters, landslides and floods for a delimited area. In this case, the territory of Sighetu Marmației Municipality and the neighboring localities were chosen.

More than 100 landslides were identified, having various causes (Figure 2).

Among the causes were deforestation of areas upstream of the landslides, the case analyzed in this paper Location 6 (Figure 3).

A case was also identified (in Sarasău Township) in which, following landslides on a slope of Solovan Hill, at the foot of which is the territory of the mentioned municipality and Sarasău village, the afforestation of the upstream area was made and thus the land was stabilized (Figure 4.).

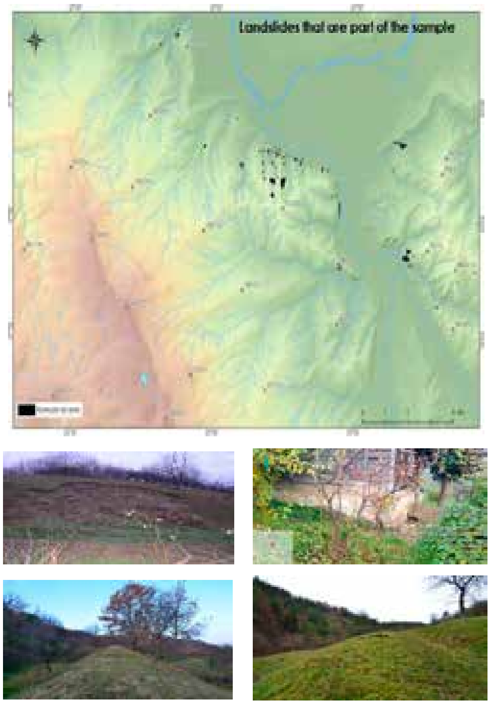


Figure 2. Landslides identified on the territory of Sighetu Marmației Municipality, within the GeoSES Project (Source: GeoSES Project)

Figure 3. Landslides identified on the Location 6. Câmpul Negru - Malec

Within the GeoSES Project, 6 areas affected by landslides were chosen, 5 from the territory of the municipality and one, previously mentioned, from Sarasău Township. These have been monitored so far through four cycles, respectively, Cycle "0" in July 2020, Cycle "1" in March 2021, Cycle "2" June 2021, Cycle "3" October 2021.

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Initially, in June 2020, there was a stage of verification of the technologies and tools that we intend to use in the monitoring process and in March 2022 a final cycle of verification of results and introduction of a new tracking technology of land behavior over time based on sensory instruments shall take place. Then, for seven years, there will be a verification cycle using UAV technology to ensure the safety of the area.

The technologies and tools used in the GeoSES Project to monitor landslides were as follows:

1. Geometric precision level, devices used, Foif DS05 Precision Level and Leica LS10 Digital Level;
2. Trigonometric level using Total Stations, Leica TS02plus total station, 3";

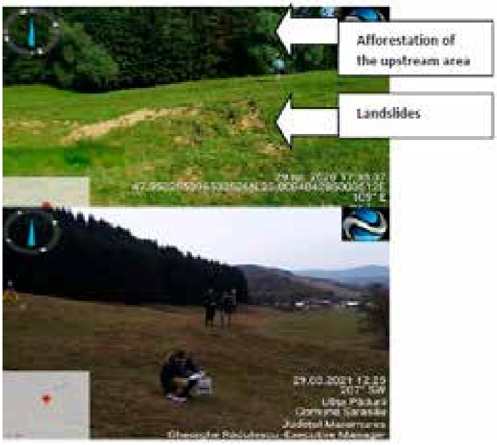


Figure 4. Landslides stabilized by afforestation (Source: GeoSES Project)

3. GNSS technology with Leica GS 08 plus and GNSS RTK L1L2 HI-TARGET V90;
4. UAV aerial photogrammetry, instruments used, DJI Phantom 4 and DJI Matrix 210 TK V2;
5. Laser scanning, instrument used, Z + F 5010x Laser scanner, Zoller + Fröhlich.
6. UAV thermal aerial photogrammetry, instruments used, Drone DJI Matrix 210
7. RTK V2 and FLIR Vue ™ Pro thermal camera;
8. Structural Monitoring Kit BeanScape, Wilow, Wireless Sensor Networks.

Figure 5 shows the operating flow in the project for four-cycle monitoring of the six selected locations.

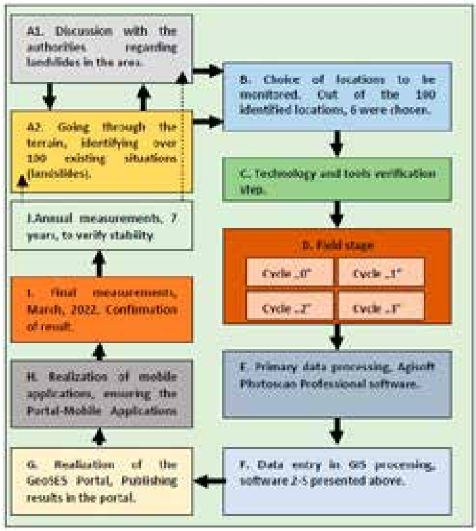


Figure 5. Technological flow in the GeoSES Project (Source: GeoSES Project, Authors)

RESULTS AND DISCUSSIONS

The deforestation that caused the landslides can be easily seen studying the evolution of the land following the deforestation produced, on orthophoto plans made in 2008, 2012 and 2020 (Figure 6).

The location affected by deforestation is located at the foot of Solovan Hill, Câmpul Negru-Malec Street (Figure 7). It is the only active landslide, of the six monitored over two years, i.e. 2020-2021.

From the GeoSES Portal we presented in Figure 8 some images, during cycle "3", taken with the DJI Matrix 210 RTK drone, purchased within the GeoSES project.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

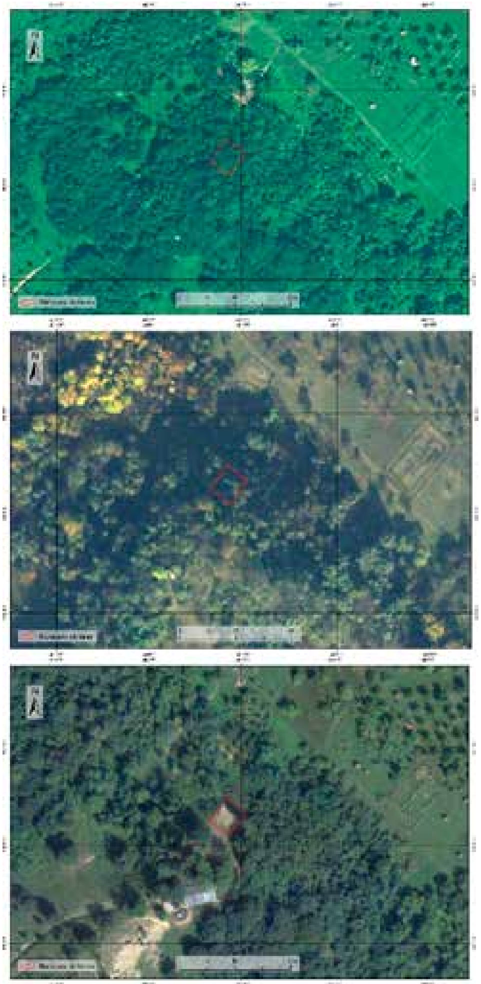


Figure 6. Location monitored 6. Câmpul Negru - Malec, Orthophotoplans made in 2008, 2012 and 2020 (Source: GeoSES Project)

Following the introduction, orthophotoplan orthomosaics, DEM Models, were obtained for each cycle of drone images. After each processing the software generates reports, being presented in Figure 10. Agisoft Photoscan Professional Software Report for Monitored Location, Cycle 4.
Orthophotoplanes and DEMs used below, using Maxent software, to obtain mathematical models, predictions, simulations, and Risk Maps for the monitored areas are presented, for the location analysed in this paper are shown in Figures 10, 11 and 12. (Images taken from the GeoSES Portal (http://geoses.cunbm.utcluj.ro/gis/).

Figure 7. Câmpul Negru-Malec Street, Sighetu Marmației, landslides due to deforestation, identified on Google Earth (Image 2022 CNES/Airbus)

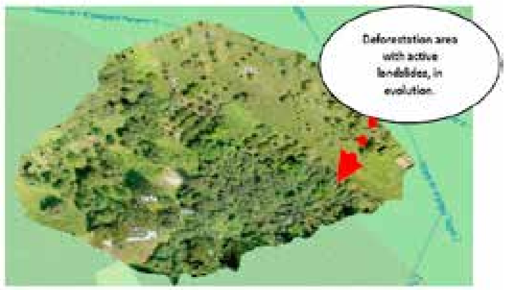


Figure 8. Câmpul Negru-Malec Street, Sighetu Marmației, landslides due to deforestation, image taken from the GeoSES Portal

Figure 9. Câmpul Negru-Malec Street, Sighetu Marmației, landslides due to deforestation, Orthophotoplans, cycles “0”, “1”, “2”, “3”

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

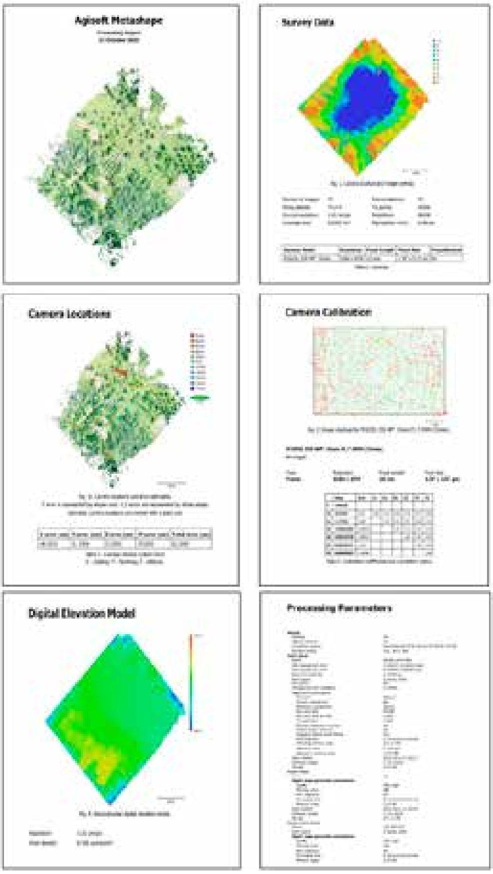


Figure 10. Agisoft Photoscan Professional Software Report, Location 6, Câmpul Negru - Malec, Sighetu Marmației, Cycle “3”

Figure 13 below shows the operating flow with Maxent software, which will finally obtain the landslide risk maps for the monitored locations, generally for the area of Sighetu Marmației Municipality and the surrounding areas. Figure 14 shows Relief Energy, Landslides and Landslides in the Area and Figure 15 shows Câmpul Negru - Malec, Landslide susceptibility.

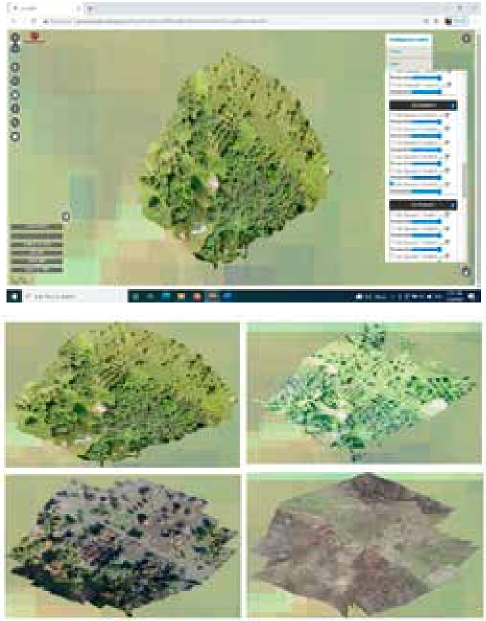


Figure 11. Câmpul Negru-Malec Street, Sighetu Marmației, landslides due to deforestation, Orthophotoplans, cycles “0”

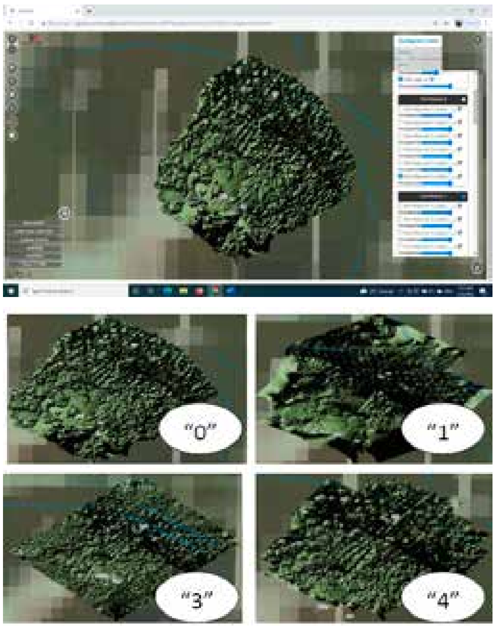


Figure 12. Câmpul Negru-Malec Street, DEMs, cycles “0”, “1”, “2”, “3”

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

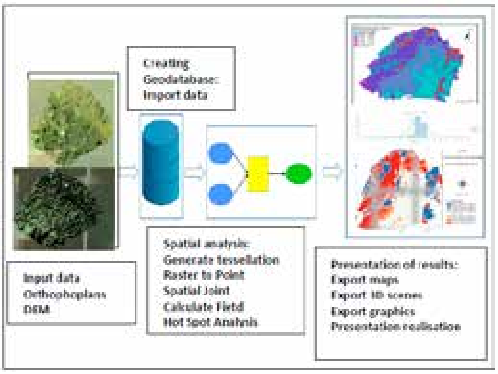


Figure 13. Landslide Deformation Analysis of Spatial Deformation in the GeoSES Project

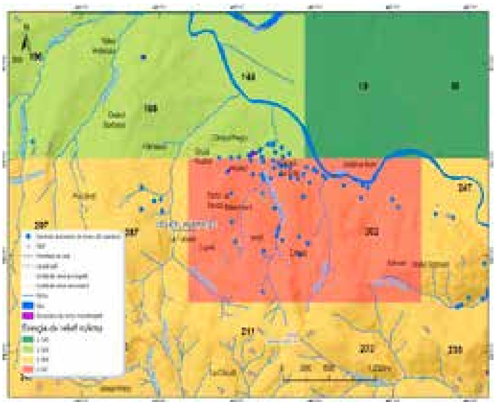


Figure 14. Câmpul Negru - Malec Relief Energy, Landslides in the Area

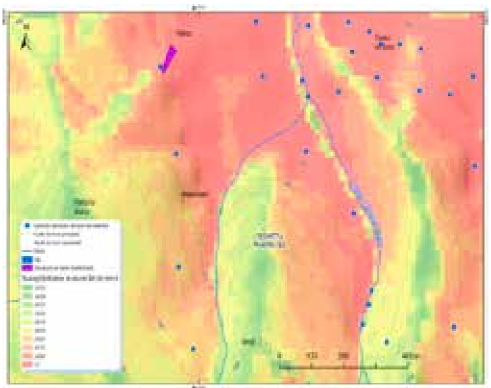


Figure 15. Câmpul Negru - Malec, Landslide susceptibility

Figure 16. Landslide risk map for the analyzed area, Câmpul Negru - Malec Street, Sighetu Marmației Municipality

As can be seen from the landslide risk map generated (Figure 16), after processing the data with the help of Maxent software, for the Municipality of Sighetu Marmatiei and the surrounding areas, the entire area at the foot of Solovan Hill, including the one studied in Câmpul Negru - Malec, are strongly exposed.
However, for the four-cycle monitoring interval (2020-2021) only the Câmpul Negru - Malec area was found to be unstable, with values of spatial displacements of maximum 120 mm.

CONCLUSIONS

"Natural hazards are extreme manifestations of natural phenomena, such as earthquakes, storms, floods, landslides, droughts, which have a direct influence on the life of each person, on society and the environment as a whole" (Cozac and Boian, 2005).
The exposure of the Romanian banks of the Tisza River to various destructive events has been known for hundreds of years.
From this summary it can be seen that the monitoring of the study area considered in the GeoSES Project must continue to take into account disastrous events in the category of landslides and floods. Our team will continue for seven years after the completion of the GeoSES Project on May 31, the results being communicated to the authorities to make the best decisions to manage the situations created.

ACKNOWLEDGMENTS

The entire activity presented in this paper was carried out within the project GeoSES - Extension of the operational "Space Emergency System" towards monitoring of dangerous natural and man-made geo-processes in the HU-SK-RO-UA cross-border region, HUSKROUA 1702/8.1./0065.

The team of authors of this paper, which is also the project team, would like to thank their colleagues from Uzhhorod National University for inviting the Technical University of Cluj Napoca as a partner in the project.

REFERENCES

Brardinoni, F., Hassan, M.A., Slaymaker, H.O., (2002), Complex mass wasting response of drainage basins to forest management in coastal British Colombia. Geomorphology 49: 109–124. DOI: 10.1016/S0169-555X(02)00166-6

Brardinoni, F., Hassan, M.A., Slaymaker, H.O., (2002), Complex mass wasting response of drainage basins to forest management in coastal British Colombia. Geomorphology 49: 109–124. DOI: 10.1016/S0169-555X(02)00166-6

Butler, R.A., (2019), Consequences of Deforestation, https://rainforests.mongabay.com/09-consequences-of-deforestation.html.

Constantine, J.A., Pasternack, G.B., Johnson, M.L., (2005), Logging effects on sediment flux observed in a pollen-based record of overbank deposition in a northern California catchment, Earth Surface Processes and Landforms 30: 813–821. DOI: 10.1002/esp.1190

Cozac, V., Boian, I., (2005). Principalele tipuri de hazarduri naturale şi impactul lor asupra mediului şi societăţii, Mediul ambiant, Natural and anthropogenic hazards, NR. 5 (23) octombrie 2005, pg. 18-25.

https://www.europarl.europa.eu/factsheets/ro/sheet/105/the-european-union-and-forests

Dhakal, A.S., Sidle, R.C., (2003), Long-term modeling of landslides for different forest management practices. Earth Surface Processes and Landforms 28: 853–868. DOI: 10.1002/esp.499

Dhakal, A.S., Sidle, R.C., (2003), Long-term modeling of landslides for different forest management practices. Earth Surface Processes and Landforms 28: 853–868. DOI: 10.1002/esp.499

Edeso, J.M.., Merino, A., González, M.J., Marauri, P., (1999), Soil erosion under different harvesting managements in steep forest lands from north- ern Spain, Land Degradation & Development 10: 79– 88.

Gomi, T., Sidle, R.C., (2003), Bedload transport in managed steep-gradient headwater streams of southeastern Alaska. Water Resources Research 39: 1336. DOI: 10.1029/2003WR002440

Gomi, T., Sidle, R.C., Swanson, D.N., (2004), Hydrogeomorphic linkages of sediment transport in headwater streams, Maybeso Experimental Forest, southwest Alaska. Hydrological Processes 18: 667–683. DOI: 10.1002/hyp.1366

http://www.mmediu.ro/app/webroot/uploads/files/National%20forestry%20accounting%20plan%20of%20Romania_RO.pdf

https://ourworldindata.org/forest-area

Jakob, M., (2000), The impact of logging on landslide activity at Clayoquot Sound, British Columbia, Catena 38: 279–300. DOI: 10.1016/ S0341-8162(99)00078-8

Keim, R.F., Skaugset, A.E., (2003), Modeling effects of forest canopies on slope stability, Hydrological Processes 17: 1457–1467. DOI: 10.1002/hyp.5121

Khan, A. N., (1994), Extent and Evaluation of the Adverse Effects of Landslides on Housing in Murree, Pakistan. Journal of Rural Development and Administration, Vol: 26 (1), P. 119-40.

Roberts, G.R., Church, M., (1986), The sediment budget in severely disturbed watershed, Queen Charlotte Ranges, British Columbia, Canadian Journal of Forest Research 16: 1092–1106.

Schmaltz, E. M., Steger, S., & Glade, T., (2017), The influence of forest cover on landslide occurrence explored with spatio-temporal information. Geomorphology, 290(Complete), 250-264. doi:10.1016/j.geomorph.2017.04.024

Sidle, R.C., Ochiai, H., (2006), Landslides: Processes, Prediction, and Land Use. Water Resources Monograph 18, American Geophysical Union: Washington, DC.

Tariq, M., Rashid, M., Wajid, R., (2014), Causes of deforestation and climatic changes in Dir Kohistan, May 2014, Journal of Pharmacy and Alternative Medicine www.iiste.org, ISSN 2222-5668 (Paper) ISSN 2222-4807 (Online), Vol. 3, No. 2, 2014, https://www.researchgate.net/publication/322522483

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

LANDSLIDE ANALYSIS USING GIS TOOLS - CASE STUDY ANALYZED IN THE CROSS-BORDER GeoSES PROJECT

Tiberiu Mihai KALMAR[1], Marcel DÎRJA[1], Adrian Traian Gh.M. RĂDULESCU[2], Petru Daniel MĂRAN[2], Virgil Mihai Gh.M. RĂDULESCU[2], Corina M. RĂDULESCU[2], Gheorghe M.T. RĂDULESCU[2], Mihai HERBEI[3]

[1]University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Manastur, Cluj-Napoca, Romania
[2]Technical University of Cluj-Napoca, 15 Constantin Daicoviciu Street, Cluj-Napoca, Romania
[3]Banat University of Agricultural Sciences and Veterinary Medicine "King Mihai I of Romania" from Timisoara, 119 Calea Aradului, Timisoara, Romania

Corresponding author email: mdirja@usamvcluj.ro

Abstract

The international cross-border project GeoSES-Extension of the operational "Space Emergency System" towards monitoring of dangerous natural and man-made geo-processes in the HU-SK-RO-UA cross-border region HUSKROUA 1702 /8.1. / 0065 was included in Thematic objective 8. TO - Common challenges in the field of safety and security, Program priority 8.1 Support to joint activities for the prevention of natural and man-made disasters as well as joint action during emergency situations of the HUSKROUA ENI CBC Program 2014-2020. Technical University of Cluj Napoca was one of the participants in the project together with the Project Leader Uzhhorod National University, Ukraine and Pavol Jozef Šafárik University in Košice, Budapest University of Technology and Ecomomics, Self-government of Szabolcs-Szatmár-Bereg County. The overall objective of the project is geo-monitoring of natural and man-made processes in the cross-border territory with the aim of preventing emergency situations. The project specific objectives are the following: 1. Reduction of the risks of natural disasters by means of geomonitoring of dangerous landslide and mudflow processes in the valley of the Tisza River; 2. Forecasting the occurrence of heavy rainstorms in cross-boundary areas with the aim of preventing unexpected river floods, 3. Development of a joint innovation strategy for preventing ecological disasters and adopting to change climate in the Carpathian Region. Located at the foot of Solovan Hill, Sighetu Marmației was subjected to numerous landslides. In these conditions, the role of the Romanian partner in the project was to monitor this situation, operations carried out both globally, for the entire municipal territory and neighborhoods and privately through six locations chosen both due to the gravity of events over time and the fact that these landslides had different causes. The paper presents the GIS mechanisms used to generate the landslide risk analysis.

Key words: *Landslide, GIS, Maxent, 3D model.*

INTRODUCTION

In 2021 we celebrated ten years of collaboration between the Department of Land Measurements and Cadastre of the Faculty of Civil Engineering at the Technical University of Cluj-Napoca and the team of specialists in Disaster Management at the National University of Uzhhorod, Ukraine. Then, after winning the position of eligible project, through the application "SPACE EMERGENCY SYSTEM", cross-border system for predicting natural disasters based on the exploitation of satellite technologies in Hungary, Slovakia, Romania and Ukraine (Program: ENPI CBC 2007-2013 Hungary - Slovakia - Romania - Ukraine, Cross-Border Cooperation Program), together with teams from the University of Miskolc, Hungary, the Vihorlat Observatory (Humenne, Slovakia), the International Association for Regional Development Institution "IARDI" (Uzhhorod, Ukraine), the project leader being the same as in this project, we carried out an intense activity of scientific research in 2014 and 2015. We wanted that the project analysed in this paper GeoSES-Extension of the operational "Space Emergency System" towards monitoring of dangerous natural and man-made geo-processes in the HU-SK-RO-UA cross-border region, Indicative

HUSKROUA 1702/8.1./0065 to continue this activity, this time in relation to the Romanian bank of the Tisza River, the area of the Municipality of Sighetu Marmației and neighborhoods, in terms of land stability (aspects presented in the paper) and the dangers of exposure to floods (Figures 1 and 2).

Figure 1. Location of the study area within the HUSKROUA program region
(Source: https://huskroua-cbc.eu/news/)

Figure 2. Area monitored (Sighetu Marmației) for landslides in the GeoSES Project
(Source: GeoSES Project)

Landslides pose a major natural hazard. Reported landslides are usually reduced for a variety of reasons (Kirschbaum et al., 2015) and thus total rates are likely to be underreported. Even so, Froude and Petley reported 32,322 deaths over seven years, a high rate that disproportionately affects the world's poorest regions (Froude and Petley, 2018). Infrastructure is also frequently affected, with damage in excess of $ 1 billion annually in the United States alone (Dale et al., 2001). Climate change is expected to lead to an increase in landslides due to more frequent storms at higher intensities (Dale et al., 2001), which historically correlates with higher landslide activity (Kirschbaum et al., 2010).

However, the long-term implications of landslides, mass removal and relocation of soil, the initiation of succession in the first place (Walker and Shiels, 2012) and the implications of potential future increases due to increased storm intensity (Jakob and Lambert, 2009) requires a strong understanding of how these ecosystems respond to and recover from landslides.

Due to climate change, the border area between Romania-Hungary-Slovakia and Ukraine could be vulnerable to landslides. In the centre of the Maramureş Depression, drained by the river Tisza, is located the town of Sighetu Marmației. The municipality of Sighetu Marmatiei is part of the North-West Region, Maramureş County, being the second city in size and importance, after the county seat, the municipality of Baia Mare. Sighetu Marmației is located at the foot of Solovan Hill, on the lower terraces of the Tisza, Iza and Ronişoara rivers, the city center being located at an average altitude of 274 m. It is very important, in this new context, in which the impact of human society on the environment is globalized, that local and even cross-border landslide risk mapping is developed. These will have to be done according to a scientific methodology and at a level of detail high enough to be useful in emergency management.

MATERIALS AND METHODS

The purpose of this study is to perform and present an analysis of the risk of landslides in the municipality of Sighetu Marmației. This analysis can contribute to the sustainable development of the Romanian-Ukrainian-Hungarian-Slovak cross-border region of the upper Tisza Basin and its tributaries.

The objective of the research is to achieve through the case study on the Municipality of Sighetu Marmației a working methodology that would be useful from the perspective of drafting risk maps for landslides in the project region.

The methodology is based on the use of geographic information systems as a tool for spatial modeling of landslides in the project region. This report refers to interim research resulting from the GEOSES project. Following the preparation of the statistical model, it was found that some variables need to be updated and the sample needs to be enlarged so that the whole model can be improved.

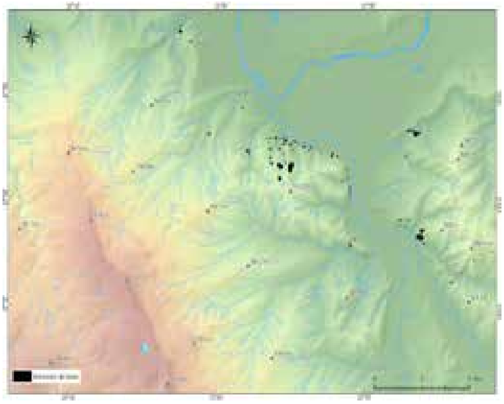


Figure 3. Spatial distribution of landslides in the area of Sighetu Marmației Municipality and surroundings (Source: GeoSES Project)

Following consultations with local authorities and project partners, the TUCN project team decided to monitor six locations (Figure 4) of which five in the Sighetu Marmației Municipality area and one in the neighboring commune of Sarasău.

Figure 4. The 6 locations monitored within the GeoSES Project (Source: GeoSES Project)

The municipality of Sighetu Marmației is located in the Maramureș Depression. Extended in the form of a large, elongated bay (over 90 km) in a northwest-southeast direction, between the eruptive chain and the central crystalline-Mesozoic area, the Maramureş Depression is one of the most characteristic natural units of this kind in the Eastern Carpathians. The boundary is the synthetic result of the combination of all geographical elements, but depending on the case, there is a dominant element: geological structure, relief energy, vegetation, soil, the organization, and exploitation of the relief. Sarasău is a township in Maramureş County, Transylvania, Romania, consisting only of the village of residence with the same name. Sarasău village, which is also a township, is

Location 1. Ulița Pădurii Street (Veterinary Dispensary), Sarasău, landslide open in several points on a length of approx. 200 m and a width-depth of approx. 100 m. The cause was the lack of vegetation, heavy rains causing landslides. About 50 years ago, the entire upstream area was reforested, and conditions were created to stabilize the area.

Location 2. Valea Hotarului Street (Bortoșoi Hill), Sighetu Marmației, landslide taking place since 2016, natural causes, steep hill without trees and without forest vegetation. The consequences are the partial destruction of the foundation of a property at the base of the hill. The measurements show that it is an active landslide.

Location 3. Câmpul Negru Street (Peșec), Sighetu Marmației, landslide taking place over the past 10 years, the cause being the construction of an access road without ensuring conditions for consolidating the destabilized slope. The upstream hill is without trees; the landslide is active.

Location 4. Valea Cufundoasă Street (N. Boar), Sighetu Marmației, very steep area, landslide taking place over the past 20 years, several areas with open landslide, the upstream area is forested, a property at the base of the hill is in danger of being affected.

Location 5. Valea Cufundoasă Street (Cheresteși), Sighetu Marmației, very steep area, landslide taking place over the past 10 years, upstream area is forested, a property at the base of the hill was destroyed and was rebuilt downstream; the area seems to be stabilized.

Location 6. Câmpul Negru Street (Malec), Sighetu Marmației, the massive deforestation carried out in the last 10 years has led to large landslides, just below the deforested area; the landslide is active; there are no properties in the vicinity.

All variables have been integrated into a geo-database developed with ArcGIS Pro. Only the landslide locations on the Romanian territory were registered. The landslides have been incorporated into the model in the form of a set of points representing the centroids of polygons with mapped landslides.

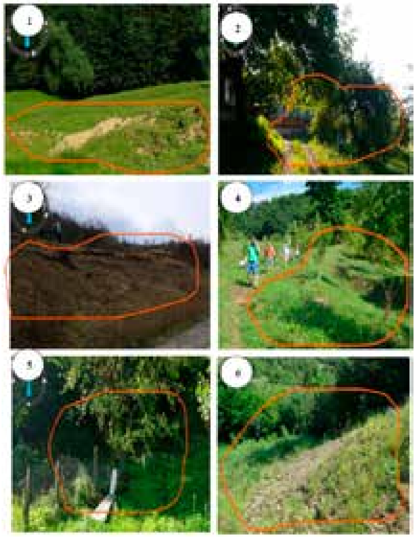


Figure 5. Images of landslides in the monitored areas (Source: GeoSES Project)

Table 1. The six monitored locations (landslides) and the coordinates of Ground Control Points (GCP) for each area monitored and the central points (Source: GeoSES Project)

	Name of area monitored for landslides	Contour point code	Latitud	Longitud	North (m)	East (m)	Altitude (Black Sea)
1	Ulița Pădurii (Dispensarul Veterinar	GPS003	47° 57' 10.11744573" N	023° 48' 29.99169320" E	717769.688	411109.275	275.956
		GPS003	47° 57' 09.71848066" N	023° 48' 31.03718003" E	717757.036	411130.779	282.836
		GPS0002	47° 57' 10.84869839" N	023° 48' 31.64564560" E	717791.751	411143.934	280.784
		GPS0001	47° 57' 11.58079161" N	023° 48' 30.09525019" E	717814.851	411112.111	272.449
		L1 Central	47° 57' 12.51223200" N	023° 48' 28.81465200" E	717844.023	411085.984	275.000
2	Valea Hotarului (Dealul Bortoșoi)	marisca4	47° 55' 43.48970093" N	023° 50' 42.94054164" E	715052.874	413828.224	335.742
		marisca3	47° 55' 44.51178717" N	023° 50' 41.52217428" E	715084.875	413799.248	336.690
		marisca2	47° 55' 44.24931185" N	023° 50' 42.14468362" E	715076.578	413812.050	334.782
		marisca1	47° 55' 43.68046693" N	023° 50' 41.74024272" E	715059.133	413803.396	338.378
		L2 Central	47° 55' 43.87418400" N	023° 50' 41.63031600" E	715065.150	413801.206	342.504
3	Câmpul Negru (Peșec)	drum4	47° 55' 10.68592094" N	023° 51' 47.82943794" E	714020.038	415160.441	323.643
		drum3	47° 55' 11.64528720" N	023° 51' 48.05824568" E	714049.599	415165.621	320.789
		drum2	47° 55' 12.67682901" N	023° 51' 50.89211653" E	714080.605	415224.916	307.115
		drum1	47° 55' 12.35489532" N	023° 51' 53.14961365" E	714069.983	415271.639	301.651
		L3 Central	47° 55' 12.48884400" N	023° 51' 52.88691600" E	714074.199	415266.249	300.979
4	Valea Cufundoasă (N. Boar)	boar6	47° 53' 59.92063976" N	023° 54' 15.62629608" E	711790.759	418198.279	324.313
		boar5	47° 54' 00.53776914" N	023° 54' 16.59384155" E	711809.538	418218.640	320.493
		boar4	47° 53' 59.32517501" N	023° 54' 18.20440637" E	711771.620	418251.566	302.607
		boar3	47° 53' 58.90698521" N	023° 54' 17.33706738" E	711758.956	418233.372	303.341
		boar2	47° 53' 57.87423999" N	023° 54' 18.11234595" E	711726.835	418249.028	291.256
		boar1	47° 53' 58.97702599" N	023° 54' 19.40236887" E	711760.52	418276.296	294.707
		L4 Central	47° 54' 00.32014800" N	023° 54' 16.47932400" E	711802.850	418216.172	311.674
5	Valea Cufundoasa (Cheresteși)	cherestes3	47° 54' 55.51048180" N	023° 53' 45.28074741" E	713516.484	417592.229	267.443
		cherestes2	47° 54' 55.40180531" N	023° 53' 44.57497211" E	713513.334	417577.528	270.628
		cherestes1	47° 54' 55.75782699" N	023° 53' 43.66482619" E	713524.596	417558.786	267.591
		L5 Central	47° 54' 55.08100800" N	023° 53' 44.41790400" E	713503.473	417574.131	274.516
6	Câmpul Negru (Malec)	drum5uunrht5	47° 55' 05.18660995" N	023° 51' 34.93088654" E	713854.083	414890.185	417.411
		drum5uunrht4	47° 55' 05.44525572" N	023° 51' 34.58740132" E	713862.175	414883.170	412.403
		drum5uunrht3	47° 55' 07.08759322" N	023° 51' 36.78028209" E	713912.236	414929.435	384.153
		drum5uunrht2	47° 55' 07.56882007" N	023° 51' 36.03392889" E	713927.324	414914.156	384.822
		L6 Central	47° 55' 05.51161200" N	023° 51' 35.96878800" E	713863.808	414911.883	402.181

RESULTS AND DISCUSSIONS

The elaboration of a statistical model for the study of landslides and the creation of geo-morphological risk maps is an activity that involves the incorporation of several explanatory variables and the establishment of correlations with the explained (dependent) variable. In order to choose the independent variables, 119 landslides were inventoried in the study area.

The free and open source Maxent software was used for the modeling. A diagnostic test was performed to verify the model that used 25% of the data from the initial sample, with the remaining 75% of the data being used to generate the model. The main result of this statistical modeling process is the map of the susceptibility to landslides in the municipality of Sighetu Marmației and its surroundings. The chance of landslides was estimated in three classes: low, medium, and high probability.

In this study, a model of the risk of landslides was used based on the probability of new landslides starting from a sample of older (stabilized) landslides and active landslides.

The first stage of work involved identifying landslides in the sample. GPS coordinates were recorded, and photos were taken.

For mapping landslides, GPS data was imported into Google Earth, where the landslides were digitized.

The Google Earth program was chosen because it is possible to visualize each digitized polygon by overlapping and analysing it visually based on a set of satellite images recorded at different dates, so the risk of including erroneous data in the sample decreased considerably. During the summer, the development of vegetation does not allow the easy identification of areas with landslides, instead the images taken in autumn or spring are much more suitable for mapping.

All variables have been integrated into a geo-database developed with ArcGIS Pro.

Figure 6. Carrying out the monitoring cycles of the six areas (Source: GeoSES Project)

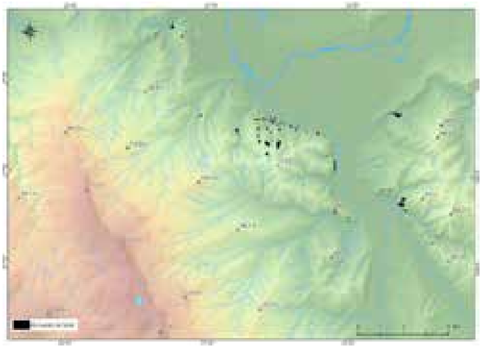


Figure 7. Spatial distribution of landslides in the area of Sighetu Marmației Municipality and surroundings
(Source: GeoSES Project)

Landslides have been incorporated into the model as a set of points representing the centroid of polygons with mapped landslides. They are observed by simply mapping a certain spatial grouping of points, and the first alternative hypotheses are formulated, which provide a relationship between landslides, slope, slope exposure and geological structure. After mapping the sample representing the dependent variable, the data necessary for the geo-processing of the explanatory variables were acquired. By digitizing, the level curves with the equidistance of 10 meters and the elevations of the altitude were taken from the topographic map 1:25.000, constructing a model of the elevation of the land with the resolution of 15 meters. From the 1:200,000 scale geological map, the geological structure was generated in vector format, then a raster with a resolution of 15 meters was generated by geo-processing. Also, through geoprocessing, starting from the land elevation model, several variables were generated: slope map, slope exposure, slope curvature, distance from the hydrographic network and relief energy. An independent variable named "Vegetation Index Normalized Difference" NDVI, was included in the model. It was generated by geo-processing based on a Landsat 8 satellite images, captured in autumn 2020, considering that the degree of coverage with clouds should be as low as possible. The eight variables are presented below in the form of thematic maps (Figures 8 to 15).

Figure 8. Variable 1. Digital Elevation Model, Sighetu Marmației Area
(Source: Proiect GeoSES, Măran and Herbei, 2021)

Figure 9. Variable 2. Slope, Sighetu Marmației Area
(Source: Proiect GeoSES, Măran and Herbei, 2021)

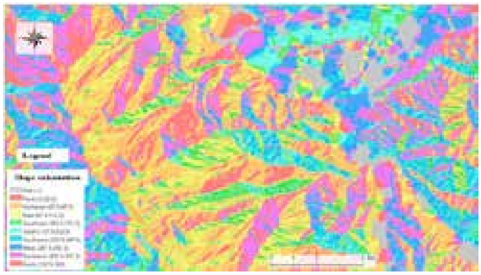


Figure 10. Variable 3. The exposure of the Slope, Sighetu Marmației Area
(Source: Proiect GeoSES, Măran and Herbei, 2021)

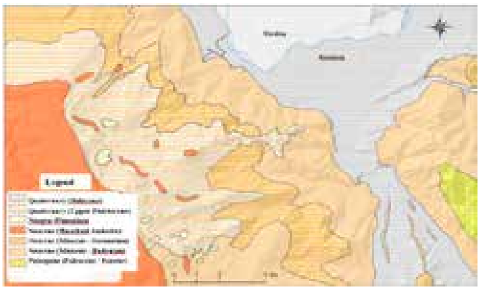


Figure 11. Variable 4. Geological Structure, Sighetu Marmației Area
(Source: Proiect GeoSES, Măran and Herbei, 2021)

Figure 12. Variable 5. Relief Energy, Sighetu Marmației Area
(Source: Proiect GeoSES, Măran and Herbei, 2021)

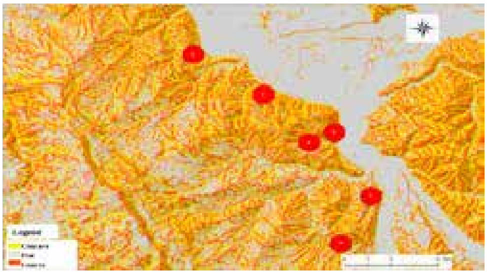


Figure 13. Variable 6. Curvature of the Slope, Sighetu Marmației area and the position of the six monitored locations
(Source: Proiect GeoSES, Măran and Herbei, 2021)

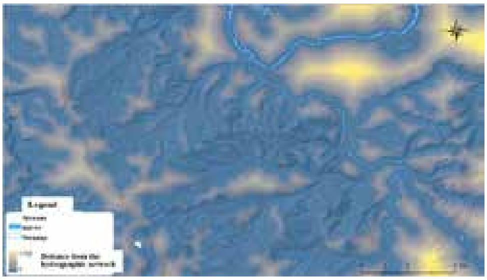


Figure 14. Variable 7. Distance from the hydrographic network
(Source: Proiect GeoSES, Măran and Herbei, 2021)

Figure 15. Variable 8. NDVI, Sighetu Marmației Area
(Source: Proiect GeoSES, Măran and Herbei, 2021)

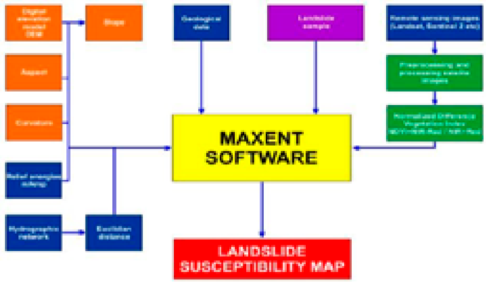


Figure 16. Workflow for Software MAXENT
(Source: Proiect GeoSES, Măran and Herbei, 2021)

The result of this workflow is the landslide risk map (Figures 17 and 18), which indicates the susceptibility to landslides through the three classes (low, medium, and high risk), (Table 2).

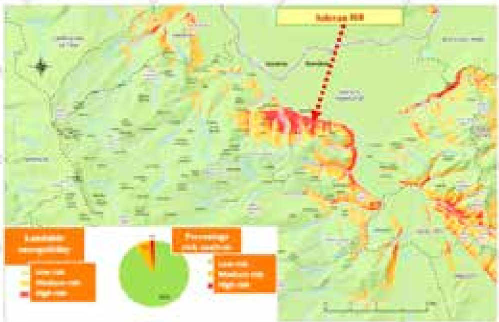


Figure 17. Sighetu Marmației Municipality - map of risk and susceptibility to landslides
(Source: Proiect GeoSES, Măran and Herbei, 2021)

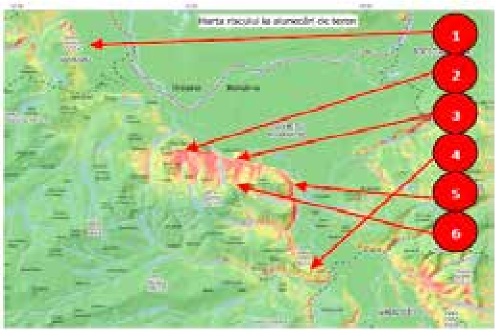


Figure 18. Position of the monitored locations on the landslide susceptibility map
(Source: Proiect GeoSES, Măran and Herbei, 2021)

It can be seen that the risk of landslides is high in the case of steep slopes and for areas occupied by rocks from the Cenozoic era, the Neogene geological period and the Miocene period.

Table 2. Landslide susceptibility - Sighetu Marmatiei (Source: Proiect GeoSES)

The level of risk	Areas, ha	%
Low risk	25243	91.61
Medium risk	1877	6.81
High risk	434	1.58
Total	27554	100.00

This period began 23 million years ago and ended 5.3 million years ago. These rocks are deposits of clays, marls and sandstones that are very prone to landslides. It can also be seen that northern and eastern exposures are more prone to landslides compared to southern or western exposures.

The classification of the contribution of the variables considered to the statistical model on landslides in the Sighetu Marmației area is presented in Table 3.

Table 3. Classification of the contribution of variables (Source: Proiect GeoSES, Măran and Herbei, 2021)

Variable code	Variable name	Contribution to model	Position
V1	Altitude (DEM)	16.2947	3
V2	Slope	35.7730	1
V3	Slope exhibition	6.1782	5
V4	Geological structure	22.7949	2
V5	Relief energy m per km	15.6407	4
V6	The curvature of the slopes	0.1910	8
V7	Distance from the hydrographic network	2.8135	6
V8	Normalized difference vegetation index (NDVI)	0.3140	7

The (MAXENT) model based on the statistical-physical principle of entropy maximization (Banavar et al., 2010) derived from information theory (Ruddell et al., 2013) provides a model of medium level complexity and high accuracy, useful in predicting spatial-temporal models of the occurrence and magnitude of variable landslides, which lead to the determination of the causes in which a particular pattern occurs (Figure 16). This paper combines landslide data from heuristic models (Catani et al., 2005) and uses a similar correlative approach to statistical methods for landslides. The model can be easily used for landslide predictions. An approach to statistical physics that focuses on similarities rather than differences in landslides is considered (Banavar et al., 2010; Ruddell et al., 2013). The principle of maximum entropy is, in fact, an interference technique for constructing an estimate (Brunetti et al. 2009, Dudik et al. 2007, Wang et al. 2011).

The Table 3 gives estimates of relative contributions of the environmental variables to the Maxent model. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable or subtracted from it if the change to the absolute value of lambda is negative.

The AUC test is a diagnostic test that can be interpreted scientifically as follows: 0.90 - 1 = excellent; 0.80 - 0.90 = good; 0.70 - 0.80 = fair; 0.60 - 0.70 = weak; 0.50 - 0.60 = failure. The AUC test in the case of the selected model has values above the threshold of 0.90 which indicates excellent results of the predictive capacity regarding the risk of landslides in the municipality of Sighetu Marmației (Figures 19 and 20).

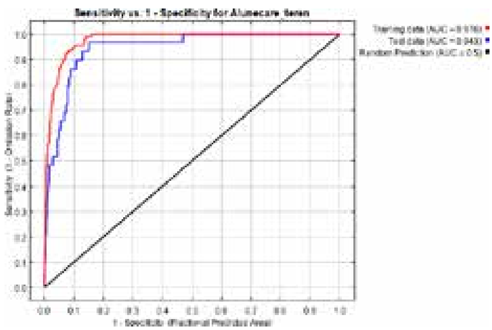


Figure 19. Model performance for Landslides Predictions in Sighetu Marmației Area
(Source: Proiect GeoSES)

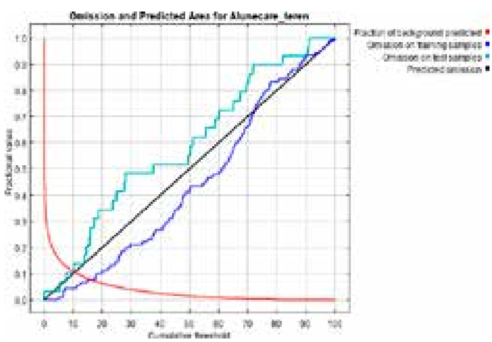


Figure 20. Omission and Predicted Area for Landslides in Sighetu Marmației Area
(Source: Proiect GeoSES)

Some common thresholds and corresponding omission rates are as follows. If test data are available, binomial probabilities are calculated exactly if the number of test samples is at most 25, otherwise using a normal approximation to the binomial. These are 1-sided p-values for the null hypothesis that test points are predicted no better than by a random prediction with the same fractional predicted area. The "Balance" threshold minimizes 6* training omission rate + .04* cumulative threshold + 1.6* fractional predicted area.

Table 4. Data processing results regarding landslides in the Sighetu Marmației area with the Maxent software
(Source: Proiect GeoSES)

Cumulative threshold	Cloglog threshold	Description	Fractional predicted area	Training omission rate	Test omission rate	P-value
1.000	0.011	Fixed cumulative value 1	0.280	0.000	0.034	1.084E-16
5.000	0.051	Fixed cumulative value 5	0.157	0.011	0.034	5.404E-33
10.000	0.110	Fixed cumulative value 10	0.109	0.014	0.100	1.308E-42
4.895	0.057	Minimum training presence	0.159	0.000	0.034	7.642E-33
19.993	0.247	10 percentile training presence	0.064	0.100	0.345	2.694E-39
15.804	0.192	Equal training sensitivity and specificity	0.078	0.079	0.276	6.58E-39
11.274	0.131	Maximum training sensitivity plus specificity	0.101	0.014	0.138	1.274E-42
10.265	0.122	Equal test sensitivity and specificity	0.107	0.044	0.100	2.018E-43
5.432	0.064	Maximum test sensitivity plus specificity	0.152	0.011	0.034	1.147E-34
3.858	0.051	Balance training omission, predicted area and threshold value	0.194	0.000	0.034	4.091E-26
13.903	0.167	Equate entropy of thresholded and original distributions	0.087	0.047	0.172	4.899E-44

This is a representation of the Maxent model for landslides. Warmer colours show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations (Figure 21).

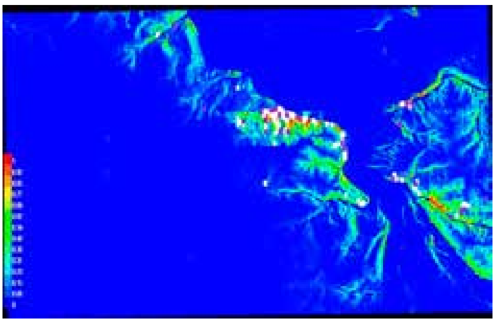


Figure 21. Plot for landslides predictions in the Sighetu Marmației area
(Source: Proiect GeoSES)

CONCLUSIONS

GIS programs can be used successfully for predictive analysis of natural hazards, but also to record and present the consequences of a disaster. The results of the GEOSES project can be useful for urban and cross-border development planning. A working methodology was developed that allowed the elaboration of the map of geo-morphological risks in the municipality of Sighetu Marmației. The sample should be analysed using spatial statistics tools to calculate global and local spatial autocorrelation indicators. Certain points can be removed from the sample if statistically significant spatial groups are identified. The null hypothesis was rejected, being accepted the alternative hypothesis that indicates a close statistical relationship between the dependent variable (landslides) and the explanatory variables. The results obtained will be useful in the project and for urban and cross-border development planning. It would be advisable to develop an alternative model by using another statistical method to better verify the results of this research.

ACKNOWLEDGMENTS

The entire activity presented in this paper was carried out within the project GeoSES - Extension of the operational "Space Emergency System" towards monitoring of dangerous natural and man-made geo-processes in the HU-SK-RO-UA cross-border region, HUSKROUA 1702/8.1./0065. The team of authors of this paper, which is also the project team, would like to thank their colleagues from Uzhhorod National University for inviting the Technical University of Cluj-Napoca as a partner in the project.

REFERENCES

Banavar, J., A. Maritan, and I. Volkov (2010). Applications of the princi-ple of maximum entropy: From physics to ecology, J. Phys. Condens. Matter,22, doi:10.1088/0953-8984/22/6/063101
Brunetti, M. T., F. Guzzetti, and M. Rossi (2009). Probability distributions of landslide volumes, Nonlinear Processes Geophys., 16, 179–188.
Catani, F., N. Casagli, L. Ermini, G. Righini, and G. Menduni (2005). Land-slide hazard and risk mapping at catchment scale in the Arno River basin, Landslides, 2, 329–342, doi:10.1007/s10346-005-0021-0.
Dale, V. H., et al. (2001). Climate change and forest disturbances: Climate change can affect forests by altering the frequency, intensity, duration, and timing

of fire, drought, introduced species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, or landslides. Bio Science 51: 723–734.

Dudik, M., S. J. Phillips, and R. E. Schapire (2007). Maximum entropy density estimation with generalized regularization and an application tospecies distribution modeling, J. Mach. Learn. Res.,8, 1217–1260.

Froude, M. J., and D. N. Petley (2018). Global fatal landslide occurrence from 2004 to 2016. Natural Hazards and Earth System Sciences 18: 2161– 2181.

https://earth.google.com/web/

https://huskroua-cbc.eu/news/programme-news/public-consultations-regarding-the-interreg

Jakob, M., and S. Lambert (2009). Climate change effects on landslides along the southwest coast of British Columbia. Geomorphology 107: 275–284.

Kalmar, T.T., Rădulescu, A.T.G.M., Rădulescu, V.M.G.M., Rădulescu, G.M.T., Dirja, M. (2021). The effect of deforestation on landslides, Case study analyzed within the GeoSES cross-border project, The Publication of the North University Centre of Baia Mare, Series D, Mining, Mineral Processing, Non-Ferrous Metallurgy, Geology and Environmental Engineering, Vol. XXXV Nr. 2 – 2021.

Kirschbaum, D. B., R. Adler, Y. Hong, S. Hill, and A. Lerner-Lam (2010). A global landslide catalog for hazard applications: method, results, and limitations. Natural Hazards 52: 561–575.

Kirschbaum, D. B., T. Stanley, and Y. Zhou (2015). Spatial and temporal analysis of a global landslide catalog. Geomorphology 249: 4–15.

Măran, P.D. and Herbei, M.V. (2021). Using GIS technologies for spatial analysis of landslides Case Study Sighetu Marmatiei Municipality, Scientific Bulletin Series D: Mining, Mineral Processing, Non-Ferrous Metallurgy, Geology and Environmental Engineering; Baia Mare Vol. 35, Iss. 2 (2021): 69-76.

Project GeoSES-Extension of the operational "Space Emergency System" towards monitoring of dangerous natural and man-made geo-processes in the HU-SK-RO-UA cross-border region, HUSKROUA 1702 /8.1./ 0065

Rădulescu, A.T.G.M., Kalmar, T.T. Rădulescu, G.M.T., Naș, S.M., Rădulescu, V.M.G.M., Măran, P.D., Rădulescu, C.M., Bondrea, M. (2021). The role of cross-border projects in Disaster Management, The Publication of the North University Centre of Baia Mare, Series D, Mining, Mineral Processing, Non-Ferrous Metallurgy, Geology and Environmental Engineering, Vol. XXXV Nr. 1 – 2021.

Rădulescu, A.T.G.M., Rădulescu, C.M., Rădulescu, G.M.T., Kalmar, T.T., Naș, S.M., Herbei, M., Rădulescu, V.M.G.M., Bondrea, M., Măran, P.D., Bondrea, M. (2021). Management of HUSKROUA Cross-border Projects, GeoSES Project Case Study, 38th IBIMA International Conference, Seville, Spain, conference proceedings (ISBN: 978-0-9998551-7-1) and (ISSN: 2767-9640)

Rădulescu, G.M.T., Naș, S.M., Rădulescu, A.T.G.M., Măran, P.D., Rădulescu, V.M.G.M., Bondrea, M., Herbei, M., Kalmar, T.T. (2021). Geomatic Technologies in Landslide Monitoring, Sarasău Case Study, Maramureș County, Romania, X International Scientific and Technical Conference «New Technologies in Geodesy, Land Planning and Management of Nature», October, 28-30 2021, Uzhhorod, Ukraine, ISBN 978-617-7825-60-8, pg. 69-75

Ruddell, B. L., N. A. Brunsell, and P. Stoy (2013). Applying information theory in the geosciences to quantify process uncertainty, feedback, scale, Eos, T. Am. Geophys. Union,94(5), 56–56, doi:10.1002/2013EO050007

Walker, L. R., and A. B. Shiels (2012). Landslide ecology. Cambridge University Press, Cambridge, UK.

Wang, J., and R. L. Bras (2011). A model of evapotranspiration based on the theory of maximum entropy production, Water Resour. Res.,3, 47, doi:10.1029/2010WR009392.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE POSITIVE EFFECTS OF CHANNELS RESTORATION IN THE DANUBE DELTA BIOSPHERE RESERVE

Maxim ARSENI, Adrian ROȘU, Ștefan Mihai PETREA, Mădălina CĂLMUC, Bogdan ROȘU, Daniel-Eduard CONSTANTIN, Cătălina ITICESCU, Puiu Lucian GEORGESCU

"Dunarea de Jos" University of Galati, 47 Domneasca Street, Galati, Romania

Corresponding author email: maxim.arseni@ugal.ro

Abstract

Ecological restoration in the Reservation of Danube Delta Biosphere is a method of sustainable development of nature and local communities, for the medium and long term. The topography and structural variety of bed channels influence the hydraulic network and ecological restoration processes. To understand the general comportment of ecological restoration processes it is important to survey the channel from a bathymetric and topographic point of view. Modeling the ecological restoration processes commonly includes measures of water level, discharge, and velocity of channel transect. The present study aims to collect and analyze the topo-bathymetric survey data obtained for two periods for the channel Ivancea and Cordon Litoral, from the Reservation of Danube Delta Biosphere. This area was come under an ecological restoration phase by dredging it. The first survey expedition was made before the dredging (august 2021), and the last expedition was made after the dredging (after august 2021). The result shows that the use of modern method and equipment for the survey, ensure the highest accuracy for water circulation system data analysis. The data analysis highlights that ecological restoration increases the discharge and the water velocity. In conclusion, the dredging process is important for ecological restoration, in the context of deltaic systems. Also, the time-to-time monitoring of this process, let us understand the sedimentation rate, and how it influences the hydraulics overall.

Key words: *ecological restoration, discharge, water velocity, hydro morphological monitoring, ADCP survey.*

INTRODUCTION

At the confluence with the Black Sea, the Danube has built an area of 5,800 km^2, which is one of the most important deltas in Europe, namely the Danube Delta, a UNESCO World Heritage Site, and a biosphere reserve (Gâştescu, 2009). The Danube Delta Biosphere Reserve (DDBR) is situated between 44°25′ and 45°30′ North latitude and 28°45′ 'and 29°46′ East longitude.

The DDBR is located in the geological unit of the Pre-Dobrogean Depression (Vespremeanu-Stroe & Preoteasa, 2015), at the edge of the Scythian Platform, the boundary between the North Dobrogea orogen and the territory occupied by the delta is given by the Sfântu Gheorghe fracture zone. Delta is located in a mobile area of the earth's crust characterized by subsidence (1.5-1.8 mm/year) and sediment accumulations (Vespremeanu-Stroe & Preoteasa, 2015).

The lake complexes, which are a significant feature of the lakes in the Danube Delta, are delimited by morphological elements (ridges, depressions, stage of evolution) and hydrographic elements (connection through canals and under the plateau or vegetation) (Banescu et al., 2020). In the DDBR the following aquatic complexes were outlined, presented in Figure 1:

- Somova - Parcheş (A) (predeltaic area);
- Şontea - Furtuna (B);
- Matiţa - Merhei (C);
- Gorgova - Uzlina (D);
- Red - Chicken (E);
- Dunavăţ – Dranov (F);
- Razim - Sinoe (G).

The ecological restoration in the DDBR has a positive effect from hidromorphological point of view.

This study aims to show the positive effects of Ivancea and Cordon Litoral channels restoration, by dredging processes.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

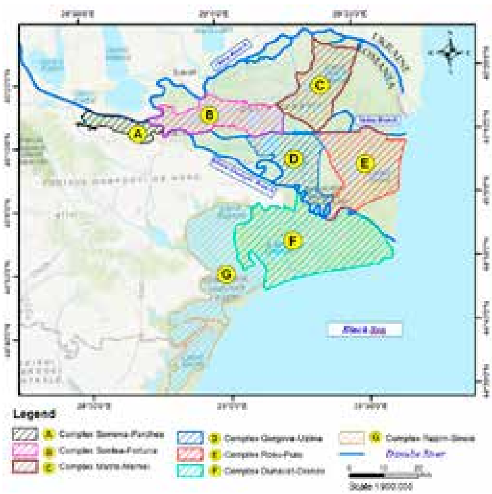


Figure 1. The map of main complexes of DDBR

MATERIALS AND METHODS

The study area is situated in the east part of Rosu-Puiu aquatic Complex, in the buffer zone of the confluence with the Black Sea. This area was supposed to a largeness process of ecological restoration, during the Operational Programme for Large Infrastructure (POIM), Project “Improving the hydrological conditions in the aquatic natural habitats of the DDBR for the conservation of biodiversity and fishery resources - Gorgova-Uzlina, Roșu-Puiu aquatic complexes” (*Operational Programme for Large Infrastructure - POIM*, 2016).

The main purpose of this restoration is to assess how the dredging processes of channel influence the sedimentation rate, discharge flow and water velocity flow, in context for improvement the hydrological condition for the aquatic natural habitats.

To understand these effects, we choose to compare two topo-bathymetric surveys for cross-section situated on Ivancea an Cordon Litoral channels. In this regard 5 cross-section was surveyed for the experimental analysis (Figure 2).

The first survey was made in August-September 2020 period when the channels was not constrained to dredging processes. The last survey was taken in period of August-September 2021, when 3 of these 5 cross-sections was dredged.

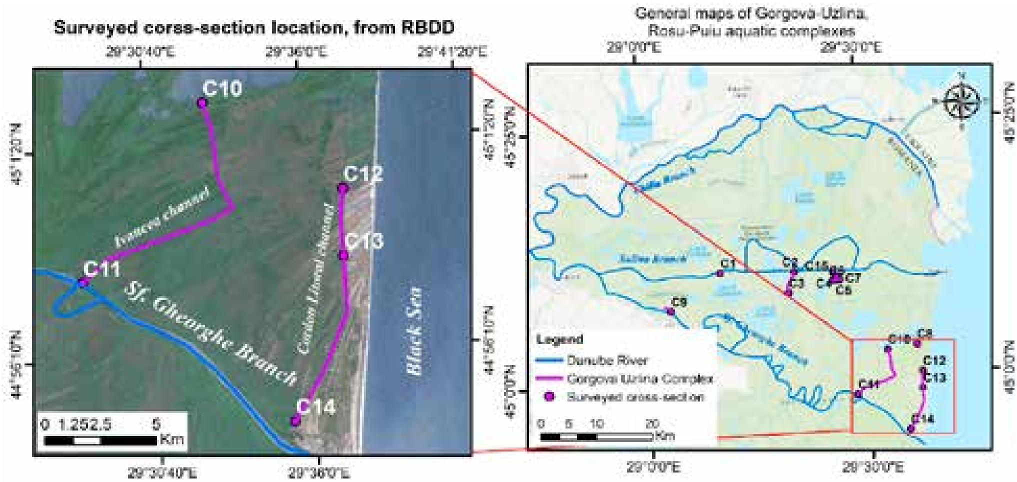


Figure 2. The geospatial position of surveyed cross-section: C10, C11, C12, C13 and C14

The survey of cross-sections was made in two phases: topographic survey for banks area, and bathymetric surveys for underwater areas (the riverbed part of channel, Figure 3 e).

The topographic surveys were made with Global Navigation Satellite System Receiver (GNSS) Topcon HiPer HR, produced by Topcon, and South S82-V GNSS equipment’s (Figure 3 a, b).

The River Surveyor M9 ADCP, produced by Xylem was used for bathymetric measurements, especially for depth, discharge and water velocity data (Figure 3 c, d). The RiverSurveyor M9 the profiler module is mounted on a powerboat which resist at small waves, but is very adaptable for rapid and accurate discharge measurements in unsteady flow conditions (Turunen et al., 2020). The width of the river and the location of vertical water column velocity and discharge is also provided by ADCP device (Wosiacki et al., 2021). To determine the water level related to national Datum - Black Sea Sulina (BS Datum), was used two levelling equipment, with millimeter precision: Leica Sprinter 250 M, produced by Leica Geosystems and Topcon DL-501, produced by Topcon Positioning Systems (Figure 3 f, g).

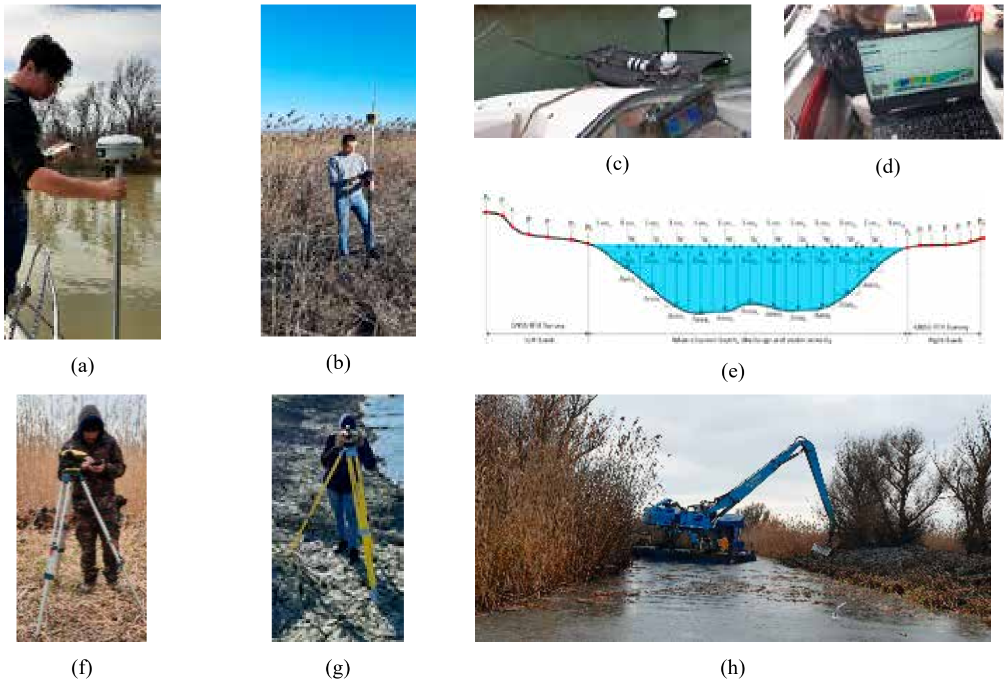


Figure 3. The main important instruments and methods used for survey campaigns, in order to assess the positive effects of channels restauration: (a) - GNSS receiver South S82-V; (b) - GNSS receiver Topcon HiPer HR; (c) - River Surveyor M9 ADCP; (d) - River Surveyor Live software for discharge and water velocity record; (e) - discharge and velocity values computing; (f) - Leica Sprinter 250 M levelling instrument; (g) - Topcon DL-501 levelling instrument; (h) - the dredging process on Ivancea channel

RESULTS AND DISCUSSIONS

The survey occurred in August-September period 2020 was limited due to the fact of accentuated sedimentation rate and the limitation of depth on the Ivancea channel. The discharge and water velocity on C11 cross-section was very reduced, caused by the high sedimentation rate and low water level in 2020 year. The abundance of vegetation and the depths between 0.5-0.15 cm cannot ensure surveys with River Surveyor M9 ADCP.

During the 2021 campaign the terrain elevations, depths, discharge and water velocity was surveyed for all five cross-sections.

The results of measured depth, discharge (Q) and water velocity survey parameters are presented in Figures 4-13.

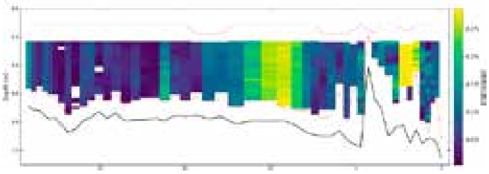


Figure 4. ADCP survey C10 cross-section (Ivancea channel) in 2020 campaign

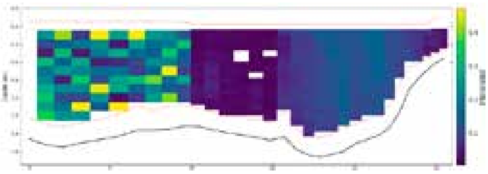


Figure 5. ADCP survey C10 cross-section (Ivancea channel) in 2020 campaign

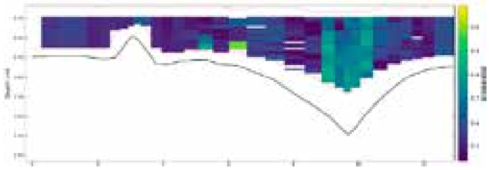


Figure 6. ADCP survey C11 cross-section (Ivancea channel) in 2020 campaign

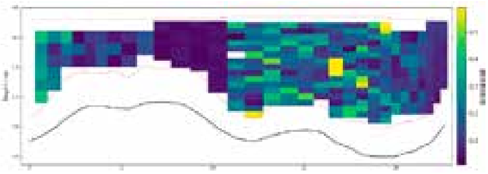


Figure 7. ADCP survey C12 cross-section (Ivancea channel) in 2021 campaign

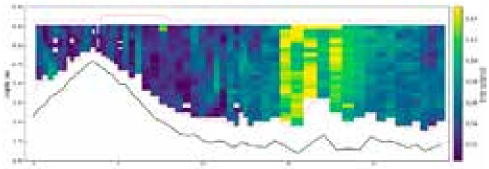


Figure 8. ADCP survey C12 cross-section (Cordon Litoral channel) in 2020 campaign

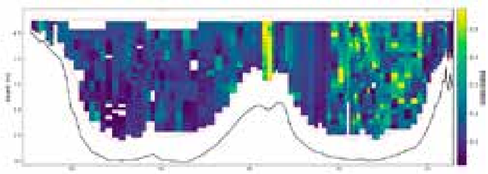


Figure 9. ADCP survey C12 cross-section (Cordon Litoral channel) in 2021 campaign

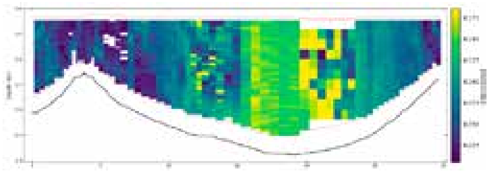


Figure 10. ADCP survey C13 (Cordon Litoral channel) cross-section in 2020 campaign

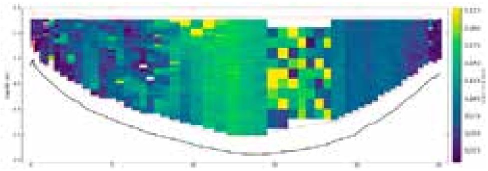


Figure 11. ADCP survey C13 cross-section (Cordon Litoral channel) in 2021 campaign

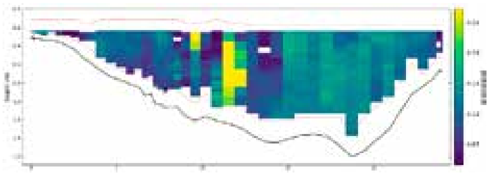


Figure 12. ADCP survey C14 cross-section (Cordon Litoral channel) in 2020 campaign

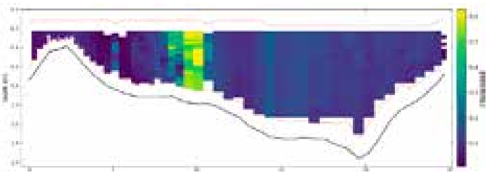
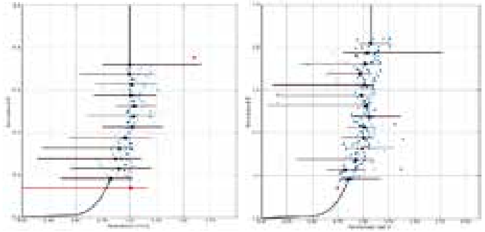


Figure 13. ADCP survey C14 cross-section (Cordon Litoral channel) in 2020 campaign

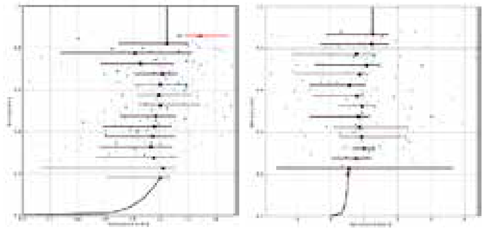
The results from ADCP survey show that the water velocity speed increase from $0.08 m \times s^{-1}$ to $0.11 m \times s^{-1}$ for C10 cross-section, from first to second survey. A significant difference for discharge and water velocity was identified for C11 cross-section. For this profile the discharge increase with 87%, and velocity with 18%. The C13 and C14 has the smallest difference between survey campaigns. The increase was less 10%.

To assess the difference between discharge and depth data, it was used the normalized distance from the streambed. Each segment was divided into 5 percent, from 0.05 to 1 (Figure 14).

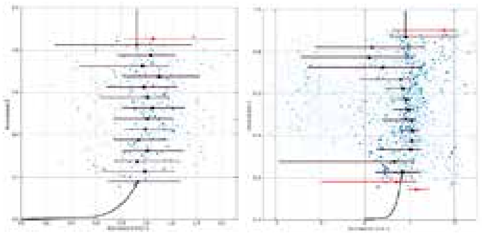
For each discharge segment was represented the median value.
All the obtained normalized value was assigned to depth data for corresponding column. All the number of points used for depth survey in cell column is reported by blue color (Figure 14). To compute the extrapolation for non-measured depth cells only the medians with sufficient points was used, by applying the 20% thresholds.



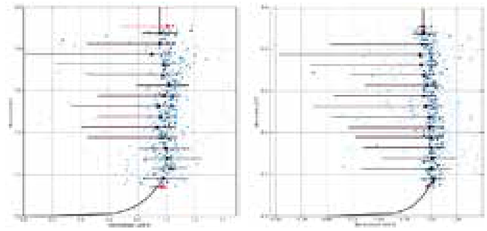
(a)



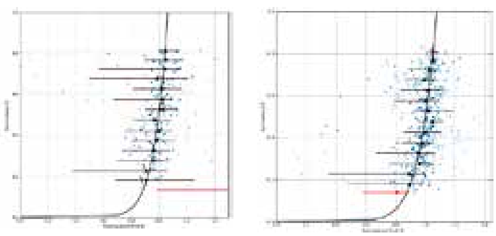
(b)



(c)



(d)



(e)

Figure 14. The extrapolation statistical analysis depending of medians for depth data of each beam cell, for cross-sections measured in 2020 survey campaign (left image) and 2021 survey campaign (right image): (a) - C10 cross-section; (b) - C11 cross-section; (c) - C12 cross-section; (d) - C13 cross-section; (e) - C14 cross-section

Figure 14 shows the medians points for an individual transect in black color. If the threshold is exceeded the dots are represented in red. The represented whiskers show the 25th percentile on each median value, and 75th percentile of all the data, for the input condition of increment. There are no significant points which fall within 50% of the limits of whiskers.
The statistical analysis of normalized data for C10-C14 cross-section point out a better fit of extrapolation results after dredging process (2021 survey campaign).

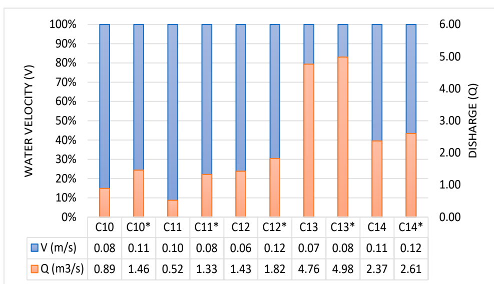


Figure 15. The discharge (Q) and water velocity increase comparison between two survey campaigns

The discharge (Q) for C13 is higher than 4.5 $m^3 \times s^{-1}$. These high values depend on fluctuation of water level in Danube River and Cordon Litoral channel junction with nearest channels. When the water flows in C14 profile direction the discharge value decrease to 2.37 in 2020 year and 2.61 in 2021. This is due of so-called effects "reverse-flow" of Danube River. These effects lead to the decrease of water velocity because the higher water level of Danube River push the water back to the channel. C14 cross-section has an accentuated sedimentation rate, versus C13 profile. The 0.125 – 0.225 $m \times s^{-1}$ water velocity value for C13 profile is proportionally distributed for more than 60% of entire length of these, contrary to C14 profile where the higher water velocity a concentrated only on left side of the cross-section. Thus, these run to sedimentation in right part of profile.

CONCLUSIONS

The ecological restoration by dredging processes of Ivancea channel and Cordon Litoral channel led to a positive effect on water flow parameter. After the ecological restoration process the average discharge for all 5 cross-sections increase with 34.82%. The water velocity also has increased its value with 25.75%, especially for C12 cross-section where the velocity increase with 66.66%, from first to second survey.

At the same moment the ecological restoration changes the entire morphology of the channel. During the first survey campaign in 2020 year, close to C11 cross-section the water depth was critically low with an average of 0.96 m, referred to BS level Datum. After the channel reconstruction the average depth at this profile climbed up to 2.04m. An important positive effect of restoration was identified for C12 cross-section, where the depth increases with more than 59.62%.

The restauration of these channel has an important role not only on hidromorphological parameters of channels, but also on the whole habitats and water ecosystems. By increases the depths, discharge and water flow velocity we facilitate the fish migrating. At the same time, by the dredging process we contribute to self-cleaning deltas water ecosystems.

The next step derived from this survey campaign is to asses from scientific point of view how we can predict the maximum discharge water flow on these channels, based on historically maximum water levels height.

ACKNOWLEDGEMENTS

The present article was supported by the project *An Integrated System for the Complex Environmental Research and Monitoring in the Danube River Area, REXDAN*, SMIS code 127065, co-financed by the European Regional Development Fund through the Competitiveness Operational Programme 2014-2020, contract no. 309/10.07.2021.

REFERENCES

Banescu, A., Arseni, M., Georgescu, L.P., Rusu, E., Iticescu, C. (2020). Evaluation of Different Simulation Methods for Analyzing Flood Scenarios in the Danube Delta. *Applied Sciences*, *10*(23), 8327. https://doi.org/10.3390/app10238327

Gâștescu, P. (2009). The Danube Delta Biosphere Reserve. Geography, Biodiversity, Protection, Management. *Rom. Journ. Geogr.*, *53*(2), 139–152.

Operational Programme for Large Infrastructure (POIM). (2016, October 24). The European Maritime Spatial Planning Platform. https://maritime-spatial-planning.ec.europa.eu/fundings/operational-programme-large-infrastructure-poim

Turunen, K., Räsänen, T., Hämäläinen, E., Hämäläinen, M., Pajula, P., Nieminen, S.P. (2020). Analysing Contaminant Mixing and Dilution in River Waters Influenced by Mine Water Discharges. *Water, Air, & Soil Pollution*, *231*(6), 317. https://doi.org/10.1007/s11270-020-04683-y

Vespremeanu-Stroe, A., Preoteasa, L. (2015). Morphology and the Cyclic Evolution of Danube Delta Spits. In G. Randazzo, D.W.T. Jackson, J.A.G. Cooper (Eds.), *Sand and Gravel Spits* (pp. 327–339). Springer International Publishing. https://doi.org/10.1007/978-3-319-13716-2_18

Wosiacki, L.F.K., Suekame, H.K., Wood, M.S., Gonçalves, F.V., Bleninger, T. (2021). Mapping of suspended sediment transport using acoustic methods in a Pantanal tributary. *Environmental Monitoring and Assessment*, *193*(8), 493. https://doi.org/10.1007/s10661-021-09266-w

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

IDENTIFICATION AND CHARACTERIZATION OF PLASTIC PARTICLES FOUND IN THE LOWER DANUBE RIVER

Mădalina CĂLMUC, Valentina Andreea CĂLMUC, Maxim ARSENI, Ira-Adeline SIMIONOV, Alina ANTACHE, Constantin APETREI, Puiu Lucian GEORGESCU, Catalina ITICESCU

[1]"Dunarea de Jos" University of Galati, 47 Domneasca Street, Galati, Romania

Corresponding author email: madalina.calmuc@ugal.ro

Abstract

Excessive production and use of plastic materials, followed by the mismanagement of plastic waste have favoured the increase of plastic particles occurrence in aquatic ecosystems. Ingestion of plastic fragments (especially micro- and nanoplastics) by aquatic fauna can lead to various diseases and disorders, which is why monitoring of plastics presence in the aquatic environment is vital. To identify the presence of plastic particles in environmental samples, several methods such as Fourier transform infrared spectroscopy (FTIR), Raman spectroscopy, microscopy, thermal extraction desorption–gas chromatography–mass spectrometry and pyrolysis–gas chromatography–mass spectrometry have been applied in the literature. In the present paper, attenuated total reflectance - FTIR spectroscopy was used to identify and characterize plastics debris found in the Lower Danube water, near the Galati City. Plastic particles collected had different shapes (i.e fragments, films, granules) and colours (blue, red, colourless). Based on infrared spectra obtained, polyethylene (PE) and polypropylene (PP) were the main polymers identified in the collected samples.

Key words: *plastic particles, FTIR spectroscopy, Lower Danube water, polyethylene, polypropylene.*

INTRODUCTION

According to the Plastics - the Facts 2021 report, annual global plastics production increased in recent years from 335 Mt (year 2016) to 367 Mt (year 2020) (Plastics Europe, 2021).

Irrational use of plastics and inadequate waste management has led the occurrence of plastic fragments in the environment (Zhang et al., 2021).

Plastics debris were found in soil, aquatic ecosystems (ocean, sea, lakes and rivers), air and biota (Ahmed et al., 2021).

The importance of monitoring plastic fragments (especially micro- and nanoplastics) in aquatic ecosystems is due to the fact that they can have toxic effects (e.g. tumor, growth inhibition, reproductive disorder, reduced survival rate, liver damage, eating disorder, inflammation) on the biota from long-term exposure (Ha and Yeo, 2018).

To assess the presence of plastics in aquatic ecosystems it is essential to identify them and characterize their chemical composition (e.g. polymer types) in order to know their origin and other information about the production process (Campanale et al., 2020).

Thermoanalytical (e.g. thermal extraction desorption coupled with gas chromatography–mass spectrometry and pyrolysis–gas chromatography coupled with mass spectrometry) and spectroscopic or spectroscopic coupled with microscopy (e.g. Fourier transform infrared spectroscopy - FTIR and Raman) methods have been used in the research literature for the identification and chemical characterization of plastic particles in environmental samples (Campanale et al., 2020).

The most used methods are the spectroscopic ones due to the fact that their main advantage is that they are non-destructive and allow the comparison of the obtained results with other instruments (Xu et al., 2019). Attenuated total reflectance (ATR) - FTIR spectroscopy is usually applied for identification of visible plastic debris (meso and macroplastics), while for microplastics analysis micro- FTIR is used (Chen et al., 2020). In this context, the main objective of this paper is to apply the ATR - FTIR spectroscopy method to confirm plastics and identify the types of polymers in the composition of visible plastic fragments taken from the lower Danube water.

MATERIALS AND METHODS

A net with 125 µm mesh was used to collect the plastic fragments from the Lower Danube water (Figure 1). The sample was taken from the sampling station located at the confluence of the Siret river with the Danube river, near Galati City - Romania (Figure 2). The sampling area was chosen strategically because this sector of the Danube represents the transport route of pollutants to the Danube Delta Biosphere Reserve (Calmuc et al., 2020).

Figure 1. Sampling of plastic particles from the Danube water

Figure 2. Location of the sampling station

In order to separate the plastic fragments from the other collected impurities (organic matter, sediments, etc.) the sample was transported to the laboratory and processed. To remove organic matter, the sample was digested with a mixture (1:1, 30 ml) of KOH 10M and H_2O_2 30% for 5 days. After digestion, the sample was neutralized with 11.67 mL formic acid (Pojar et al., 2021). Plastic debris were separated from the sediment and other impurities in a separation funnel with zinc chloride ($ZnCl_2$) 60-70% to obtain a final density of about 1.6-1.8 g/mL (Stock et al., 2019). After separation, the plastics were filtered on a quantitative filter paper with a pore size of 10 µm (Figure. 3). Plastic particles collected were analysed with ATR-FTIR spectrophotometer Bruker ALPHA (Bruker Optik GmbH, Ettlingen, Germany), (Figure 4).

Figure 3. Plastics separation

Figure 4. Analysis of plastics with ATR-FTIR

RESULTS AND DISCUSSIONS

Different types of plastic fragments were collected from the Danube water in the sampling station located near the city of Galati. Figure 5 represents a picture with plastic fragments of different shapes and colours. Based on visual observation, the collected plastics are classified according to shape into films (6 particles indicated with red arrows), fragments (3 indicated with blue arrows) and a single granule (yellow arrow). Mostly film-type plastics were

sampled (60%) (Figure 6). The colours found were red, blue and colourless.
In order to confirm the plastics and identify the type of specific polymers, each particle was analysed using ATR-FTIR spectroscopy method. This method is based on the molecular vibration of the sample after IR irradiation and obtaining information on specific bonds of plastics. To identify the type of polymer, the IR spectrum obtained is compared with the reference spectra (Käppler et al., 2016).

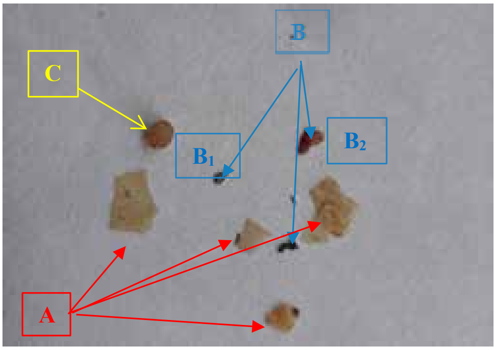


Figure 5. Visual observation of plastic particles collected from Danube water

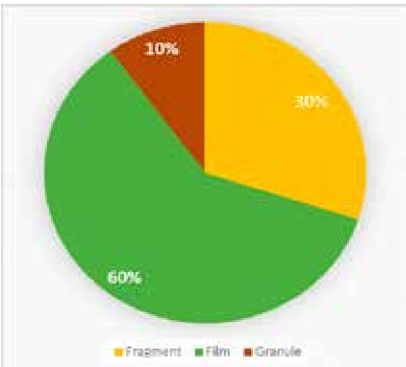


Figure 6. Types of plastic particles collected

Figures 7 and 10 show the IR reference spectra of the polyethylene and polypropylene polymers ("FTIR Polymers Spectra".). Figure 8 illustrates the IR spectrum obtained from the analysis of type A - particles (which had similar spectra). Results show significant peaks at 2915 and 2848 cm^{-1} that correspond to the C-H stretching (Syakti et al., 2018), an intense peak at 1030 cm^{-1} corresponding to -H-C-H- twisting and wagging. A medium band was observed at 717 cm^{-1} related to stretching CH_2 -CH_2 network and at 1457 cm^{-1} for CH_2 bending (Suardy et al., 2020). Based on this information, the particle A were confirmed as polyethylene (PE).

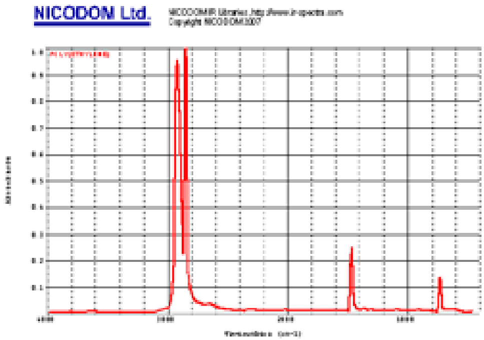


Figure 7. IR reference spectra of polyethylene

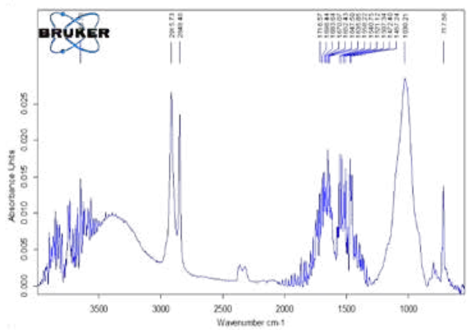


Figure 8. IR spectrum of the plastic particles A

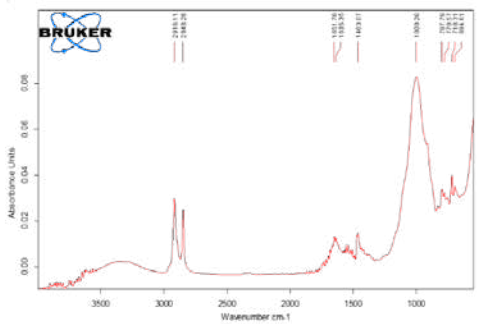


Figure 9. IR spectrum of the plastic particle C

A similar spectrum was observed for particle C (Figure 9), a medium peak in fingerprint regions at 2916 and 2848 cm^{-1} and a strong absorption band at 1000 cm^{-1} were noticed.
IR spectra for B_1 and B_2 particles represented in Figures 11 and 12 confirm the presence of the polypropylene polymer (PP) in the composition

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

of these two analysed fragments. This result is due to the presence of CH_3 stretching peaks at 2950 cm^{-1} for B_1, respectively 2950 cm^{-1} and 2867 cm^{-1} for B_2.
Furthermore, absorption band for CH_2 stretching also was observed at 2919 cm^{-1} for B_1, respectively 2918 cm^{-1} and 2839 cm^{-1} for B_2.
Table 1 summarizes the main sources of the most common polymers in the environment (Li, 2018). Bags and bottles are the main sources of polyethylene plastic particles, while the most common sources of polypropylene are bottle caps, drinking straws, yogurt containers and. tanks.
Table 2 shows reference peaks for polyethylene & polypropylene and observed IR peaks that confirmed the type of polymer in the composition of particles A, B_1, B_2 and C.

Table 1. Origin of the plastic fragments found in the environment (Li, 2018)

Type of polymer	Origin
Polyester (PES)	Fibers and textiles
Polyethylene terephthalate (PET)	Drinks bottles, jars, plastic film, tubes, pipes, insulation
Polyethylene (PE)	Bags, plastic bottles
High-density polyethylene (HDPE)	Detergent and milk bottles, tubes, pipes, insulation
Low-density polyethylene (LDPE)	Outdoor furniture, floor tiles, films
Polypropylene (PP)	Bottle caps, drinking straws, yogurt containers, tanks
Polystyrene (PS)	Packaging foam, containers, plastic tableware, CD, cassette
Polyvinyl chloride (PVC)	Plumbing pipes, window, frames, flooring, films
High-impact polystyrene (HIPS)	Refrigerator liners, packaging, cups, electronics
Polyamides (PA) (nylons)	Fibers, toothbrush bristles, fishing line, films for food packaging
Acrylonitrile butadiene styrene (ABS)	Electronic equipment cases, pipes, bumper bars
Polycarbonate (PC)	Compact disks, eyeglasses, security windows, traffic lights, lenses, construction materials

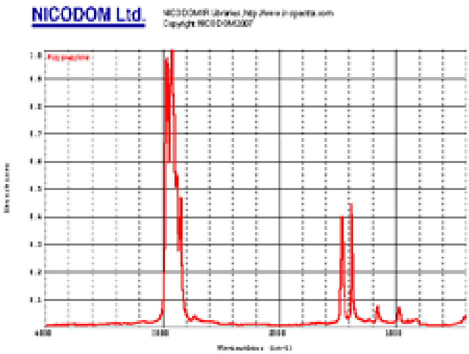


Figure 10. IR reference spectra of polypropylene

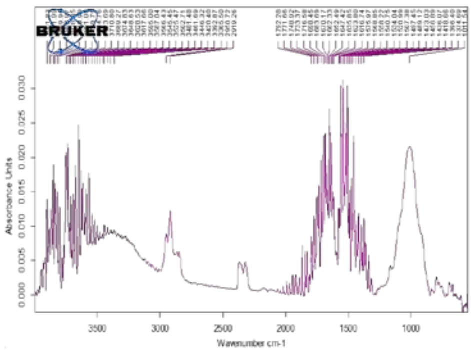


Figure 11. IR spectrum of the plastic particle B_1

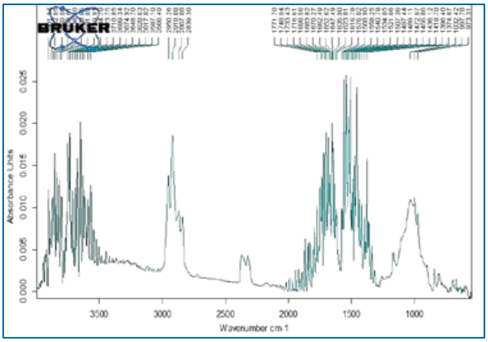


Figure 12. IR spectrum of the plastic particle B_2

Table 2. IR peaks for particles A, B1, B2, C comparison with reference peak for PE and PP

Functional group	Reference peak PE (cm^{-1}) (Suardy et al., 2020)	Reference peak PP (cm^{-1}) (Smith, 2021)	Particle A peak (cm^{-1})	Particle B_1 peak (cm^{-1})	Particle B_2 peak (cm^{-1})	Particle C peak (cm^{-1})
C-H sp^3 stretching	2911 and 2845	-	2915 and 2848	-	-	2916 and 2848
Stretching H-C-H deformation	1144	-	1030	-	-	1000
CH_2 bending	1460	-	1457	-	-	1463
Stretching CH_2 -CH_2 network	715	-	717	-	-	-
CH_3 asymmetric and symmetric stretches	-	2956 and 2875	-	2950	2950 and 2867	-
CH_2 asymmetric and symmetric stretches	-	2921 and 2840	-	2919	2918 and 2939	-

CONCLUSIONS

Plastic debris of different shapes (fragments, films, granule) and colours (blue, red, colourless) were collected from Lower Danube water. Film-type particles were mostly found (60%).

After the plastic particles were separated and isolated from the impurities, they were analysed using ATR-FTIR spectroscopy method.

Based on the obtained IR spectra, typical absorption peaks were observed that confirmed the presence of polyethylene (PE) and polypropylene (PP) polymers in the composition of the analysed plastic particles. Most of the plastic debris analysed were of the polyethylene type.

The results of this study demonstrated that the ATR-FTIR spectroscopy method is suitable for the identification and chemical characterization of visible plastics particles found in the Lower Danube water.

ACKNOWLEDGEMENTS

The present article was supported by the project An Integrated System for the Complex Environmental Research and Monitoring in the Danube River Area, REXDAN, SMIS code 127065, co-financed by the European Regional Development Fund through the Competitiveness Operational Programme 2014-2020, contract no. 309/10.07.2021.

REFERENCES

Ahmed, M.B., Rahman, Md.S., Alom, J., Hasan, MD.S., Johir, M.A.H., Mondal, M.I.H., Lee, D.-Y., Park, J., Zhou, J.L., & Yoon, M. H. (2021). Microplastic particles in the aquatic environment: A systematic review. *Science of The Total Environment*, *775*, 145793.

Calmuc, M., Calmuc, V., Arseni, M., Topa, C., Timofti, M., Georgescu, L.P. & Iticescu, C., (2020). A Comparative Approach to a Series of Physico-Chemical Quality Indices Used in Assessing Water Quality in the Lower Danube. *Water, 12*, 3239.

Campanale, C., Savino, I., Pojar, I., Massarelli, C., & Uricchio, V.F., (2020). A Practical Overview of Methodologies for Sampling and Analysis of Microplastics in Riverine Environments. Sustainability, *2*, 6755.

Chen, Y., Wen, D., Pei, J., Fei, Y., Ouyang, D., Zhang, H. & Luo, Y., (2020). Identification and quantification of microplastics using Fourier-transform infrared spectroscopy: Current status and future prospects. *Current Opinion in Environmental Science & Health, Environmental Chemistry: Innovative Approaches and Instrumentation in Environmental Chemistry*, *18*, 14–19.

FTIR Polymers Spectra URL http://www.ftir-polymers.com/soon.htm (accessed 28.05.2022)

Ha, J., Yeo, & M.-K., (2018. The environmental effects of microp lastics on aquatic ecosystems, *Mol. Cell. Toxicol. 14*, 353–359.

Käppler, A., Fischer, D., Oberbeckmann, S., Schernewski, G., Labrenz, M., Eichhorn, K.-J. & Voit, B., (2016). Analysis of environmental microplastics by vibrational microspectroscopy: FTIR, Raman or both?, *Anal Bioanal Chem, 408*, 8377–8391.

Li, W.C., (2018). Chapter 5 - The Occurrence, Fate, and Effects of Microplastics in the Marine Environment, in: Zeng, E.Y. (Ed.), Microplastic Contamination in Aquatic Environments. *Elsevier*, pp. 133–173.

Plastics - the Facts 2021 • Plastics Europe, Plastics Europe. https://plasticseurope.org/knowledge-hub/plastics-the-facts-2021/(accessed 16.04.2022).

Pojar, I., Kochleus, C., Dierkes, G., Ehlers, S.M., Reifferscheid, G., & Stock, F. (2021). Quantitative and qualitative evaluation of plastic particles in surface waters of the Western Black Sea. *Environmental Pollution 268*, 115724.

Smith, B.C. (2021). The Infrared Spectra of Polymers III: Hydrocarbon Polymer. *Spectroscopy, 36*, 22–25.

Stock, F., Kochleus, C., Bänsch-Baltruschat, B., Brennholt, N., & Reifferscheid, G. (2019). Sampling techniques and preparation methods for microplastic analyses in the aquatic environment – A review. *TrAC Trends in Analytical Chemistry, 113*, 84–92.

Suardy, N.H., Abu Tahrim, N. & Ramli, S. (2020). Analysis and Characterization of Microplastic from Personal Care Products and Surface Water in Bangi, Selangor. *JSM, 49*, 2237–2249.

Syakti, A.D., Hidayati, N.V., Jaya, Y.V., Siregar, S.H., Yude, R., Suhendy, Asia, L., Wong-Wah-Chung, P. & Doumenq, P. (2018). Simultaneous grading of microplastic size sampling in the Small Islands of Bintan water, Indonesia. *Marine Pollution Bulletin, 137*, 593–600.

Xu, J.-L., Thomas, K.V., Luo, Z. & Gowen, A.A., (2019). FTIR and Raman imaging for microplastics analysis: State of the art, challenges and prospects. *TrAC Trends in Analytical Chemistry, 119*, 115629.

Zhang, K., Hamidian, A.H., Tubić, A., Zhang, Y., Fang, J.K.H., Wu, C., & Lam, P.K.S. (2021). Understanding plastic degradation and microplastic formation in the environment: A review. *Environmental Pollution 274*, 116554.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE STUDY OF HYDROLOGICAL REGIME MODELING USING HEC-RAS MODEL. CASE STUDY RIVER BASIN BAHLUEȚ

Gabriela DAMIAN (DORIN), Claudiu PRICOP, Florian STĂTESCU

"Gheorghe Asachi" Technical University of Iasi, 65 D. Mangeron Blvd, Iasi, Romania

Corresponding author email: gabriela.dorin@student.tuiasi.ro

Abstract

This paper presents the results of a hydrological simulation using HEC-RAS model within the Bahlueț river basin. In this study, the basin was modelled from the headwaters to the Târgu Frumos hydrometric station. 6 date profiles were processed between the source and Târgu Frumos hydrometric station. Precipitations were measured directly at the 2 stations considered, Cârjoaia and Târgu Frumos. Data recorded by rainfall stations over 3 days, in May 2021, were taken into account for hydrological modelling. Values reach up to 175 mm/h were recorded during the rain. At the Târgu Frumos station were recorded rainfall values of 12 mm/h, which proves the heterogeneity of the rain. Also, it is observed that the rain starts in Târgu Frumos around 16:00, stopping around 18:00. The rain continues measured at the Cârjoaia rainfall station from 18:40, with values of 175 mm/h being recorded. The data recorded at both rainfall stations shows that the river basin is subject to a variable rainfall in space and time.

Key words: *hydrological simulation, HEC-RAS, precipitations, runoff.*

INTRODUCTION

Water is one of the fundamental resources for life. The occurrence of extreme events such as droughts and floods, resulting from land use and climate change, has increased in recent decades. Over the years, land use has changed through: expansion of agriculture, increased deforestation, intensive grazing and increased urbanisation. Understanding the associated effects of land use and climate change on water resources is of paramount importance for prevention and mitigation actions.

Many studies have focused on understanding the relevant hydrological processes to create flood risk management plans. Knowledge of the different hydrological variables is an important aspect for the proper management of water resources. In this way, researchers in different fields have improved and implemented several tools related to water resources, including hydrological models.

According to Abbaspour et al. (2015), hydrological models are important for planning water resources to meet various demands by helping in their sustainable use. Hydrological modelling is the mathematical modelling of the rainfall-runoff process on slopes, resulting in a hydrograph of flow in the closing section of a catchment.

Hydrological modelling predicts the runoff from rainfall in a catchment and hydraulic modelling aims to assess the area flooded by rainfall.

Regardless of their degree of complexity, hydrological methods have at least one thing in common: they cannot do without the information provided by measurement networks, and their performance is closely linked to the availability of data (in time and space).

Flood hazard maps provide information on the extent of flooded areas, water depth and, where appropriate, water velocity, for floods that may occur over a given period. These maps are produced using various techniques such as hydrological and hydraulic modelling based on detailed mapping of the river and major riverbed.

MATERIALS AND METHODS

The study was carried out on the Bahlueț catchment which has a cumulative area of 551 km², Figure 1.

The average rainfall in the basin is 502.3 mm at Târgu Frumos and the annual temperature is 9.1°C. Hydrometrically, the basin has a temperate continental climate with cold winters and warm summers with more frequent winds from the NW in winter and from the SE in spring. This climate is characterised by heavy rainfall in early summer, which generates flooding, but also has periods of dry season.

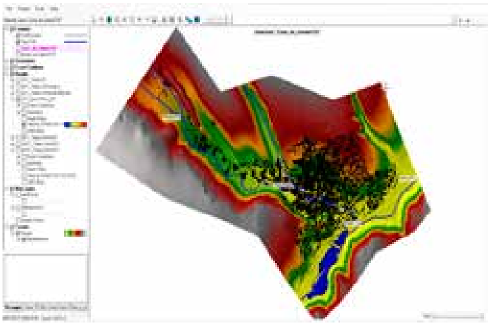


Figure 1. Area of interest under study

Seasonal precipitation losses occur in this area as surface fluxes: winter: 13.96%, spring 48.62%, summer 27.58%, autumn 9.84%.
The city of Târgu Frumos, due to its geographical position, is vulnerable to flooding. The Bahlueț River is the subject of the present study, constituting a potential hazard for the city and its surroundings. It is in this perspective that this study comes to create and manage the database on flood risk in the Bahlueț basin.
The chosen approach involves a hydrological study, the choice of profiles and the construction of a model using the most common free modelling software HEC-RAS (Hydrologic Engineering Center - River Analysis System).
For the catchment under consideration for which recorded flow data were available, the program provides, from local rainfall data, the calculation of rainfall in the catchment and its transformation into flow by HEC-RAS.
In this study, hydrological modelling was performed with the HEC- RAS 6.0 program with two-dimensional version and according to the following methodology:
1. Preparation of topographic data. Topographic data provide a physical description of the area. The DTM for the area of interest was extracted using ARCGIS and Global Mapper software.
2. Preparation of hydrological data. These data include rainfall, input data and boundary conditions.
3. Development of a hydrological model that simulates rainfall-runoff modelling processes and generates results for the study area.
4. Validation of HEC-RAS model results.
In terms of input data, the HEC-RAS model requires a stream of observed data, knowledge of the topography of the catchment using a digital terrain model, a land use map of the study area and other information that will ultimately lead to valuable results.
However, water pathways, from the moment the raindrop meets the land surface to the possible flow in a river, depend on a multitude of factors variable in space and time (HL - hydraulic length, representing the longest path of a water droplet from the point of rainfall to the control section); Tlag - the time between the centre of gravity of the rain and the top of the flow hydrograph; Concentration time - the time it takes for the furthest droplet to reach the control section (equals in principle 1.67 Tlag and represents the duration of the computational rainfall) (Balan, I. et al., 2015).

RESULTS AND DISCUSSIONS

In the case of the study, sub-basin modelling was carried out from the source to the Târgu Frumos hydrometric station within the Bahlueț catchment over an area of 63 km² (Figure 2).

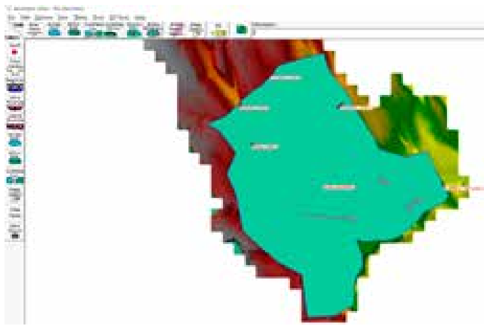


Figure 2. The simulation area considered

The hydrological behaviour of the catchment is governed by all the physical characteristics. Slope, geology, pedology, degree of anthropisation, vegetation cover are all physical factors that can have an impact on runoff velocity, runoff rate, infiltration and flood control (Stătescu et al., 2011).

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Characteristic land use layers and information on existing soils within the study catchment were added to determine the CN (Figure 3).

Figure 3. Land use in the Bahlueț catchment area

Land use within the Bahlueț watershed is predominantly agricultural, with cultivated land and pasture (Figure 4).

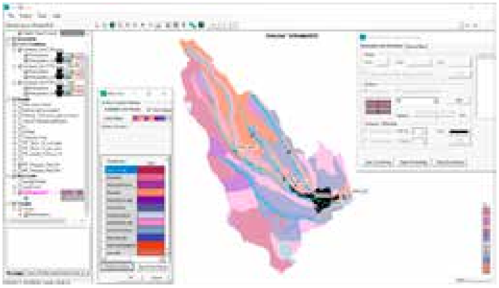


Figure 4. Soils within the Bahlueț catchment area

Physico-chemical characterisation of the initial state of soils is carried out to determine the condition of a site before any work is started.
Research carried out in the Bahlueț catchment revealed a variety of soil cover. According to their characteristics and limitations, soils in the studied area were classified into 5 classes, from II to VI (SRTS 2012) (Dorin G. et al., 2021).
The predominance of soils of the cernoziom type is observed: cambic, clayey but also grey soils, erodic anthrosoil, rocky, pseudoglacial, lacustrine and pseudorendzine. They are soils of different fertility due to their physico-chemical properties (Dorin G. et al., 2021).
Data recorded by rain gauge stations during 3 days from May 1 to May 3, 2021 were taken into account for the hydrological modelling. The two rain gauge stations were chosen because of their favourable position with respect to the whole basin.
Precipitation was measured directly at the two stations considered, at Cârjoaia and Târgu Frumos.
The analysis of the rainfall recorded at the rain gauge stations shows significant differences between the two rain gauge stations Cârjoaia and Târgu Frumos, (Figure 5).

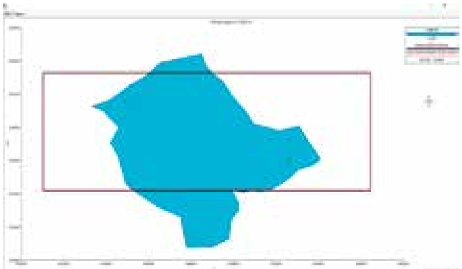


Figure 5. Rain gauge and hydrometric stations

The data of 6 profiles between the top of the basin and the Târgu Frumos hydrometric station were processed (Figure 6).

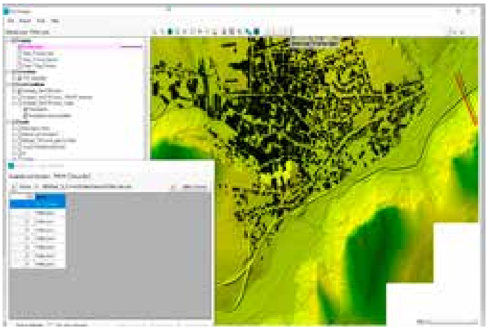


Figure 6. Implementation of line profiles

The selected profiles are perpendicular to the direction of flow, they do not intersect each other, cover the entire floodplain and take into account the geomorphological changes of the major riverbed.
A rain gauge allows only a single measurement which is not always representative of the rainfall received by a catchment. For the selected sub-basin from the top of the catchment to the Târgu Frumos hydrometric station, rainfall was calculated using the Thiessen polygon method (Figures 7 and 8).

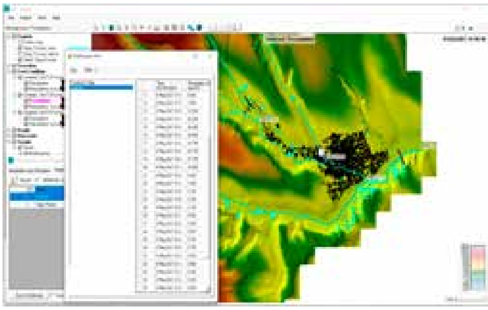


Figure 7. Precipitation calculated by Thiessen method at Cârjoaia rain gauge station

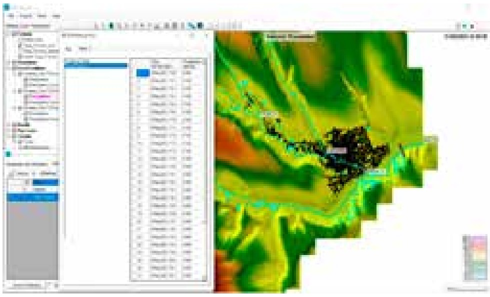


Figure 8. Precipitation calculated by Thiessen method at Târgu Frumos rain gauge station

Based on the entered rainfall data as well as the other parameters, the program was run to simulate the entered rainfall. The run was carried out in several steps and was analysed with great care (Figure 9).

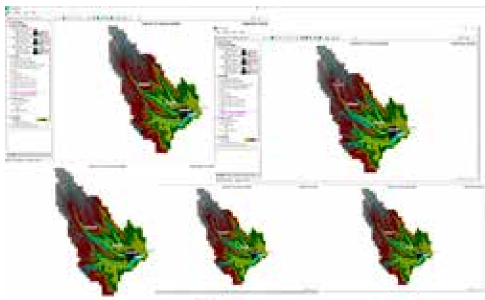


Figure 9. Hydrological rainfall simulation results

It is noted that during the rainfall considered, values of up to 175 mm/h were recorded. At the Târgu Frumos rain gauge station rainfall values of 12 mm/h were recorded, which proves the heterogeneity of the rainfall.
The rain started in Târgu Frumos around 16:00 and stopped around 18:00. The rain continues from 18:40 at the Cârjoaia rain gauge station, recording cumulative rainfall values of 175 mm/h (Figure 10).

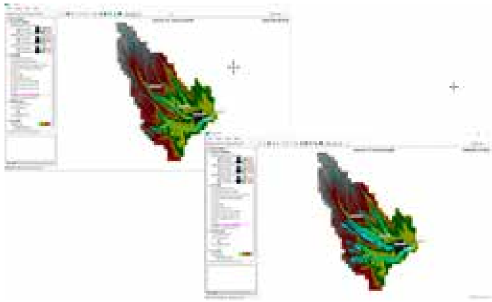


Figure 10. Hydrological rainfall simulation results

Modelling is the basis for identifying and prioritising the right measures. It can flag potential problems/risks before they arise. Modelling answers the "what if" question. Allows modelling of urban areas that usually have complex two-dimensional behaviour, surface runoff and sewerage system (Balan, I. et al., 2016).
The data recorded at the two rain gauge stations show that the catchment is subject to a spatially variable rain field. In order to limit the dispersion of the shape coefficient it is indicated to avoid too large time steps therefore a time step of 10 minutes was chosen in the study.
It is observed that the magnitude is consistent in areas with regular slopes, whether they are steep or not.
Modelling runoff from hydrological precipitation allowed us to both visualise surface runoff and predict it in the studied catchment (Figure 11).

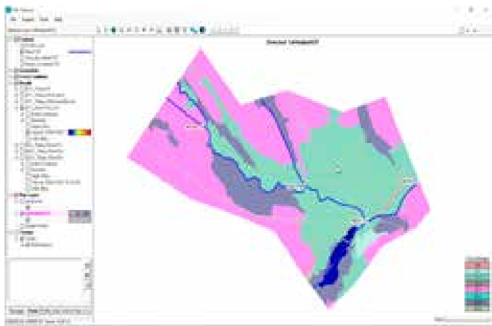


Figure 11. Curve number CN

Forested areas show low surface runoff values due to their excellent infiltration capacity as well as their ability to recycle water back into the atmosphere creating a perfect balance for the environment. These forested areas have flood mitigation potential if they are located upstream of the catchment or if a substantial part of the catchment is occupied by continuous forests.

Grasslands have the most balanced water retention capacity compared to arable and artificial land, and have a high potential for interception, infiltration and storage of rainwater falling on the soil surface.

Arable land shows high values of surface runoff with low water holding capacity compared to other vegetation types especially where the soil through different agricultural practices can be compacted.

Artificial areas, such as housing, industrial and commercial buildings, have a substantial local impact on water runoff, as soil sealing and compaction prevent or drastically decrease the capacity of soils to allow water infiltration and exchange with the atmosphere, favouring the shutdown of the natural circuit and increasing temperatures (Stătescu et al., 2004).

It has been shown that the volumes of water transported by floods and the volumes of runoff generated by rainfall follow the same spatial distribution.

At the same time, flood amplification or attenuation downstream of the basin depends on the amount of rainfall received by the basin, but a flood can be attenuated downstream even if the rainfall amounts are significant.

Rainfall can be evenly distributed over a period or can vary greatly over the same period. The duration can also be long or very short.

The hydrological study is a very important step in the study of flood protection, its objective being to recognise floods by peak flow aspects. This stage is essential for the hydraulic simulation of the Bahlueț River.

CONCLUSIONS

The second half of the 20th century saw considerable advances in the understanding of rainfall-runoff processes, emphasizing the fundamental role of saturated zones in the generation of streamflow. Also, due to increasing resource capacity, hydrological modelling has increased enormously from global to distributed modelling.

Adequate knowledge of rainfall runoff processes is essential to estimate the amount of runoff produced in a basin for planning and management of sustainable water resources projects. Activities for estimating runoff volumes and flood peaks can be easily simplified by adopting a modelling concept and understanding rainfall partitioning and the main factors that trigger runoff.

The process of transforming rainfall into runoff over a basin is complex and exhibits both temporal and spatial variability. However, within a catchment the variability is mainly controlled by the physical and chemical properties of the ground surface.

Runoff occurs when the rainfall rate over a given area exceeds the rate at which water can infiltrate into the soil. Runoff occurs more frequently in areas where rainfall intensities are high and the infiltration capacity of the soil is reduced due to surface sealing.

The generation of runoff is an important factor in both soil loss and the movement of nutrients from the soil surface, resulting in reduced soil productivity and crop yields, especially in agricultural land. Some studies have shown that in areas with fine textured soils, runoff can range from 8% to 49% of annual rainfall depending on prevailing conditions.

The Bahlueț catchment covers an area of 551 km². Within the catchment, lands with slopes ranging from 9-19% dominate, thus showing that slopes create the dominant landscape of the studied area and it is observed that most of the catchment describes a hilly landscape.

The town of Targu Frumos and its surroundings have experienced excessively violent floods over time causing significant damage. Overflows of the Bahlueț River during rainy periods are one of the main sources of flood risk for the city which continues to increase due to human action.

This study presents a simulation of the May 2021 flood event and focuses on the upstream section from the headwaters to the Tg. Frumos. This simulation is performed using the two-dimensional capabilities of the new HEC-RAS version 6.0 program. The simulation provides very useful information for decision makers.

The simulation results are used to estimate and assess flood damage as well as for flood control planning.

A better knowledge of the rainfall amounts during floods, in particular their spatial distribution, will increase model performance.

Estimation of received rainfall at the basin scale could be improved with the enriched network of automatic rain gauge stations.

The importance of soils as well as land use in the rainfall-runoff process has been proven, therefore: analysis of soil properties, detailed analysis of land use in the inundation area, impact of land use changes and further on different scenarios can be analysed to obtain the best results.

Modelling aims to limit flood risks and prevent droughts through better land management. Hydrological modelling can also be complemented by hydraulic modelling to develop flood scenarios for different volumes of water to improve flood risk management. (Stătescu et al., 2010)

Putting modelling to work as a tool for understanding the hydrological functioning of catchments and as a decision aid is one of the best methods recognised as both simple and with high quality results.

REFERENCES

Balan, I., Crenganiş, L., Pricop, C. (2015). Flood analysis using hydrological modeling. case study– the flood in the upper catchment of river Geru, Galaţi county, Romania. *Present Environment and Sustainable Development*, (2), pp. 125-138.

Balan, I., Crenganiş, L., Corduneanu, F., Pricop, C. (2016). Popoiu, L. A., Infiltration Losses Calculated for the Flash Flood in the UpperCatchment of Geru River, Galaţi County, Romania. *Present Environment and Sustainable Development*, 10(2), pp. 219-234.

Dorin G., Stătescu F., Stan A. N., Pavel V. L., Marcoie N. (2021). Analysis for soils characterization in the purpose of rainfall-runoff process modelling.

Stătescu F. (2004). *Evolution of ameliorative soils*, Politehnium Publishing House, Iasi.

Stătescu F., Cotișcă-Zaucă D., Pavel V.L. (2010). Parametric models for the soil hydraulic functions, Ovidius University Annals - Constanza, Civil Engineering.

Stătescu F., Cotișcă-Zăucă D., Pavel V.L. (2011). Soil porosity and pore size distribution, Scientific Bulletin of the Polytechnic University of Timișoara, *Hydrotechnical Series*, Tom 56(70), Fascicola 1, 59-62.

Stătescu F., Pavel V.L. (2011). *Soil Science*, Politehnium Publishing House, Iasi.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

CONTINUOUS ADJUSTMENT WITHIN WASTEWATER TREATMENT PLANTS OPERATION TO MEET NATURAL RECEPTORS DISCHARGE CONDITIONS

Dragos DRACEA, Augustina TRONAC, Sebastian MUSTATA

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: augustina.tronac@yahoo.com

Abstract

Wastewater treatment plants are designed for input data considered constant and are checked for maximum values according to the imposed loads. During operation, the values of flows and loads at the wastewater treatment plant entrance point change within wide limits. In order to achieve the treatment efficiency, exploitation measures are adopted to ensure the water discharge within the legal admissible limits. These safety measures involve additional operating costs or risk in discharging water with quality indicators not allowed compared to those required by current legislation. Technological adjustment mechanisms must be provided in the design and operation stages.

The present paper highlights a procedure for technological processes regulating when occurs significant loads variation at the wastewater treatment plant entrance point and demonstrates its importance.

Key words*: natural receptors discharge conditions, wastewater treatment plant, treatment efficiency.*

INTRODUCTION

Sewage systems serve communities with the aim of taking over domestic or industrial wastewater, transporting it to wastewater treatment plants and disposing it in quality conditions that do not affect the environment. The treated water can be discharge or used for agricultural purposes (Panaitescu, 2014) and sludge, by-product of the wastewater treatment, must be discharged or used in correlation with their qualities (Preda, Tanase, Vrinceanu, 2017). The importance of the quality indicators values at the discharge point of wastewater treatment plants is special cause to the fact that wastewater is relatively nutrient-rich, has contaminating potential and could degrade the environment (Sanderson et al., 2019), effluents could be source of nutrient for different aquatic systems (Kendall, Doctor, Young, 2014) that unbalance when they are not well treated.

Sewage systems could be separative or unitary, the realized variants implying, through the collected and transported waters, flows time-variable in wide range. Flow variations depend on the hourly consumption coefficients for domestic activities, the industrial activities type, the sewage system, the water supply networks losses, the amount of water coming from the drainage systems, the meteorological phenomena.

Wastewater treatment plants host physical, chemical, biological processes difficult to describe and manage in particular cause to the variability of quantities and characteristics of inlet water (Nasr et al., 2021). The use of appropriate techniques leads to remove wastewater pollutants such as organic matter and nitrogen, diminishing wastewater adverse effects (Bassin et al., 2021).

Under these conditions, the amount of water, the concentrations and the quantities of pollutants at the entrance to the wastewater treatment plants register significant hourly variations. For each sewage system and wastewater treatment plant is important to make Mathematical models of the transport system, measurements of flows and concentrations at the plant admission point, as well as the implementation of operating procedures adapted to the conditions recorded at the entry section.

In order to highlight the hourly variations of the quality indicators for the wastewater at the plant admission point, laboratory measurements

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

of the main indicators were performed in different stages.

MATERIALS AND METHODS

CASE STUDY NO. 1

Following the main indicators for a treatment plant designed for 100,000 equivalent inhabitants (e.i.) by measurements over 8 days, the variation of the wastewater suspensions concentration before the treatment plant entering point is represented (Figure 1).

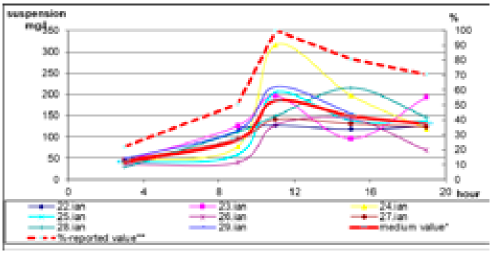


Figure 1. Variation of suspension concentrations at the treatment plant entrance point: *hourly average values, **reported values - percentage of hourly average from the value of the maximum hourly average

Wastewater suspension concentration at the treatment plant entrance point registers hourly variations between 40 mg/l and 320 mg/l. The minimum value is recorded during the night, corresponding to a low water consumption, a high degree of dilution due to water loss and settling and deposition at low flow rates in the sewage system. The maximum value corresponds to the morning hours, when there are registered high water consumption, and the highest transit flows.

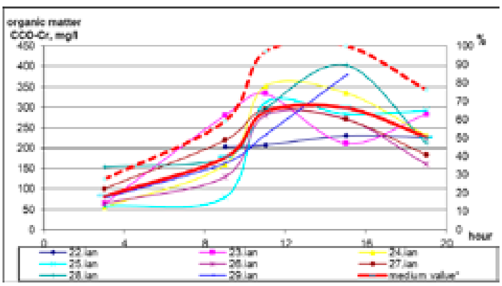


Figure 2. Chemical oxygen consumption variation, CCO-Cr for wastewater at the treatment plant entrance point: *average hourly values, **reported values - the percentage of the hourly average from the value of the maximum hourly average

Also, for the same time period, the CCO variation for raw wastewater is recorded and represented.

The quality indicator chemical oxygen consumption, CCO-Cr has a similar evolution as suspension concentration, the registered values being situated between 50 mg O_2/l and 400 mg O_2/l.

Regarding the ammonia nitrogen content in the wastewater at the treatment plant entrance point, the same significant variations identified in the previous indicators presented are found; the recorded values are between 5 mg/l and 30 mg/l. There are relatively close values for the time period (16.00-20.00) hours close to about 60% of the maximum value recorded in the morning. The morning peak value recorded can be justified by the wastewater load, also by the anaerobic fermentation processes in the sewage system and the deposits entrainment at flow rate and speed corresponding to the peak consumption.

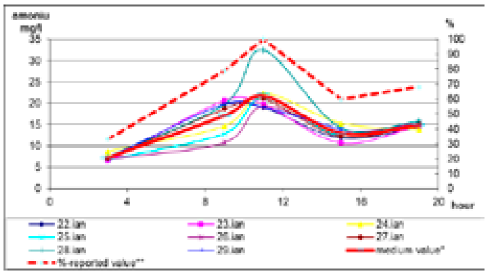


Figure 3. Variation of wastewater ammonia nitrogen content at the treatment plant entrance point: * hourly average values, ** reported values - percentage of hourly average from the value of the maximum hourly average

The analysis of the pollutant concentrations evolution at the treatment plant entrance point highlights the following characteristic periods:

- period between 1.00 am and 9.00 am is characterized by low concentration due to low socio-economic activity;
- peak values concentration is registered between 10.00 am and 1.00 pm;
- the landing period between 1.00 pm and 1.00 am.

Low flow rates during night involve reduced flow speed in sewage pipes, suspension settling and fermentation processes. Increased flow rates during morning involves self-cleaning phenomena in the transport pipes. Concentration peak concentration corresponds to the transport time, to the length of the sewage system.

The evolution graphs identify the minimum suspension concentration (c.ss.min) being 20% of the maximum determined value, the minimum chemical oxygen consumption is 25% of the maximum value, and the minimum ammonia nitrogen concentration is 30% of the maximum value.

The collected wastewater quantities by the sewerage systems are established according to the calculation flows of the water supply systems they serve. Large water supply systems involve minimum flow, night rates are of about 40-60% of the maximum flow value. The high flows can be motivated by the distribution networks water losses, the economic activity and large drainage surfaces. Under these conditions, the pollutants quantities values at the wastewater treatment plant entrance point change in the range of 100% to (10-15)%.

Corresponding to the treatment plant load evolution, the technological processes must be adapted and adjusted for the two characteristic periods:

- with reduced load between 1.00 am and 11.00 am;
- with high load for the rest of the day.

Depending on the treatment plant technological type, the discharged water minimum concentrations values will be registered between 6.00 am and 3.00 pm, the maximum values will be found between 4.00 pm and 0.00 am.

CASE STUDY NO. 2

Performing the same type of measurements for a wastewater treatment plant operated for 30,000 e.i., the results obtained previously are confirmed.

Presented hourly flows evolution in wastewater treatment plant during 3 days (Figure 4), there are found reduced flows of wastewater during the night, indicating minimum volumes of water from infiltration due to water supply network water losses; minimum flow value is about 12.5% of the maximum flow value recorded. Flow variations during operation indicate the presence in the sewage system of some wastewater pumping stations with large storage volumes.

During the same period, the measurements of the suspended matter quantities at the wastewater treatment plant entrance point show significant variations between the night and day operating regimes; the suspended matter quantities change in wide limits, from 10 kg/h to 250 kg/h.

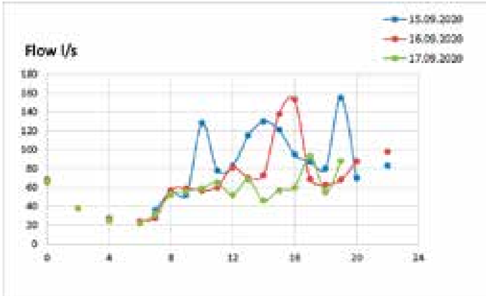


Figure 4. Hourly flows evolution in wastewater treatment plant of 30 000 e.i. during 3 days

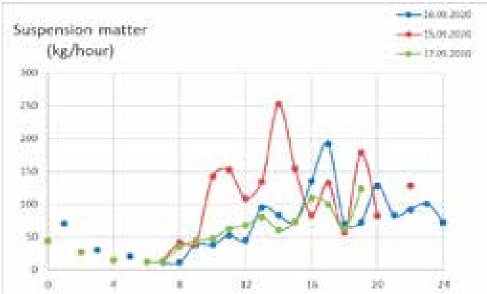


Figure 5. Suspension matter quantities evolution at the wastewater treatment plant of 30000 e.i. entrance

Ammonia nitrogen indicator evolution at the wastewater treatment plant entrance point highlights significant variations between the two operating regimes, the minimum value being 3 kg/h and the maximum one of 40 kg/h.

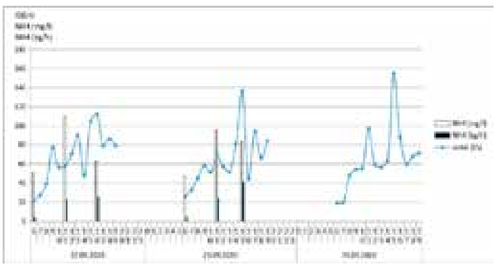


Figure 6. Flows and ammonia nitrogen quantities evolution at the wastewater treatment plant of 30 000 e.i. entrance point

CASE STUDY NO. 3

Wastewater treatment plants equipped with specific devices for quality indicators continuous monitoring highlight the hourly variations. For one of those, serving 100000 e.i., Figure 7 shows the evolution of ammonia nitrogen determined continuously.

Figure 7. Ammonia nitrogen and chemical oxygen consumption evolution for a wastewater treatment plant of 100000 e.i.

The continuous measurements performed in the wastewater treatment plant show that the values obtained using laboratory equipment and presented previously lead to the same conclusions regarding the hourly evolution of the concentrations and quantities of pollutants.

Determining the pollutants and flows quantities allow the adoption of efficient exploitation measures and the reduction of the exploitation costs by: adapting the technological treatment chain, regulating the reagent doses, regulating the internal and external recirculation flows, regulating the aeration systems, balancing the nitrification and denitrification processes corresponding to the amounts of nitrates, ammonia nitrogen and the C:N ratio.

PROCESSES ADJUSTMENT OF WASTEWATER TREATMENT PLANTS

The mechanisms for regulating the processes in the wastewater treatment plants depend on the pollutant's concentrations at the entrance point and on the degree of treatment required (NP 133, 2013).

Mainly, the process control mechanisms in urban wastewater treatment plants are related to: technological treatment chain, coagulant dose in primary decanters and chemical dephosphorylation, dissolved oxygen level, activated sludge concentration, internal recirculation, external recirculation, technological times for the nitrification and denitrification phases at the stations with sequential operation, the nutrient doses including additional carbon.

In Romania, the treatment required degree is high, the treatment plants with a capacity of over 10,000 e.i. have the task of reducing the nutrients to low values with the need to adopt complete channels with nitrification and denitrification.

Due to the low limits for ammonia nitrogen imposed by the environmental protection legislation specified in operating permits issued (total nitrogen values less than 15 mg/l) low-capacity plants also must take additional measures to reduce nitrogen through denitrification processes.

From the energy point of view, the highest consumption is recorded for biological basins aeration and for the internal recirculation necessary for denitrification in the case of wastewater treatment plants with a pre-denitrification stage.

The sequentially functioning basins do not have internal recirculation systems, the energy consumption being mainly coming from the aeration, mixing and pumping of the water in the discharge phase.

The other processes, those related to wastewater supply, sludge management and automation are found at treatment plants regardless of the architecture adopted.

In the case of sequential operation plants, the size of the batch depends on the wastewater ammonia nitrogen concentration and the degree of treatment required. Consequently, the size of the batches could be variable, with large volumes during the technological gap and with long durations at high concentrations of ammonia nitrogen.

In the case of sequential systems operated with pre-denitrification phase and discharge limits, ammonia nitrogen less than 2 mg/l, nitrates less than 25 mg/l and total nitrogen less than 10 mg/l, the batch size will involve a final concentration at feeding and pre-denitrification phase less than 7 mg/l of N-NH_4; after the nitrification phase (which involves the assimilation of 15%-20% of nitrogen, there will be a concentration of about 6 mg/l of N

transformed mainly up to 1.5 mg/l of N-NH_4 and the difference 4.5 mg/l of N-NO_3 (4.5 x 4.427≈20 mg/l NO_3).
Under these conditions, the size of the batch is given by:

$$V_{batch} \langle \frac{7}{C_{NH_4entrance}} . V_{reactor} \quad (1),$$

where:
V_{batch} - volume of the supply batch at one cycle;
$C_{NH_4entrance}$ - ammonia nitrogen concentration at the wastewater plant entrance point;
$V_{reactor}$ - biological reactor total volume.

When inlet concentration of 30 mg/l NH is registered, the batch size will be a maximum of 23% to ensure discharge with concentrations of NH_4 < 1.5 mg/l and NO_3 < 20 mg/l.
When adopting the continuous monitoring of NH_4 and NO_3 indicators in the biological basin, the water supply and the duration of the biological process phases will be automated based on the determined values, as follows: wastewater supply until reaching the level of 7 mg NH_4/l, denitrification until upon removal of NO_3, aeration to (1-1.5) NH_4 and NO_3 < 20 mg/l.
Sequential operation reactors do not ensure reliability in the case of ammonia nitrogen high concentrations wastewater. High values of concentrations require the use of a treatment flux with low batch and successive denitrification-nitrification phases that are repeated on low feed volumes and check the relationship (1); the aim is to use carbon from wastewater and obtain a high CBO_5/NO_3 ratio.
In the case of treatment plants having pre-denitrification and recirculation basin, the value of the recirculation flow verifies relationship (1) applied at the denitrification compartment exit point:

$$Q_{entrance} . \frac{C_{NH_4entrance} - 7}{7} \langle Q_{recirculation},$$

so:

$$Q_{recirculation} \rangle Q_{entrance} . \frac{C_{NH_4entrance} - 7}{7} \quad (2)$$

The design norm NP 133-2013 stipulates that the internal recirculation rate (r_i) is calculated:

$$r_i = \frac{C^D_{N-NO_3}}{C^{efl}_{N-NO_3}} - r_e \quad (3),$$

where:
r_e - external recirculation rate;
$C^D_{N-NO_3}$ - nitrogen concentration to be denitrified;
$C^{efl}_{N-NO_3}$ - nitrogen concentration permissible for discharge.
The application of relationships (2) and (3) implies close results for discharge conditions of NO_3 < 25 mg/l.
Ammonia nitrogen concentrations variations in entrance wastewater impose to change the recirculation flow value; at present, the regulation according to the plant entrance flow is usually used.
In case of biological reactor equipped with NO_3-NH_4 monitoring equipment, the technological flow can be controlled and the internal recirculation can be regulated according to the values determined at the denitrifyication compartment discharge point. Monitoring at the end of the NO_3-NH_4 biological stage and automation according to these values implies the increase of the response time to the change in the treatment flow due to the process inertia. The internal recirculation will be adjusted in order to ensure the following condition at denitrification compartment exit point:

$$N - NH_4 + N - NO_3 \langle 7 \text{ mg/l} \quad (4)$$

In practice, the internal and external recirculation are regulated as a percentage of the inlet flow without taking into account the variable concentrations of nitrogen at the wastewater treatment plant entrance point. Ensuring the compliance for the entire operation period involves high recirculation rates and unjustified electricity consumption. The qualitative and/or quantitative control of the input flows creates the mechanisms for the adoption of the necessary and sufficient recirculation with the reduction of the operating cost and ensuring the process reliability. Based on the determined values, the wastewater treatment plant operation can be performed based on the adoption of recirculation rates based on the nitrogen concentrations at the entrance point; these rates must be changed

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

hourly, values determined by statistic calculation or by continuous flow measurements.

CONCLUSIONS

The wastewater quality conditions at the treatment plant entrance point are continuously changing, registering cyclical exploitation situations, with characteristic periods: periods with low loads during the night and early morning, periods with peak loads recorded between 9 am and noon, periods with relatively constant loads in the afternoon.
In order to ensure the necessary wastewater treatment efficiencies, performant process control systems are required, depending on the pollutant quantities at the treatment plant entrance point and the effect of the pollutant concentrations in the discharged water.
Classical systems have control methods depending on the measured inlet flows and the dissolved oxygen concentration. The paper highlights the hourly variations of concentrations and quantities at the entrance point of some monitored treatment plants for the main indicators: suspensions, ammonia nitrogen and carbon. The usual adjustments cannot ensure the process regulation because the variations of the quality indicator concentrations variations change in the limits of (20-100)%, and the hourly pollutant quantity variation in a range of (10-100)%.
In the case of pre-denitrification treatment processes and related recirculation, the classical system provides percentage recirculation depending on the treated flow. In the design phase, the recirculation flows calculation is determined based on the amount of nitrate to be denitrified, amount that depends on the concentration and amount of ammonia nitrogen of the inlet biological reactor wastewater flows. The optimization of the denitrification process can be achieved only by nitrate and ammonia nitrogen indicators monitoring in the denitrification compartment; process monitoring and automating by measuring the exhaust indicators implies inertia due to technological times and the instability of regulation process. In the denitrification phase, the highest nitrogen reduction efficiency is registered, this must be controlled. Excessive recirculation flows can alter the denitrification process by transferring oxygen and reducing the C: N ratio, especially during periods of low load.
If the wastewater treatment plant does not have nitrate and ammonia nitrogen measuring equipment, the recirculation rate required for denitrification can be adjusted by introducing correction coefficients depending on the treated water flow and the values of hourly average ammonia nitrogen concentrations determined similar to those presented in this scientific paper.

REFERENCES

Bassin, J.P., Duarte Castro, F., Rocha Valerio, R., Pontes Santiago, E., Lemos Ribeiro, F., Bassin, I.D. (2021). *The impact of wastewater treatment plants on global climate change in Water conservation in the era of global climate change*, pp. 367-410.
Kendall, C., Doctor, D.H., Young, M.B. (2014). *Treatise on geochemistry*, second edition, Vol.7, pp. 273-327.
Nasr, M., Mohamed, K., Attia, M., Ibrahim, M.G. (2021). *Sustainable management of wastewater treatment plants using A.I. techniques in Soft computing techniques in solid waste and wastewater management*, pp.171-185.
NP 133-2013 - Normativ privind proiectarea, executia si exploatarea sistemelor de alimentare cu apa si canalizare a localitatilor (Norm regarding the design, execution and operation of water supply and sewage systems of localities)
Panaitescu, C. (2014). Study regarding the use of sludge and efluent from wastewater plants in agriculture, *Scientific Papers Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*, *vol. III*, pp. 9-12.
Preda, M., Tanase, V., Vrinceanu, N.O. (2017). Levels of persistent organochlorine compounds in sewage sludge form wastewater treatment plants, *Agrolife Scientific Journal vol.6, no.2*, pp. 161-166.
Sanderson, H., Brown, S.R., Hania, P., McAllister, A.T, Majury, A., Liss, S.N. (2019). *Management of Emerging public health and risks - multidisciplinary approaches to the changing environment, Chapter 7*. pp. 147-187.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

MONITORING THE PHYSICOCHEMICAL PARAMETERS OF WATER QUALITY FROM LAKE HERĂSTRĂU BUCHAREST - 2015 -2020

Constanța MIHAI[1], Bogdan ERGHELEGIU[1], Cosmin Constantin NIȚU[1], Cristina-Elena MIHALACHE[1, 2]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania
[2]Institute of Geography, 12 Dimitrie Racovita, Bucharest, Romania

Corresponding author email: mihalachecristina19@gmail.com

Abstract

Water is the most valuable natural resource and the protection of its quality is necessary. Water is a unique vital resource, without which life as we know it could not exist. Water is also a transport corridor and a very efficient climate regulator. The aim of this paper is to evaluate the effects of physicochemical indicators on water quality of Herăstrău Lake from Bucharest. Water samples were taken bi-monthly, from 2015 to 2020, 12 samples from each point and were monitoring 8 parameters, in order to design a monitoring network. Physicochemical analyzes of water samples are performed according to standardized methods. The analyzed parameters are: pH, EC, NTU, DO, BOD, COC-Mn, the concentration of nitrites and nitrates by spectrophotometry. Following the statistical analysis, a significant difference was found between the values of the studied parameters, and their correlation was verified by determining some regression functions. The results of the analyzes obtained can be used to generate thematic models on water quality monitoring and management to improve and protect biodiversity and quality of life.

Key words: *monitoring, physicochemical indicators, thematic models, water quality.*

INTRODUCTION

Water is a renewable but vulnerable and limited natural resource. It is an indispensable element for life and society, and at the same time a raw material for productive activities, a source of energy and a means of transport, and finally a determining factor in maintaining ecological balance.

Water is an excellent biological fluid. This is not only an environment containing gases, minerals or organic substances in solution, but also a living environment. All life forms need water, and through oxygen, carbon dioxide and the mineral salts it contains, it makes animal and vegetable life possible. Human activities have a profound impact on aquatic ecosystems. The result is a change in the chemical composition of natural waters and a disruption in the stability of biocenosis.

All this has led to the need to monitor the quality of surface waters, the current ecological status of surface waters, determine the sources of pollution and develop new methods of treatment, which has become a priority. Consequently, maintaining water quality is becoming more and more important (Smuleac et al., 2017).

Regardless of their location, the quality of groundwater resources is influenced by various natural and anthropogenic factors, especially if hydro geomorphological settings allow pollutants to reach the aquifer from the ground surface. Previous studies have shown that the quality of groundwater parameters may vary greatly as a result of natural conditions and human activities. (Zereg et al., 2018; Bhurtun et al., 2019).

Among the ecological problems in the aquatic environment, a major problem is eutrophication, which represents secondary pollution (Stachelek, J. et al., 2018). The major cause of water eutrophication is the supplementation, beyond the water body calibration capacity and often beyond permitted legal limits, of nutrients containing phosphorus and nitrogen. Their excess determines the abnormally increased production of algae and higher plants, leading to increased turbidity and lower dissolved oxygen concentrations,

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

phenomena which are accompanied by the disappearance of aquatic fauna. It is generally accepted that the eutrophication of surface water bodies is a major problem of water quality because it affects both economic and social environments (Violeta M.R. et al., 2019).
Water quality monitoring is important and is of increasing global concern with respect to the quality and quantity of water resources available for multiple purposes. Collecting reliable water quality data is one of the most important aspects of protecting and developing robust management plans for our rivers and lake systems. Environmental data monitoring can also be used to understand the type and severity of water quality impairments and to help decision-makers set achievable targets for improving water quality (Daniela Cîrțînă et al., 2011).
Dissolved oxygen concentration (DO) is one of the most important water quality parameters, as it reflects the balance between oxygen-producing processes (e.g. photosynthesis) and oxygen-consuming processes (e.g. chemical oxidation). DO itself depends on many interacting factors such as salinity, temperature and other water quality parameters (Liu et al., 2012; Missaghi et al., 2017) and is clearly an important element in the assessment and sustainability of complex ecological systems.
The main aim of the present work was to monitor water quality indicators that influence surface water quality.
To monitor the evolution of surface water quality in Herăstrău Lake - Bucharest, the main indicators such as pH, electrical conductivity (EC), Turbidity (NTU), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen consumption COC-Mn, nitrite (NO_2-N) and nitrate (NO_3-N) were used and analysed in the period 2015-2020.
The results obtained were interpreted according to legal standards in order to classify Herăstrău Lake into a suitable quality class and allowed to estimate the vulnerability of water resources and predict the water quality in the studied area for the period mentioned above.

MATERIALS AND METHODS

Herăstrău Lake is an anthropogenic lake placed in the northern part of Bucharest, with a surface area of 77 hectares, with 2.3 million cubic meters of water with depths up to 5 meters. Located upstream of Băneasa Lake and downstream of Floreasca Lake, it is disposed on the Colentina River and is used for fishing, irrigation, flood mitigation, recreation. Presented in Figure 1 is the map of Herăstrău Lake - Bucharest, Romania and the points used for sampling the water.

Figure 1. Map of sampling points - Herăstrău Lake, Bucharest

The water samples points from Herăstrău Lake, showed in Figure 1, were taken from six different points, in glass containers, every March between 2015 and 2020. The water samples were taken about 30 cm below the surface layer. The samples were then stored in mobile cold rooms at 4°C for transport as soon as possible to the place of analysis in order to minimize physical and chemical changes (Mala-Maria Stavrescu-Bedivan et al., 2016). Water sampling was done according to ISO 5667-6:2009 (Panaițescu et al., 2013).
The location of the 6 points was determined based on geographical coordinates, and in this way the water samples could be taken from the same place in order to maintain the accuracy of the results from a comparative point of view. This was done using a handheld GNSS receiver by determining the coordinates of the corresponding points, the points being marked by paint in the field at the lakeshore.
The geographical coordinates (longitude and latitude) of the 6 points are as follows:

- Point 1
  - Latitude: 26004’37,74114’’N
  - Longitude: 44028’35,32287’’E
- Point 2
  - Latitude: 26004’16,14375’’N
  - Longitude: 44028’21,08029’’E
- Point 3
  - Latitude: 26005’10,82811’’N
  - Longitude: 44028’38,61264’’E
- Point 4
  - Latitude: 26004’42,47064’’N
  - Longitude: 44028’44,20116’’E
- Point 5
  - Latitude : 26004’58,56988’’N
  - Longitude: 44028’58,69324’’E
- Point 6
  - Latitude: 26004’38,35277’’N
  - Longitude: 44028’55,24198’’E

The geographical coordinates were transformed into the Stereographic 1970 national coordinate system using the TransDatRO version 4.06 transcalculation program, which resulted in the following points:

- Point 1
  - East (m): 585812.10
  - North (m): 331316.96
- Point 2
  - East (m): 585340.68
  - North (m): 330871.03
- Point 3
  - East (m): 586541.88
  - North (m): 331428.30
- Point 4
  - East (m): 585912.95
  - North (m): 331592.37
- Point 5
  - East (m): 586262.69
  - North (m): 332044.41
- Point 6
  - East (m): 585817.41
  - North (m): 331931.91

The analysis was performed according to current standards using the appropriate equipment and devices, as the pH was potentiometrically determined using the pH meter, electrical conductivity (EC) with conductivity meter WTW MULTI 340i, turbidity was determined using a turbidimeter whit unit of measurement NTU (nephelometric turbidity units), dissolved oxygen (DO) - Winkler titration, biochemical oxygen demand (BOD) 5-days incubation - Winkler titration and chemical oxygen consumption COC-Mn-permanganate titration. The concentrations of nitrite (NO_2-N) and nitrate (NO_3-N) were determined by the spectrophotometric means, for nitrates was used phenoldisulphonic method and nitrites was quantified by the Griess reaction (the sample was treated with sulphanilic acid and naphthyl-1-amine in acidic medium).

To represent the evolution over time of the values of the parameters studied, thematic maps have been created using the QGIS software. QGIS is an open-source desktop geographic information systems application that supports visualization, editing and analysis of geospatial data.

Thematic maps have been developed for the first and last water sampling years (2015 and 2020 respectively). The variation of the parameters for the entire period monitored is presented in the graphs which show the evolution recorded in the 6 points throughout the period analysed.

The annual average parameter values were compared using confidence levels (significance level alpha = 0.05), which were calculated using the Microsoft Excel Data Analysis Module. Some important statistical differences between the years analyzed have been observed. The 2D and 3D regression curves were determined in Excel, and the 3D charts were created in the 3D plotter from the website https://academo.org/.

RESULTS AND DISCUSSIONS

The physico-chemical results of the analysed samples from Herăstrău Lake - Bucharest, Romania are presented in Table 1 and are compared with the maximum permissible values provided by the national and European legislation in force.

The approach to the surface water quality objectives was carried out through the assessment according to the provisions of Regulation 161/2006, which classifies surface waters from a chemical and ecological point of view, and the European Parliament and Council Directive 2000/60/EC establishing a framework for Community action in the field of water policy.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Table 1. Outcomes of water quality parameters in Herăstrău Lake between 2015 and 2020

Parameter	CMA	Points / years	P_{1m}	P_{2m}	P_{3m}	P_{4m}	P_{5m}	P_{6m}
pH	6.5÷8.5	2015	7.68	7.73	7.59	7.63	7.65	7.69
		2016	8.03	8.15	7.85	7.93	7.73	7.91
		2017	9.24	9.21	9.08	9.18	8.93	9.15
		2018	9.15	9.18	9.13	9.21	9.11	9.16
		2020	8.67	8.62	8.68	8.60	8.58	8.65
		Interval	7.59 ÷ 9.24					
EC (µS/cm)	250	2015	385	393	365	378	369	381
		2016	425	416	395	421	411	423
		2017	436	438	437	438	435	438
		2018	476	474	470	471	469	473
		2020	508	510	506	508	505	507
		Interval	365 ÷ 510					
Turbidity (NTU)	≤ 5	2015	5.45	5.68	5.35	5.42	5.32	5.51
		2016	5.73	5.82	5.65	5.59	5.71	5.81
		2017	5.79	6.20	5.62	5.45	5.34	5.43
		2018	5.85	6.10	5.98	5.85	5.92	6.10
		2020	6.10	5.92	6.40	6.35	6.21	6.15
		Interval	5.35 ÷ 6.40					
DO (mg O_2/l)	9 ÷ ≤ 4	2015	4.56	4.34	5.35	5.89	4.63	5.24
		2016	4.72	4.65	5.63	6.05	4.82	5.92
		2017	4.65	4.24	5.67	6.15	5.35	5.82
		2018	8.65	9.35	8.83	9.65	8.74	9.24
		2020	9.29	11.50	9.50	11.30	10.21	10.45
		Interval	4.24 ÷ 11.50					
BOD (mg O_2/l)	3 ÷ >20	2015	7.15	6.83	7.64	7,22	7.55	6.95
		2016	7.43	7.10	7.22	7,13	7.34	7.25
		2017	6.88	7.22	8.67	7,35	7.64	8.15
		2018	6.74	6.33	7.84	7,05	6.82	7.43
		2020	6.54	5.77	7.15	6,92	6.75	6.93
		Interval	5.77÷ 8.67					
COC-Mn (mg O_2/l)	5 ÷ >50	2015	14.8	16.5	15.6	17.3	15.3	16.8
		2016	15.8	16.9	15.4	16.8	15.2	16.5
		2017	16.3	17.1	16.6	17.9	16.8	17.3
		2018	11.3	12.6	11.6	14.6	12.4	13.2
		2020	9.7	8.7	9.3	8.3	8.8	9.4
		Interval	8.3 ÷ 17.9					
NO_2-N (mg/l)	0.5	2015	0.02	0.01	0.3	0.3	0.05	0.1
		2016	0.3	0.02	0.3	0.2	0.2	0.3
		2017	0.01	0.03	0.3	0.3	0.3	0.3
		2018	0.2	0.2	0.3	0.2	0.3	0.2
		2020	0.33	0.33	0.31	0.30	0.32	0.31
		Interval	0.01 ÷ 0.33					
NO_3-N (mg/l)	25-50	2015	58.23	57.45	59.05	58.68	57.25	58.15
		2016	59.15	58.63	58.85	59.15	58.23	58.05
		2017	61.04	61.32	61.18	61.32	59.86	60.75
		2018	68.35	65.45	63.58	66.45	64.53	65.35
		2020	71.12	70.56	68.86	69.58	69.68	70.25
		Interval	57.45 ÷ 71.12					

The pH values ranged from 7.59 to 9.24 pH units (Figure 2), which are in the slightly neutral to moderately alkaline range and show a slightly increasing gradient from 2015 to 2020. pH values above 8.5 can be disturbing to aquatic life and the basic environment could lead to decreased fecundation in some fish species. These values indicate pollution with inorganic compounds and correlated with high salinity content, while turbidity ranged from

5.35 to 6.40 (Figure 3) that places the water from the lake under investigation in Quality Class III.

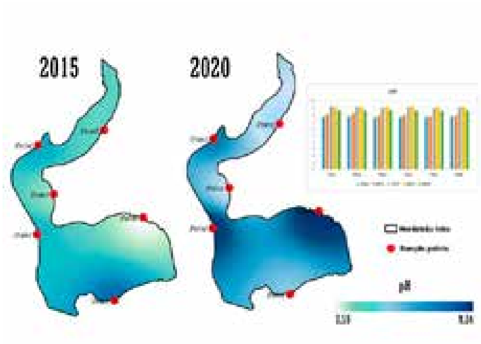


Figure 2. Results of pH and generated model maps

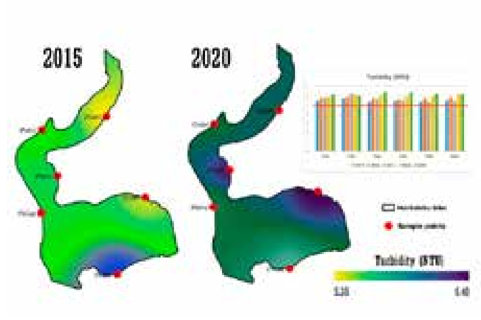


Figure 3. Results of Turbidity and generated model maps

The conductivity of water is one of the indicators used in assessing the degree of mineralization of waters by the determination of dissolved salts in the water.
Quality indicators specific to salinity, such as calcium, magnesium, sodium, and potassium, are substances of natural origin and are not related to pollution. It is proportional to the mineralization of the water, so the richer the water is in ionized mineral salts, the higher the conductivity (Derwich et al., 2010).
Following the measurements, with electrical conductivity values between 365 and 510 µS/cm, the water of Herăstrău Lake is considered to be mineralised (Figure 4) and falls into the second quality class of surface water, as EC values of 250 µS/cm are considered optimal and the water is in good condition.
Quantifying the concentration of dissolved oxygen DO (Figure 5) in the water of a hydrological system is a rather important factor because it is involved in most of the chemical and biological processes in these aquatic environments (Rodier et al., 1984; Brahimi and Chafi, 2014).

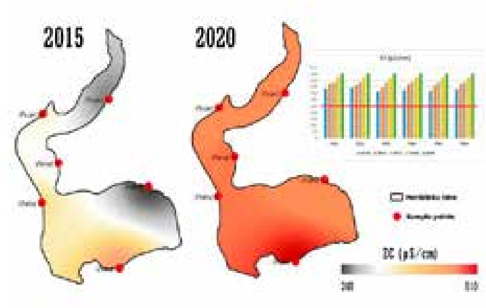


Figure 4. Results of EC and generated model maps

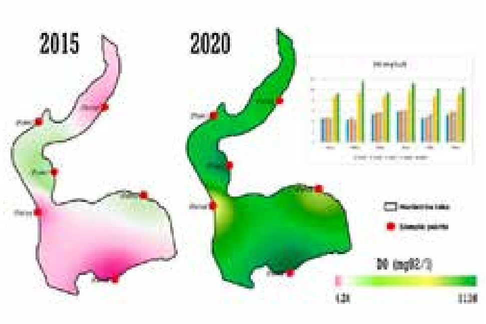


Figure 5. Results of DO generated model maps

The evolution of dissolved oxygen in the water Herăstrău Lake samples shows a significant degradation of the quality of this water during 2015-2017 correlated with high turbidity values, but improving for the following years (Figure 5).
The BOD values in the analyzed samples fall in the third quality class indicating a poor ecological status of the water (Figure 6). Biochemical and chemical oxygen analyses are low, with values obtained ranging from 5.77-8.67 mg O_2/l BOD and 8.3-17.9 mg O_2/l COC-Mn therefore (Figure 7), these parameters classify the studied water body in quality class III in 2015 compared to the values obtained in 2020, which falls in quality class II.

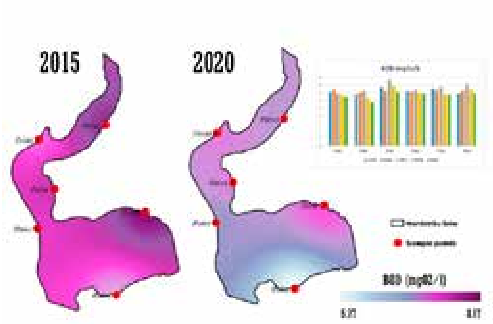


Figure 6. Results of BOD and generated model maps

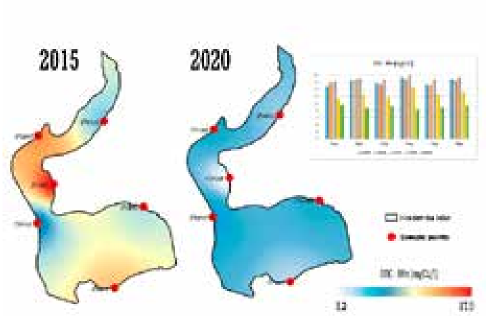


Figure 7. Results of COC-Mn and generated model maps

The assessment of nitrite concentration led to a classification of the monitored water as quality class I, according to MO 161/2006, and from the graphical representation (Figure 8) of the nitrate variation, it can be observed the increasing trend of NO_3-N concentration which recorded a maximum of 71.12 mg O_2/l in 2020.

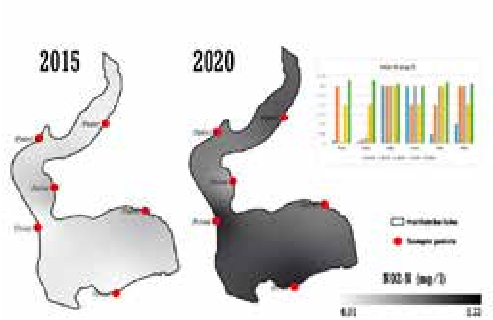


Figure 8. Results NO_2-N and generated model maps

The variation of nitrate (Figure 9) content in the water of Herăstrău Lake was also monitored, where it recorded high values between 57.45-71.12 mg NO_3-N/l, indicating the final mineralization phase of organic nitrogen compounds and a high degree of eutrophication. As a result of this process, the balance of aquatic organisms is deteriorating and the quality of surface waters is decreasing.

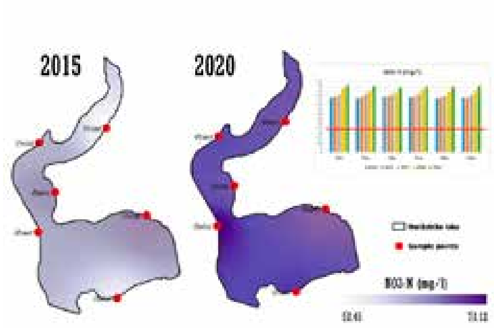


Figure 9. Results of NO_3-N and generated model maps

To conclude, overall, the values of the parameters monitored progressively increased between 2015 and 2020, with an upward trend. Regarding these data, univariate and multivariate statistical analyzes (similarity tests) were performed for the main components, to determine the different correlations between these studied parameters.
Regarding the parameters pH and EC, from one year to another the confidence interval did not intersect, the differences between the means are significant. At the same time, the differences between the means of turbidity are significant berween the years 2015-2016 (Figure 10).

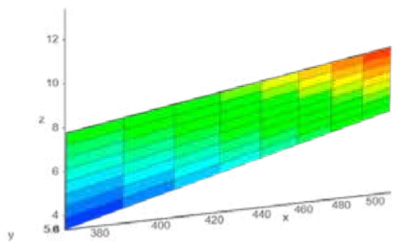


Figure 10. Correlation between pH, EC and Turbidity parameters

In the case of the DO parameter the differences between the means are significant between the years 2015-2016, 2017-2018. Analyzing the

BOD_5 was found that the differences between the means are nonsignificant from one year to another (Figure 11).

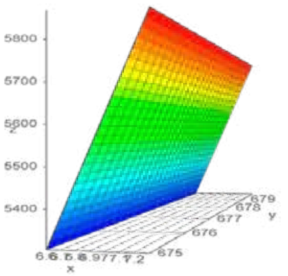


Figure 11. Correlation between DO, BOD_5, COC-Mn parameters

Further, the following analyzed parameters showed significant differences between the means as follows: COC-Mn between the years 2017-2018, 2018-2020 (Figure 11), NO_2 between the years 2018-2020 and NO_3 between the years 2016-2017, 2017-2018, 2018-2020 (Figure 12).

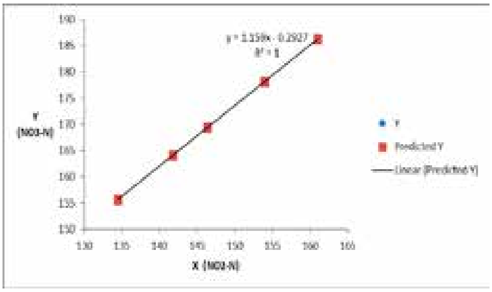


Figure 12. Correlation between NO_3-N and NO_2-N parameters

CONCLUSIONS

Based on the quality parameters evaluated, their structure was analyzed in quality classes for the lake being evaluated. It has been found that the monitored indicators are generally included in the quality classes II and III according to MO 161/2006, although the concentration of nitrates in Herăstrău Lake are specific to values of quality class IV according to the above-mentioned order. Comparing the national legislation in force (Order of the Minister of the Environment and Water Management no. 161/2006 for the approval of the Regulation on the classification of surface waters in order to determine the ecological status of water bodies) with the results obtained on the water quality of Herăstrău Lake, led to the following conclusions: - for the dissolved oxygen indicator, DO, values were recorded below the DO content corresponding to quality class a-II (O.D.=7 mg/l); - for the indicator chemical oxygen consumption, COC-Mn (maximum allowed concentration is 50 mg/l, quality class III), no exceedances were recorded; - for the indicator electrical conductivity, EC, no exceedances were recorded (EC (µS/cm) = 250, quality class II); - for the indicator nitrates NO_3-N/l, exceedances were recorded (mg NO_3-N/l=50, quality class IV).
Other quality indicators showed similar values for the six sampling points. As a result of this study, Herăstrău lake was classified as a mesotheutrophic lake.
Water quality in this lake is influenced by human activities along the shoreline, including residential areas not connected to the sewer system and small industrial units. Sources of water degradation include vegetation or pesticides produced by park treatments.

ACKNOWLEDGEMENTS

The present work was funded by the University of Agronomic Sciences and Veterinary Medicine of Bucharest – Romania, Research Project 1262/30.07.2021, acronym Feed4fish in the competition IPC 2021.

REFERENCES

Bhurtun, P., Lesven L., Ruckebusch C., Halkett C., Cornard J.P. & Billon G. (2019). Understanding the impact of the changes in weather conditions on surface water quality. *Science of the Total Environment,* 652, pp. 289-299.

Brahimi, A. & Chafi, A. (2014). Contribution to the Study of surface Waters pollution of Wadi Meboudja. *J. Mater. Environ. Sci. 5*(5), pp. 1671-1682.

Cîrţînă, D. (2011). Aspecte privind monitorizarea calităţii apelor de suprafaţă. *Annals of the „Constantin Brâncuşi" University of Târgu Jiu, Engineering Series, 1*, pp. 101.

Derwich, E., Benaabidate, L., Zian, A., Sadki, O. & Belghity, D. (2010). Caracterisation physico-chimique dex eaux de la Nappe alluviale du haut sebou en aval de sa confluence avec oued fes. *Larhyss Journal, 08*, pp. 101-112.

Meteoblue weather parameters, Retrieved January 14, 2019. Retrieved from www.meteoblue.com.

Missaghi, S. & Hondzo, M., W. (2017). Herb Prediction of lake water temperature, dissolved oxygen, and fish habitat under changing climate. *Clim. Chang., 141* (4), pp. 747-757.

Order 621/2009 concerning the threshold values for groundwater bodies from Romania.

Ordin MMGA nr.161/2006 pentru aprobarea Normativului privin clasificarea calitatii apelor de suprafata in vederea stabilirii starii ecologice a corpurilor de apa, Monitorul Oficial, Partea I, nr. 511. Retrieved from /legislatie.just.ro.

Panaițescu, C. & Onutu, I. (2013). Monitoring the quality of the sludge resulted from domestic wastewater treatment plants and the identification of risk factors. *Environmental engineering and management journal,12*, pp. 351-358.

Radu, V. M., Radu, P., Ionescu, P., Deak, G., Ivanov, A., A., Diacu, E. & Anghel A.M. (2019). Quality Assessment of Some Freshwater Resources Located in Bucharest and Surrounding Areas III. Case Study: Trophic Status Assessment of Mogosoaia, Herastrau and Pantelimon Lakes. *Rev.Chim. (Bucharest),* DOI: 10.37358/RC.19.11.7646

Stachelek, J., Ford, C., Kincaid, D., Kink, K., Miller, H. & Nagelkirk, R. (2018). Earth Syst., pp. 81.7.

Stefan, D.S., Neacsu, N., Pincovschi, I. & Stefan, M. (2017). Quality Assessment of Some Freshwater Resources Located in Bucharest and Surrounding Areas III. Case Study: Trophic Status Assessment of Mogosoaia, Herastrau and Pantelimon Lakes. *Rev. Chim.(Bucharest), 68, no.1,(11).*

The European Council Directive 80/68/CCE concerning the groundwater protection. Retrieved www.eur-lex.europa.eu

Stavrescu-Bedivan Mala-Maria, Vasile Scaeteanu Gina, Madjar Roxana Maria, Manole Mali Sanda, Staicu Andrea Cristina, Aioanei Florin Teodor, Plop Eugen Florin, Toba George Leonard, Nicolae Carmen Georgeta (2016). Interactions between Fish Well-being and Water Quality: A Case Study from MoriiLake Area, Romania, Agriculture and Agricultural Science Procedia, Volume 10, pp. 328-339, ISSN 2210-7843, https://doi.org/10.1016/j.aaspro.2016.09.071.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

QUALITATIVE ANALYSIS AND STATISTICAL MODELS BETWEEN SPRING WATER QUALITY INDICATORS IN ALBA COUNTY, ROMANIA

Maria POPA[1], Ioana GLEVITZKY[2], Gabriela-Alina DUMITREL[3], Dorin POPA[1], Ana VIRSTA[4], Mirel GLEVITZKY[1]

[1]University "1 Decembrie 1918" of Alba Iulia, 11-13 Nicolae Iorga Street, Alba Iulia, Romania
[2]University Politehnica of Timisoara, 2 Victoriei Square, Timisoara, Romania
[3]"Lucian Blaga" University of Sibiu, 4 Emil Cioran Street, Sibiu, Romania
[4]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: mirel_glevitzky@yahoo.com

Abstract

Based on contemporary environmental issues, related to water scarcity, the research outlines the current situation regarding the quality of spring waters in Alba County. Spring water is an alternative that is less and less investigated and exploited if it is a free, natural, untreated source. The quality of spring drinking water is regulated by Law no. 458/2002 (transposing the Directive 98/83/EC on the quality of drinking water). Five areas with 132 water sources were monitored, and for the most representative and polluted springs, their monitoring (physico-chemical and microbiological indicators) was performed for a period of 3 years. Most sources are microbial contaminated regardless of the season or the water catchment and spring arrangement. There is also a diffuse microbiological pollution in some localities, which indicates that the phenomena of natural purification no longer occur. It was found that in Alba County the percentage of drinking spring water sources is relatively low as follows: Alba Iulia-Teiuș area - 37%, Sebeș-Cugir - 48%, Câmpeni-Zlatna - 72%, Blaj - 25%, Aiud-Ocna Mureș - 20%. The correlative analysis shows that between the total viable count and other physico-chemical parameters (ammonium, nitrates and nitritesions) of spring water there are appreciable correlations. The correlation coefficients between these parameters vary between 0.67 and 0.92. The equations of the statistical models can approximate the variation in time of the microbial growth. These represent a control and prediction tool for the appreciation of the spring water quality in time, knowing only the physico-chemical parameters.

***Key words**: contamination, nitrogen cycle, quality, spring water, statistics.*

INTRODUCTION

According to the Drinking Water Directive (Directive 2000/60), water is not a commercial good, but a heritage that must be protected, and treated as such. Water is a fundamental social requirement and is an essential "element" for the maintenance and development of life on our planet (Dinka, 2018).
Water, although it was thought to be an inexhaustible gift of nature, nowadays there is a water crisis, especially at the regional level. It is estimated that around 2020-2025 the water crisis will manifest itself globally (Jelev, 2008). Clean drinking water is an essential element in ensuring public health and quality of life. Water registers various sources of contamination (Ecoaqua, 2002).
Public water systems use only surface water (lakes, rivers). Spring water is important because these sources can be bottled and traded (Directive 2009/54). The consumption of spring and well water appears as a new situation generated by the idea that it is healthier than tap water and is free (Glevitzky & Popa, 2012).
The potability of the water is given by its quality indicators.The Romanian Law no. 311/2004 (L.311, 2004) which modify and revise the Law no. 458/2002 (L.458, 2002) on drinking water quality, it isharmonized with the EU legislation (Directive98/83/EC) on the quality of water intended for human consumption.
The paper tests the quality of spring waters in Alba County. The results of the study show the variation of the physico-chemical and microbiological parameters for these waters. At the same time, the interdependence of these parameters over time is determined using mathematical models.

The purpose of this paper is to investigate the quality of five spring waters in Alba County, Romania. The results of the study show that the nitrate content and microbiological parameters have values that exceed the limits for drinking water.

MATERIALS AND METHODS

In a first stage, an analysis of the data related to Alba County for public groundwater sources was used. Thus, in 2017, several 132 public water sources were monitored. For a better data management, the county was divided into 5 zones, as follows: Area I: Alba Iulia - Teiuş; Area II: Sebeş - Cugir; Area III: Cîmpeni - Zlatna; Area IV: Blaj and Area V: Aiud - Ocna Mureş. For the relevance of the results, physico-chemical and microbiological parameters were investigated according to European regulations.
Three physico-chemical parameters of the water were monitored in the period 2017-2019 on the most polluted spring in each area. These are: ammonium, nitrates and nitrites content. The methods of the rapid spectrophotometric determinations involve the use of the spectrophotometer Spectroquant NOVA 60 and SQ specific kits.
The determined microbiological parameters are: total number of bacteria growing 37°C (SR EN ISO 6222, 2004), detection and counting of *Escherichia coli* and coliform bacteria Part 1: Membrane filtration method (SR EN ISO 9308-1, 2004; SR EN ISO 7889-2, 2002) and identification and counting of intestinal enterococci Part 2: Membrane filtration method (SR ISO 21528-1/2, 2004). The statistical analysis of the obtained data can provide information related to the evolution in time of the most important water parameters.

RESULTS AND DISCUSSIONS

During 2017-2019, a number of 132 public water sources from Alba County were moni-tored. Of these, only 38 sources were potable. The other 94 have one or more physico-che-mical and microbiological parameters above the limits.
In Figure 1 are depicted the results of the analyses related to quality indicators of water sources from Alba County for 2017.

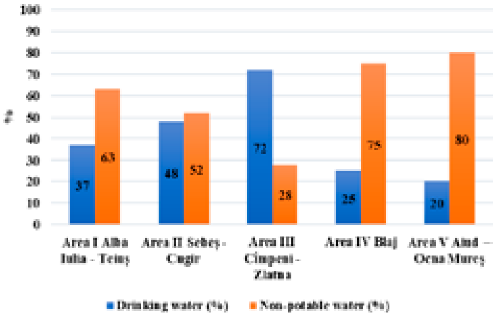


Figure 1. Quality of public groundwater sources in Alba County for the 5 areas

The analysis of the obtained results (Figure 1) shows that most of the investigated groundwater sources (springs) are not drinkable. The highest percentage of non-potability is found in area V - Aiud-Ocna Mureş (80%), and the lowest in area III - Câmpeni-Zlatna (28%). At the same time, it is observed that in the mountain region (area III) has provided safe, high-quality water compared to the other regions. The mountainous region (Câmpeni area) is the closest to the drinking water standard in Alba County.
Living organisms, dead organic matter, mineral and organic compounds dissolved in an aquatic ecosystem are never in an inert state. They are in a permanent transformation and circulation that conditions the existence of living systems. Thus, complex relationships are created between the components of the ecosystem that ensure the evolving stability of these components or the balance of the entire structure.
Nitrogen, an important nutrient in aquatic ecosystems, enters in water in several ways and is found in many forms: molecular nitrogen, nitrogen oxides, ammonia, ammonium, nitrites and nitrates.
In the ecosystem, nitrogen enters the biogeochemical circuit, determined by an interactional complex of factors in the aquatic ecosystem. Algae can use both free nitrogen from water and ammoniacal salts (NH_3) and, after depletion, nitrate-nitrogen (NO_3^-) (Botnariuc and Vădineanu, 1982). Bacteria plays vital role in the circulation of nitrogen in the specific circuit of aquatic ecosystems. The phases of bacterial transformations of nitrogen compounds are reversible, the direction of the

processes being dependent mainly on the concentration of dissolved oxygen.

Water samples were analysed in time, monthly, from January 2017 to December 2019. Experimental data obtained from the analysis of physico-chemical parameters over 3 years are presented comparatively for the representative sources in the five areas in Figures 2-4.

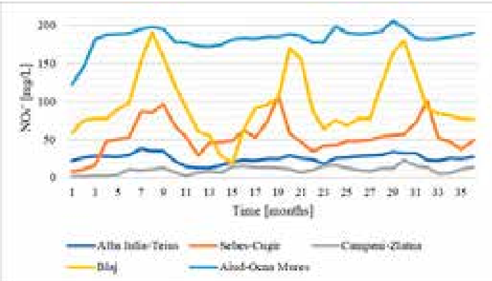


Figure 2. Variation of nitrate content in time for the 5 springs

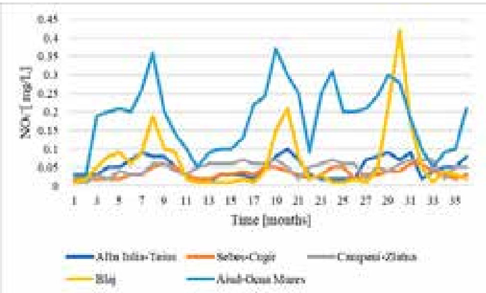


Figure 3. Variation of nitrite content in time for the 5 springs

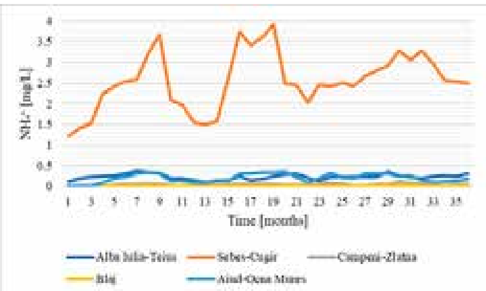


Figure 4. Variation of ammonium ion content in time for the 5 springs

Nitrites are present in water due to pollution with organic substances, either by partial oxidation of the amino radical or by reduction of nitrates. Their presence indicates an older pollution, but together with high concentrations of ammonium ions show that the pollution is continuous (Glevitzky et al., 2020).

Ammonium ions appear because of water pollution with various organic substances, which decompose, being the first stage of degradation of nitrogenous substances. Its presence indicates recent pollution.

The experimental data obtained from the analysis of microbiological parameters over a period of three years are presented comparatively for the representative sources in the five areas in Figures 5-8.

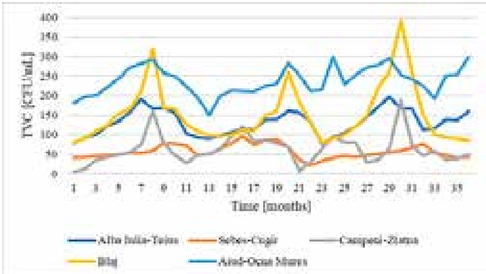


Figure 5. Variation of the total number of mesophilic aerobic bacteria in time for the 5 springs

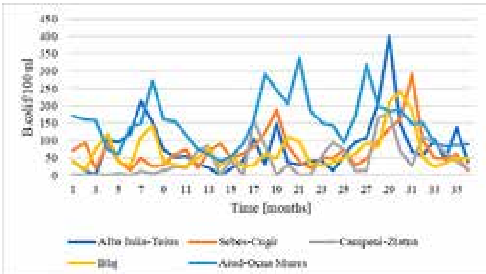


Figure 6. Variation of the number of coliform bacteria in time for the 5 springs

It is found that water from springs located in different areas has a high microbial load. The plain areas of Aiud-Ocna Mureș, Alba Iulia-Teiuș, Blaj and Sebeș have a higher microbiological load, with large variations depending on the season. For mountain and hill areas, there are small fluctuations in microbiological parameters over time.

An increased number of mesophilic aerobic bacteria indicate a risk of waterborne pathogens (bacteria, viruses, fungi, parasites). As a result of exceeding the allowed limits for these parameters, it can be considered that the springs are polluted and due to infiltrations from wastewater, manure, etc. (Glevitzky et al., 2020).

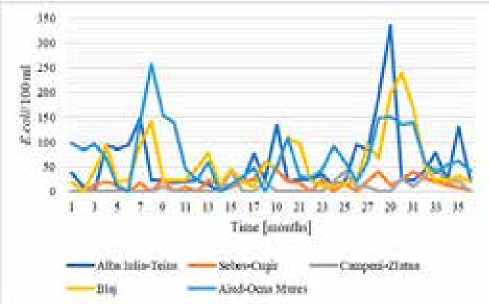


Figure 7. Incidence of *E. coli* bacteria in time for the 5 sources

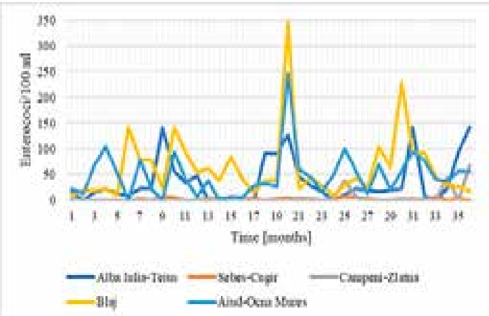


Figure 8. Incidence of intestinal enterococci in time for the 5 sources

Escherichia coli can be transmitted through water consumption and causes gastroenteritis and sepsis in children and young people of different animal species (Mănescu, 1989). *E. coli* can survive in drinking water from wells for 6 months and in canal water for 4 months (Drăghici, 2002). There is also a diffuse microbiological pollution in some localities, which indicates that the groundwater is polluted and therefore the phenomena of natural purification undergo transformations; nature no longer manages, by its own means, to fulfil its role of purifier.

In many cases the connection between two or more parameters that describe a particular process is close enough that the variation of one parameter can be controlled and expressed based on the variation of the other parameters. Functional links of this kind are called stochastic or probabilistic links. The study of such links has led to the development of multiple correlation theory (Savii and Luchin, 2000).

To develop statistical models, the influence of two parameters was assessed by performing a multiple correlation analysis. The microbial load (aerobic bacteria) was the dependent variable, respectively the content of nitrates, nitrites and ammonium ions over time, being independent variables. Starting from the nitrogen cycle in water - the dependence of the total number of germs depending on the presence of ammonium ions, nitrates or nitrites over time, as case studies for these statistical mathematical models were analysed for 3 years per month the most polluted sources of spring water from the 5 areas of Alba County.

To describe as accurately as possible, the dependence between nitrates, nitrites, ammonium content, and microbial load over time, it was desired to obtain a second order polynomial equation. Equation (1) represents the general form of mathematical models that describe the second order polynomial correlation.

$$y=a_0+a_1x_1+a_2x_2+a_3x_1x_2+a_4x_1^2+a_5x_1^2 \qquad (1)$$

In equation (1) ai represents the coefficients of the equation, and the variables x_1, x_2 and y correspond to the following parameters:

y - total number of aerobic bacteria, log [cfu/mL];

x_1 - NO_3^-, NO_2^-, NH_4^+ content [mg/L];

x_2 - time [months].

Using the Matlab® program, the system of equations was solved and, the experimental data were processed and analysed. The equations of the statistical models obtained based on the multiple regression are presented in Table 1. They are valid on the studied value range.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Table 1. Equations of the statistical models obtained in the case of the spring from Area I - Alba Iulia-Teiuș

Variable	Equations of statistical models
Nitrates (NO_3^-)	$y=1.891 - 0.002 \cdot x_1 + 0.004 \cdot x_2 + 1.777 \cdot 10^{-4} \cdot x_1 \cdot x_2 + 2.662 \cdot 10^{-4} \cdot x_1^2 - 1.598 \cdot 10^{-4} \cdot x_2^2$
Nitrites (NO_2^-)	$y=1.796 + 7.060 \cdot x_1 + 0.006 \cdot x_2 - 0.055 \cdot x_1 \cdot x_2 - 23.232 \cdot x_1^2 - 6.020 \cdot 10^{-5} \cdot x_2^2$
Ammonium (NH_4^+)	$y=1.750 + 1.279 \cdot x_1 + 0.006 \cdot x_2 + 0.007 \cdot x_1 \cdot x_2 - 0.06 \cdot x_1^2 - 1.522 \cdot 10^{-4} \cdot x_2^2$

The experimental data and the surfaces generated by the statistical models for Area I - Alba Iulia-Teiuș are presented in Figures 9 to 11.

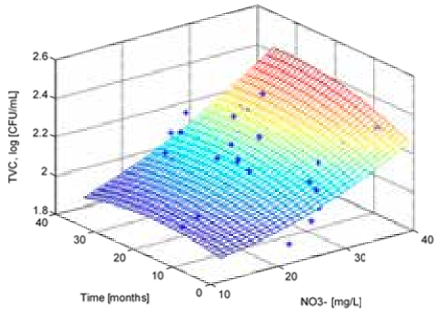


Figure 9. Variation of the microbial load depending on the nitrate content and time for the spring in Area I - Alba Iulia-Teiuș

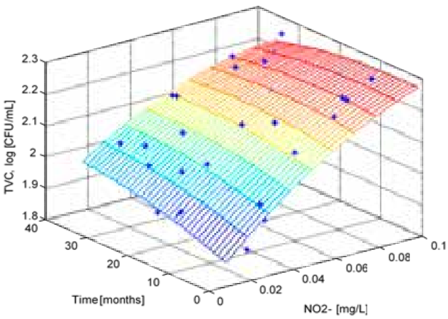


Figure 10. Variation of the microbial load depending on the nitrite content and time for the spring in Area I - Alba Iulia-Teiuș

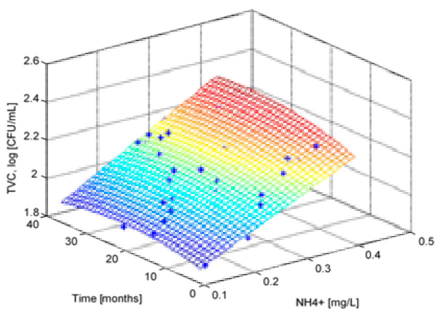


Figure 11. Variation of the microbial load depending to the ammonium ion content and time for the spring in Area I - Alba Iulia-Teiuș

After calculating the model coefficients, it is necessary to make a comparison between the model predictions and the data provided by the process. Dispersion σ^2, standard deviation σ, correlation coefficient R, accuracy coefficient R^2 were used as indicators of model adequacy (Table 2).

Table 2. Adequacy indicators of the determined statistical models

Variable	σ^2	σ	R^2	R
Nitrates	0.004	0.065	0.654	0.808
Nitrites	0.002	0.043	0.847	0.920
Ammonium	0.003	0.060	0.716	0.846

The values of the concordance indicators argue for a good capacity to predict statistical models. The experimental data together with the surfaces generated by the statistical mathematical models for Area II - Sebeș-Cugir are presented in Figures 12-14.

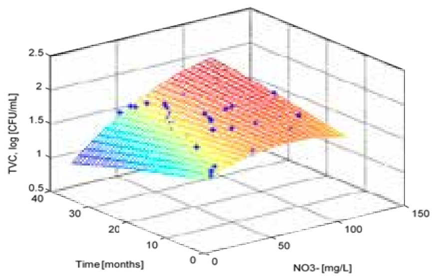


Figure 12. Variation of the microbial load depending on the nitrate content and time for the spring in Area II - Sebeș-Cugir

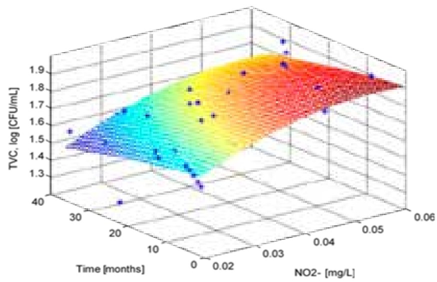


Figure 13. Variation of the microbial load depending on the nitrite content and time for the spring in Area II - Sebeș-Cugir

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

The equations of the statistical models obtained after the nonlinear multiple regression are presented in Table 3. They are valid on the studied value range.

Table 3. Equations of the statistical models obtained in the case of the spring from Area II – Sebeș-Cugir

Variable	Equations of statistical models
Nitrates (NO_3^-)	$y = 1.520 + 0.009 \cdot x_1 - 0.015 \cdot x_2 + 2.498 \cdot 10^{-4} \cdot x_1 \cdot x_2 - 7.052 \cdot 10^{-5} \cdot x_1^2 - 6.262 \cdot 10^{-5} \cdot x_2^2$
Nitrites (NO_2^-)	$y = 1.314 + 21.790 \cdot x_1 - 0.003 \cdot x_2 + 0.015 \cdot x_1 \cdot x_2 - 198.024 \cdot x_1^2 - 4.505 \cdot 10^{-5} \cdot x_2^2$
Ammonium (NH_4^+)	$y = 1.730 - 0.057 \cdot x_1 - 0.010 \cdot x_2 + 0.006 \cdot x_1 \cdot x_2 + 0.020 \cdot x_1^2 - 2.749 \cdot 10^{-4} \cdot x_2^2$

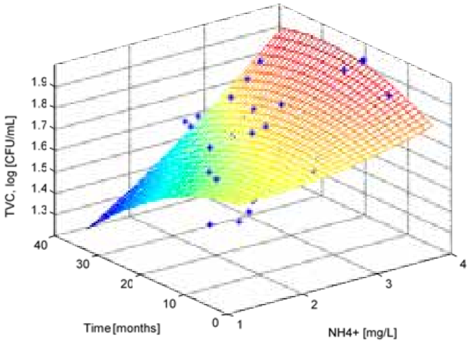


Figure 14. Variation of the microbial load depending to the ammonium ion content and time for the spring in Area II - Sebeș-Cugir

In order to compare the model prediction and the data provided by the actual process, the suitability indicators of the model presented in Table 4 were calculated.

Table 4. Adequacy indicators of the determined statistical models

Variable	σ^2	σ	R^2	R
Nitrates	0.008	0.091	0.564	0.751
Nitrites	0.011	0.103	0.449	0.670
Ammonium	0.010	0.097	0.505	0.711

Results of the concordance indicators for the statistical models confirm appreciable correlations between the studied parameters.

The experimental data together with the surfaces generated by the statistical mathematical models for Zone III - Câmpeni - Zlatna are presented in Figures 15-17.

The equations of the statistical models obtained following the nonlinear multiple regression of order 2 are presented in Table 5. They are valid on the studied value range.

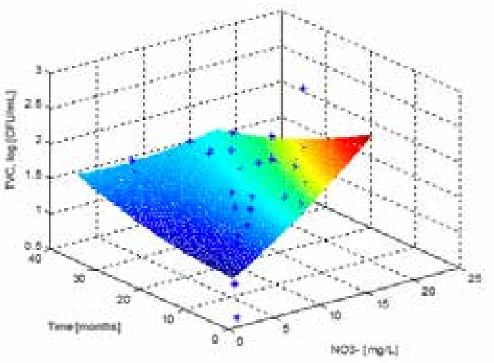


Figure 15. Variation of the microbial load depending on the nitrate content and time for the spring in Area III - Câmpeni-Zlatna

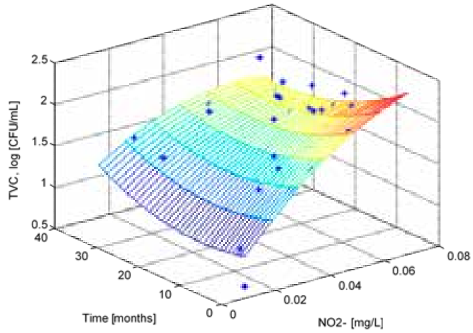


Figure 16. Variation of the microbial load depending on the nitrite content and time for the spring in Area III – Câmpeni-Zlatna

Table 5. Equations of the statistical models obtained in the case of the spring from Area III - Câmpeni-Zlatna

Variable	Equations of statistical models
Nitrates (NO_3^-)	$y = 1.089 + 0.078 \cdot x_1 + 0.0036 \cdot x_2 - 0.0027 \cdot x_1 \cdot x_2 + 0.0015 \cdot x_1^2 + 3.3753 \cdot 10^{-4} \cdot x_2^2$
Nitrites (NO_2^-)	$y = 0.592 + 42.040 \cdot x_1 - 0.011 \cdot x_2 - 0.424 \cdot x_1 \cdot x_2 - 219.871 \cdot x_1^2 + 6.406 \cdot 10^{-4} \cdot x_2^2$
Ammonium (NH_4^+)	$y = 0.685 + 26.003 \cdot x_1 + 0.040 \cdot x_2 - 0.856 \cdot x_1 \cdot x_2 + 44.453 \cdot x_1^2 - 3.244 \cdot 10^{-4} \cdot x_2^2$

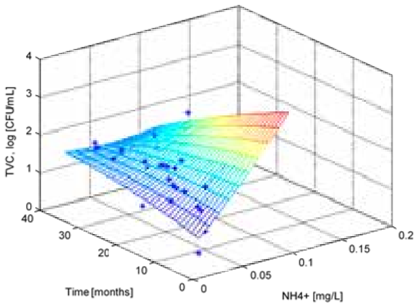


Figure 17. Variation of the microbial load depending to the ammonium ion content and time for the spring in Area III – Câmpeni-Zlatna

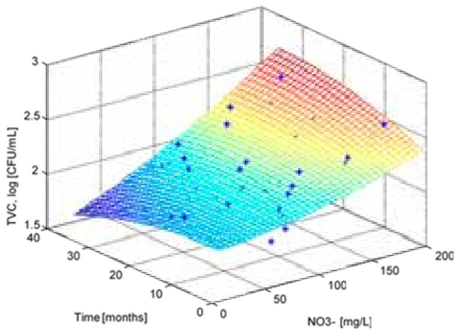


Figure 18. Variation of the microbial load depending on the nitrate content and time for the spring in Area IV - Blaj

The adequacy indicators of the statistical models obtained by comparing the model predictions with the data provided by the actual process are presented in Table 6.

Table 6. Adequacy indicators of the determined statistical models

Variable	σ^2	σ	R^2	R
Nitrates	0.049	0.221	0.574	0.757
Nitrites	0.039	0.197	0.660	0.812
Ammonium	0.048	0.219	0.583	0.763

In the case of polynomial equations of the second order, the correlation coefficients prove a functionally satisfactory relationship between the investigated variables.

The experimental data together with the surfaces generated by the statistical mathematical models for Zone IV - Blaj are presented in Figures 18-20.

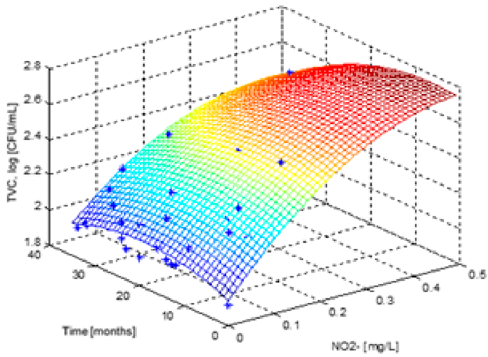


Figure 19. Variation of the microbial load depending on the nitrite content and time for the spring in Area IV - Blaj

The equations of the statistical models obtained from the nonlinear multiple regression are presented in Table 7 and the adequacy indicators in Table 8.

Table 7. Equations of the statistical models obtained in the case of the spring from Area IV - Blaj

Variable	Equations of statistical models
Nitrates (NO_3^-)	$y = 1.946 + 4.329 \cdot 10^{-4} \cdot x_1 + 8.790 \cdot 10^{-5} \cdot x_2 + 9.191 \cdot 10^{-5} \cdot x_1 \cdot x_2 + 7.895 \cdot 10^{-6} \cdot x_1^2 - 2.396 \cdot 10^{-4} \cdot x_2^2$
Nitrites (NO_2^-)	$y = 1.881 + 3.217 \cdot x_1 + 0.013 \cdot x_2 - 0.018 \cdot x_1 \cdot x_2 - 2.999 \cdot x_1^2 - 3.147 \cdot 10^{-4} \cdot x_2^2$
Ammonium (NH_4^+)	$y = 2.193 - 28.933 \cdot x_1 + 0.007 \cdot x_2 + 0.051 \cdot x_1 \cdot x_2 + 1239.3 \cdot x_1^2 - 2.709 \cdot 10^{-4} \cdot x_2^2$

Table 8. Adequacy indicators of the determined statistical models

Variable	σ^2	σ	R^2	R
Nitrates	0.005	0.071	0.843	0.918
Nitrites	0.007	0.082	0.793	0.890
Ammonium	0.012	0.109	0.635	0.797

The values of the correlation coefficients are appreciable, which indicates a good correlation in the case of multiple 2nd order regression.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

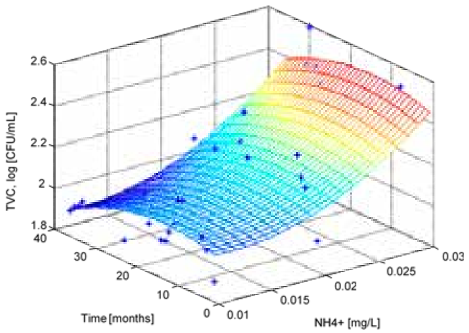


Figure 20. Variation of the microbial load depending to the ammonium ion content and time for the spring in Area IV - Blaj

The experimental data together with the surfaces generated by the statistical mathematical models for Zone V - Aiud-Ocna Mureș are presented in Figures 21-23.

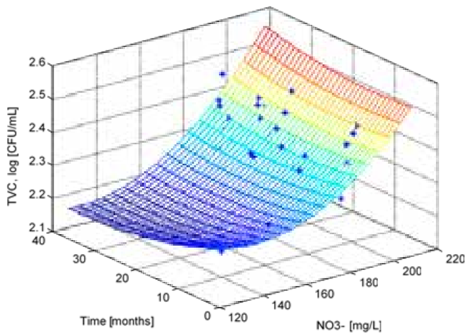


Figure 21. Variation of the microbial load depending on the nitrate content and time for the spring in Area V - Aiud-Ocna Mureș

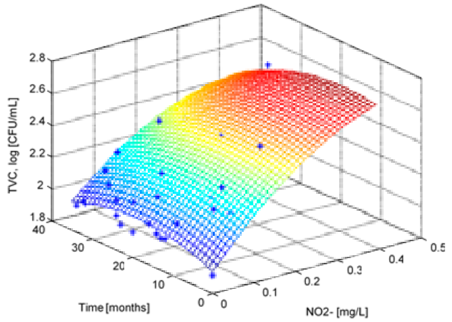


Figure 22. Variation of the microbial load depending on the nitrite content and time for the spring in Area V - Aiud-Ocna Mureș

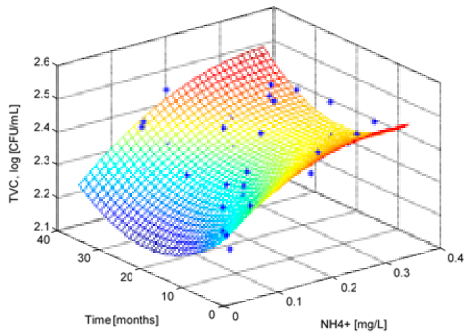


Figure 23. Variation of the microbial load depending to the ammonium ion content and time for the spring in Area V - Aiud-Ocna Mureș

The equations of the statistical models obtained from the nonlinear multiple regression are presented in Table 9.

Table 9. Equations of the statistical models obtained in the case of the spring from Area V - Aiud-Ocna Mureș

Variable	Equations of statistical models
Nitrates (NO_3^-)	$y = 1.946 + 4.329\cdot10^{-4}\cdot x_1 + 8.790\cdot10^{-5}\cdot x_2 + 9.191\cdot10^{-5}\cdot x_1\cdot x_2 + 7.895\cdot10^{-6}\cdot x_1^2 - 2.396\cdot10^{-4}\cdot x_2^2$
Nitrites (NO_2^-)	$y = 1.881 + 3.217\cdot x_1 + 0.013\cdot x_2 - 0.018\cdot x_1\cdot x_2 - 2.999\cdot x_1^2 - 3.147\cdot10^{-4}\cdot x_2^2$
Ammonium (NH_4^+)	$y = 2.193 - 28.933\cdot x_1 + 0.007\cdot x_2 + 0.051\cdot x_1\cdot x_2 + 1239.3\cdot x_1^2 - 2.709\cdot10^{-4}\cdot x_2^2$

Table 10. Adequacy indicators of the determined statistical models

Variable	σ^2	σ	R^2	R
Nitrates	0.002	0.041	0.659	0.812
Nitrites	0.007	0.082	0.793	0.890
Ammonium	0.002	0.041	0.645	0.803

Calculated correlation parameters argue for a good prediction capacity of mathematical models. The performed analyses show that one or all the determined parameters, in most spring water samples, are well above the maximum limit allowed by law.

CONCLUSIONS

The research outlines the current situation regarding the quality of spring waters in Alba County. If public drinking water supply systems use only surface water (lakes, rivers), spring water is a less and less investigated and exploited alternative even if it is a free, natural, untreated source of particular importance.

Five areas with 132 water sources from Alba County were monitored. The most representative and polluted sources were monitored (physico-chemical and microbiological indicators) for a period of 3 years. It was observed that most of them were microbiologically polluted. It was found that in Alba County the percentage of drinking spring water sources is relatively low as follows: Alba Iulia-Teiuș (I) area - 37%, Sebeș-Cugir (II) - 48%, Câmpeni-Zlatna (III) - 72%, Blaj (IV) - 25%, Aiud-Ocna Mureș (V) - 20%.

The equations of the statistical models obtained can be used as prediction models. With their help, the microbial load in the spring waters can be approximated, knowing the time of year when the sample is collected and the content of nitrates, nitrites, respectively the ammonium ion content of the sample. Correlation parameters argue for a good prediction capacity of statistical mathematical models.

REFERENCES

Botnariuc, N.&Vadineanu, A. (1982). *Ecologie*, Bucureşti, RO: Didactică şi Pedagogică Publishing House.

Committee for the Approval of Methods and Methodologies of Veterinary Medical Diagnosis, Sub-Committee for Approval Methods of Hygiene Diagnosis and Environmental Protection. Approved Methods (2004). Chap. 10.

Dinka, M.O. (2018). *Safe Drinking Water: Concepts, Benefits, Principles and Standards*. In: Glavan, M., (Ed.), *Water Challenges of an Urbanizing World* [Internet]. London: IntechOpen.

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, OJ L 327, 22.12.2000.

Directive 2009/54/EC of the European Parliament and of the Council of 18 June 2009 on the exploitation and marketing of natural mineral waters. O.J. L 164, 26.6.2009, 45–58.

Drăghici, C. (2002). *Igiena animalelor şi protecția mediului*. Cluj-Napoca, RO: Academic Pres Publishing House.

Ecoaqua (2002). *Drinking water*. Brochure, Bucharest, Romania.

Glevitzky, I., Dumitrel, G.A., Glevitzky, M., Bungău, S., Popa, M. (2020). Aspects Concerning the Management of Groundwater in the Farau Area - Alba County, Romania. *Journal of Environmental Protection and Ecology*, *21*(2), 433-453.

Glevitzky, M. & Popa, M. (2012). *Calitatea apelor freatice - Principii teoretice şi studii de caz*, Alba Iulia, RO: Aeternitas Publishing House.

Jelev, I. (2008). *Indicators for the Assessment of Climate Change and Some Aspects Specific to the Mountain Area*, Romanian Academy, Terra National Conference and Life.

Law no. 311 (2004). Published in O.G., Part I no. 582 din 30.06.2004 pentru modificarea si completarea Legii nr. 458/2002 privind calitatea apei potabile (In Romanian).

Law no. 458 (2002). Published in O.G., Part I, no. 552 din 29.07.2002 privind calitatea apei potabile publicat in Monitorul Oficial al Romaniei (In Romanian).

Mănescu, S. (1989). *Microbiologie sanitară.* Bucureşti, RO: Medicală Publishing House.

Savii, G.&Luchin, M. (2000). *Modelare şi simulare*, Timişoara, RO: Eurostampa Publishing House.

SR EN ISO 6222/2004, Numararea microorganismelor de cultura. Numararea coloniilor prin insamantare in mediu de cultura agar, 2004.

SR EN ISO 8199:2008 ≈ ISO 8199: 2005, Calitatea apei. Ghid general de numărare a microorganismelor din cultură, 2008.

SR EN ISO 6887-1/2002, Microbiologia alimentelor şi furajelor. Pregătirea probelor pentru analiză, a suspensiei iniţiale şi a diluţiilor decimale pentru examenul microbiologic. Partea 1: Reguli generale pentru pregătirea suspensiei iniţiale şi a diluţiilor decimale, 2002.

SR EN ISO 9308-1/2004, SR EN ISO 7889-2/2002, Detectia si numararea de Escherichia coli si bacterii coliforme Partea 1: Metoda prin filtrare pe membrana, 2004.

SR ISO 21528-1/2 2004, Microbiologia alimentelor si nutreturilor. Metoda orizontala pentru detectia si enumerarea Enterobacteriaceaelor, 2004.

SR EN ISO 7889-2/2002, Identificarea si numararea enterococilor intestinali. Partea 2: Metoda prin filtrare pe membrana, 2002.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE EFFECTS OF OPTIMIZING A SIMULATED WASTEWATER TREATMENT PLANT ON EFFLUENT QUALITY

Bogdan ROȘU, Adrian ROȘU, Maxim ARSENI, Ștefan-Mihai PETREA, Cătălina ITICESCU, Puiu Lucian GEORGESCU

"Dunarea de Jos" University of Galati, 47 Domneasca Street, Galati, Romania

Corresponding author email: bogdan.rosu@ugal.ro

Abstract

Wastewater treatment plants with activated sludge behave like a filter to protect the aquatic environment and also the health of those who use and consume the water. These treatment plants are used to remove nutrients from wastewater, such as nitrogen, that can have a great impact on the evolution of the aquatic ecosystem if we consider the eutrophication process that is intensified worldwide due to agriculture and other industrial activities. In this study, a wastewater treatment plant model called Benchmark Simulation Model No.2 (BSM2) was used to regulate ammonium and nitrate concentrations by implementing a control strategy. The strategy optimization was performed by applying the relaxation method. The reference data considered are the results of the simulation with the BSM2's base control strategy in a closed loop. Also, the data obtained in the first attempt of optimizing the treatment plant were considered. This study aims to identify if the optimization of the simulated wastewater treatment plant can improve the effluent quality thus reducing the risk of aquatic environment pollution with nutrients.

Key words: *aquatic environment, effluent, simulation, optimization, wastewater.*

INTRODUCTION

Water is essential; without it, our planet won't meet the necessary conditions to support and maintain life.

Even if our planet is rich in water, only a small portion of it is freshwater. About 70% of Earth's surface is covered in water, representing approximately 1386 million of km^3 of water. From this total amount, freshwater represents just 2.5%. If we consider the availability of fresh water to humans and other creatures, the percentage gets even lower. Almost 70% of the total amount of freshwater is present in form of glaciers and snow, and another part is found underground, making it hard to reach. Thereby, readily accessible freshwater represents just 0.26% of the total amount of fresh water, and it is found under forms of surface water (lakes, rivers, streams, wetlands, swamps, etc) (Baker, B.H., Aldridge, C.A., & Omer, 2016; Shiklomanov, 1998).

The qualitative and quantitative aspects of water can be considered indices of prosperity. Many biological cycles and processes, present in the aquatic ecosystems, can be perturbed if the water quality is affected by pollution. Likewise, the ecosystem can suffer or even disappear in time if the quantity of water is not sufficient to cover the needs of the inhabitants. These aspects can also be indices of human life quality. Good quality freshwater sources can sustain food production and other industrial activities without extra costs spent on water treatment. On the other side of the coin, if the wastewater resulting from such processes is not treated it can produce in time a shortage in usable freshwater due to pollution.

Statistically, 80% of the total amount of wastewater is discharged without any treatment directly into oceans, seas, lakes, and rivers.

Romania's river basin, presented in Figure 1, covers approximately 76% of the territory's surface.

Poorly developed countries have the disadvantage of lack of infrastructure or modern technology, meaning that they are unable to treat wastewater efficiently. Countries that are found in this situation can treat around 38% of the total generated wastewater. On the other hand, heavily developed countries, are aware of the economic importance of the quality of water, and with the proper infrastructure, they can treat about 70% of their wastewater (Max Roser, 2021; UNESCO, 2017; *Water Scarcity |Knowledge for Policy*, n.d.)

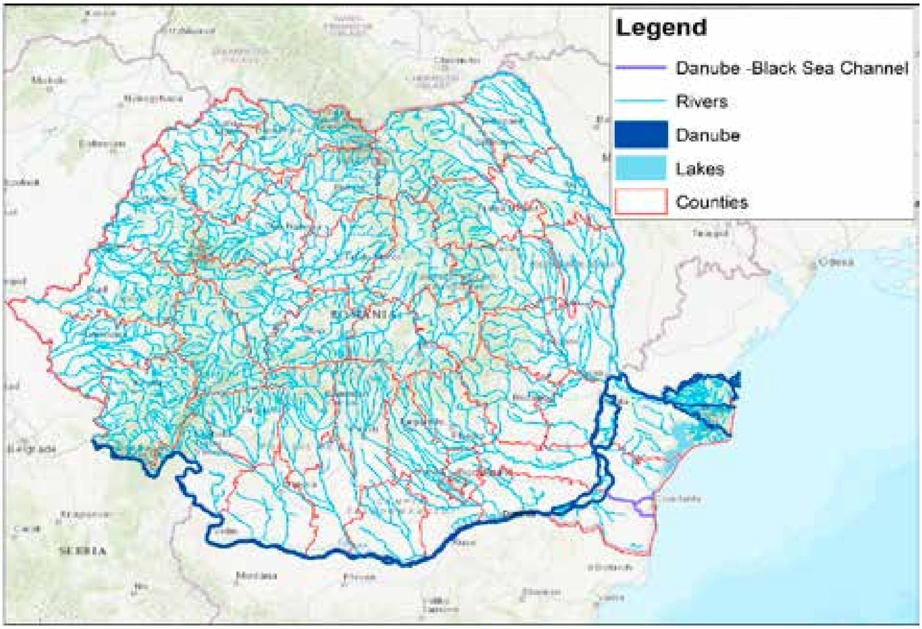


Figure 1. Romania's hydrological basin

Aquatic ecosystems are very vulnerable in case of pollution, many creatures that are part of these ecosystems are sensitive to changes in physicochemical properties of water such as temperature, total dissolved solids, turbidity, pH, alkalinity, dissolved oxygen (DO), biological oxygen demand (BOD_5), chemical oxygen demand (COD), etc. (Rosette et al., 2020). These parameters are also used to monitor the quality of a WWTP's (Wastewater Treatment Plant) effluent (Sastry et al., 2013).

The intense use of phosphorus and nitrogen-based fertilizers in agriculture represents a real ecological concern for aquatic ecosystems. Many other sources of these nutrients are available, but their combined effect can lead to the appearance of eutrophication phenomena, known also as an algal bloom. The problem with eutrophication is that it affects both, salt water and fresh water ecosystems (Wilkinson, 2017).

The effects of eutrophication on aquatic ecosystems are devastating. Oxygen depletion and accelerated growth of algae can cause a gradual decline in the biodiversity of the aquatic ecosystem (Dorgham, 2014).

A solution to this global issue is the use of WWTPs with activated sludge (Ardern & Lockett, 1914). The nutrients present in wastewater in high concentrations are removed by specific processes such as nitrification and denitrification, which help in reducing the amount of nitrate in water (Elmerich, 2002).

WWTPs can be optimized to run at their full potential by using methods from the control engineering domain. Instead of experimenting on a pilot plant, which involves some environmental risks, the use of mathematical models with the same specifications as the considered WWTP, is more reliable.

There are many benefits of using these types of mathematical models, for example, different control strategies can be applied and tested at low costs, compared with the use of some expensive equipment on a pilot plant.

BSM2 (Benchmark Simulation Model NO. 2), developed by the International Water Association (IWA), was chosen to be used in this study to perform the simulations and the evaluation of the plant performance. This paper aims to observe the effects of fine-tuning during the optimization process of an applied control strategy to the simulated WWTP. The total optimization score of the plant might vary depending on the EQI (Effluent Quality Index) and OCI (Overall Cost Index) variation caused by different input values of the control variables. The main objective is to identify if the EQI index shows any signs of improvement during the fine-tune compared to the default output values of BSM2 in a closed loop. A lower EQI score is better and it indicates that the effluent quality has improved.

MATERIALS AND METHODS

The BSM2 model, presented in Figure 2, was used in this study to simulate the WWTP. The model can evaluate the ecological and economical performances of the WWTP by analyzing the data obtained after each simulation.
The BSM2 model can simulate 2 stages of treatment that are present in a regular WWTP with activated sludge. The first stage, the wastewater treatment, is done by specific units: primary clarifier, biological reactor, and secondary clarifier. The first unit in which the influent enters is the primary clarifier, where water is separated for the first time from the sludge. The total tank volume of the primary clarifier is 900 m^3 (Alex et al., 2008).
The second, and the most important unit in the wastewater treatment stage, is the biological reactor. This unit is separated into 5 divisions, where, divisions 1 and 2 are under an anoxic regime, where the denitrification takes place. Divisions 3, 4, and 5 are under an aerated regime, where the nitrification process takes place. The total volume of the simulated biological reactor is 12000 m^3 (Alex et al., 2018; Nopens et al., 2010).
The secondary clarifier has a total volume of 6000 m^3, being modeled as a unit with 10 levels, where each level is 0.4 m tall. The purpose of the secondary clarifier is to separate the sludge from the treated water. The treated water found at the 10'th layer of the secondary clarifier is removed from the installation, representing the effluent. The secondary clarifier is considered biologically and chemically inert (Alex et al., 2018).
The second stage, the sludge treatment, is conducted by different units: thickener, one anaerobic digester, and the dewatering installation.
The most important unit in the sludge treatment stage is the anaerobic digestor, an installation where methane gas is obtained in the process of sludge reduction, the produced biogas is further used for the energetical autonomy of the plant.

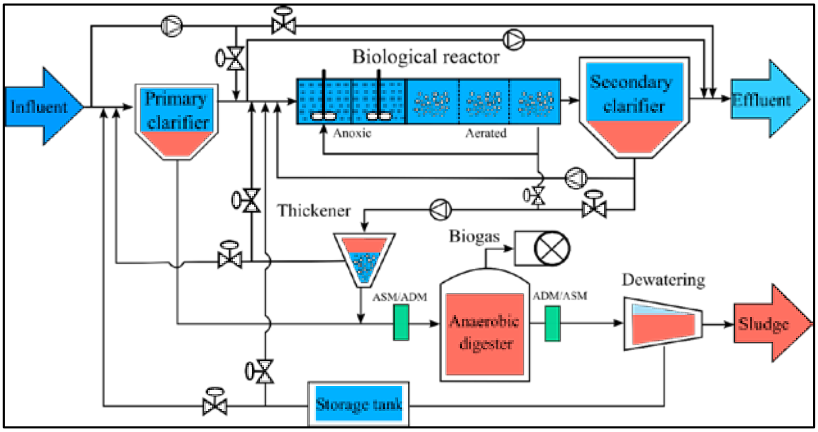


Figure 2. BSM2 plant layout (adapted after Alex et al., 2018; Nopens et al., 2010)

BSM2 imports an external file that contains the data for the influent components for 609 days. BSM2 simulates 609 days in which the WWTP operates, the first 245 days represent the stabilization period, followed by 364 days of observation (Alex et al., 2018).
The ecological performance of the WWTP is defined by the EQI expressed as kg pollution unit/day. This index is calculated during the observation period as an average value of the effluent loads of compounds that have a great impact on the aquatic ecosystems.
The EQI is represented in the work of Alex et al., 2018, with the formula:

$$EQI = \frac{1}{t_{obs} \cdot 1000} = \int_{t=245\ dayss}^{t=609\ dayss} \begin{pmatrix} B_{TSS} \cdot TSS_e(t) + B_{COD} \cdot COD_e(t) + B_{NKj} \cdot S_{NKj,e}(t) \\ +B_{NO} \cdot S_{NO,e}(t) + B_{BOD5} \cdot BOD_e(t) \end{pmatrix} Q_e\,(t) \cdot dt \quad (1)$$

where: TSS – total suspended solids, COD – chemical oxygen demand, NKj – Kjeldahl nitrogen concentration, NO – nitrite and nitrate concentration, BOD_5 represents the biochemical oxygen demand.

The OCI represents the economic performance of the simulated WWTP during the observation period. The OCI index is presented in the work of (Alex et all…cite) on the technical description of BSM2, with the following formula (Alex et al., 2018):

$$OCI=AE+PE+3 \cdot SP+3 \cdot EC+ME-6 \cdot MET_{prod}+HE_{net} \quad (2)$$

where: AE - aeration energy, PE - pumping energy, SP - sludge production, EC - external carbon consumption, ME - mixing energy, MET_{prod} - biogas, HE_{net} - heating energy.

This paper is a continuation of the investigations regarding the use of the control strategy α_1, presented for the first time in Roșu et al., 2021, where the first and the second iterations were performed. The third and the fourth iterations were performed and evaluated in the content of this paper. The α_1 control strategy was used in this study to compare its results obtained during the fine-tune with the default BSM2 performance and to observe the impact on the effluent quality. The applied strategy α1 is proposed to regulate the concentrations of NO_3^-, and NH_4^+ by carbon insertion in the second division of the biological reactor, and, respectively, by oxygen addition in the fifth division of the same unit.

The third iteration was performed using the results obtained during the second iteration presented in (Roșu et al., 2021). The values for the control variables used in the third iteration were chosen using a 0.25 step in the range of the previously obtained values, 1.3 g N/m^3 for $S_{NO,div2}$ (NO_3^- control) and 0.7 g N/m^3 for $S_{NH,div5}$ (NH_4^+ control).

The fourth iteration was performed by using the data from the third iteration, this time for the $S_{NO,div2}$ the step was 0.2, and for $S_{NH,div5}$ was kept at 0.25, this was done to fine-tune the variables in such a way that the range will become narrower.

BMS2 uses a default control strategy for the closed-loop simulation to sustain the DO concentrations in the 5’th division of the biological reactor at a preset of 2 g (-COD)/m^3. The process is done by controlling the actuator model representing the oxygen transfer coefficient (K_La_4) in the 4’th division of the biological reactor in such a way that the following requirements are met: $K_La_3 = K_La_4$; $K_La_5 = K_La_4/2$. Furthermore, the default strategy also involves the addition of external carbon in the first anoxic division of the biological reactor, at a rate of 2 m^3/day, to increase the denitrification potential (Alex et al., 2018).

The results obtained with the default strategy can be used as a benchmark for other user-made control strategies. In this paper, the results of the BSM2’s default strategy simulation are considered only as a secondary reference. The main reference used for comparison is the data obtained during the first iteration.

BSM2 uses the following concentration limit values for 5 essential effluent quality parameters: total nitrogen (N_{tot}) < 18 g N/m^3, COD_{tot} < 100 g COD/m^3, ammonia and ammonium nitrogen (S_{NH}) < 4 g N/m^3, TSS < 30 g SS/m^3, BOD_5 < 10 g BOD/m^3. The considered parameters are calculated during the evaluation period of the simulated WWTP, all the values above these limits contribute to an increased EQI final score.

To simplify the results, an optimization criterion (O_c) was used as in Luca et al., 2017:

$$O_c=\beta(EQIs+TD_{Ntot}+TD_{SNH,e})/3+(1-\beta)OCIs \quad (3)$$

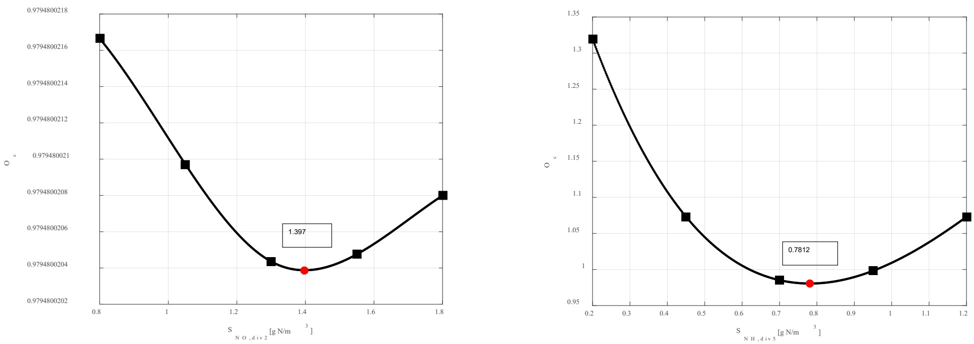
where: EQIs and OCIs represent the scaled EQI and OCI values, TD_{Ntot} and $TD_{SNH,e}$ are the scaled values of the time when the concentration limits for N_{tot} and $S_{NH,e}$ were exceeded. The β factor can have any value between 0 and 1, this factor indicates the importance of the economic and effluent quality impact. In our case, the β factor was set at the 0.5 value. The scaling factors are EQI, OCI, $N_{tot,}$ and $S_{NH,e}$ obtained during the first iteration of α_1 strategy.

The optimization process is based on the relaxation method. The first step is to optimize independently the control variables $S_{NO,div2,}$ and $S_{NH,div5}$; 5 values are attributed for each variable per iteration and are chosen around the reference value with a preferred step of 0.25 or lower. After each simulation, the interest values from the results are scaled and the optimization criterion formula is applied. The next step is to obtain the polynomial interpolation between O_c and the $S_{NO,div2,}$ and $S_{NH,div5}$ values. At this point, we must identify the minimum point from the polynomial interpolation and use the identified value for the control variable as a reference set point for the next iteration. Near the end of the optimization process, a final simulation is performed, where we use both of the final optimized values for N_{tot} and $S_{NH,e}$, obtained during the individual optimization process. At this point, a final O_c value is obtained, summarizing the final score of the control strategy per iteration.

RESULTS AND DISCUSSIONS

The α_1 control strategy, described in the previous chapter, was applied and used with the BSM2.

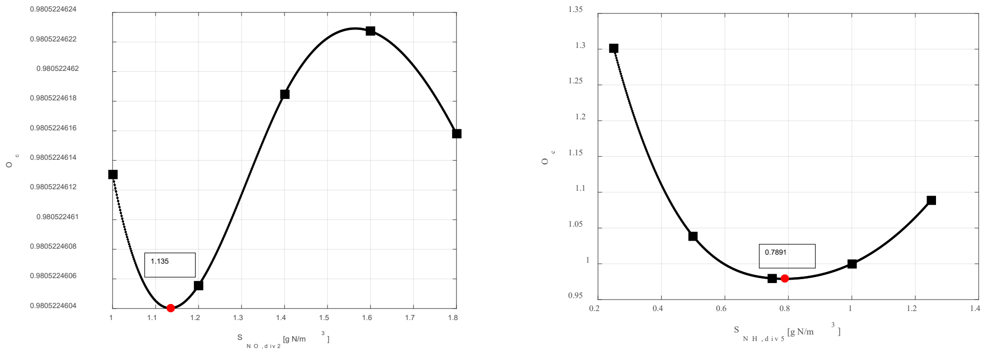
Figures 3 a) and b) represent the interpolation curve of the data obtained during the independent optimization of the control variables from the third iteration. In this stage, 10 simulations were performed to optimize $S_{NO,div2}$, and $S_{NH,div5}$. The minimum point which indicates the most optimized value for $S_{NO,div2}$ was determined at 1.397 g N/m^3. In the case of $S_{NH,div5}$ variable, the minimum point was identified at 0.781 g N/m^3. In both cases, the curve has a descending evolution from the first simulation until it reaches the minimum point, which was found in both cases between simulation no. 3 and 4.



a) b)

Figure 3. Optimisation process of control variables during iteration no. 3

Figures 4 a) and b) represent the interpolation curve obtained during the 4'th iteration. For $S_{NO,div2}$, the optimal value was identified between the first and the second simulation at 1.135 g N/m^3. Figure 4 b) presents the case for the $S_{NH,div5}$ control variable. The minimum point from the interpolation was identified between simulations no. 4 and 5 at a value of 0.789 g N/m^3. It is noticeable that the interpolated curve presented in Figure 4 a) has a different shape compared to the one from the third iteration and, also, did find the optimal value faster. This could be caused by the lower step used in the range of the chosen values for $S_{NO,div2}$.



a) *b)*

Figure 4. Optimisation process of control variables during iteration no. 4

A simulation with the optimal values for the control variables was performed at the end of each iteration, to test how the performance is affected when both optimized control variables are used. Figure 5 presents the final data obtained for the optimization criterion from all 4 iterations. The lowest EQI value is recorded in the 4th iteration, but this comes at a cost with an increased OCI value, being the highest recorded from all 4 iterations.

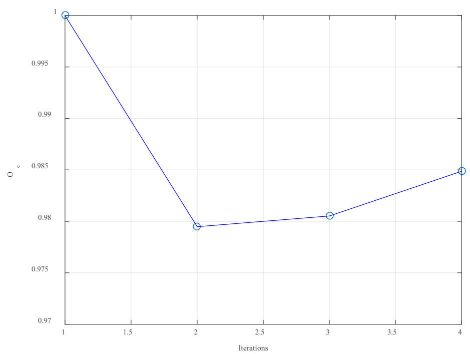


Figure 5. Final score for O_c during the optimization process

Figure 6 shows a direct comparison between the EQI values obtained with the default control strategy of BSM2 (EQI_{def}) and the EQI obtained at the 4th iteration with α_1 strategy ($EQ_{\alpha1,it4}$).

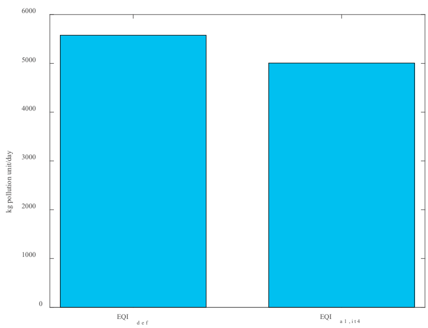


Figure 6. EQI data comparison between the default BSM2 strategy and α_1 strategy in the 4'th iteration

CONCLUSIONS

WWTPs play a major role in maintaining the aquatic ecosystems clean. By optimizing the performance of these installations, better water quality can be obtained. The optimization method used in this paper has proven to be useful to fine-tune user-made control strategies for the BSM2 model, which simulates a WWTP. The optimization has shown to have a good ecological impact, that being shown by the final EQI score obtained at the 4th iteration, which indicates an improved quality of the effluent. Further investigations might be needed to be done to reach the iteration at which the optimization criteria will stabilize.

ACKNOWLEDGEMENTS

The present research/article/study was supported by the project An Integrated System for the Complex Environmental Research and Monitoring in the Danube River Area, REXDAN, SMIS code 127065, co-financed by the European Regional Development Fund through the Competitiveness Operational Programme 2014-2020, contract no. 309/10.07.2021.

REFERENCES

Alex, J., Benedetti, L., Copp, J., Gernaey, K. ., Jeppsson, I., Nopens, I., Pons, M. ., Rosen, C., Steyer, J., & Vanrolleghem, P. (2018). Benchmark Simulation Model no. 2 (BSM2). *Water Science & Technology*, *2*(2), 1–99.

Alex, J., Benedetti, L., Copp, J., Gernaey, K.V, Jeppsson, U., Nopens, I., Pons, M.-N., Rieger, L., Rosen, C., Steyer, J.P., Vanrolleghem, P., Winkler, S., Magdeburg, I.E.V, & Benedetti, G.L. (2008). Benchmark Simulation Model no. 1 (BSM1) Benchmark Simulation Model no. 1 (BSM1) Contributors. *Benchmark Simulation Model*, *1*(1BSM1), 1–58.

Ardern, E., & Lockett, W.T. (1914). Experiments on the oxidation of sewage without the aid of filters. *Journal of the Society of Chemical Industry*, *33*(10), 523–539. https://doi.org/10.1002/jctb.5000331005

Baker, B. H., Aldridge, C. A., & Omer, A. R. (2016). Water: Availability and use. *Mississippi State University Extension.*, p 3011.

Dorgham, M. M. (2014). Effects of Eutrophication. *Eutrophication: Causes, Consequences and Control*, *2*, 29–44. https://doi.org/10.1007/978-94-007-7814-6_3

Elmerich, C. (2002). *Nitrification and denitrification in the activated sludge process*. Research in Microbiology. https://doi.org/10.1016/s0923-2508(02)01315-3

Luca, L., Ifrim, G., Ceanga, E., Caraman, S., Barbu, M., Santin, I., & Vilanova, R. (2017). Optimization of the wastewater treatment processes based on the relaxation method. *Proceedings - 2017 5th International Symposium on Electrical and Electronics Engineering, ISEEE 2017*, *2017-Decem*, 1–4. https://doi.org/10.1109/ISEEE.2017.8170690

Max Roser (2021). *Global poverty in an unequal world: Who is considered poor in a rich country? And what does this mean for our understanding of global poverty?* Our World in Data, University of Oxford. https://ourworldindata.org/higher-poverty-global-line

Nopens, I., Benedetti, L., Jeppsson, U., Pons, M.N., Alex, J., Copp, J.B., Gernaey, K.V., Rosen, C., Steyer, J.P., & Vanrolleghem, P.A. (2010). Benchmark Simulation Model No 2: Finalisation of plant layout and default control strategy. *Water Science and Technology*, *62*(9), 1967–1974. https://doi.org/10.2166/wst.2010.044

Rosette, Z.L., Nina, P.M., Bakaki, F., & Munir, A.Y. M. (2020). The Influence of Water Quality Parameters on Fish Species abundance and distribution near shoreline of lake victoria. *African Journal of Environment and Natural Science Research.*

Roșu, B., Condrachi, L., Roșu, A., Arseni, M., & Murariu, G. (2021). *Contemporary Scientific and Technological Aspects towards an Entrepreneurial Approach Optimizing the Performance of a Simulated Wastewater Treatment Plant by the Relaxation Method*. *47*, 300–305.

Sastry, S.V.A.R., Rao, B.S., Nahata, K., Professor, S.A., Professor, A., & Student, M.T. (2013). Study of Parameters Before And After Treatment of Municipal Waste Water From An Urban Town. *Global Journal of Applied Environmental Sciences*. http://www.ripublication.com/gjaes.htm

Shiklomanov, I. a. (1998). World Water Resources. A new appraisal and assessment for the 21st century. *United Nations Educational, Scientific and Cultural Organization*, 40. https://unesdoc.unesco.org/ark:/48223/pf0000112671

UNESCO (2017). The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource. In *The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource. Paris, UNESCO*.

Water scarcity | Knowledge for policy. (n.d.). Retrieved January 24, 2022, from https://knowledge4policy.ec.europa.eu/foresight/topic/aggravating-resource-scarcity/water-scarcity_en

Wilkinson, G.M. (2017). Eutrophication of Freshwater and Coastal Ecosystems. *Encyclopedia of Sustainable Technologies*, 145–152. https://doi.org/10.1016/B978-0-12-409548-9.10160-5

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

STUDY OF THE INFLUENCE OF MANNING PARAMETER VARIATION FOR WATERFLOW SIMULATION IN DANUBE DELTA, ROMANIA

Adrian ROȘU, Maxim ARSENI, Bogdan ROȘU, Ștefan-Mihai PETREA, Cătălina ITICESCU, Puiu Lucian GEORGESCU

"Dunărea de Jos" University of Galați, 47 Domneasca Street, Galați, Romania

Corresponding author email: adrian.rosu@ugal.ro

Abstract

The paper aims to present the results of the influence of variation of Manning parameter in 1D water flow simulation on one of the most important channels in the Danube Delta, located in Tulcea county, Romania. The data used for the 1D simulations include water velocity, discharge, depths and was measured using the RiverSurveyor ADCP system in the summer of 2021, on the Magistral A.P. Chilia channel located in the north of the Danube Delta. The field data were collected in two measurement stations located along the Magistral A.P. Chilia channel. The uniflow cross-section model use Cross-Section Hydraulic Analyzer which is a model developed by the United States Department of Agriculture. All the simulations were performed using the unidirectional water flow model for the measured cross-sections by varying the manning parameter. The variation of the Manning parameter used in the simulations was based on the information found at the time of the field measurements and used according to other study findings. The results of the study show the importance of the Manning parameter in the 1D water flow simulation on medium channels, also underline the importance of water flow simulation regarding the water level regime that can have an important effect on channel morphology and also on the biodiversity of the area.

Key words*: uniflow simulation, 1D water flow simulation, Manning parameter, Danube Delta, roughness.*

INTRODUCTION

Danube Delta is one of the most important ecosystems in the world with more than 3500 flora and 1800 fauna species (Gâştescu, 2009). Water flow and water level regimes in large ecosystems like Danube Delta are very important to study subjects mostly for their impact on the biota and biodiversity and have an important impact on navigation and fishing activities. Also, the study of water flow in Danube Delta channels is a subject of many studies including sediment transport and quality (V.A. Calmuc et al., 2021b; Keller et al., 1998; Tiron et al., 2009), pollutants transport (L.P.G. Calmuc, n.d.; M. Călmuc et al., 2018; M. Calmuc, Calmuc, Arseni, et al., 2020; V.A. Călmuc et al., 2018; V.A. Calmuc et al., 2021a; Cristofor et al., 1993), flood studies (Arseni, Roșu, et al., 2019; Arseni et al., 2020a; Cristofor et al., 1993; Tiron et al., 2009), trophic gradients (Arseni et al., 2018; Poncos et al., 2013), nutrients dynamics (Cristofor et al., 1993), water quality studies (L.P.G. Calmuc, n.d.; Călmuc et al., 2018; M. Calmuc, Calmuc, Georgescu et al., 2020; V.A. Calmuc et al., 2021b).

To study the water flow through a channel it is necessary to have precise data regarding the shape of the studied cross-section for depth and the underwater terrain elevation in a specific geographic location, therefore modern and precise topographic equipment are required to gather these data. Also, data regarding the interaction between the surface and the water is necessary to study the water flow regime using a variation of Manning parameters.

In channels with almost stable boundaries, it is necessary to know the total resistance to flow using data from the interaction for a bundle of elements. These parameters are particle size of riverbed material, bank irregularity, vegetation, channel alignment, bed configuration, channel obstructions, converging or diverging streamlines, sediment load, and surface waves.

The present knowledge shows that the quantitative effect of the majority of these factors is not determinable and must be estimated. This kind of data can be obtained using bathymetry measurements coupled with topography determinations but it is time-consuming if a long river or channel is the subject of the study. Similar studies were made in large rivers like the Siret river, one of the most important affluent of Danube, using a single beam echosounder coupled with flood risk maps (Arseni, 2018; Arseni et al., 2020b; Arseni, Voiculescu, et al., 2019).

In our study we aim to study the water flow through simulation in a channel in Danube Delta, using describing bathymetry and topographic measurements data in specific cross-sections by varying the Manning roughness coefficient. The variation of Manning roughness coefficient in uniflow simulations have the purpose of calibrating the simulation so that the water flow in a specific cross-section will be similar to real data and the obtained simulation parameters can be used for other channel or river cross-sections.

MATERIALS AND METHODS

Study area

The subject of this study is the Magistral A.P. Chilia channel located in the Matiţa - Merhei depression located in the wing northern part of the Danube Delta (between the arms of Chilia and Sulina). The channel location in the Matiţa - Merhei aquatic complex can be observed in Figure 1.

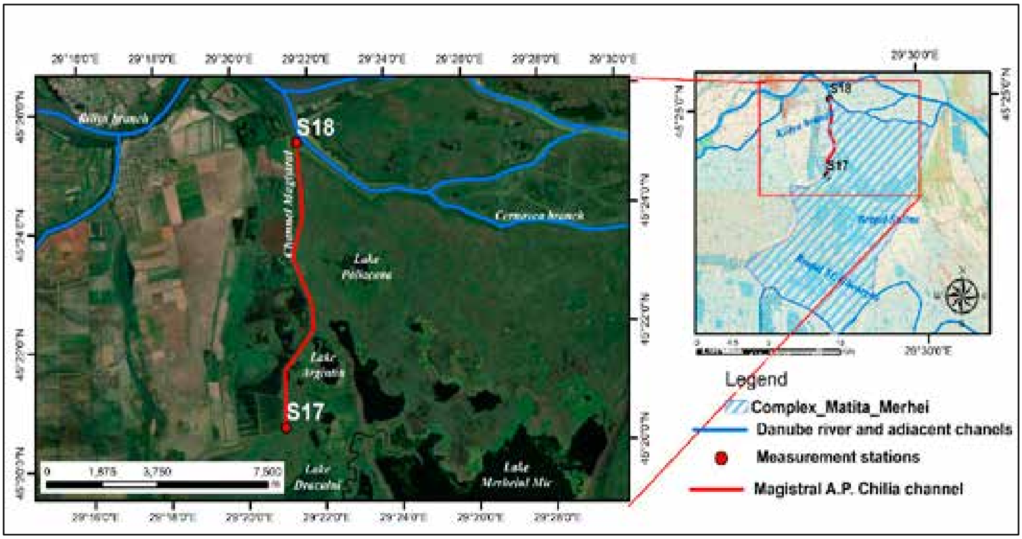


Figure 1. Detail map of Matiţa - Merhei aquatic complex (upper right map). Monitoring points on Magistral A.P. Channel Cell between the Cernovca arm and the Radacinoase canal: S17, S18 (left map)

Figure 1 is presented the map of the Matiţa – Merhei aquatic complex, also the spatial locations of the two measurements field stations are presented with the used codes S17 and S18.

Data gathering

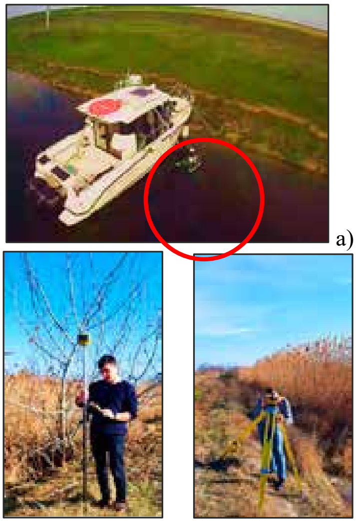
The data that describes the spatial location and shape of the Magistral A.P. Chilia channel in the measurement field stations were collected using topographic equipment along with bathymetric equipment, which was used in station data measurements in the wetland, including water level, depth, discharge, and velocity. Topographic measurements on banks were done using Topcon HiPer HR GNSS receiver and Topcon DL-501 electronic digital level (Figure 2).

The bathymetry measurements of the wetland in the measurements stations were done using the Riversurveyor M9 ADCP (Acoustic Doppler Current Profiler) system presented in the next figure during the field measurements alongside the boat Parker 900 which were used for the measurements and travel to measurement stations. The Riversurveyor M9 ADCP system measurement can be used in obtaining data regarding the water depth, velocity, and discharge.

All the equipment used is high-end topographic and bathymetric equipment so that the data collected present the best accuracy that range

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

between 0.1-5 cm on all tridimensional axis. The bathymetric system was used to measure the wetland and the topography equipment was used to obtain data on the dry land in the field station located along the Magistral A.P. Chilia channel.



a) b) c)

Figure 2. Equipment used for data collecting in the two field stations on Magistral A.P. Chilia channel: a) Mobile platform (boat Parker 800) for RiverSurveyour M9 ADCP bathymetric system (red circle); b) Topcon HiPer HR GNSS; c) Topcon DL-501 electronic digital level

Method used

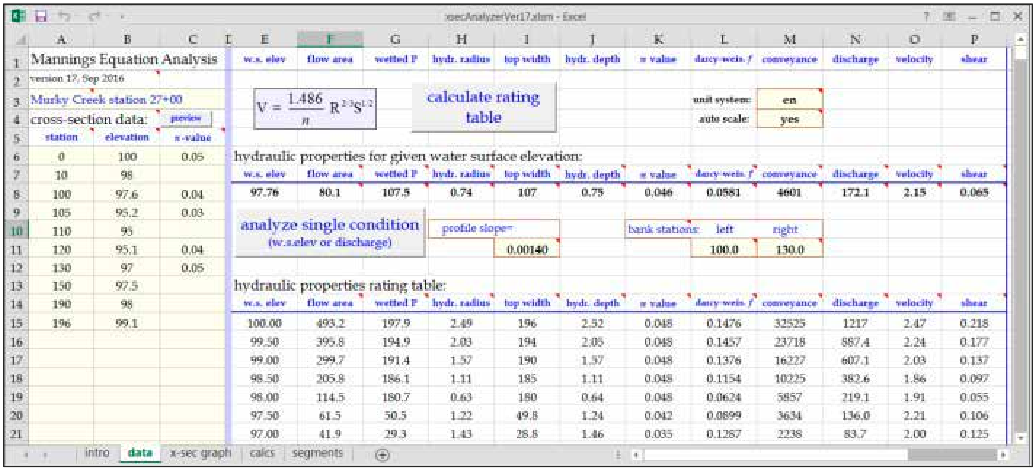
The water flow simulations were performed using the uniflow model Cross-Section Hydraulic Analyzer “xsecAnalyzerVer18.xlsm” developed by the Natural Resources Conservation Service (NRCS) Water Quality and Quantity Technology Development Team from the United States Department of Agriculture (*Cross-Section Hydraulic Analyzer*, n.d.).

The uniflow simulation model tool enables you to examine stream or river cross-sections and determine hydraulic parameters, such as flow area, discharge, and average velocity.

The below image shows the data entry sheet. The user may input data into any cell with a light-yellow background.

Cross-section station-elevation coordinates, data gathered with bathymetric and topographic equipment, are entered in columns A and B, along with Manning parameters as “n-values” in column C. In cells L11 and M11, the user is required to enter bank stations.

The reason these data are required is that, for many natural cross-section shapes, the results are affected by how overbank flow is accounted for. See details below in the section "overbank flow".



xsecAnalyzerVer17.xlsm - Excel

Mannings Equation Analysis
version 17, Sep 2016
Murky Creek station 27+00
cross-section data: preview

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

calculate rating table

unit system: en
auto scale: yes

station	elevation	n-value
0	100	0.05
10	98	
100	97.6	0.04
105	95.2	0.03
110	95	
120	95.1	0.04
130	97	0.05
150	97.5	
190	98	
196	99.1	

hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
97.76	80.1	107.5	0.74	107	0.75	0.046	0.0581	4601	172.1	2.15	0.065

analyze single condition (w.s.elev or discharge)

profile slope= 0.00140

bank stations: left 100.0 right 130.0

hydraulic properties rating table:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
100.00	493.2	197.9	2.49	196	2.52	0.048	0.1476	32525	1217	2.47	0.218
99.50	395.8	194.9	2.03	194	2.05	0.048	0.1457	23718	887.4	2.24	0.177
99.00	299.7	191.4	1.57	190	1.57	0.048	0.1376	16227	607.1	2.03	0.137
98.50	205.8	186.1	1.11	185	1.11	0.048	0.1154	10225	382.6	1.86	0.097
98.00	114.5	180.7	0.63	180	0.64	0.048	0.0624	5857	219.1	1.91	0.055
97.50	61.5	50.5	1.22	49.8	1.24	0.042	0.0899	3634	136.0	2.21	0.106
97.00	41.9	29.3	1.43	28.8	1.46	0.035	0.1287	2238	83.7	2.00	0.125

intro | data | x-sec graph | calcs | segments

Figure 3. Example of a filled uniflow simulation model using Cross-Section Hydraulic Analyzer spreadsheet

The Manning or roughness parameter can be estimated using data from previous studies or estimated using data from literature tables in which variation of Manning parameter is displayed according to the wetted surface composition and in dependence with it. Such

Manning tables that were used in our study are presented in the below Table 1 (Arseni, 2018; Limerinos, 1970a).

Table 1. Values of Manning parameters used in previous water flow, hydrodynamic studies, based on in-field measurements (Arseni, 2018; De Doncker et al., 2009; García Díaz, 2005; Limerinos, 1970b; Tiron et al., 2009)

***Natural flow channels (rivers)*- Minor bed**			
Surface/Area characteristics	Manning lowest value	Manning highest value	Manning averaged value
Clean, small slope, without rocks	0.025	0.030	0.033
Clean, small slope, with rare rocks, little vegetation	0.030	0.035	0.040
Clean, meandering, rare stones, a few sandbanks	0.033	0.040	0.045
Clean, meandering, rare stones with vegetation and large stones	0.035	0.045	0.50
Clean, meandering, rare stones and steep slopes	0.040	0.048	0.055
Clean, meandering, sandbanks, many stones	0.045	0.050	0.060
Slow, vegetated and very deep courses	0.050	0.070	0.080
Courses with abundant vegetation, deep depths or courses with many stones, and dense woody vegetation	0.070	0.100	0.150

To use this uniflow simulation model it is necessary that the bank stations must be specified because, for many natural cross-sections, the total section output is significantly affected by how overbank flow is treated. The issue relates to how wetted perimeter varies with depth. If the cross-section has a relatively wide flat overbank, then the wetted perimeter can increase significantly with a minor increase in flow depth (between in-channel flow and out-of-bank flow). As a result, the hydraulic radius will decrease with an increase in-depth, along with a reduction in computed total discharge.
If the overbank hydraulic parameters are computed separately from the channel, then this computational artifact is avoided. However, the onus remains upon the user to select appropriate bank stations (*Cross-Section Hydraulic Analyzer*, n.d.). The uniflow model is based on the next equation:

$$n = \frac{0.0926 R^{1/6}}{1.16 + 2.0 \log\left(\frac{R}{d_{84}}\right)} \quad (1)$$

where n is the surface roughness parameter, R is the hydraulic radius, d_{84} is the gravel size.

The method used for this article was first to identify the n parameters and try to estimate them using field data (site observation) and other studies' findings of the value of the rugosity parameter. The second step was to have a precise measurement of the channel cross-sections in the field stations using advanced topographic and bathymetric equipment.
The data about water depth, velocity, and discharge was collected using the ADCP system. The measurement method used is presented in Figure 4.

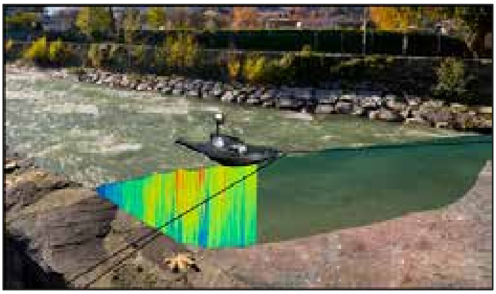
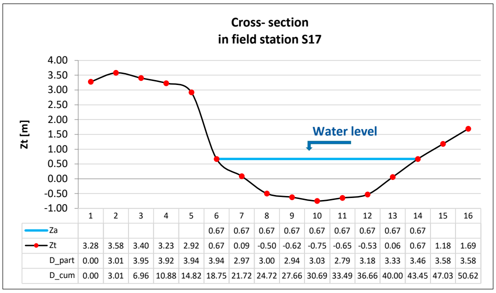


Figure 4. Bathymetric measurements using ADCP system in a river /channel cross-section. The colour ramp represents the variation of the water velocity in the measured cross-section by using an ADCP system.

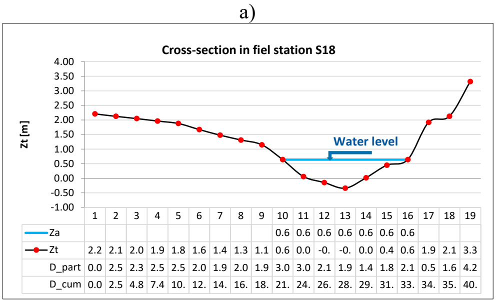
RESULTS AND DISCUSSIONS

The measured profiles in the two Magistral A.P. Chilia channel stations (S17 and S18) using bathymetry and topographic measurements are presented in Figure 5. The field data were post-process to eliminate gaps or errors caused by the flow debriefs or other aquatic noises to obtain clean and abundant data sets that would describe the real cross-section in the field station.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064



a)



b)

Figure 5. Magistral A.P. Chilia channel cross-sections for the S17 (a) and S18 (b) field stations.

In the above figure are presented the post-processed data from the two cross-sections from the field station S17 and S18 on the Magistral A.P. Chilia channel chosen for our uniflow modelling study. The data was processed from bathymetry and topography data from the locations of the study. As we can see in the above figure the resulting cross-section is simple and includes a maximum of 16 points of elevation for S17 and 19 for S18. The resulted cross-sections are obtained from the interpolation of hundreds of elevation points in each cross-section, data gathered with advanced bathymetric and topographic equipment. The abridgment of each cross-section through interpolation was done to simplify the cross-sections so the uniflow simulation can be performed fast without the need for large computational resources. Also, this method using interpolation of large datasets can result in the accurate shape of the cross-sections without losing the contribution of each elevation point measured with advanced bathymetry and topographic equipment. In Figure 5 it is presented the water level in the cross-section measured and referenced to the national reference "0 m" elevation point known as Marea Neagra Sulina (MNS). All data regarding the depth and elevation was referenced to MNS.

All the elevation points of the S17 cross-section were used in the uniflow model Cross-Section Hydraulic Analyzer "xsecAnalyzerVer18.xlsm" as elevation and the length from one point to another along the cross-section were defined as point stations. Several simulations were performed to obtain similar water discharge and velocity as it was measured by our ADCP system. The input data for the uniflow model is presented in Figure 6.

station	elevation	*n*-value
0.00	3.28	0.05
3.01	3.58	0.05
6.96	3.40	0.05
10.88	3.23	0.05
14.82	2.92	0.025
18.75	0.67	0.025
21.72	0.09	0.025
24.72	-0.50	0.025
27.66	-0.62	0.025
30.69	-0.75	0.025
33.49	-0.65	0.025
36.66	-0.53	0.025
40.00	0.06	0.025
43.45	0.67	0.05
47.03	1.18	0.05
50.62	1.69	0.05

Figure 6. Printscreen of the input data for the uniflow simulation in the S17 cross-section on the Magistral A.P. Chilia channel using Cross-Section Hydraulic Analyzer "xsecAnalyzerVer18.xlsm"

As we can observe in the above figure (and Figure 5 a) the n-value was set to 0.05 for the dry area of the cross-section and 0.025 for the wetted area, according to in-field findings of the area in the cross-section. Also, the n-value was approximated using the findings of previous studies as is presented in Table 1. A bundle of uniflow of water simulation were performed for this cross-section using different inputs of n-value, according to infield approximation in the S17 located on the Magistral A.P. Chilia channel. The most representative result of the uniflow simulations is presented in Figure 6 where the best fit with the field data of the n-value is presented.

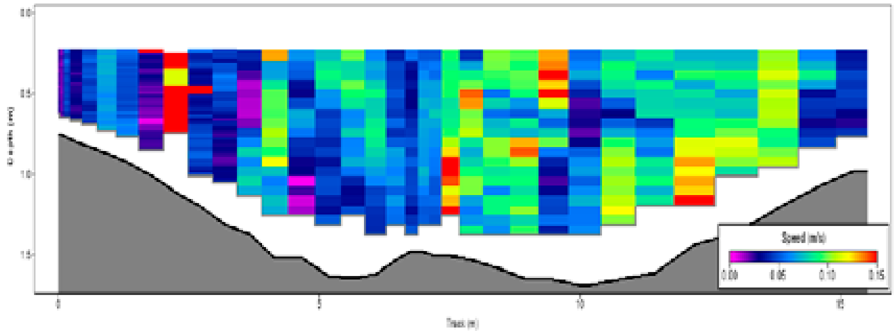


Figure 7. Results of water velocity during the in-field measurements in the S17 field station on the Magistral A.P. Chilia channel using RiverSurveyour M9 ADCP bathymetric system

In Figure 7 we can see the measured water velocity profile for the S17 field station on the Magistral A.P. Chilia channel show water velocity ranged between 1.4 m/s and 1.6 m/s, and an average value of 1.37 m/s.

Results of the ADCP measurements and uniflow simulations using Cross-Section Hydraulic Analyzer “xsecAnalyzerVer18.xlsm” for S17 field station on the Magistral A.P. Chilia channel are presented in Table 2.

As we can observe in Table 2, the errors using the uniflow simulation are very low and ranged between 10% and 12% of the measured values in all cases.

This was found when using proper input parameters for the simulations. These results show that if we had just the elevation of the cross-section measured with just a single beam acoustic doppler, which is low-cost equipment, and using an approximated n-value (Manning parameters) with respect to other research findings we can obtain by using Cross-Section Hydraulic Analyzer “xsecAnalyzerVer18.xlsm” values similar to the infield measurements.

Table 2. Comparison and errors between measured and simulated water discharge and velocity for S17

Instrument/Simulation Model	w.s. elev (m)	*n* value	Discharge (m^3/s)	Velocity (m/s)
“xsecAnalyzer Ver18.xlsm”	0.670000	0.029000	1.440000	0.065000
RiverSurveyour M9 ADCP batimetic system	0.670000	N/A	1.370000	0.067000
Erorr Model vs ADCP system	0.000000	N/A	0.070000	-0.002000
MSE	0.000000	N/A	0.004900	0.000004

Same input values as for S17 were used in the uniflow simulation of the S18 field station using Cross-Section Hydraulic Analyzer “xsecAnalyzerVer18.xlsm”. the results are presented in Table 3 along with the in-field verification of the results using the same ADCP system as it was used for S17 measurements.

As expected, the results showed (Table 3) very small errors when we apply the same settings of the uniflow simulations on the same channel. Therefore, this method can be used to obtain precise data regarding the discharge and water velocity in known channels cross-sections with respect to infield approximations of the Manning parameter distribution along the cross-section. Also, for this method to work, it is necessary to have some data regarding the water depth in certain cross-sections (using a simple ADCP) and the elevation value of the waterline.

Table 3 Comparison and errors between measured and simulated water discharge and velocity for S18

Instrument/Simulation Model	w.s. elev (m)	*n* value	Discharge (m^3/s)	Velocity (m/s)
“xsecAnalyzer Ver18.xlsm”	0.670000	0.029000	0.160000	0.02000
RiverSurveyour M9 ADCP batimetic system	0.670000	N/A	0.160000	0.021000
Erorr Model vs ADCP system	0.000000	N/A	0.000000	-0.001000
MSE	0.000000	N/A	0.00000	0.000001

CONCLUSIONS

The results of the study show that by using the uniflow model Cross-Section Hydraulic

Analyzer “xsecAnalyzerVer18.xlsm”, by using approximated Manning parameter with respect to literature and infield approximations, also using simple bathymetry (single beam equipment) we can obtain precise data regarding the water flow (water velocity and discharge data). The use of uniflow simulated results calibrated on several profiles can contribute to obtaining fast results for the entire section of the channel without the need to travel in the field and thus reduce costs and make predictions that can be subsequently be verified in selected profiles. Random checks of the model can be performed by carrying out bathymetric measurements in random cross-sections of the channel taken into study.

Also, this technique using the profile method requires a long time to measure in the field, using this method considerably reduces the time of working in the field and the processing of the data collected from the field measurements. By running such water flow simulations, we can obtain data that can be used in conducting sediment and pollutants transport studies in the channels and assess the environmental impact of their spatial distribution.

ACKNOWLEDGEMENTS

The present research/article/study was supported by the project An Integrated System for the Complex Environmental Research and Monitoring in the Danube River Area, REXDAN, SMIS code 127065, co-financed by the European Regional Development Fund through the Competitiveness Operational Programme 2014-2020, contract no. 309/10.07.2021.

REFERENCES

Arseni, M. (2018). Tehnici moderne GIS pentru determinarea riscurilor teritoriale [PhD Thesis]. Universitatea" Dunărea de Jos" din Galați.

Arseni, M., Rosu, A., Calmuc, M., Calmuc, V. A., Iticescu, C., & Georgescu, L. P. (2020a). Development of flood risk and hazard maps for the lower course of the Siret River, Romania. *Sustainability*, 12(16), 6588.

Arseni, M., Rosu, A., Calmuc, M., Calmuc, V. A., Iticescu, C., & Georgescu, L. P. (2020b). Development of flood risk and hazard maps for the lower course of the Siret River, Romania. *Sustainability*, 12(16), 6588.

Arseni, M., Roșu, A., Iticescu, C., Georgescu, L. P., Timofti, M., Pintilie, V., Călmuc, M., & Roman, O. (2018). A review of bathymetric measurements from August 2018 campaign on the lower course of the Danube. Analele Universității” Dunărea de Jos” Din Galați. Fascicula II, Matematică, Fizică, Mecanică Teoretică/*Annals of the” Dunarea de Jos” University of Galati. Fascicle II, Mathematics, Physics, Theoretical Mechanics*, 41(2), 212–219.

Arseni, M., Roșu, A., Murariu, G., Georgescu, L. P., Iticescu, C., Calmuc, M., & Calmuc, V. (2019). The role of river channel roughness for water level modeling during the 2005 year flood on Siret river using HEC-RAS model. Analele Universității” Dunărea de Jos” Din Galați. Fascicula II, Matematică, Fizică, Mecanică Teoretică/*Annals of the” Dunarea de Jos” University of Galati. Fascicle II, Mathematics, Physics, Theoretical Mechanics*, 42(1), 68–76.

Arseni, M., Voiculescu, M., Georgescu, L. P., Iticescu, C., & Rosu, A. (2019). Testing different interpolation methods based on single beam echosounder river surveying. Case study: Siret River. *ISPRS International Journal of Geo-Information*, 8(11), 507.

Calmuc, L. P. G. (n.d.). Preliminary Analysis on the River Danube Water Quality by Using Different Kinds of Methods.

Călmuc, M., Călmuc, V. A., Dragu, M. D., Rosu, A., Munteanu, D., Rosu, B., & Murariu, G. (2018). Comparative study of descriptive statistics on physico-chemical parameters describing water quality. Case study-the Danube River in the Galati area. *Annals of the University Dunarea de Jos of Galati: Fascicle II, Mathematics, Physics, Theoretical Mechanics*, 41.

Calmuc, M., Calmuc, V. A., Georgescu, L. P., Iticescu, C., & Arseni, M. (2020). Assessment of nutrients and oxygen regime in the Lower Danube water. Analele Universității” Dunărea de Jos” Din Galați. Fascicula II, Matematică, Fizică, Mecanică Teoretică/*Annals of the” Dunarea de Jos” University of Galati. Fascicle II, Mathematics, Physics, Theoretical Mechanics*, 43(1), 68–74.

Călmuc, M., Călmuc, V. A., Țopa, M. C., Timofti, M., Ilticescu, C., & Georgescu, L. P. (2018). Review on water quality assessment in the Danube River basin. Analele Universității” Dunărea de Jos” Din Galați. Fascicula II, Matematică, Fizică, Mecanică Teoretică/*Annals of the” Dunarea de Jos” University of Galati. Fascicle II, Mathematics, Physics, Theoretical Mechanics*, 41(2), 189–195.

Calmuc, M., Calmuc, V., Arseni, M., Topa, C., Timofti, M., Georgescu, L. P., & Iticescu, C. (2020). A Comparative Approach to a Series of Physico-Chemical Quality Indices Used in Assessing Water Quality in the Lower Danube. *Water*, 12(11), 3239. https://doi.org/10.3390/w12113239

Calmuc, V. A., Calmuc, M., Arseni, M., Topa, C. M., Timofti, M., Burada, A., Iticescu, C., & Georgescu, L. P. (2021a). Assessment of heavy metal pollution levels in sediments and of ecological risk by quality indices, applying a case study: The Lower Danube River, Romania. Water, 13(13), 1801.

Calmuc, V. A., Calmuc, M., Arseni, M., Topa, C. M., Timofti, M., Burada, A., Iticescu, C., & Georgescu, L. P. (2021b). Assessment of Heavy Metal Pollution Levels in Sediments and of Ecological Risk by Quality

Indices, Applying a Case Study: The Lower Danube River, Romania. *Water*, 13(13), 1801. https://doi.org/10.3390/w13131801

Călmuc, V. A., Călmuc, M., Țopa, M. C., Timofti, M., Iticescu, C., & Georgescu, L. P. (2018). Various methods for calculating the water quality index. Analele Universității" Dunărea de Jos" Din Galați. Fascicula II, Matematică, Fizică, Mecanică Teoretică/*Annals of the" Dunarea de Jos" University of Galati. Fascicle II, Mathematics, Physics, Theoretical Mechanics*, 41(2), 171–178.

Cristofor, S., Vadineanu, A., & Ignat, G. (1993). Importance of flood zones for nitrogen and phosphorus dynamics in the Danube Delta. *Hydrobiologia*, 251(1), 143–148.

Cross-Section Hydraulic Analyzer. (n.d.). Retrieved March 8, 2022, from https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/?cid=stelprdb1042510

De Doncker, L., Troch, P., Verhoeven, R., Bal, K., Meire, P., & Quintelier, J. (2009). Determination of the Manning roughness coefficient influenced by vegetation in the river Aa and Biebrza river. *Environmental Fluid Mechanics*, 9(5), 549–567.

García Díaz, R. (2005). Analysis of Manning coefficient for small-depth flows on vegetated beds. Hydrological Processes: An International Journal, 19(16), 3221–3233.

Gâştescu, P. (2009). The Danube Delta biosphere reserve. Geography, biodiversity, protection, management. *Rev Roum Géogr*, 53(2), 139–152.

Keller, B. E., Lajtha, K., & Cristofor, S. (1998). Trace metal concentrations in the sediments and plants of the Danube Delta, Romania. *Wetlands*, 18(1), 42–50.

Limerinos, J. T. (1970a). Determination of the Manning coefficient from measured bed roughness in natural channels.

Limerinos, J. T. (1970b). Determination of the Manning coefficient from measured bed roughness in natural channels.

Poncos, V., Teleaga, D., Bondar, C., & Oaie, G. (2013). A new insight on the water level dynamics of the Danube Delta using a high spatial density of SAR measurements. Journal of Hydrology, 482, 79–91.

Tiron, L. J., Le Coz, J., Provansal, M., Panin, N., Raccasi, G., Dramais, G., & Dussouillez, P. (2009). Flow and sediment processes in a cutoff meander of the Danube Delta during episodic flooding. *Geomorphology*, 106(3–4), 186–197.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE CURRENT STATE OF WATER IN CIRCULAR ECONOMY IN ROMANIA

Mihaela TIMOFTI[1], Adriana Magdalena PIENARU[2]

[1]"Dunărea de Jos" University of Galați, 47 Domneasca Street, Galați, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: Mihaela.Timofti@ugal.ro

Abstract

The circular economy approach has an increasing interest in water reuse, reclaimed water, or recycled wastewater in connection to water scarcity concerns and increased water demands by all sectors.
Given pollution and degraded ecosystems, inequity, and low numbers or, in some cases, the lack of a sustainable urban drinking water and sewerage service, in response to the closure of the water loop and to extend the life of water resources, consider water reuse, with economic costs, social and environmental benefits. Circular economy initiatives can also help attract the private sector by creating new business models, adding new funding sources. The European Union policy identifies the use of treated wastewater as one potential solution to water scarcity. The International Water Association (IWA) developed the 5Rs approach to water management – Reduce, Reuse, Recycle, Restore and Recover – for companies to consider and adopt as common practice.
This paper explores the relationship between the principles of the circular economy and sustainable water management, identifying the opportunities that are offered through applying these principles to water systems in Romania.

Key words*: circular economy, water, EU policy.*

INTRODUCTION

Water provides the basic needs for the population and it is the most important motor for supporting the economy through all the activities from agriculture, industry, transportation, tourism, etc. (Sandu & Virsta, 2021). Life's existence on earth depends on maintaining both the quantity and the good quality of water so it is imperiously necessary to think of new ways to use and reuse water because we are in a continuous world population growth which means increased consumption of natural resources, especially water resources (Virsta et al., 2020)
In addition to the problems related to water resources, we must also take into account the natural phenomena that can cause serious problems regarding the quality of water needed to carry out daily activities, such as: volcanic eruptions, floods, natural disasters, etc. (Ene, 2011; Global Water Partnership, 2020).
Now, 97.5% of the total amount of water covers two-thirds of the planet's surface; the rest of 2.5% is freshwater from which only 1% is easily accessible, with much of it trapped in glaciers and polar caps (Gleick, 1996). Therefore, it can be easily understood that freshwater sources are finite and vulnerable resources and the key to solving some of the related water problems is to use the water in such ways that allow to protect in any possible ways both the quality of water and refreshing the water resources.
Many studies were made in order to show the importance of protection of water resources (Blanco et al., 2022; Calmuc et al., 2021; Crovella et al., 2020; Murariu et al., 2018; Voiculescu et al., 2011).
Society is on the verge of collapse and the effects on the environment and climate will be irreversible if current consumption patterns will continue and, therefore, will be needed to reinvent itself (Momete, 2016). This reinvention implies an authentic approach of sustainable economic growth which needs different approaches regarding efficient use of natural resources, and optimization of water uses (Momete, 2020).

The traditional linear economy is based on large quantities of cheap and easily accessible materials, energy and water and after the product is consumed it is thrown away because it was designed to have a limited lifespan in order to encourage consumers to buy it again (Virsta et al., 2020). Still, when a product reaches the end of its life, its materials can be kept and used again and again, thereby creating further value. That is why in this moment more and more producers lift back the linear economy and look forward to circular economy. An important role in circular economy and industrial development is played by water which is a fundamental need for both animal and plants life forms (Decision No 1386/2013/EU, 2013)

In the recent years, in the context of world and EU policy development regarding the circular economy, this concept has gained increasing prominence in promoting of sustainable production and consumption and new business practices.

The European Union Action Plan for the Circular Economy was adopted for the first time in 2015 (*First circular economy action plan (europa.eu)*. In March 2020 EU adopted a new circular economy action plan (European Commision, Action Plan, 2020) Circular economy refers to a model that describes the way on how the life cycle of a product is extended. This means the producers try to find a model of production which involves "*to reduce*" waste to a minimum, "*to reuse*" materials, "*to recycle*" products, "*to restore*" and "*to recover*" as long as possible, in order to obtain a finite product with minimum impact on the budget, on the environment and on the human health (Figure 1).

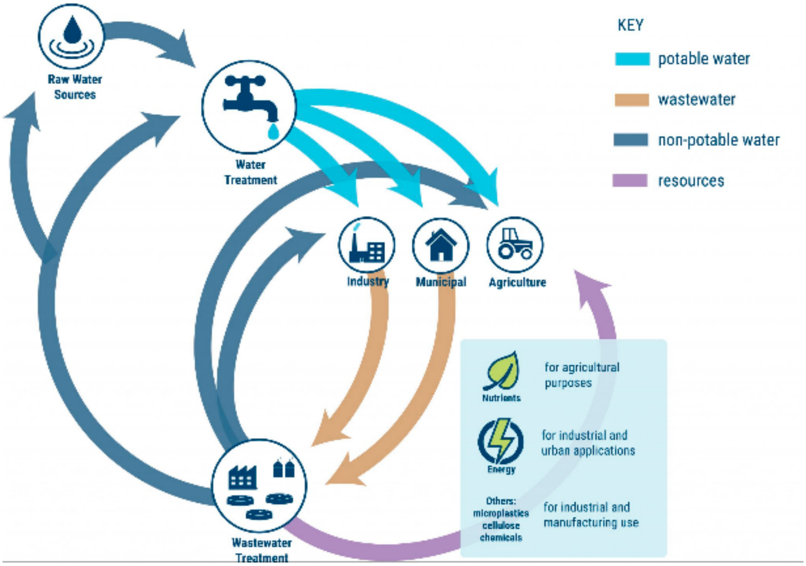


Figure 1 Water in the circular economy
(Water in the circular economy - Water Reuse Europe (water-reuse-europe.org))

Basically, the circular economy is based on three principles: *eliminate* waste and pollution, *keep* products and materials in *use and regenerate* natural systems. It is and inclusive economic model and it is based on new ways to obtain renewable energy and materials using (digital) innovation.

By the new water reuse regulation circular approaches to water reuse in irrigation, landscape irrigation, industrial reuse, groundwater recharge, etc. will be encouraged (European Commision, Action Plan, 2020; Pikaar et al., 2020). As a result of the actions aimed at creating circularity, the EU expects an improvement regarding the competitiveness and economic growth and decreasing the environmental impact and dependence on resources (Calisto Friant et al., 2021).

Circular Economy

Circular Economy (CE) is described by Korhonen et al. (Korhonen et al., 2018) as a topical notion with various meanings that has political support and is a "promising concept" among the business community. As this approach could lead to the exclusion of certain valences, the same authors argue that it is impossible to draw up a single definition of the circular economy.

Because of the limitation of the linear economy and the anthropogenic activity which conduct to environmental damage and climate change it is an increase interest in application of the Circular Economy (CE) objectives. The concept and the transition process of CE are different impact on perception and level of awareness of the stakeholders: researchers, economists and administration (Kevin van Langen et al., 2021).

In response to environmental issues, the transition to the CE has emerged as one of the best solutions at the same time as more sustainable global development (Cainelli et al., 2020). Also, it is a prerequisite to halt biodiversity loss and to achieve the EU's 2050 climate neutrality target (European Commision, Action Plan, 2020).

The main objectives of CE established by EU Commission refer to reducing the pressure on natural resources and creating sustainable growth and jobs. Since 2015 when were adopted the first action plan for the CE, EU Member States try, in their own way, to achieve CE objectives. With the help of the quantitative indicators that assess the degree of transition in the implementation of CE achieved by each member state were evaluated both their actions and their impacts on it. There are studies that clearly indicate a positive correlation between the rate of the implementation of CE objectives and the socio-economic development of a specific country. For example, countries that have a strong economic development have the most developed circular economy, too (Germany followed by the Netherlands, France, and Austria). On the opposite pole, countries with less economic growth have a less rate of implementation of CE (Romania, Bulgaria). (Marino & Pariso, 2020; Stanković et al., 2021).

Different state adopted different strategies but only a few of these can be effective in achieving the CE objectives of the European Union. Although in EU implementation of circular economy is a popular concept, Romania is still in the "well-intended actions" state. However, it is necessary to specify the fact that there are projects which are developed and implemented in Romania among other Eu member states such as:

- ✓ "The Danube Goes Circular" is under the Interreg MOVECO project which involved sixteen partners from the ten Danube countries. This project is a circular economy platform. (Chamber of Commerce and Industry of Slovenia et al., n.d.);
- ✓ "Circular Economy Coalition (CERC)" is a platform that promotes the key objectives of the EC Circular Economy Action Plan. CERC communicates with Romanian authorities to improve the legislative framework on circular economy and monitors both national and EU policies in the field of circular economy (Coaliția pentru Economie Circulară (economiecirculara.eu)).

The Member States made efforts to shift their social and economic activities towards "circularity" and had fostered changes in the business model and labour market. A new business model and new opportunities were results from the implementation of the Reduce, Reuse, Recycle, Restore and Recover (5Rs), models that conducted to an increasing by 5% for the number of jobs linked to the circular economy in the EU, between 2012 and 2018, that means an approximatively 4 million new jobs (European Commision, Action Plan, 2020).

Water in Circular Economy

In the context in which, now, it was demonstrated that we are big consumers of water resources, the possibility of using this resource less and less and reusing it more and more must be considered. Therefore, water in the circular economy is a concept and a very current topic much discussed at European level. According to EU Action plan in circular economy, the Commission will monitor and support the implementation of the requirements of the Drinking Water Directive in order to reduce dependence on bottled water and prevent packaging waste (European Commision, Action Plan, 2020).

The full value of water regarding it source of energy and carrier of materials or nutrients or as an input to processes, and as finite resource demonstrate the necessity of using it in a circular economic way (Delgado et al., 2021)

The main cause of water waste and, implicitly, its incorrect use is the inability to recognize the value of water. There are massive water leaks in distribution systems around the world, leaks that represent 25 to 50% of the total amount of water that is supplied to the population and which, in some cases, reach 75% (Delgado et al., 2021). These losses overlap with few and even non-existent incentives to encourage the lowest possible water consumption by the population and/or industry, agriculture, farmers, etc. In fact, in low water areas it is used more wastefully and inefficiently than in areas with more water precisely because of inadequate policies, prices and incentives (Damania, 2017).

EU policies. Romanian policies

To make Europe cleaner and more competitive, the European Commission adopted a new Circular Economy Action Plan (CEAP) in March 2020 and has a new priority – European Green Deal. CEAP is based on laws relating to waste (*Waste Framework Directive*), batteries (*Proposal for a Battery Regulation*), plastics (*Disposable Plastics Directive*) and water reuse (*Water Reuse Regulation*).

The *Waste Framework Directive* (Directive 2008/98/EC, 2020) has been issued to make clarifications that have been deemed necessary and sets out measures to protect the environment and human health. These measures are intended to prevent or reduce the negative impact of waste, the overall impact of resource use and to improve the efficiency of such use.

The European Parliament and the European Council have proposed in December 2020 a new regulation on batteries and used batteries (*Proposal for a Battery Regulation*), which is intended to repeal Directive 2006/66/EC and to amend Regulation (EU) 2019/1020 (European & European, 2020).

The *Disposable Plastics Directive* primarily aims to reduce the amount of waste generated, gives priority to sustainable and non-toxic reusable products and reuse systems over disposable products and, most importantly, promotes circular approaches (European Council, 2019);

The *Water Reuse Regulation* is a regulation that creates a favourable framework for those Member States that want or need to practice water reuse and has stated the purpose of facilitating water reuse, regardless of the number of times this reuse is applied in a way that ensures economic efficiency (Parliament European & Council European, 2020)

All new regulations that are related to circular economy have as main subject chemicals, plastics, secondary raw materials, and sustainable development.

Thus, in addition to the Action Plan for the New Circular Economy and the First Action Plan for the Circular Economy (2015-2019), there are new strategies related to the main topics mentioned above: Chemical Strategy for Sustainability, Zero Pollution Action Plan, Biodiversity Strategy for 2030, Plastics Strategy, Critical Raw Materials Action Plan, New Industrial Strategy.

In 2008, one year after Romania's accession to the EU, the Romanian Government approved the National Strategy for Sustainable Development "Horizons" 2013-2020-2030 and in 2016, the Romanian Senate adopted a decision certifying Romania's openness to the circular economy model and declaring the Romanian state's intention to build a legislative framework to support this model.

The National Strategy for Sustainable Development "Horizons" 2013-2020-2030 proposed practical objectives for the transition to sustainable development. The results obtained had to be reflected in an economic growth that would significantly reduce the economic gaps between Romania and the other EU member states.

In the Horizon Strategy for the period 2013-2020-2030, the following specifications can be made (Târțiu et al., 2019):

- ✓ a report on the state of implementation of the strategy adopted in 2008 is still not yet available
- ✓ In order to monitor the National Strategy, 13 sustainable development indicators applicable at national level and 10 territorial

sustainable development indicators were developed;
- ✓ to align with the 2030 Agenda for Sustainable Development, in 2018 a process of revision of the National Sustainable Development Strategy began under the direct supervision of the Department for Sustainable Development within the Romanian Government.

So far, in Romania, the following pieces of legislation have been adopted:
- ✓ Law no. 211/2011 on waste management (based on the Waste Directive 2008/98 / EC (Waste Framework Directive),
- ✓ Law no. 249/2015 on the management of packaging and packaging waste (based on Directive 94/62 / EC)),
- ✓ Law no. 2012/2015 on vehicle management (this is the result of the transposition of Directive 2000/53 / EC),
- ✓ GEO (Government Emergency Ordinance) no. 5/2015 on waste electrical and electronic equipment (Directive 2012) / 19 / EU) - with subsequent amendments.

One of the concrete actions undertaken by the Romanian Government meant to consolidate and promote the implementation of the EC is to participate in the meeting of the Visegrad + 4 group (Informare de presă - Participarea delegatiei Ministerului Mediului la cea de-a 5-a Conferință a Părților la Convenția - cadru privind protecția și dezvoltarea durabilă a Carpaților (Convenția Carpatică) | Ministerul Mediului (mmediu.ro)).

The current state in Romania

The incidence of water in circular economy is known in Romania, here are some facts to prove this statement:

● In 2012 an independent non-governmental association has been established as "The Institute for Research in Circular Economy and Environment "Ernest Lupan" – IRCEM, through an initiative of the Technical University of Cluj-Napoca. In 2017, IRCEM/CIOS became the official partner in the Circular Economy Platform of Stakeholders (ECESP) from the European Economic and Social Committee of the European Commission. More information about this subject can be found on IRCEM.RO or https://circulareconomy.europa.eu/platform/en/dialogue.

● IRCEM implemented the project "Romania's strategy for the transition to a circular economy (ROCES) 2020-2030", aiming to define the pillars which will support Romania's transition to a circular economy by involving all relevant stakeholders (i.e., civil society, public administration, industry, academics, social infrastructure), and by attracting the necessary financial support. The study aimed to collect all the opinions from relevant actors on the level of penetration of the circular economy in terms of regional collaboration, such that we achieve our vision of Romania being a leader in Central and South-East Europe in the circular economy.

● Aquademica Foundation, https://aquademica.ro/open-source-aqua-circular-2020/, uses an open-source approach, to create, socialize and globally disseminate solutions for building local circular economies. Aqua Circular On-line Conference 2020 promoted the innovative solutions for all the interested stakeholders in Western Romania, but also from neighbouring regions of Hungary and Serbia. The main purpose of the conference was to organize the frame for matching demand and supply in the circular water sector, with the aim to improve the competitiveness of local stakeholders within the regional water market. The conference was an innovative mixture of circular water project presentations and debates, with the aim of creating business opportunities in regional markets and building strong partnerships among regional water operators, decision makers and technicians from regional utilities, local industry and agriculture, local start-ups, regional universities and R&D centers, technology providers, local and central administrations. In October 2021, a new conference, organized on-line, with the same topics regarding water and circular economy (https://aquademica.ro/conferinta-internationala-aqua-circular-2021-un-eveniment-stiintific-timisorean-de-anvergura/).

● Conditions for Circular Water Solutions - NextGen Water project, 2018-2022 - partners from 9 EU countries plus Romania - City of Timisoara - AQUATIM - (Horizon 2020) - for Timisoara - with technologies for Sludge management with production of by products and/or energy and Reuse of effluent for urban industrial and agricultural applications.

● NanoTermo - Patented technology for the circular economy. Increasing the efficiency and reducing the operating costs of existing and new, small, and medium treatment plants, by KEMATRONIC SRL, Romania.

● Interesting article on "Industrial Symbiosis through the Use of Biosolids as Fertilizer in Romanian Agriculture", elaborated in 2021, and published in Recycling 2021, https://www.mdpi.com/journal/recycling, showing the application of Biosolids enhancing soil fertility and crop yield in amended soils. Still, "the characteristics of the biosolids must be controlled and monitored to minimize the potential impact on the environment and human health. At the same time, the characteristics of the land must be monitored too, in order to receive the permit for biosolids' use in agriculture. Additionally, Romanian legislation prohibits the use of sludge in vegetable and fruit crops growing in shrubs, vines, pastures and restricts the use of sludge in orchards. The use of sewage sludge is profitable also from the point of view of the savings it assumes. Thereby, at the country level, if all the sludges had been used in agriculture, the fertilizer replacement value would be worth the equivalent of about 3 million Euros for 2018 only and 2.9 million Euros for 2019. Moreover, water suppliers can achieve exceptional savings if they avoid discharge of sewage sludge at landfills. In this way, the water operators can maintain their operational costs at lower levels."

● In the Operational Program for Sustainable Development under Priority Axis 2: Development of water and wastewater infrastructure and the transition to a circular economy, projects and investments would be implemented.

● In the National Recovery and Resilience Plan, under the Component 1 - Water Management, projects and investments would be implemented for water in connection with the circular economy.

● on the website of the Romanian Water Association, in the section dedicated to members, there are monthly newsletters, in which a special section is dedicated to the topic on circular economy, with news on research and findings regarding national and international best practices.

CONCLUSIONS

An analysis of several basic, internal macroeconomic indicators was made following which it was found that at the level of "absorption" of the circular economic model "Romania is the least performing economy in the European Union" and "uses more and more natural resources, but it produces low economic value" (Is Romania prepared for the circular economy? (green-report.ro)).

Thus, regarding water, in the same analysis, it is specified that Romania "is again on the last place in Europe, producing an economic value of 10 euros for every m^3 of water extracted from the natural environment".

In Romania, the very poor performance in terms of water productivity is the direct result of public policies in the field of water resources management, policies which, as they are presented, encourage excessive use of water to the detriment of the economy of this precious resource (Vermeşan et al., 2020).

Therefore, the efforts to implement the principles of the circular economy must be intensified so that the 5 Rs (*Reduce, Reuse, Recycle, Restore and Recover*) can be applied in Romania to a greater extent. In this regard, lessons of good practice can be considered from other EU Member States with experience in implementing the objectives and applying the principles of the CE. The involvement of specialists and the education and training of new specialists in the field of water and the CE is a key factor that could make, in Romania, a faster and better implementation of European directives of this domain than it is made today.

It is also necessary for the Romanian authorities, responsible for issuing legislative acts in the field of water protection, to draft a package of laws through which the European directive on water reuse can be implemented in Romania.

In addition, in order to make a better transition to a CE, this paper addresses the need for public policy development in which the results of scientific research in the field of water are intertwined with the legislative, economic, social, and educational components.

ACKNOWLEDGEMENTS

The present research/article/study was supported by the project An Integrated System for the Complex Environmental Research and Monitoring in the Danube River Area, REXDAN, SMIS code 127065, co-financed by the European Regional Development Fund through the Competitiveness Operational Programme 2014-2020, contract no. 309/10.07.2021.

REFERENCES

Blanco, E., Raskin, K., & Clergeau, P. (2022). Towards regenerative neighbourhoods: An international survey on urban strategies promoting the production of ecosystem services. *Sustainable Cities and Society*, *80*(September 2021), 103784. https://doi.org/10.1016/j.scs.2022.103784

Cainelli, G., D'Amato, A., & Mazzanti, M. (2020). Resource efficient eco-innovations for a circular economy: Evidence from EU firms. *Research Policy*, *49*(1), 103827. https://doi.org/10.1016/j.respol.2019.103827

Calisto Friant, M., Vermeulen, W. J. V., & Salomone, R. (2021). Analysing European Union circular economy policies: words versus actions. In *Sustainable Production and Consumption* (Vol. 27, pp. 337–353). https://doi.org/10.1016/j.spc.2020.11.001

Calmuc, V. A., Calmuc, M., Arseni, M., Topa, C. M., Timofti, M., Burada, A., Iticescu, C., & Georgescu, L. P. (2021). Assessment of heavy metal pollution levels in sediments and of ecological risk by quality indices, applying a case study: The lower danube river, romania. *Water (Switzerland)*, *13*(13). https://doi.org/10.3390/w13131801

Chamber of Commerce and Industry of Slovenia, And, M. of the E., & Spatial Planning, R. of S. (n.d.). *The Danube goes circular- Transnational Strategy to Accelerate Transition Towards a Circular Economy in the Danube Region*.

Coaliția pentru Economie Circulară (economiecirculara.eu)

Crovella, T., Paiano, A., Lagioia, G., Stanković, J. J., Janković-Milić, V., Marjanović, I., Janjić, J., Chen, Z., Huang, L., Petrescu-Mag, R. M., Petrescu, D. C., Azadi, H., Momete, D. C., Predeanu, G., Slăvescu, V., Bălănescu, M., Dorina Mihalache, R., Mihaly, M., Marin, A. C., Czirok, L. (2020). Optimizing the Methodology of Characterization of Municipal Solid Waste in EU under a Circular Economy Perspective. *Journal of Cleaner Production*, *136*(June), 124132. https://doi.org/10.1016/j.indic.2021.100150

Damania, R. (2017). Uncharted Waters The economics of water scarcity and variability. In *Oxford Review of Economic Policy* (Vol. 36, Issue 1). https://doi.org/10.1093/oxrep/grz027

Decision No 1386/2013/EU. (2013). Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 "Living well, within the limits of our planet." *Official Journal of the European Union*, *1600*, 171–200. http://eur-lex.europa.eu/legal-content/en/txt/pdf/?uri=celex:32013d1386&from=en

Delgado, A., Rodriguez, D. J., Amadei, C. A., & Makino, M. (2021). Water in Circular Economy and Resilience (WICER). *International Bank for Reconstruction and Development / The World Bank*.

Directive 2008/98/EC. (2020). Directive 2008/98/EC of the European Parliament and of the Council. *Fundamental Texts On European Private Law*, 3–30. https://doi.org/10.5040/9781782258674.0028

Ene, S. A. (2011). *Studii privind amprenta ecologica a apei si aplicatii in managementul integrat al resurselor de apa - rezumay teza doctorat*.

European Commision, Action Plan, 2020 a. (2020). Circular Economy Action Plan. In *Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions*.

European Council. (2019). *Directive 2019/904 of the European Parliament and of the Council on the reduction of the impact of certain plastic products on the environment*. *2019*(March), 1–19. https://www.plasticseurope.org/en/resources/publications/1689-working-together-towards-more-sustainable-plastics%0Ahttps://www.plasticseurope.org/en/resources/publications%0Ahttps://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0904&from=EN

European, P., & European, C. (2020). Proposal for a regulation of the EUROPEAN PARLIAMENT and of the EUROPEAN COUNCIL concerning batteries and waste batteries. *European Commission*, *0353*(2019). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020PC0798

First circular economy action plan (europa.eu)

Gleick, P. H. (1996). Basic water requirements for human activities: Meeting basic needs. *Water International*, *21*(2), 83–92. https://doi.org/10.1080/02508069608686494

Global Water Partnership. (2020). *GWP in Action: 2020 Annual Report*. https://gwp.org/annualreport2020

green-report.ro

Informare de presă - Participarea delegatiei Ministerului Mediului la cea de-a 5-a Conferință a Părților la Convenția - cadru privind protecția și dezvoltarea durabilă a Carpaților (Convenția Carpatică) | Ministerul Mediului (mmediu.ro)

Kevin van Langen, S., Vassillo, C., Ghisellini, P., Restaino, D., Passaro, R., & Ulgiati, S. (2021). Promoting circular economy transition: A study about perceptions and awareness by different stakeholders groups. *Journal of Cleaner Production*, *316*(June), 128166. https://doi.org/10.1016/j.jclepro.2021.128166

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular Economy: The Concept and its Limitations. *Ecological Economics*, *143*, 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041

Marino, A., & Pariso, P. (2020). Comparing European countries' performances in the transition towards the Circular Economy. *The Science of the Total Environment*, *729*, 138142. https://doi.org/10.1016/j.scitotenv.2020.138142

Momete, D. C. (2016). Building a sustainable healthcare model: A cross-country analysis. *Sustainability (Switzerland)*, *8*(9). https://doi.org/10.3390/su8090836

Momete, D. C. (2020). A unified framework for assessing the readiness of European Union economies to migrate to a circular modelling. *Science of the Total Environment*, *718*, 137375. https://doi.org/10.1016/j.scitotenv.2020.137375

Murariu, G., Murariu, A. G., Iticescu, C., Timofti, M., & Georgescu, L. (2018). Investigation of water quality state dynamics of danube river in the eastern part of Romania. *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM*, *18*(1.5).

Parliament European, & Council European. (2020). Regulation (EU) 2020/741, Minimum requirements for water reuse. *Official Journal of the European Union*, *177/33*(May 2020), 32–55.

Pikaar, I., Guest, J., Ganigué, R., Jensen, P., Rabaey, K., Seviour, T., Trimmer, J., Kolk, O. Van Der, Vaneeckhaute, C., & Verstraete, W. (2020). *Resource recovery*.

Sandu, M.A., & Vîrsta, A. (2021). *The water footprint in context of circular economy*. *10*(2).

Stanković, J. J., Janković-Milić, V., Marjanović, I., & Janjić, J. (2021). An integrated approach of PCA and PROMETHEE in spatial assessment of circular economy indicators. *Waste Management*, *128*, 154–166. https://doi.org/10.1016/j.wasman.2021.04.057

Târțiu, V. E., Ștefănescu, M., Petrache, A.-M., & Gurau, C. R. (2019). *Tranziția către o economie circulară. De la managementul deșeurilor la o economie verde în România Autori*. www.ier.gov.ro

Vermeşan, H., Mangău, A., & Tiuc, A. E. (2020). Perspectives of circular economy in Romanian space. *Sustainability (Switzerland)*, *12*(17), 1–29. https://doi.org/10.3390/SU12176819

Virsta, A., Sandu, M.A., & Daraban, A.E. (2020). Dealing with the transition from in line economy to circular economy - public awareness investigation in Bucharest. *Agrolife Scientific Journal*, *9*(1), 355–361.

Voiculescu, M., Georgescu, L. P., Dragan, S., Timofti, M., & Caldararu, A. (2011). Study of anthropogenic effects on the quality of the lower Prut river. *Journal of Environmental Protection and Ecology*, *12*(1).

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

SEDIMENTATION RATE OF LIQUID-SOLID SUSPENSIONS, AS A PARAMETER OF WASTEWATER TREATMENT

Bianca-Ştefania ZĂBAVĂ, Paula TUDOR, Gheorghe VOICU, Gabriel-Alexandru CONSTANTIN, Mirela-Nicoleta DINCĂ

Politehnica University of Bucharest, 313 Splaiul Independentei, Bucharest, Romania

Corresponding author email: paulavoicu85@yahoo.com

Abstract

The need to separate the solid phases from the liquid ones is probably the most common requirement for separation in the wastewater treatment process, the most common method being by gravity, called sedimentation. Sedimentation rate is an important hydrodynamic quantity for the characterization of particle motion and for the technological design of equipment used to separate heterogeneous systems through the sedimentation process. Our work aims is to determine the sedimentation rate in the case of three types of suspension consisting of water - calcium carbonate, water - soil, water - blue clay, with concentrations of 2%, 4%, 6%, 8% and 10%. The particle size for calcium carbonate and blue clay was 0.2 mm and that of the soil was 0.4 mm. Stokes' law was applied to determine the sedimentation rate of solid particles and the following parameters were determined: material particle density (using the pycnometer), dynamic density and viscosity of the suspension (using the Hoppler viscometer). The obtained results showed that the sedimentation rate is influenced by the concentration, size and density of solid particles, these results being correlated with the results obtained from the literature.

***Key words**: wastewater treatment, sedimentation rate, dynamic viscosity, density.*

INTRODUCTION

A major challenge facing a sustainable global future is the growing demand for clean water. The continuous growth of the world's population has led to an increase in the demand for drinking water, so that during the years 1942-1990 the process of taking drinking water from rivers, lakes, reservoirs and groundwater sources has increased significantly, more than four times (Bagtzoglou et al., 1992). The availability of a clean and safe source of water is essential for human health and well-being, as well as for agriculture, industry and transport (Veolia, 2014).
At European level, the most effective methods of environmental protection are constantly sought, the main method of combating water pollution, and a means of improving the quality of wastewater is the treatment process, which is currently the most widely used (Figure 1).
The term water pollution occurs when the presence of any foreign substance (organic, inorganic, biological or radiological), contaminates a water source, degrading its quality and making it toxic to humans or the environment (Denchak, 2018; The Romanian Water Law, 1996).

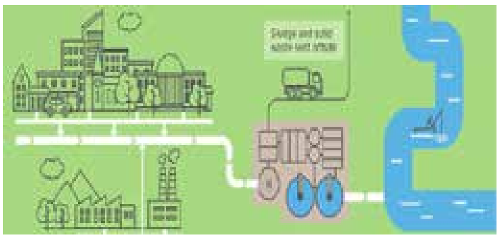


Figure 1. Urban wastewater circuit (EPA, 2019)

The European Union's Urban Wastewater Treatment Directive sets standards for the treatment of urban wastewater in urban areas. Standards are set to protect the environment and human health from the adverse effects of wastewater discharges.
In the European Union, comparisons between water consumption in Member States are not always straightforward.
Recent efforts to address the protection of water resources have led to the development of

new processes for purification and improvement of water management techniques. However, over the next 20 years, human behavioural changes and technological innovations will be needed to find a balance between water supply and demand (Ichem E., 2007).

Wastewater treatment is mandatory to protect future sustainable economic growth (Special Report, 2015).

Wastewater treatment is a basic method for the protection and reuse of water resources, which is clearly demonstrated by the consequences of its implementation in many countries around the world.

Scientific research in recent decades has made great strides in understanding the complex and interdisciplinary aspects of the biological, biochemical, chemical, and mechanical processes involved in wastewater treatment (Gavrila, 2001; Ichem E., 2007; Florea & Robescu, 1982; Florescu, 2007; Panaitescu, 2011; Robescu et al., 1999; Safta et al., 2012; Vanderhasselt & Vanrolleghem, 2000).

The wastewater treatment process is a complex process that includes several stages that allow the gradual elimination of different types of impurities: coarse, fine, mineral or organic. There are two basic steps in the treatment process: primary and secondary treatment, (EPA, 1998).

The removal of solids by gravity is, according to studies in the literature, the main method of water purification from treatment plants.

The process of separating the liquid-solid mixture is influenced by many factors related to both the solid component, the liquid component and the construction parameters of the decanter.

Following studies by Camp and Fitch researchers on the settling of various types of suspensions, they classified the phases of the settling process according to the concentration of the suspension and the nature of the solid particles as follows: type I clarification, type II clarification, mass sedimentation and sediment compaction (Figure 2) (EPA, 1997).

Data on the rate of the sedimentation process are very important for the design of equipment used in chemical and metallurgical practices for the separation of suspended solid particles from liquid or gaseous flow (Mondal and Majumdar, 2004).

Through the sedimentation process, the sedimentation rate of a particle increases until the settling force (the particle's own weight) becomes equal to the resisting forces. In this case, there is a balance between the forces acting on the particle, for which (dvp/dt) = 0.

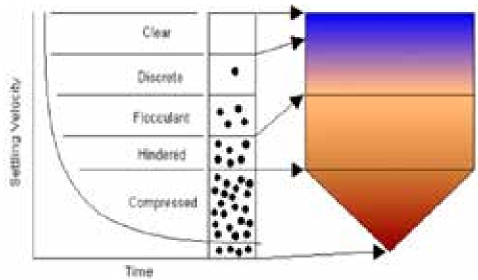


Figure 2. Diagram of the settling phases (Suntech, 2020)

Sedimentation rate is an important hydrodynamic quantity for the characterization of particle motion and for the technological design of equipment used to separate heterogeneous systems by sedimentation, (Coldea & Ionescu, 2005; Gavrila, 2001).

The settling rate varies greatly depending on the concentration of solid particles. The weight of the particles G, the strength of Archimedes F_A and the viscous resistance F_R act on the spherical particles isolated from the fluid (Figure 3). Gravity tends to deposit particles on the bottom of the tank, and the other two forces prevent the particles from settling. In the steady state of the force system, the sedimentation rate of the particles can be evaluated according to the scheme (Racoviteanu, 2003):

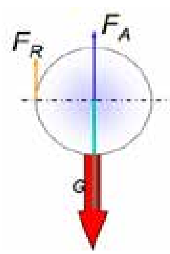


Figure 3. The system of forces acting on the solid particle in the suspension (Gavrilă, 2001)

Several models have been reported in the literature to estimate settling rates. Al-Naafa and Selim (1992) studied both theoretically and experimentally two-dimensional gravitational sedimentation and three-dimensional concentrated suspensions ranging from 13 to 45% (by volume). The authors concluded that the model equations developed by Mirza and Richardson (1979) and later used by Selim et al. (1983) for two-dimensional suspensions were valid.

In another study by Tarpagkou R. et al. (2013), the results showed that at low water temperatures, more precisely in the region of non-linear density, the efficiency of the sedimentation process decreases, the viscosity of the water increases, the resistance as the solid particles increase and, as a result, the sedimentation rate decreases, the turbidity at the free surface increases (Tarpagkou et al., 2013).

The work aims to determine the sedimentation rate in the case of three types of suspension consisting of water - calcium carbonate, water - soil, water - blue clay, concentrations 2%, 4%, 6%, 8% and 10%, for solid particle size of 0.2 and 0.4 mm.

MATERIALS AND METHODS

To determine the sedimentation rate of the three types of suspension consisting of water - calcium carbonate, water - soil, water - blue clay, concentrations 2%, 4%, 6%, 8% and 10% respectively and the particle size of 0.2 mm in the case of calcium carbonate and blue clay and 0.4 mm in the case of soil, Stokes' law was applied:

$$v = \frac{{d_p}^2 \cdot g \cdot (\rho_p - \rho_S)}{18 \cdot \vartheta \cdot \rho_S} = \frac{{d_p}^2 \cdot g \cdot (\rho_p - \rho_S)}{18 \cdot \eta} \quad (1)$$

where:

d_p - particle diameter, (m); g - gravitational acceleration, (m/s^2); ρ_p - solid particle density (kg/m^3); ρ_S - suspension density, (kg/m^3); η - dynamic viscosity of the suspension, (Pa·s); ϑ - the kinematic viscosity of the suspension, (m^2/s).

In order to determine the sedimentation rate, the following parameters had to be determined, in turn: the density of the three types of material, the density of the suspension and the dynamic viscosity of the suspension.

Determination of the density of the three types of solid particles

The density of the three types of solid particles was determined using a pycnometer, using a Kern analytical balance, and xylene was used as the working liquid, which has a known density of 860 kg/m^3.

The empty pycnometer was first weighed using the analytical balance, filled with working liquid - xylene, and then weighed again. 2-5 g of material was added to the empty and dry pycnometer using a funnel and weighed again. Knowing the mass of the empty pycnometer, the exact mass of the material under analysis was obtained by subtraction. The reference liquid was added over the amount of material to the pycnometer mark, stirred gently so that no air gaps remained between the material particles, the outside of the pycnometer was wiped with filter paper and weighed (Torfs et al., 2016).

The density of the analysed material was determined by relation (2):

$$\rho_p = \frac{(m_c - m_a) \cdot \rho_l}{(m_b + m_c) - (m_a + m_d)} \quad (2)$$

where:

ρ_p represents the density of the analysed material (g/cm^3); m_a - empty pycnometer mass (including capillary plug) (g); m_b - the mass of the pycnometer filled with the reference liquid (g); m_c - mass of the pycnometer with 2-5 g of material (g); m_d - mass of the pycnometer with material and filled with the reference liquid to the mark (g); ρ_l - density of the reference liquid (g/cm^3).

Determination of the density of the liquid-solid mixture

To calculate the density of the liquid-solid mixture of 2%, 4%, 6%, 8% and 10% concentration, the calculation formula was used:

$$\rho_S = \frac{m}{V} \quad (3)$$

where:

ρ_S represents the density of the liquid-solid mixture (g/cm^3); m - suspension mass (g); V - suspension volume (cm^3).

A graduated cylinder with a known volume of 50 cm^3 was used, the mass of solid particles corresponding to the five concentrations being 1 g, 2 g, 3 g, 4 g, 5 g. These masses were weighed using the analytical balance, each quantity was subsequently added to the cylinder, the mass of the empty cylinder being determined first, and distilled water was added to the 50 mL mark. The mixture was homogenized to remove air gaps between the solid particles and the cylinder was subsequently weighed using the Kern electric balance to determine the mass of the suspension.

Determination of the dynamic viscosity of the liquid-solid mixture

The dynamic viscosity of the three liquid-solid mixtures for each concentration was measured using the Hoppler ball viscometer (Figure 4).

Figure 4. Determination of viscosity using a Hoppler ball viscometer

Before starting the determinations, the glass tube of the viscometer was washed with distilled water to remove various impurities, then it was fixed on the support of the viscometer and overturned, detaching the lid with which it is provided. The suspension was placed in the viscometer tube approximately 2 cm below its upper edge and the temperature value, displayed by the thermometer incorporated in the apparatus, was expected to stabilize at 25°C. The appropriate ball was selected for the viscosity range to be investigated (approx. 1 to 7 mPas) and was inserted into the tube using tweezers (the ball of choice was the one with the following characteristics: density 8.126 g/cm^3, correction factor K 0.1167). Cover the empty stopper with the rubber stopper and replace the screw cap. The tube was brought to the original position, timing the time of the sphere falling between marks A and C, marked on the glass tube. The stopwatch was triggered when the lower part of the sphere reached the A mark and stopped when the lower part of the sphere reached the C mark.

After the sphere reached the bottom of the vessel, the tube was returned to its original position and the steps were repeated three times, the chosen time being the average of the three measurements (LD Leaflets Chemistry).

Viscosity was determined using the relationship (4):

$$\eta = \frac{2}{3} \cdot \frac{(\rho_2 - \rho_S) \cdot g \cdot r^3}{d^2} \cdot t \cdot ln\frac{R}{r} = k \cdot (\rho_2 - \rho_S) \cdot t \qquad (4)$$

where:

ρ_2 - ball density (kg/m^3); ρ_S - suspension density (kg/m^3); g - gravitational acceleration (m/s^2); r - tube radius (m); R - radius of the ball (m); d - ball radius (m); t - time (s); k - the constant that characterizes the device and the sphere used.

RESULTS AND DISCUSSIONS

In determining the density of the three types of solid particles, the same steps were performed for all three materials. For each material, three types of tests were performed, the final density value being the average of the three determinations (ρ_{pm}).

Table 1 presents the experimental results, which have values close to those found in the literature (ρ_{lit}).

Table 1. Experimental results obtained for the calculation of the density for three samples of material, using the pycnometer

Material type	m_a, g	m_c, g	m_b, g	m_d, g	ρ_l, g/cm^3	ρ_p, g/cm^3	ρ_{pm}, g/cm^3	ρ_{lit}, g/cm^3
Calcium carbonate	25.194	27.315	45.759	47.049	0.86	2.195	2.412	2.93
	25.196	28.517	45.746	47.941	0.86	2.536		
	25.204	27.975	45.752	47.572	0.86	2.506		
Blue clay	25.284	28.452	45.811	47.733	0.86	2.186	2.384	2.52-2.78
	25.257	27.739	45.714	47.289	0.86	2.354		
	25.489	28.158	45.786	47.579	0.86	2.619		
Soil	25.237	27.406	45.769	47.134	0.86	2.319	2.564	2.55-2.60
	25.319	27.213	45.709	47.000	0.86	2.692		
	25.257	27.384	45.727	47.172	0.86	2.682		

To determine the density of the liquid-solid mixture, the same steps were taken for each mixture, for all five related concentrations. The experimental results are presented in Table 2.

Table 2. Experimental results obtained for the density of the three types of liquid-solid mixture, of known concentrations

Material type	c, %	ρ_S, g/cm^3		c, %	ρ_S, g/cm^3		c, %	ρ_S, g/cm^3
Calcium carbonate	2	1.011	Blue clay	2	1.014	Soil	2	1.006
	4	1.016		4	1.036		4	1.019
	6	1.023		6	1.047		6	1.024
	8	1.045		8	1.059		8	1.041
	10	1.067		10	1.063		10	1.060

The second part of the formula (4) was used to determine the viscosity, the steps taken to perform the determinations were the same for all three liquid-solid mixtures.

The experimental results obtained are presented in Table 3.

Given that all parameters are known, the experimental data obtained for all three types of liquid-solid mixture, for the five concentrations for each mixture, were used to determine the sedimentation rate, according to Table 4.

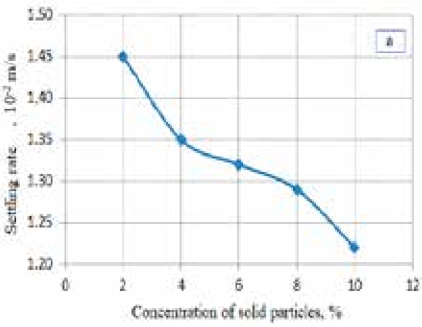
Table 3. Experimental results obtained for the dynamic viscosity of the three types of liquid-solid mixture

Material type	c, %	t, s	η, mPa·s		c, %	t, s	η, mPa·s		c, %	t, s	η, mPa·s
Calcium carbonate	2	2.54	2.101	Blue clay	2	2.76	2.282	Soil	2	2.72	2.252
	4	2.72	2.249		4	2.80	2.308		4	2.81	2.322
	6	2.78	2.296		6	2.92	2.403		6	2.89	2.386
	8	2.81	2.313		8	2.99	2.457		8	2.99	2.463
	10	2.93	2.405		10	3.08	2.529		10	3.07	2.522

Table 4. Sedimentation rate values for three types of liquid-solid mixture

Material type	c, %	v, m/s		c, %	v, m/s		c, %	v, m/s
Calcium carbonate	2	$1.45 \cdot 10^{-2}$	Blue clay	2	$1.31 \cdot 10^{-2}$	Soil	2	$6.03 \cdot 10^{-2}$
	4	$1.35 \cdot 10^{-2}$		4	$1.27 \cdot 10^{-2}$		4	$5.80 \cdot 10^{-2}$
	6	$1.32 \cdot 10^{-2}$		6	$1.21 \cdot 10^{-2}$		6	$5.63 \cdot 10^{-2}$
	8	$1.29 \cdot 10^{-2}$		8	$1.17 \cdot 10^{-2}$		8	$5.39 \cdot 10^{-2}$
	10	$1.22 \cdot 10^{-2}$		10	$1.13 \cdot 10^{-2}$		10	$5.20 \cdot 10^{-2}$

Based on the experimental results, the variation curves of the sedimentation rate were plotted, according to Stokes' law, depending on the concentration of solid particles, for each type of liquid-solid mixture separately (Figure 5 and Figure 6).



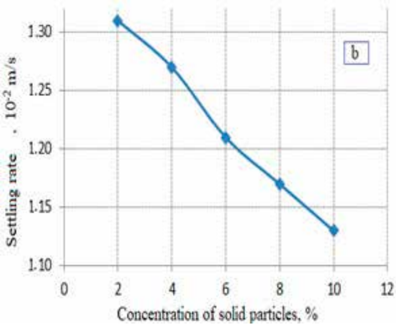


Figure 5. Variation of settling rate depending on the concentration of solid particles, in the case of the suspension water - calcium carbonate (a), water - blue clay (b)

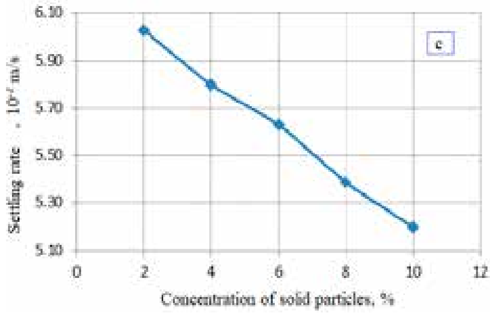


Figure 6. Variation of settling rate depending on the concentration of solid particles, in the case of the suspension water - soil

Numerous studies have been performed regarding the sedimentation rate of solid particles, as a result of which results have been obtained in correlation with those of the study performed in this paper.

For example, in (Torfs et al., 2016) it was studied the sedimentation rate of a particle with a diameter of 400 μm and a density of 1.010 kg/m^3. The authors obtained that it has a value of 2-9 m/h for temperatures between 5-40°C. At low temperatures, it was observed that the separation of small and low-density particles (with typical settling speeds below ± 5 m/h) became difficult.

Tarpagkou R. et al. (2013) found that wastewater temperature plays an important role in the settling process. At a temperature of 29°C a sedimentation rate of 1.5 m/h was obtained, while at a temperature of 11°C the sedimentation rate decreased to 0.95 m/h, for a solid particle concentration of 60 mg/ml.

Experimental results have shown that at low water temperatures, the efficiency of the sedimentation process decreases, the viscosity of the water increases, the resistance to the advancement of solid particles increases and as a result the sedimentation rate decreases, the efficiency of the settling process reaches 50%, compared to 80% in case of summer temperatures.

CONCLUSIONS

The removal of solids by gravity is, according to studies in the literature, the main method of water purification in treatment plants.

The process of separating the liquid-solid mixture is influenced by many factors related to both the solid component, the liquid component and the construction parameters of the decanter. Data on the speed of the sedimentation process are very important for the design of equipment used in chemical and metallurgical practices for the separation of suspended solid particles from liquid or gaseous flow.

In the experiment, in order to determine the sedimentation rate, the following parameters had to be determined, in turn: the density of the three types of material, the density of the suspension and the dynamic viscosity of the suspension.

The highest density of solid particles was obtained in the case of soil (2.564 kg/m^3), followed by that of calcium carbonate (2.412 kg/m^3), and finally that of blue clay (2.384 kg/m^3), the highest high sedimentation rate is obtained in the case of water-soil suspension, its value decreasing as the concentration of solid particles increased.

According to the experimental results obtained from the study, it can be noticed that the sedimentation rate is influenced both by the concentration of solid particles (speed decreases as the concentration of particles increases), by the size of solid particles (speed increases as the size of particles increases), but also the density of solid particles (as their density increases, so does the rate of sedimentation).

The results obtained are correlated with the results obtained in the literature.

REFERENCES

Al-Naafa, M.A., Selim, M.S. (1992). Sedimentation of monodisperse and bidisperse hard-sphere colloidal suspensions. *AI. ChE. Journal, 38*(10), 1618–1630.

Antoniu, R., Negulescu, C. (1987). *Industrial wastewater treatment, Vol. 1 and 2*. Technical Publishing House, Bucharest.

Bagtzoglou, A.C., Dougherty, D.E., Tompson, A.F.B. (1992). Application of particle methods to reliable identification of groundwater pollution sources, *Water Resour. Manage*. 6, 15-23.

Cirtina, D. (2007). Wastewater treatment, Academica Brancusi, Targu Jiu.

Coldea, S., Ionescu, Gh. C. (2005). *Elements of fluid physics and hydraulics*, Matrix Rom Publishing House, Bucharest.

Denchak, M. (2018). Water Pollution: Everything You Need to Know. Natural Resources Defense Council-NRDC, available on https://www.nrdc.org/stories/water-pollution-everything-you-need-know, accessed at 18.11.2019.

Florea, J., Robescu D. (1982). *Hydrodynamics of hydropneumatic transport and water and air depollution installations*, Didactic and Pedagogical Publishing House, Bucharest.

Florescu, I. (2007) *Fluid Mechanics, course notes for student use*, Alma Mater Publishing house, Bacau.

Gavrilă, L. (2001). Unit operations in the food and biotechnology industries, University of Bacău.

Hasim, A.M.H., El-Hafiz, A.A., El Baz, A.R., & Farghaly S.M. (2017). Study the performance of circular clarifier in existing potable water treatment plant by using computational fluid dynamics, *World Water Congres*, Cancun.

Mondal, P., Majumdar C.B (2004). Sedimentation of Hematite Water Slurries, *J. Inst. Eng.* (I), 85, 20-23.

Mory, M., Michallet, H. (2002). Proceedings in Marine Science. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/settling-velocity/pdf

Mirza, S., & Richardson, J.R. (1979). Sedimentation of suspensions of particles of two or more sizes. *Chem. Eng. Sci.*, 34, 447–454.

Panaitescu, M. (2011). *Wastewater treatment techniques. Wastewater treatment plant design guide*, Editura Nautica.

Racoviteanu, G. (2003). The theory of water settling and filtration, MATRIX ROM Publishing, Bucharest.

Robescu, D., Robescu, D., Băran, Gh. (1999). *Wastewater treatment*, Bren Publishing house, Bucharest.

Safta, V.V., Toma, M.L., Ungureanu, N. (2012). *Experiments in the field of water treatment*, PRINTECH Publishing, Bucharest.

Selim, M.S., Kothari, A.C., & Turian, R.M. (1983). Sedimentation of multisized particles in concentrated suspensions. *AI.ChE. Journal,* 29 (6), 1029–1038.

Tarpagkou, R., Pantokratoras, A., Papadakis, N. (2013). The influence on the flow field and performance of a sedimentation tank for potable water treatment due to low (winter) and high (summer) temperatures, *Environ. Sci. Technol. Athens*, vol. 13.

Torfs, E., Nopens, I., Winkler, M.K.H., Vanrolleghem, P.A., Balemans, S., Smets, I.Y. (2016). Experimental Methods In *Wastewater Treatment, Chapter 6*, Published by IWA Publishing, London, UK, 235-261.

Vanderhasselt, A., Vanrolleghem, P.A. (2000). Estimation of sludge sedimentation parameters from single batch settling curves. *Water Res.*, 34(2), 395-406.

***Environmental Protection Agency, Waste Water Treatment Manuals Primary, Secondary and Tertiary Treatment (1997), Ireland.

***Environmental Protection Agency, Urban Waste Water Treatment (2018).

***Environmental Protection Agency, Urban Waste Water Treatment in 2018, ISBN: 978-1-84095-863-8, 2019.

***Water Law no. 107/1996, available at http://legislatie.just.ro/Public/DetaliiDocument/856 5, accessed on 23.06.2019.

***Veoila. Sustaining growth via water productivity: 2030/2050 scenarios (2014), Lecture.

***Special Report: EU Funds for Urban Wastewater Treatment Plants in the Danube River Basin: Further Efforts Needed to Help Member States Meet EU Wastewater Policy Objectives (2015), no.2.

***Suntech Geometallurgical Laboratories, https://www.suntechgeomet.co.za/servi ces/metallu rgical-testing/sedimentation-testing, accessed on 17.02.2020.

***The Institution of Chemical Engineers (IchemE) - A roadmap for 21st century chemical engineering (2007). Institution of Chemical Engineers, Rugby, England.

***United States Environmental Protection Agency, How Wastewater Treatment Works.The Basics (1998). EPA 833-F-98-002.

***LD Leaflets Chemistry, Determination of viscosity with the falling ball viscometer according to Höppler, available la https://www.ld-didactic.com, accessed at 04.10.2020.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ESTIMATION OF THE OPTIMAL THICKNESS OF THE SOIL MASS BULK LAYER IN THE LAND RECLAMATION PROFILES

Oleksandr MYTSYK, Mykola KHARYTONOV, Natalia HONCHAR, Oleksandr HAVRYUSHENKO, Mykhailo BABENKO, Svitlana LEMISHKO

Dnipro State Agrarian and Economic University, 25 Sergiy Yefremova Street, Dnipro, Ukraine

Corresponding author email: mykolakh@ua.fm

Abstract

The lands disturbed by iron open pit mining are undergoing a long process of restoration. It is possible to create special-purpose lands in manmade landscapes by varying the thickness of the bulk layer of the black soil mass. The thickness of the applied soil layer on rocks or their mixtures is determined by the genetic parameters of zonal soils, the physical and biological properties of the soil mass, the soil excavation technology, and the adaptive potential of cultivated crops. The potential fertility of the same soil layer of the main mass of the first transitional horizon is 69%, the second transitional horizon is 38%. The mixing of soil masses of the humus and the first transitional horizons (H+Hp) forms the fertility at the level of 90%, the three-humus horizons (H+Hp+Phk) - 72% of the fertility of the humus horizon. The activity of two enzymes is higher in mixtures of genetic horizons than in transitional horizons, but lower than in the humus horizon. The yield of cultivated crops largely depends on the thickness of the bulk layer of soil mass, on the contribution of mineral fertilizers. The optimal thickness of the bulk layer should correspond to 50 cm.

Key words*: open pit mining, soil bulk layer, land reclamation profile.*

INTRODUCTION

Construction of minelands with good quality soil materials and desirable physical properties is essential to attain productivity levels necessary for bond release (Dunker and Darmody, 2005). The thickness of the covering topsoil layer depends on the properties of the soil used in reclamation and the projected land use after reclamation regarding to UNEP environmental guidelines for the restoration and rehabilitation of land and soils after mining activities (UNEP, 1983). The biologically active layer of reclaimed minelands should be at least 80-120 cm thick for farming lands and 120-200 cm thick for the trees. Meantime, topsoil can be placed in 25-40 cm thick layers on well - leveled and stabilized ground surfaces. Both corn grain and biomass yields increased with the addition of topsoil and decreased with the removal of topsoil (Jagadamma et al., 2009). Increased soil thickness is conducive to the storage of more water and available nutrients (Hu et al., 2018). Determination of the optimal thickness of the soil layer and the choice of a favorable underlying rock is of key importance for solving environmental, biological and economic problems (Ignatyeva et al., 2020). An increase in the thickness of the bulk layer of soil mass from an economic point of view is associated with an increase in capital costs for the reclamation of disturbed lands (Terekhov et al., 2021). The thickness of the humus layer of soil and the content of humus and physical clay in the arable layer were chosen as the quantitative indicators, which are stable over time and considerably affect the yield of agricultural crops and fully reflect the essence of soil fertility (Yeterevska et al., 2019). They should not be lower than the fertility of potentially fertile breeds and meet the requirements of agricultural and forestry crops grown in concrete biogeographic zones. Numerous experiments on the restoration of disturbed lands have identified approaches to land reclamation in different countries (Bender J., 1983; Feagley and Hossner, 2000; Beniston et al., 2015; Oggeri et al., 2019). Severe compaction is one of the major factors limiting the achievement of pre-mining yields on land being returned to cropping (Dunker and Barnhisel, 2000). Soil removal and placement influence the degree of soil compaction and

structural breakdown that inevitably occurs during these procedures (Bell, 2004). The main requirement is that the restored lands should not yield to undisturbed zonal soils in terms of fertility. Moreover, it assumed that with the help of reclamation it is possible to create lands of special purpose in man - made landscapes. Sites allocated for open pit mining may have different thicknesses of removal and different thicknesses of stacking of disturbed soil mass.
The main objective of the research is to determine the optimal thickness of the soil layer in the conditions of open pit mining.

MATERIALS AND METHODS

The experiments were conducted at the land reclamation station located on the area of the abandoned quarry “A” of Kamysh-Burun syncline of Kerch iron ore basin. The leveling of the dump surface was carried out in the preparatory period for the creation of an experimental field using a bulldozer. Works on filling the excavations with soil mass of black soil (technical mixture of humus-accumulative and first transitional horizons) with a thickness of 30, 50 and 80 cm were carried out using a scraper complex to the level of the earth's surface (Figure 1).

Figure 1. Leveling the surface of the field with a bulldozer

The excavation of the applied soil layer on rocks or their mixtures is determined by several reasons. The first one are the genetic parameters of zonal soils (as a rule, two genetic horizons are involved in the development - H+Hp or A+B). Second one are additional resources of soil mass (approximately 70-80% of the disturbed lands of the quarry) to return it to biological use including the adjacent slopes and steep slopes of external dumps intended for forestry plantations and hayfields. Third one is the mining technology, when overburden work is carried out by excavators (Figure 2).

Figure 2. Selective excavation of top soil and subsoil at the open pit quarry

The depth increments were assigned to general soil horizons with correspondence to the Russian and Ukrainian soil taxonomy system noted in parentheses: A (H) - upper horizon with very prominent humus accumulation; B_1(Hp) - upper transition horizon, with considerable humus; B_2(Ph) - lower transition horizon, with little humus; C(P) - underlying parent material (Kravchenko et al., 2012).
Averaged samples of the top and subsoil’s were selected for analyses, pot and field experiments. All soil samples were taken in the field situated in three genetic horizons: H (0-38 cm), Hp (38-62 cm) and Phk (62-92 cm).
The use of pea variety Ukosny 5 in the growing experiment as a biological indicator of soil fertility explains as follows. It is known that pea is a moderately demanding crop and, due to nitrogen fixation, to a large extent removes the restrictions caused by the unequal nitrogen content in genetic horizons, i.e. can subtly indicate such changes in environmental conditions to which plants of other ecological-trophic groups are unable to respond. The pot experiment with peas of the Ukosny 5 variety lasted for 104 days under artificial lighting. The experiment was carried out in triplicate in plastic vessels containing 0.8 kg of dry soil mass. The scheme of the pot experiment included the following trials: H - soil mass of the humus horizon; Hp - soil mass of the first transitional horizon; Phk - soil mass of the second transitional horizon; H + Hp - a mix of

soil masses of humus and the first transitional horizons; H + Hp + Phk - a mixture of soil masses of three humus horizons. Each substrate included the following fertilizer options: without fertilizers - control; P - single application of phosphorus; NP - joint application of nitrogen and phosphorus; P + R - joint application of phosphorus with rhizobium bacteria (bacterial fertilizer "Rhizotorphin').

Mineral fertilizers applied when laying soil masses in vessels at the rate of 0.15 g of the active substance per 1 kg of dry substrate. Nitrogen introduced in the form of urea, phosphorus - in the form of double superphosphate. Pea seeds were inoculated with rhizobium bacteria including fertilizer ("Rhizotorphin") before sowing in the fourth fertilizer option. Field experiments with three varieties of peas and three hybrids of corn carried out on a rock-mixed dump containing loess-like loam.

The soil mass of black soil (H+Hp+Phk) was taken off, piled up, and heaped onto the land in three strata: 30, 50, and 80 cm after the rock was replaced. The 30-cm layer of black soil mass covering to a mixture of rocks was taken as a control.

Traditional research methods were applied to estimate soil and crop samples properties (Kharytonov et al., 2004). The statistical data treatment was made using Statistica 6.

RESULTS AND DISCUSSIONS

The most important properties of the soil masses of the genetic horizons of the black soil studied. The texture data of the soil layers is presented in Table 1.

Table 1. Texture of genetic horizons of black soil

Horizon	Soil particle size (mm) and content (%)						Sum of particles < 0.01 mm, %
	1-0.25	0.25- 0.05	0.05-0.01	0.01-0.005	0.005-0.001	< 0.001	
H	1.44	12.35	28.29	8.30	5.21	44.41	57.92
Hp	0.96	3.38	32.85	7.71	11.55	43.55	62.81
Phk	1.06	8.88	22.20	14.49	6.47	46.90	67.86

Fractions of coarse dust and silt prevail in all genetic horizons of the black soil. Humus horizon H has a lighter texture than the first and second transitional horizons.

The general physical properties of the soil masses of the genetic horizons of the black soil are presented in Table. 2.

Table 2. Physical properties of genetic horizons black soil

Horizon	Bulk density, g/cm^3	Porosity, % of soil volume	
		Total	Capillary
H	1.28	51.9	36.0
Hp	1.37	49.4	29.4
Phk	1.46	45.7	27.3

Bulk density of productive natural soils generally ranges from 1.1 to 1.5 g/cm^3. High bulk density limits rooting depth in mine soils (Maiti and Ghose, 2005). An increase in soil bulk density from 1.28 g/cm^3 to 1.37 and 1.46 g/cm^3 (in the first and second transitional genetic horizons) occur with depth. The highest total porosity was in the humus horizon - 51.9%, and the lowest - in the second transitional horizon - 45.7%. A similar trend was recorded also for capillary porosity. Moisture content in a dump is a fluctuating parameter influenced by the time of sampling, height of dump, stone content, amount of organic carbon, and the texture and thickness of litter layers on the dump surface (Donahue et al., 1990). Several indexes of soil moisture for topsoil and two subsoil present in table 3. A large amount of the clay fraction, high porosity, and differences in the humus content determined the high rates of the lowest water capacity and moisture content of stable wilting of plants in the humus horizon (28.4 and 13.5%, respectively). The range of active moisture allows the accumulation in the horizons of 19.1, 17.3 and 17.7 mm in terms of 10 cm layer of each stratum.

Table 3. Water properties of genetic horizons of black soil

Horizon	Lowest moisture capacity,%	Maximum hygroscopicity,%	Moisture resistant wilting plants, %	Active moisture range, %	Reserve of productive moisture, mm	
					for the whole horizon	for 10-cm layer
H	28.4	10.1	13.5	14.9	72.5	19.1
Hp	25.2	9.4	12.6	12.6	41.4	17.3
Phk	21.9	7.3	9.8	12.1	53.0	17.7

Data on the content and reserves of humus in the soil layers are given in Table 4.

Table 4. Fertility of individual genetic horizons and their main mixtures of black soil, determined by humus reserves

Soil horizons and their mixtures	Humus content, %	Humus reserve, t/ha	Humus reserves per 10 cm layer	
			t/ha	%
H	2.25	111	29	100
Hp	1.47	49	20	69
Phk	0.76	34	11	38
H+Hp	1.95	160	26	90
H+Hp+Phk	1.56	194	21	72

Thus, the potential fertility of the humus horizon is 2.3 times higher than the first transitional horizon and 3.3 times higher than the second transitional horizon. The results of determining the humus reserves made it possible to assess the potential fertility of the genetic horizons of the black soil and their main mixtures as follows:H (100%) > H+HP (90%) > H+HP+Phk (72%) > HP (69%) > Phk (38%). Removal of topsoil from a mining site and mixing it with underlying soil considerably reduces the relative proportion of organic carbon (Visser et al., 1984). The mixing of three genetic horizons forms a soil mass with a humus content of 1.56%, which is 2.0 times more than in the second transitional horizon and 1.1 times than in the first transitional horizon, and 1.4 times less than in the humus horizons. Total humus reserves per 10 cm layer of the humus horizon amounted to 29 t/ha. The results of assessing the productive potential of peas obtained in the growing experiment shown in Figure 3.

The most favorable conditions for the growth of pea plants developed in the trial of a single application of phosphorus with inoculation of seeds with rhizotorphin on all studied substrates. The results of studying the activity of soil enzymes presented in Figure 4.

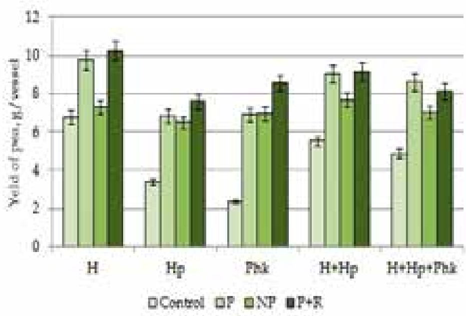


Figure 3. Yield of pea grown on soil mass top, subsoil and their mixtures (g/vessel)

The enzymes activity was highest in the upper accumulative horizon. A decrease in the activity of both enzymes (especially urease) noted in the transitional horizons in all fertilizer trials. An application of rhyzotorphin together with phosphate fertilizer increases the activity of urease in mixtures and reduces the activity of phosphatase. The productivity of three early, mid, and late- ripening pea varieties (Akatsievidny 1, Ukosny 7, and Ukosny 5) was studied in a field experiment with peas (Figure 5). An increase in the thickness of the bulk soil layer to 50 and 80 cm increased the yield of peas, on average for three varieties, by 12.7 and 19.8%, respectively. The greatest responsiveness to increased power (80 cm) shown by the early ripe variety Akatsievidny 1. In the field experiment reported here, heavy metals content in dry aboveground green mass of pea did not exceed the WHO/FAO standards, such feed being safe for animals (Table 5). The results of field experiments with three corn hybrids are presented in Figure 6.

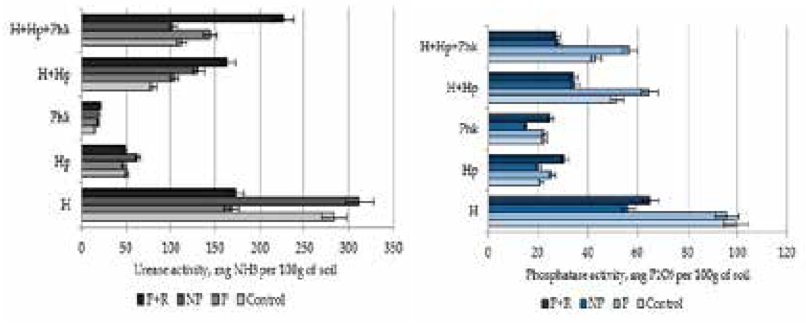


Figure 4. Enzyme activity in the genetic horizons of black soil

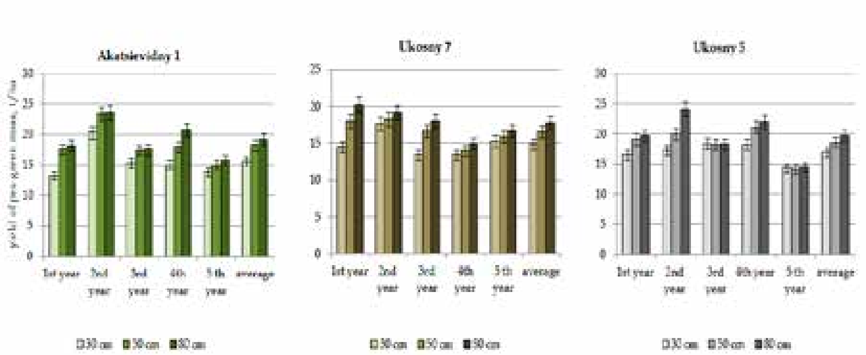


Figure 5. Yield of green mass of pea varieties in trials with bulk layers of black soil, t/ha

Table 5. Heavy metals content in green mass of pea, mg/kg

Trial	Zn	Cu	Mn	Cr	Ni	Cd	Pb
Ukosny 7							
30cm	30.8±2.9	6.7±0.6	50.0±4,1	2.5±0.3	4.1±0.3	0.2±0.02	3.2±0,4
50cm	15.2±1.3	6.1±0.5	43.0±3.6	2.2±0.3	5.6±0.2	0.25±0.02	4.8±0.4
80cm	26.0±2,3	6.4±0.5	37.0±3.5	1.7±0.2	3.5±0.3	0.15±0.01	4.9±0.5
Akatsievidny 1							
30cm	17.4±1.5	7.3±0.6	26.0±2.1	1.9±0.2	5.4±0.4	0.2±0.01	7.3±0.5
50cm	36.6±33	5.8±0.5	26.0±2.2	2.5±0.2	5.0±0.4	0.3±0.02	1.6±0.2
80cm	41.2±3.9	5.3±0.5	35.0±2.9	2.0±0.1	4.4±0.3	0.4±0.023	4.1±0.3

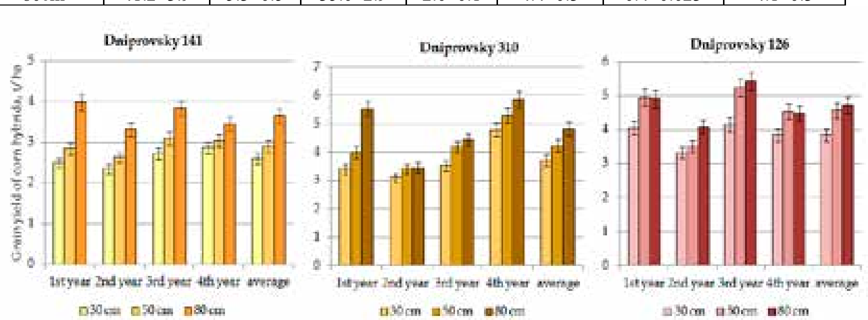


Figure 6. Grain yield of corn hybrids in trials with bulk layers of black soil, t/ha

The yield of corn grain increased with an increase in the thickness of the applied layer of soil mass for all hybrids. The early maturing hybrid Dniprovsky 141 showed the greatest responsiveness to the subsequent increase in the thickness of the bulk layer. Hybrids with longer growing seasons provided a higher yield compared to the early maturing hybrid. The maximum yield increase due to the biological characteristics of the hybrids was in the variant with a 50-cm layer of black soil mass.

Reclamation of mine lands is a very complex process. Most researchers agree that reclamation success is needed in estimation from several points of view including physic-chemical properties of soil horizons, and presence of vegetation on the site (Filip, 2002; Bell, 2004; Sheoran, 2010). The top soil was severely damaged if it was not taken out separately with a view to replace it on the filled void surface area to use it for the next step of land reclamation (Kundu and Ghose, 1998).

The top soil must be uniformly redistributed in a manner which assures placement and compaction compatible with the needs of the species that will be used to restore the distributed area to its pre-mined potential (Ghose, 2005). The question of the thickness of the layer removing and selective extraction in the mining process remains poorly understood (Thomas et al., 1995; Dunker and Barnhisel, 2000). The planning of the restored landscape causes a redistribution of the thickness of the soil mass. This leads to the formation of soil heterogeneity. Backfilling the soil in a 30-cm layer is not a guarantee of overlapping the underlying rocks. The formation of heterogeneity of the arable layer at a thickness of 50 cm practically excluded.

CONCLUSIONS

Fractions of coarse dust and silt prevail in all genetic horizons of the black soil. Humus horizon H has a lighter texture than the first and second transitional horizons. An increase in soil bulk density from 1.28 g/cm^3 to 1.37 and 1.46 g/cm^3 (in the first and second transitional genetic horizons) occur with depth. The highest total porosity was in the humus horizon - 51.9%, and the lowest - in the second transitional horizon - 45.7%. A similar trend was recorded also for capillary porosity. A large amount of the clay fraction, high porosity, and differences in the humus content determined the high rates of the lowest water capacity and moisture content of stable wilting of plants in the humus horizon. Evaluation of the exceptional fertility of each genetic horizon is the main thing with selective withdrawal in identifying and symptomatic them. Taking the value of the upper accumulative horizon as 100%, we expect that the potential fertility of the same soil layer of the main mass of the first transitional horizon is 69%, and the second transitional horizon is 38%. The mixing of three genetic horizons forms a soil mass with a humus content of 1.56%, which is 2.0 times more than in the second transitional horizon and 1.1 times than in the first transitional horizon, and 1.4 times less than in the humus horizons. The results of the study of the activity of soil enzymes urease and phosphatase revealed a strong dependence on soil genetic horizons and a significant proportion of contributions. The activity of two enzymes is higher in mixtures of genetic horizons than in transitional horizons, but lower than in the humus horizon. The planning of the land reclamation leads to the formation of soil heterogeneity. The formation of heterogeneity of the soil arable layer at a thickness of 50 cm practically excluded.

ACKNOWLEDGEMENTS

This study was supported by the Ukrainian Ministry of Education and Science.

REFERENCES

Bell, L.C. (2004). Construction and protection of new soils in diverse biogeographic zones – the challenge for successful rehabilitation in the Australian mining industry. *ISCO 2004.13th International Soil Conservation Organisation Conference – Brisbane*, July 2004. Conserving Soil and Water for Society: Sharing Solutions, pp. 8.

Bender, J. (1983). Theoretical basis of technigenic landscape recultivation. Proceedings of the International Conference. Gyongyos, pp. 160-168;

Beniston, J.W., Lal, R. & Mercer, K.L. (2015). Assessing and managing soil quality for urban agriculture in a degraded vacant lot soil. *Land Degradation & Development, 27* (1), pp. 996–1006. https://doi.org/10.1002/ldr.2342;

Donahue, R.L., Miller, R.W. & Shickluna, J.C. (1990). Soils: An introduction to soils and plant growth (5th ed.). Prentice-Hall, pp. 234.

Dunker, R.E. & Barnhisel, R.I. (2000). Cropland reclamation. In book: *Reclamation of Drastically Disturbed Lands*. R.I. Barnhisel, R.G. Darmody & W.L. Daniels (Eds.), pp. 323-369.

Dunker, R.E. & Darmody, R. (2005). Rowcrop response to topsoil replacement on high traffic vs low traffic soil reconstruction systems. *22nd American Society of Mining and Reclamation Annual National Conference*, pp. 302-327. doi: 10.21000/JASMR05010302

Feagley S.A. & Hossner L.R. (2000). *Reclamation of lignite-mined lands*. Amer. Soc. of Agron., Madison, WI., pp. 415-432. https://doi.org/10.2134/agronmonogr41.c16

Filip, Z. (2002). International approach to assessing soil quality by ecologically-related biological parameters. Agriculture, *Ecosystems and Environment, 88*, pp. 169-174. doi: 10.1016/S0167-8809(01)00254-7

Ghose, M.K. (2005). Soil conservation for rehabilitation and revegetation of mine-degraded land. *Teri Information Digest on Energy and Environment*. *4*(2), pp. 137-150.

Hu, Z., Linghua Duo, L. & Fang Shao, F. (2018) Optimal Thickness of Soil Cover for Reclaiming Subsided Land with Yellow River Sediments. *Sustainability*, *10*, 3853. doi:10.3390/su10113853

Ignatyeva, I., Yurak, V. & Pustokhina, N. (2020). Recultivation of Post-Mining Disturbed Land: *Review of Content and Comparative Law and Feasibility Study Resources*, *9*, pp. 73. doi:10.3390/resources9060073

Jagadamma, S., Lal, R., Rimal, B.K. (2009). Effects of topsoil depth and soil amendments on corn yield and properties of two Alfisols in central Ohio. *Journal of Soil and Water Conservation. 64*(1), pp. 70-80. doi:10.2489/jswc.64.1.70

Kharytonov, M., Bagorka, M. & Gibson, P. (2004). Erosion effects in the central steppe chernozem soils of Ukraine. I. Soil Properties. *Agricultura*. *3*. № 1, pp. 12-18.

Kravchenko, Y., Rogovska, N, Petrenko, L, Zhang, X, Song, C & Chen, Y. (2012). Quality and dynamics of soil organic matter in a typical Chernozem of Ukraine under different long-term tillage systems. *Can. J. Soil Sci., 92*, pp. 429-438. https://doi.org/10.4141/cjss2010-053

Kundu, N.K., & Ghose, M.K. (1998). Studies on the existing plant communities in Eastern coalfield areas with a view to reclamation of mined out lands. *Journal of Environmental Biology*. 19 (1), pp. 83-89.

Maiti, S.K. & Ghose, M.K. (2005). Ecological restoration of acidic coal mine overburden dumps- an Indian case study. *Land Contamination and Reclamation, 13*(4), pp. 361-369. doi: 10.2462/09670513.637

Oggeri, C., Fenoglio, T.M., Godio, A. & Vinai, R. (2019). Overburden management in open pits: options and limits in large limestone quarries. *International Journal of Mining Science and Technology*, *29*, pp. 217–228. https://doi.org/10.1016/j.ijmst.2018.06.011

Sheoran, V., Sheoran, A.S. & Poonia, P. (2010). Soil Reclamation of Abandoned Mine Land by Revegetation: A Review. *International Journal of Soil, Sediment and Water, 3*, 2, pp. 1-20. https://scholarworks.umass.edu/intljssw/vol3/iss2/13

Terekhov, Ye., Litvinov, Yu., Fenenko, V. & Drebenstedt, C. (2021). Management of land reclamation quality for agricultural use in opencast mining. *Mining of Mineral Deposits*, *15*, 1, pp. 112-118. https://doi.org/10.33271/mining15.01.112

Thomas, E.C., Gardner, E.A., Littleboy, M.M. & Shields, P. (1995). The cropping systems model PERFECT as a quantitative tool in land evaluation: an example for wheat cropping in the Maranoa area of Queensland. *Australian Journal of Soil Research,* 33, pp. 535-554. doi:10.1071/SR9950535

UNEP (1983) Environmental guidelines for the restoration and rehabilitation of land and soils after mining activities. *UNEP environmental management guidelines, No 8*, pp. 26.

Visser, S., Fujikawa, J., Griffiths, C.L. & Parkinson, D. (1984). Effect of topsoil storage on microbial activity, primary production and decomposition potential. Plant Soil, 82, pp. 41–50. https://doi.org/10.1007/BF02220768.

Yeterevska, L., Momot, H., Shymel, V. & Sukhova, L. (2019). Criteria and of soils grouping on fitness of humus layer for recultivation and soiling. *Bulletin of Agricultural Science. 4*, pp. 67-73. https://doi.org/10.31073/agrovisnyk201904-10

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

CADMIUM ACCUMULATION IN SOME LEAFY VEGETABLES FROM PRIVATE GARDENS IN COPȘA MICĂ

Nicoleta Olimpia VRÎNCEANU, Dumitru Marian MOTELICĂ, Mihaela COSTEA, Bogdan OPREA, Georgiana PLOPEANU, Vera CARABULEA, Veronica TĂNASE, Mihaela PREDA

National Research and Development Institute for Soil Science, Agrochemistry and Environment, 61 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: veronica.tanase@icpa.ro

Abstract

Many previous studies have reported high levels of cadmium content in soils and vegetation from area affected by historical contamination in Copșa Mică area. Furthermore, cadmium can be slowly and consistently transferred from contaminated soils into food crops increasing Cd exposure to human beings in the long-term through the food chain. Regarding individual gardens from contaminated area, humans can be exposed via ingestion/inhalation of soil particles and consumption of contaminated vegetables. Therefore, this study attempts to quantify quality and safety of some leafy vegetables grown in individual gardens from contaminated area, Copșa Mică. The cadmium contents in leafy vegetables were positively correlated to total contents of cadmium in soil. Additionally, models were developed to predict the accumulation of Cd in different leafy vegetables (parsley, celery and lettuce) based on cadmium content in soils. The results of this study are important to estimate the Cd accumulation in vegetables from individual gardens, while also improving the safety of foodstuff produced in contaminated areas.

Key words: *cadmium, accumulation, vegetables, Copsa Mica.*

INTRODUCTION

Vegetables constitute an important part of the human diet and in recent years, their consumption is increasing gradually, particularly due to the increased awareness on the food value of vegetable. Sometimes, they contain toxic elements over a wide range of concentrations (Bidar et al., 2020).

Heavy metals are one of the important types of contaminants that can be found on the surface and in the tissue of fresh vegetables. In order to protect public health, it is essential to keep contaminants at levels which are toxicologically acceptable, so Commission Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs.

Among heavy metals, Cd is highly toxic to plants and animals even at very low concentrations due to its non-essentiality in living organisms (Rizwan et al., 2016). Due to highly mobility in soil, cadmium can be slowly and consistently transferred from contaminated soils into food crops increasing Cd exposure to human beings in the long-term through the food chain (Liu et al., 2018). The high dose exposure to cadmium (Cd) by ingestion can cause severe stomach disease. Long-term exposure to low doses causes kidney disease, which damages the renal tubules and impedes the absorption of calcium (Ca), leading to brittle bones that are less resistant to breakage (Huang et al., 2021).

Therefore, the European Food Safety Authority adopted an opinion on cadmium in food and, in view of the toxic effects of cadmium the Authority established a tolerable weekly intake for cadmium of 2.5 μg/kg body weight. It also concluded that subgroups such as vegetarians, children, smokers and people living in highly contaminated areas may exceed the tolerable weekly intake by about 2-fold. As measure to achieve this target, the values limits for cadmium in some foodstuff were reduced according with Commission Regulation (EU) 2021/1323.

According with previous studies, a large number of national environmental agencies recommend investigating the environmental factors related to the plant Cd uptake (Swartjes et al., 2013; Augustsson et al., 2015) and despite of this recommendation there are few studies focused on this subject. Cadmium is one of the main contaminants that posed a risk to the health of the population in the area affected by pollution from most important factory for processing non-ferrous ores - Copșa Mică, Romania.

Local community can cease to cultivate of highly contaminated fields to avoid the harmful effects of cadmium on human health but there are still a lot of individual gardens where owners continue to use them for vegetables production. Since many communities rely on home gardens for dietary vegetable consumption, soil metal contamination is a concern for residents in close proximity to industrial emissions (Ferri et al., 2015; Kim et al., 2015; Bidar et al., 2020).

Data from previous studies indicates that vegetables could be classified according with their ability to accumulate heavy metals in edible parts, as follows: leafy/stem vegetables > root vegetables > tubercles > fruiting vegetables/fruits. Besides the vegetable species and cultivars, the cadmium uptake is also governed by the physico-chemical parameters of soils. The total cadmium content in soils is considered as a good predictor parameter on cadmium accumulation in vegetables.

Main leafy vegetables identified in studied area were lettuce, celery and parsley. A better understanding of the influences of Cd accumulation in leafy vegetables is critical to produce vegetables with low amounts of Cd.

Therefore, this study attempts to quantify quality of some leafy vegetables grown in individual gardens from contaminated area, Copșa Mică.

The study will provide a theoretical reference for a safe production of leafy vegetables in contaminated areas.

MATERIALS AND METHODS

The present study was carried out during 2019-2021 in one of the critical areas in terms of heavy metal contamination, Copșa Mică.

The studied area includes seven localities: Avente Sever, Agârbiciu, Soala, Micăsasa, Târnava, Copșa Mica and Bazna. This area presents the highest risk of interception of heavy metals through locally produced local food, due to the large abundance of agro-systems in the structure of local socio-ecological systems.

During this study were collected 55 soil samples, 55 parsley (*Petroselium crispum*), 45 celery (*Apium graveolens*) and 20 lettuce (*Latuca sativa*) samples from individual gardens located in contaminated area. Each soil sample was a mixture of 6 sub-samples that were collected from the surface soil (0-20cm). The corresponding leafy vegetables was a mixture of shoots and leaves from mature plants from each garden.

The soil samples were air-dried at room temperature and then crushed and sieved through 2 and 0.2 mm meshes, before storage and analysis.

The withered and decay tissues were removed from the leafy vegetables samples and then the edible parts were washed twice in tap water before being cut and frozen.

Soil pH was measured using the potentiometric method (1:2.5 w/v, soil: water). The soil organic carbon content (SOC) was determined on 0.2mm grounded soil samples using dichromate oxidation followed by titration with ferrous ammonium sulphate (Walkley and Black, 1934).

The available phosphorus and potassium in soil were extracted with ammonium acetate lactate (AL extractable) at pH 3.75 (Romanian Standard STAS 7184/19-82 based on the Egner-Riehm-Domingo method, Egner et al., 1960) and analysed by flame photometry (for potassium content) and UV/Vis spectrometry (for phosphorus content).

The pseudo-total concentration of Cd was determined only in the soil samples by atomic absorption spectrometry, after extraction by the aqua regia - microwave digestion method. Microwave digestion was performed using 10 mL of aqua regia (7.5 mL HCl and 2.5 mL HNO_3) at 140°C for 30 min, method developed according to SR ISO 11466:1999. A certified soil reference material (ERM–CC141) was used to ensure the accuracy of the analytical data. The average recovery value of Cd in the reference soil was 85%.

The vegetable samples were digested with nitric acid in a microwave digestion system. The metal content was measured using atomic absorption spectrometry (Flame GBC 932AA or Graphite furnace GBC SavanatAAZ).

Means of data were compared by least significant difference tests at $p < 0.05$. Linear regression analyses were performed using the statistical package STATISTICA CSS (Complete Statistical System by StatSoft, Tulsa, OK, USA).

RESULTS AND DISCUSSIONS

A summary of main soil chemical characteristics and metals contents are presented in Table 1. Soil pH ranged from slightly acid (pH 6.34) to slightly alkaline (pH 8.26) with mean pH value was 7.47.

Soil organic carbon (SOC) ranged from 1.47 to 3.92% with average value 2.44%, nitrogen content in soil ranged from 0.16 to 0.60% with average value 0.27%, levels of available phosphorus (P_{AL}) ranged from 67 mg kg^{-1} to 744 mg kg^{-1} with average value 379 mg kg^{-1} and K_{AL} contents ranged between 262 mg kg^{-1} and 1360 mg kg^{-1} with average content 615 mg kg^{-1}. Also, the average contents for Cd, Cu, Pb and Zn exceeds the alert thresholds for sensitive use of land (according with Order 756/1997). These soils have a great variability in their chemical parameters as well as the large range of multiple contaminations.

Table 1. Summary of soil properties and metals contents in soil

		Range of variation	Geometric mean	Median	Arithmetic mean
pH		6.34 - 8.26	7.46	7.58	7.47
Cd	mg/kg	0.10 - 35.81	2.77	4,92	6.03
Pb	mg/kg	19 - 952	117	133	171
Zn	mg/kg	124 - 1811	366	358	454
Cu	mg/kg	25 - 132	63	62	67
Mn	mg/kg	219 - 910	569	621	592
Organic C	%	1.47 - 3.92	2.37	2.35	2.44
Total N	%	0.16 - 0.60	0.26	0.26	0.27
Available P (PAL)	mg/kg	67 - 744	335	348	379
Available K (KAL)	mg/kg	262 - 1360	559	580	615

The high anthropization level and the diversity of cultivation practices have effects on the chemical parameters of soils collected from private gardens included in this study.
The different cultivation practices such as liming, organic fertilization or irrigation could explain the heterogeneity of the pH values (Scheromm, 2015).
The intense application of fertilizer increases the contents of nitrogen (N), phosphorus (P), and potassium (K) in garden soils. Similar results were reported by other studies regarding urban kitchen gardens (Burghardt et al., 2018; Joimel et al., 2016).
Total Cd in soils ranged from 0.10 to 35.8 mg kg^{-1} covering a range that has been classified as background levels to highly polluted soil.
The soil physico-chemical properties as pH, soil texture and depth of contamination, soil OM, salinity, potential redox, and nutrient status are known to be important factors that control the metals uptake in vegetables (Bidar et al., 2020).
The influence of these parameters on metals accumulation in vegetables can be assessed by using predictive approaches.
The soil-plant transfer model is the most used model for predict metal in vegetables. Bidar et al. (2020) considered that in this type of model, metal concentrations in plant tissues ($[M]_{plant}$) are often linked to total and extractable metal concentrations in soil ($[M]_{soil}$) by regression analysis using Freundlich-type equation (linear or log transformed data: $[M]_{plant} = 10^a\ [M]^b_{soil}$ or $\log [M]_{plant} = a + b \log[M]_{soil}$).
Therefore, in our study, the total cadmium content was used as variable to develop the stochastic models for estimating the cadmium content of leafy vegetables. The selection of this parameter was also based on the fact that it

is the only indicator for which reference values are found in the regulations for assessing the degree of pollution (Order 756/1997).

According to log-log diagram (Figure 1), the parsley (leaf) plant accumulated high amounts of cadmium. The values of cadmium contents in parsley were correlated with total cadmium content in soil by means of a power regression equation.

For cadmium, the value of linear correlation coefficient (r = 0.373**), corresponding to linear form of the regression equation was significantly ($p<0.05$) indicating a good correlation between the cadmium content in parsley plant and the cadmium content in soil.

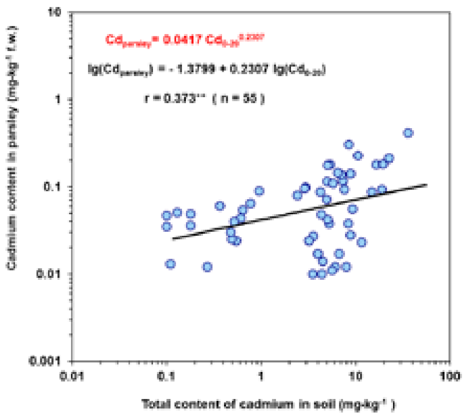


Figure 1. Log-log diagram for power regression curve that estimates the stochastic dependency between total cadmium content in soil and cadmium content in parsley (leaves)

According with EU Regulation 2021/1323, the maximum allowable value for cadmium for leafy vegetables is 0.10 mg kg^{-1}, except aromatic herbs. For aromatic herbs the maximum allowable limits is 0.20 mg kg^{-1} Cd reported to fresh material.

The cadmium content values in parsley plants collected during this study ranged between 0.010 mg kg^{-1} and 0.415 mg kg^{-1}. The high cadmium accumulation capacity of aromatic herbs, like parsley, was observed by other authors (Mihali et al., 2012; Säumel et al., 2012) in studies carried out in another contaminated areas.

In order to assess the quality of celery plants cultivated in individual gardens from studied area, 45 samples were collected. The cadmium content values in celery collected during this study ranged between 0.072 mg kg^{-1} and 3.424 mg kg^{-1}.

The Figure 2 presents the dependency of cadmium in edible parts of celery (leaf) on total cadmium content in soil.

The value of linear correlation coefficient (r = 0.724***), corresponding to linear form of the regression equation was highly significant indicating a very strong correlation between the cadmium content in celery plant and the cadmium content in soil.

Our results are in agreement with those of Xiao et al. (2018), who reported that total Cd in soil can be used to estimate soil-crop Cd transfer in celery plant.

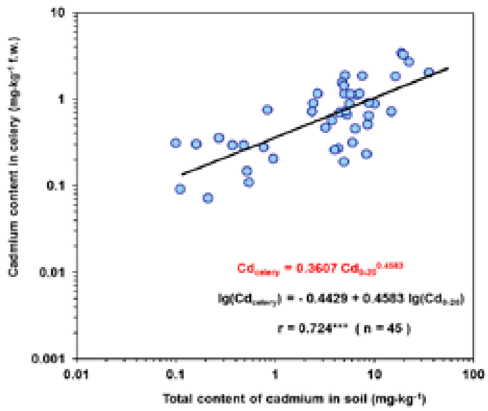


Figure 2. Log-log diagram for power regression curve that estimates the stochastic dependency between total cadmium content in soil and cadmium content in celery (leaves)

Celery potential to accumulate Cd was previously reported by Piekut et al. (2018) the authors observed a serious Cd contamination of agricultural soil and vegetables grown on that soil, where even 77% of analysed celery samples exceeded permissible level for Cd, while the same was recorded for only 14% of parsley samples. Based on plant growth associated with Cd accumulation, celery was considered as a hyper-tolerant species (Arsenov et al., 2021).

Lettuce is one of the most widely cultivated and consumed leafy vegetables worldwide (Bidar et al., 2020). According with these authors, lettuce has high capacity of accumulating cadmium.

In our study, the values of cadmium content in lettuce ranged between 0.015 mg kg^{-1} and 1.820 mg kg^{-1}. The dependency of cadmium content in lettuce on total cadmium content in soil is presented in Figure 3.

The value of linear correlation coefficient (r = 0.754***), corresponding to linear form of the regression equation was highly significant indicating a very strong correlation between the cadmium content in lettuce leaves and the cadmium content in soil.

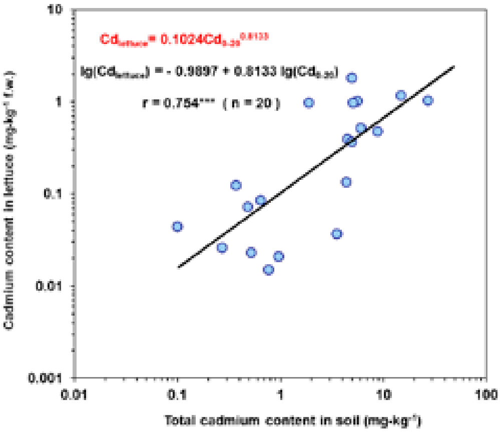


Figure 3. Log-log diagram for power regression curve that estimates the stochastic dependency between total cadmium content in soil and cadmium content in lettuce (leaves)

Similar results were reported by Tokalioğlu et al. (2006) in a study carried out in Turkish urban gardens.

The investigations relied on a large-scale field survey and the results indicated that all vegetables included in this study have high capacities to accumulate cadmium in edible parts. There were many vegetables collected from studied area whose cadmium concentrations exceeded the threshold values (0.10 mg kg^{-1}). Considering this, leafy vegetables ability to accumulate cadmium can be a problem when it comes to edible parts, since that can lead to misinterpretation that vegetables are healthy for human consumptions. Taking all that into account, metals transferring in soil-plant system, associate with food safety, became a major public concern all around the world (Sun & Zhang, 2020).

CONCLUSIONS

Gardening, which is a wide spread activity in studied area, could contribute to human exposure through the consumption of home-grown vegetables. Also, the consumption of self-produced vegetables is of great concern because these products are not subject to control of the metal concentrations unlike commercial foodstuff production, which is constrained to regulatory threshold values established by EC.

Besides the vegetable species, the cadmium uptake by vegetables is also governed by the physico-chemical parameters of soils. The total cadmium content of individual gardens soils is considered as a good predictor parameter on cadmium concentration in celery and lettuce leaves.

Using the regression equations developed during this study, cadmium accumulation in parsley, celery and lettuce were quantitatively predicted by the measurement of total cadmium content in soil.

The results of our study can be used in all contaminated areas where individual gardens exist, to ensure a comprehensive understanding of where potential hazards exist and how to reduce the risk on human health.

ACKNOWLEDGEMENTS

This work was supported by two grants of the Romanian Ministry of Research, Innovation and Digitization, project number PN 34.05.01 entitled: "Modeling the bioaccumulation of heavy metals in vegetables - a method used as scientific tool for development of a Good Practices Guide for growing vegetables in households in areas affected by industrial pollution" and project number 44 PFE /2021, Program 1 – Development of national research-development system, Subprogramme 1.2 – Institutional performance – RDI Excellence Financing Projects.

REFERENCES

Arsenov, D., Župunski, M., Pajević, S., Borišev, M., Nikolić, N., & Mimica-Dukić, N. (2021). Health assessment of medicinal herbs, celery and parsley related to cadmium soil pollution-potentially toxic elements (PTEs) accumulation, tolerance capacity and antioxidative response. *Environmental Geochemistry and Health, 43(8),* pp. 2927–2943. https://doi.org/10.1007/s10653-020-00805-x

Augustsson, A.L.M., Uddh-Söderberg, T.E., Hogmalm, K.J., Filipsson, M.E.M. (2015). Metal uptake by homegrown vegetables - the relative importance in human health risk assessments at contaminated sites. *Environmental Resources, 138*, pp. 181–190.

Bidar, G., Pelfrêne, A., Schwartz, C., Waterlot, C., Sahmer, K., Marot, F. & Douay, F. (2020). Urban kitchen gardens: Effect of the soil contamination and parameters on the trace element accumulation in vegetables – A review. *Science of the Total Environment, 738, 139569*

Burghardt,W., Heintz, D. & Hocke, N. (2018). Soil fertility characteristics and organic carbon stock in soils of vegetable gardens comparedwith surrounding arable land at the center of the urban and industrial area of Ruhr, Germany. *Eurasian Soil Science, 51 (9)*, pp. 1067–1079.

Ferri, R., Hashim, D., Smith, D. R., Guazzetti, S., Donna, F., Ferretti, E., Curatolo, M., Moneta, C., Beone, GM. & Lucchini, R. G. (2015). Metal contamination of home garden soils and cultivated vegetables in the province of Brescia, Italy: Implications for human exposure. *Science of The Total Environment, 518–519*, pp. 507–517

Huang, W-L., Chang, W.H., Cheng, S.F., Li, H.Y., & Chen, H.L. (2021), Potential Risk of Consuming Vegetables Planted in Soil with Copper and Cadmium and the Influence on Vegetable Antioxidant Activity. *Applied Sciences, 11, no. 9: 3761*. https://doi.org/10.3390/app11093761

Joimel, S., Cortet, J., Jolivet, C.C., Saby, N.P.A., Chenot, E.D., Branchu, P., Consalès, J.N., Lefort, C., Morel, J.L. & Schwartz, C. (2016). Physico-chemical characteristics of topsoil for contrasted forest, agricultural, urban and industrial land uses in France. *Science of the Total Environment, 545–546*, 40–47.

Kim, H.K., Jang, T.I., Kim, S.M. & Park, S.W. (2015). Impact of domestic wastewater irrigation on heavy metal contamination in soil and vegetables. *Environmental Earth Sciences, 73 (5)*, pp. 2377–238

Liu, C., Chang, C., Fei, Y., Li, F., Wang, Q., Zhai, G &Lei, J. (2018). Cadmium accumulation in edible flowering cabbages in the Pearl River Delta, China: Critical soil factor and enrichment models, *Environmental Pollution, 233*, pp. 880–888.

Mihali, C., Michnea, A., Oprea, G., Gogoaşa, I., Pop, C., Senilă, M. &Grigor, L. (2012). Trace element transfer from soil to vegetables around the lead smelter in Baia Mare, NW Romania. *Journal of Food, Agriculture and Environment*. 10 (1), pp. 828–834.

Piekut, A., Baranowska, R., Marchwińska-Wyrwał, E., Ćwieląg-Drabek, M., Hajok, I., Dziubanek, G., & Grochowska-Niedworok, E. (2018). Is the soil quality monitoring an effective tool in consumers' protection of agricultural crops from cadmium soil contamination?—A case of the Silesia region (Poland). *Environmental Monitoring and Assessment, 190*, 25.

Rizwan, M., Ali, S., Abbas, T., Zia-ur-Rehman, M., Hannan, F., Keller, C., Al-Wabel, M.I., & Ok, Y.S. (2016). Cadmium minimization in wheat: a critical review. *Ecotoxicol. Environ. Saf., 130*, pp. 43–53.

Säumel, I., Kotsyuk, I., Hölscher, M., Lenkereit, C.,Weber, F.& Kowarik, I. (2012). How healthy is urban horticulture in high traffic areas? Trace metal concentrations in vegetable crops from plantings within inner city neighbourhoods in Berlin, Germany. *Environmental Pollution, 165,* pp. 124–132.

Scheromm, P. (2015). Motivations and practices of gardeners in urban collective gardens: the case of Montpellier, *Urban Forestry & Urban Greening, 14*, pp. 735–742.

Sun, X., & ZhangJ, L. L. (2020). Spatial assessment models to evaluate human health risk associated to soil potentially toxic elements. Environmental Pollution. https://doi.org/ 10.1016/j.envpol.2020.115699.

Swartjes, F.A., Versluijs, K.W.& Otte, P.F. (2013). A tiered approach for the human health risk assessment for consumption of vegetables from with cadmium contaminated land in urban areas. *Environmental Resources, 126*, pp. 223–231.

Tokalioğlu, S., Kartal, S. & Gültekin, A. (2006). Investigation of heavy-metal uptake by vegetables growing in contaminated soils using the modified BCR sequential extraction method. International *Journal of Environmental Analytical Chemistry*, 86 (6), pp. 417–430.

Xiao, W., Ye, X., Zhang, Q., Che, D., Hu, J. & Gao, N. (2018). Evaluation of cadmium transfer from soil to leafy vegetables: Influencing factors, transfer models and indication of soil threshold contents, *Ecotoxicology and Environmental Safety,* 164, pp. 355–362.

***COMMISSION REGULATION (EU) 2021/1323 of 10 August 2021 amending Regulation (EC) No 1881/2006 as regards maximum levels of cadmium in certain foodstuffs

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

TOPOGRAPHIC AND GEODETIC SUPPORT FOR THE DEVELOPMENT OF THE GIS REGISTER OF POLISH BURIALS - CASE STUDY ON BAIKOVE CEMETERY IN KYIV

Taras IEVSIUKOV[1], Boris CHETVERIKOV[2], Ivan OPENKO[1], Ivan KOVALCHUK[1], Oleksandr SHEVCHENKO[1], Yanina STEPCHUK[1], Ruslan TYKHENKO[1], Oleksandr MAKAROV[1]

[1]National University of Life and Environmental Sciences of Ukraine, 17 Vasylkivska Street, Kyiv, Ukraine
[2]Lviv Polytechnic National University, 12 Bandery Street, Lviv, Ukraine

Corresponding author email: stepchuck.yanina@gmail.com

Abstract

The purpose of this paper is to elaborate of creating web-GIS of Polish burials at the Baikove Cemetery in Kyiv. Achieving this goal involves the following tasks: to develop the structure of the geographic information system, its framework and to fill the file database. For fulfilment of established tasks, a technological scheme consisting of 12 stages is offered. In the first stage, field surveys were performed to determine the coordinates of each grave of the Polish burials of the Baikove Cemetery using a GIS tablet. The total number of point coordinates was 565, which were concentrated in 7 sections of the cemetery. At the eighth stage of the technological scheme the structure of layouts of each html-page of the created online GIS was developed. In the case of the Baikove Cemetery scheme, plots with Polish burials were marked. At the tenth stage, 5 sheets of topographic plans of burials were generated. The eleventh stage is devoted to the creation and filling of a file database on Polish burials. This database contained the following structure: photo of the burial, coordinates, surname and name, years of life, additional photographs, sex of the buried person, interpreted inscription on the tombstone, as well as, if possible, detailed information and profession of the buried person, its outstanding achievements and accomplishments. At the last stage, the hyperlinks of the transition between the pages were configured and the system was tested. The scientific novelty lies in the development of the concept of joint use of various applications of geoinformation and non-geoinformation purposes. The technological scheme of creation of WEB-GIS of Polish burials of the Baikove Cemetery in Kyiv is offered. The implemented geographic information system is designed for inventory of burials, analysis of the condition of tombstones and their spatial location in the cemetery.

Key words*: WEB-cartography, Polish burials, Baikove Cemetery, historical GIS, file database, burial inventory.*

INTRODUCTION

GIS technologies have found practical application almost everywhere - in forestry, construction, cartography, ecology, seismology, etc. (Openko et al., 2020a, 2020b; Openko et al., 2019; Openko et al., 2017; Openko, 2019a, 2019b).
They are studied in universities and research institutions. GIS technology is a whole industry that affects almost all aspects of human life.
GIS allows mapping of world objects, and their analysis for a large number of parameters, visualization.
Based on this data we can then predict a variety of events and phenomena (Ievsiukov & Openko, 2014; Martyn et al., 2019). This powerful technology allows us to solve a huge number of both global and local problems (Kryvoviaz et al., 2020).
Preservation of cultural heritage is a problem of international importance, as evidenced by the Convention for the Protection of the World Cultural and Natural Heritage, adopted by UNESCO. Solving the problem of cultural heritage preservation is closely related to mapping. The creation of heritage maps is attracting increased attention of researchers and has now developed into a special area of thematic mapping, which needs further development. In addition to the main purpose - inventory of heritage in order to protect it, mapping provides society with new information and knowledge, promotes understanding of the past, present, future. The creation of data banks and heritage maps

allows for a fuller assessment of the importance of cultural monuments, and also to expand programs for their preservation and restoration. Heritage mapping is especially important for historic cities, such as Kyiv.
The current state of collection and storage of materials on monuments of historical and cultural importance is characterized by a variety of documents used to create archives, registers and records. Accounting and information storage services spend large amounts of time on the preparation and issuance of the necessary materials, both to customers and their own departments that are part of the security body.
The materials used by these services are very diverse: textual documentation, historical notes, technical passports, plans of land plots, results of stereo photogrammetric survey (digital models of facades, dimensional drawings), photographic materials, etc. (Pidlisetska, 2015). As the flow of documents increases, it becomes increasingly difficult to record, store, issue and share them with different services and consumers. The development of modern technologies allows us to optimize the overlay of data sources (or datasets), which gave impetus to the idea of creating an information system "Atlas of Polish burials at the Baikove Cemetery in Kyiv" together with our Polish colleagues.
Many foreign and domestic scholars have worked on the creation of various methods for mapping historical and cultural heritage sites. The method of mapping cultural heritage objects using a combination of interpretation of archival aerial photographs and georadar surveying is covered in a scientific article (Chetverikov et al., 2017). The mapping of cultural heritage objects on archival cartographic and aerial representations is described in a number of publications (Chetverikov, 2019, 2020; Arnoud de Boer, 2010; Knowles, 2008). Along with the mapping of historical and cultural heritage sites, the issues of 3D modeling and reconstruction of architectural structures are important (Apollonio et al., 2012; Clini et al., 2017). The use of spatial data and remote sensing data to monitor historical and cultural heritage sites has been previously described (Ehlers & Rhein, 1996; McKeague et al., 2012; Remondino, 2007; Vacca et al., 2018). Methods of creating geoportals with data on cultural heritage sites are covered in previous research (Fiedukowicz et al., 2018; Gregory & Ell, 2007). The design of any atlas is based on the previous achievement of scientists working in the field of integrated atlas mapping for various research objects. For example, Bainozarov A.M. covers the method of designing cartographic products for the the educational complex of Ukraine. Prasul Yu.I. (2004) substantiates the list, structure and content of plans, series of maps and atlases that make up the regional system of cartographic works for tourism. Polyvach K.N. (2007) considers the cultural heritage and its impact on the development of the regions of Ukraine as an object of socio-geographical research, etc.

MATERIALS AND METHODS

To achieve our goal, a technological scheme was proposed, consisting of 12 stages (Figure 1).
The first stage involved the collection of cartographic and descriptive data on the territory of the study area, as well as the search for possible registers of Polish burials. The input graphic materials used were:
- a portion of the topographic plan of Kyiv at a scale of 1: 2000, created in 2009 (since the territory of the cemetery did not change since then, the year of creation for the plan satisfied us) (Figure 2);
- the scheme of the Baikove Cemetery made on the basis of an orthophoto plan (Figure 3);
- maps and satellite images from the online resource Google Maps.

In addition, descriptive materials of figures buried in the cemetery were collected from the Internet and a paper register of Polish burials of the Baikove Cemetery were used as input data.

RESULTS AND DISCUSSIONS

In the second stage, field surveys were conducted to determine the coordinates of each grave of the Polish burials of the Baikove Cemetery using a GNSS controller with RTK antenna LT700H.

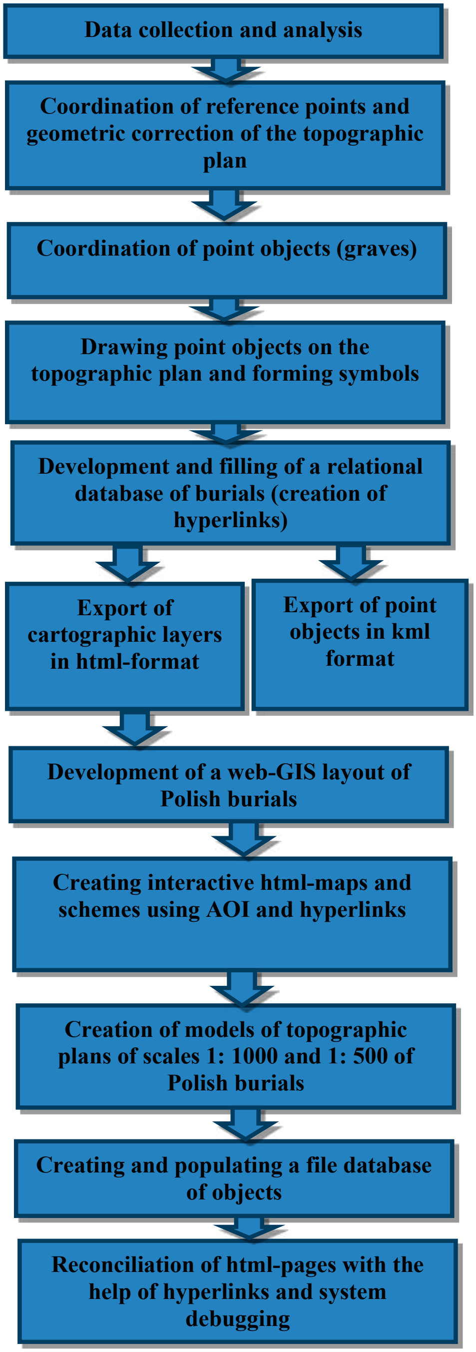


Figure 1. Workflow for web-GIS of Polish burials in Baikove Cemetery

To do this, we evaluated the accuracy of satellite observations. 104 measurements were performed, 77% of which were performed in built-up territory, 23% - in open territory. The research was conducted in the city of Kyiv, the capital of Ukraine, which has a multi-million populations and an oversaturation of built-up territory.

Figure 2. Fragment of the topographic plan of the Baikove Cemetery at a scale of 1: 2000

Figure 3. Scheme of Baikove Cemetery

As the empirical method shows, of the total number of measurement results in 37.50% of errors for GNSS observations are in the 0-2 meters range, 49.04% - 2-5 meters and the other 13.46% - 5-10 meters.
A direct relationship was established between the built-up territory and the accuracy of positioning. With this dependence, not only the height of buildings is important, but also their proximity to the location of the GNSS observation.
According to research, GPS error in large cities and built-up areas can reach more than 5 meters (13.46% of measurement results confirm this). In this case, the height of the adjacent buildings varied from 2 to 20 floors.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

According to results, it can be argued that the presence of high-rise buildings significantly affects the accuracy of GPS-positioning when using modern gadgets (in this case, GNSS-tablet - controller). However, in the conditions of "open sky" the maximum accuracy of GPS-positioning can reach 0-5 meters. The magnitude of this error is equivalent to "raw" (raw) satellite observations obtained using specialized geodetic GNSS receivers.
Given that the determined accuracy did not meet the conditions for filming at the Baikove Cemetery, we decided to conduct further filming using RTK corrections with a RTK-antenna LT700H. The application of RTK in satellite observations has improved the predetermined accuracy to 0.30 m.
In the second stage, field surveys were performed to determine the coordinates of each grave of the Polish burials of the Baikove Cemetery using a GIS tablet with an RTK antenna LT700H with accuracy up to 0.30 m.
There were a total of 565 such points in seven sections of the cemetery. The coordinates are obtained in the coordinate system Latitude/Longitude of the WGS84 projection, which are later translated into fractions of a degree for processing point objects in GIS.
Coordinates of reference points were obtained at characteristic points along the perimeter and inside the cemetery by GNSS survey using the ElNav i70 receiver.
The third stage included the coordination of reference points and the binding of this fragment in the GIS MapInfo fragment of the topographic plan of Kyiv at a scale of 1: 2000 on the territory of the Baikove Cemetery. Eleven reference points were used. The transformation was performed according to the polynomial model of the second degree. The maximum binding error is 2 pixels, which corresponds to 0.2 m on the ground (Figure 4).
In the fourth stage, all point objects were spaced according to their coordinates on the map and symbols were chosen (Figure 5).
The standard icon from the MapInfo symbol library - a rectangle with a cross - is selected for the symbol. The symbol was assigned a red colour for contrast display on the background of the topographic plan and size was set to 12 (Figure 6).

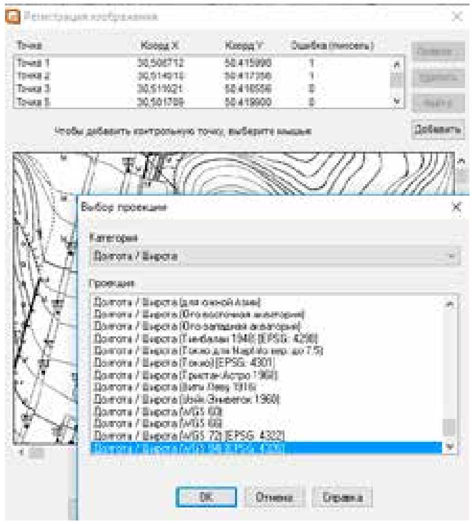


Figure 4. Topographic plan binding window

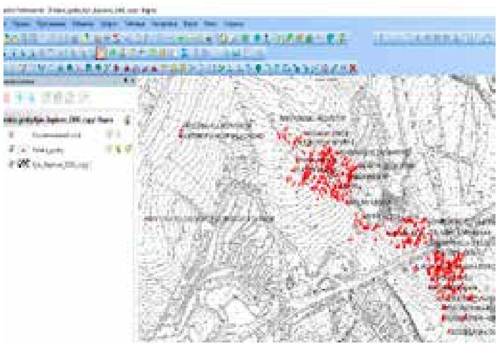


Figure 5. Visualization of the applied point objects of burials on the topographic plan of the Baikove Cemetery

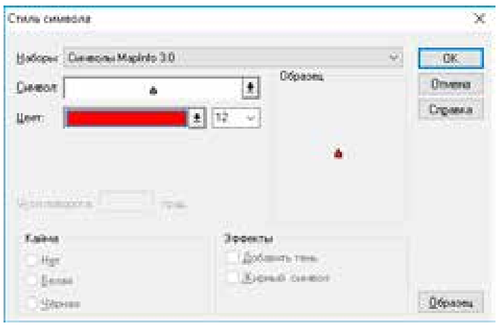


Figure 6. Symbol settings window

The next step was to develop and populate a relational database (Figure 7) for point objects, which included the following columns:

- grave number;
- surname and name of the buried person;
- coordinates of the grave;
- hyperlinks to burial information in the file database.

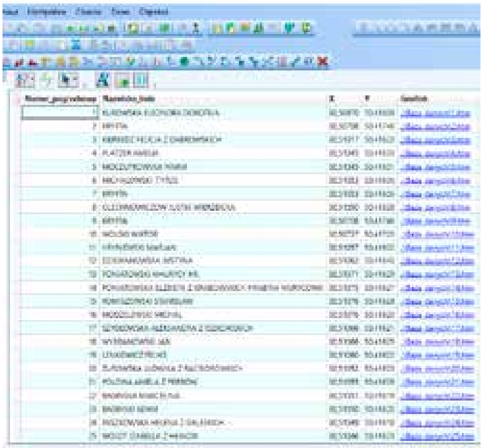


Figure 7. Filled tabular database to the vector layer of point objects

Next, all map layers were exported to html format, and the point object layer was exported to kml format using an universal translator, which allowed viewing of burial data in GoogleEarth (Figure 8).
To export data to html-format we used the application MapInfo HTML-map, written in the programming language MapBasic. This appendix specifies the layer and column that will be used to define the hyperlink. The title of the map and its size in the browser window were also set (Figure 9).

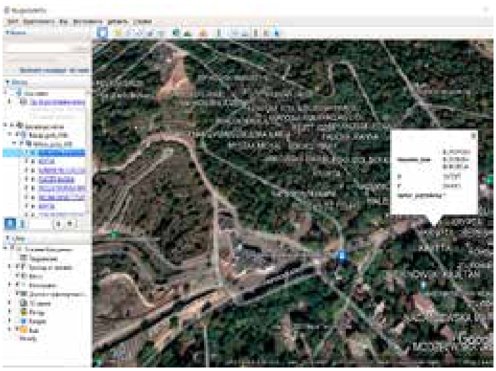


Figure 8. Exported burial dots layer in kml format, opened in Google Earth

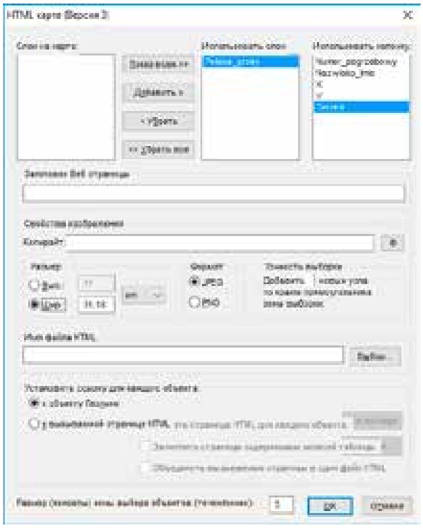


Figure 9. HTML map creation window

At the eighth stage of the workflow the structure of layouts of each html-page of the online GIS was developed (Figure 10).

Figure 10. The main page of the developed GIS

The satellite image on the main page of the system served as a hyperlink to GoogleMaps to view the location of the object and the surrounding infrastructure (Figure 11).

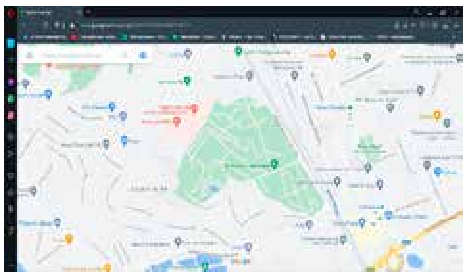


Figure 11. GoogleMaps transition window

All map data had hyperlinks to the selected AOI objects. In the case of the scheme of the Baikove Cemetery, if the areas where there are Polish burials were selected and when clicked on, a topographic plan with marked point burials opens (Figures 12 and 13).

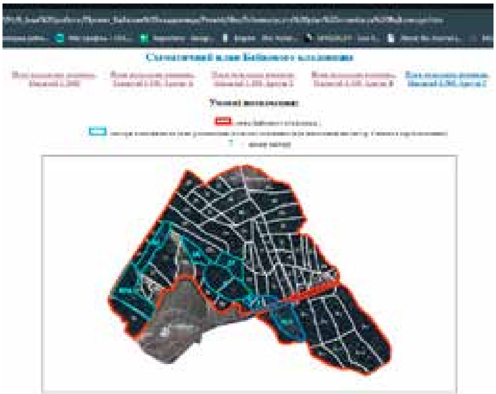


Figure 12. The location scheme of the Baikove Cemetery with configured hyperlinks territories to topographic plans

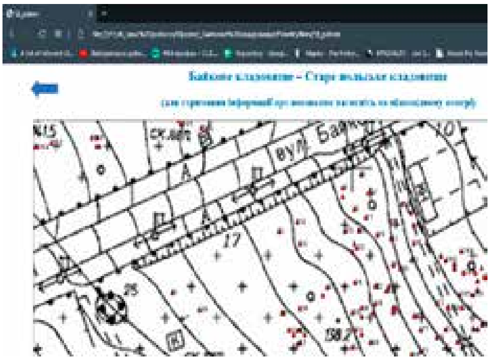


Figure 13. Example of one of the territories of the cemetery in the form of a topographic plan with point objects with programmed hyperlinks to the file database

In turn, when clicking on them, information about the burial appears from the file database (Figure 14).

At the tenth stage, 5 sheets of topographic plans with burials were generated. One sheet at scale 1: 2000 and four sheets at scale 1: 500, for better "spreading" and initialization of burials (Figure 15).

During the eleventh stage, a file database on Polish burials was created and filled. It included the following data: photo of the burial, coordinates, surname and name, years of life, additional photographs (if possible), sex of the buried person, interpreted inscription on the tombstone, as well as, if possible, supporting information and profession of the buried person (Figures 16 and 17).

Figure 14. Example of a database file with burial information

Figure 15. Example of displaying one of the topographic plans with spot objects of Polish burials

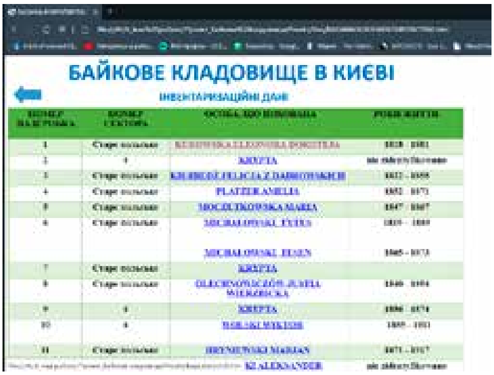


Figure 16. Page with inventory data on Polish burials

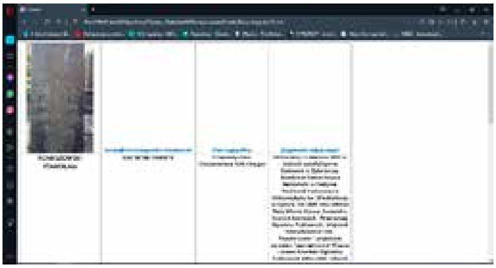


Figure 17. Example of a database files with burial information

Finally, the hyperlinks of the transition between the pages were configured and the system was tested.

The technological scheme of creation of WEB-GIS of Polish burials of the Baikove Cemetery in Kyiv is thus offered. The implemented geographic information system is designed for inventory of burials, analysis of the condition of tombstones and their spatial location in the cemetery. In addition, the created GIS can be used for tourism purposes and in the study of historical figures of Polish origin.

CONCLUSIONS

During the study, the maximum accuracy of GNSS - observations for the development of the GIS register in the city of Kyiv was calculated. Using the LT700H controller, we evaluated the accuracy of satellite positioning. In particular, we found that in 37.50% of cases the total positioning error of the measurement results is in the range of 0-2 meters, in 49.04% - 2-5 meters and in 13.46 of cases - 5-10 meters. Based on these results, we decided to use an RTK antenna for the LT700H controller, which allowed for an increase of the positioning accuracy to 0.3 m, for further field work.

As a result of realization of the set purpose the online geoinformation system of the Polish burials on the Baikove Cemetery which includes the following sections is created:

- areas of the cemetery with Polish burials, which are reflected in the topographic plan M 1: 2000, linked in the coordinate system WGS84;
- point objects of each tomb of Polish burials were identified using a GIS tablet with an accuracy of 0.30 m. The objects were plotted on a topographic support and geo-links were created to the corresponding file from the system database;
- models of plans with Polish burials in scales 1: 2000 and 1: 5000;
- inventory table of Polish tombs in the cemetery with the sector of burials, number of the tomb, the person buried and years of life. The person's last name and first name are linked by a geolink to a file database that includes 565 objects;
- generated file with kml extension for viewing burial spot data using GoogleEarth software.
- the system is connected to GoogleMaps.

ACKNOWLEDGEMENTS

This research was carried out with the support of Consulate of the Republic of Poland in Ukraine and was financed from the International Association of Polish Entrepreneurs in Ukraine.

The project was implemented in cooperation with Ukrainian scientists from the Consulate of the Republic of Poland in Ukraine.

REFERENCES

Apollonio, F. I,Gaiani, M., & Sun Z. (2012). 3Dmodeling and data enrichment in digital reconstruction of architectural heritage. ISPRS Archives, 13(5), pp. 43–48.

Arnoud de Boer (2010). Processing old maps and drawings to create virtual historic landscapes. e-Perimetron, 5(2), pp. 49–57.

Clini, P., El Mehtedi, M. E., Nespeca, R., Ruggeri, L., & Raffaelli, E. (2017). A digital reconstruction procedure from laser scanner survey to 3D printing: The theoretical model of the arch of Trajan (Ancona). SCIRES-ITSCIentific RESearch and Information Technology, 7(2), pp. 1–12.

Chetverikov, B., Bondar, K., Khomenko, R., Didenko, S., & Sheikhet, M. (2017). Determination of the location of historical objects using the photogrammetric method and methods of ground-based non-destructive research. Geodesy, cartography and aerial photography, (85), pp. 94–103. doi: 10.23939/ istcgcap2017.01.094

Chetverikov, B. (2019). Methods for determining the foundations of destroyed buildings from archival aerial photographs for the restoration of historical and cultural heritage sites. Modern achievements of geodetic science and production, 37, pp. 100–105. doi: 10.33841 / 1819-1339-2019-1-37-100-105

Chetverikov, B. (2020). Methods of creating GIS concentration camps of Nazi Germany in the period

1941-1944. Modern achievements of geodetic science and production, 1(39), pp. 103–109. doi: 10.33841/1819-1339-1-39-17

Ehlers, M., & Rhein, U. (1996). The role of remote sensing and Operational state-wide environmental monitoring. International archives of photogrammetry and remote sensing, 21, pp. 684–689.

Fiedukowicz, A., Glazewski, A., Kolodziej, A., Koszewski, K., Kowalski, P., Olszewski, R., & Wlochynski, L. (2018). Map Portal as a Tool to Share Information on Cultural Heritage Illustrated by the National Heritage Board Geoportal. Advances in Digital Cultural Heritage. Lecture Notes in Computer Science, 10754, 48–64. doi: 10.1007/978-3-319-75789-6_4.

Gregory, I., & Ell P. (2007). Historical GIS. Technologies, Methodologies and Scholarship, Cambridge: Cambridge University Press.

Ievsiukov, T., & Openko, I. (2014). An Inventory Database, Evaluation and Monitoring of Especially Valuable Lands at Regional Level in Ukraine. Abstracts. 3rd International Geography Symposium, Geomed 2013, 120, pp. 513–523. doi: 10.1016/j.sbspro.2014.02.131

Knowles, A. (2008). Placing History. How Maps, Spatial data, and GIS Are Changing Historical Scholarship, Redlands, California, USA: ESRI Press.

Kryvoviaz, E., Openko, I., Tykhenko, R., Shevchenko, O., Tykhenko, O., Tsvyakh, O., & Chumachenko, O. (2020). Recovery of losses for inappropriate use of land. Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, IX, pp. 175–182, from http://landreclamationjournal.usamv.ro/pdf/2020/Art26.pdf

Martyn, A., Openko, I., Ievsiukov, T., Shevchenko, O., & Ripenko, A. (2019). Accuracy of geodetic surveys in cadastral registration of real estate: value of land as determining factor. 18th International Scientific Conference ENGINEERING FOR RURAL DEVELOPMENT, Proceedings, 18, pp. 1818-1825. DOI: 10.22616/ERDev2019.18. N236

McKeague, P., Corns, A., & Shaw, R. (2012). Developing a Spatial Data Infrastructure for Archaeological and Built Heritage. International Journal of Spatial Data Infrastructures Research, 7, pp. 38–65.

Openko, I., Kostyuchenko, Y., Tykhenko, R., Shevchenko, O., Tsvyakh, O., Ievsiukov, T., & Deineha, M. (2020). Mathematical Modelling of Postindustrial Land Use Value in the Big Cities in Ukraine. International Journal of Mathematical, Engineering and Management Sciences, 5(2), pp. 260–271. doi: 10.33889/IJMEMS.2020.5.2.021

Openko, I., Shevchenko, O., Tykhenko, R., Tsvyakh, O., & Moroz, Yu. (2020). Assessment of inequality to forest resources access in the context of sustainable rural development. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 20(1), pp. 405– 410.

Openko, I., Shevchenko, O., Tykhenko, R., Tsvyakh, O., & Stepchuk, Ya. (2019). Economic analysis of deforestation impact on the yield of agricultural cultures in Ukraine. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 19(4), pp. 233– 237.

Openko, I., Shevchenko, O., Zhuk, O., Kryvoviaz, Ye., & Tykhenko, R. (2017). Geoinformation modelling of forest shelterbelts effect on pecuniary valuation of adjacent farmlands. International Journal of Green Economics, 11(2), pp 139–153.

Openko, I. (2019a). Correlation analysis of the impact of the existing public administration system on forest land use in Ukraine. Ekonomika ta derzhava, 7, pp. 55–62.

Openko, I. (2019b). Ecological and economic productivity of land use in Ukraine. Ahrosvit, 13-14, 44–52.

Polyvach, K. (2007). Cultural heritage and its influence on the development of the regions of Ukraine (socio-geographical research): author's ref. dis. for science. degree of Cand. geogr. Science: special. 11.00.02 "Economic and social geography". Kyiv.

Prasul, Yu. (2004). Scientific bases of system mapping of regions of Ukraine for the needs of tourism (on the example of Kharkiv region): author's ref. dis. for science. degree of Cand. geogr. Sciences: special: 11.00.12 "Geographical cartography". Kyiv.

Remondino, F. (2007). Digital preservation, documentation and analysis of heritage with active and passive sensors. Madrid, Spain: Proc. of LACONA 2007 Conference.

Shevchenko, O., Openko, I., Tykhenko, R., Tsvyakh, O., Zhuk, O., Kryvoviaz, E., Volk, P. (2021). Assessment of economic losses caused by degradation processes of agricultural land use. Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, X, pp. 102–109.

Tykhenko, R., Tykhenko, O., Openko, I., Shevchenko, O., Bavrovska, N., Zhuk, O., Stepchuk, Ya. (2021). The assessment of impact ecological stability of territory on the organization of rational land use of agricultural enterprises. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 21(2), pp. 685–692.

Vacca G., Fiorino D. R., & Pili D. (2018). A Spatial Information System (SIS) for the Architectural and Cultural Heritage of Sardinia (Italy). ISPRS International Journal of Geo-Information, 7 (2), pp. 49. doi: 10.3390/ijgi7020049.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

GIS HYDROLOGICAL MODELING IN AN AGRICULTURAL RIVER BASIN WITH HIGH POTENTIAL FOR WATER EROSION

Gabriela BIALI, Paula COJOCARU

"Gheorghe Asachi" Technical University of Iasi, Romania

Corresponding author email: gbiali@yahoo.com

Abstract

This paper presents a study on the use of GIS technology in determining the leakage caused by water erosion in a river basin of 370 ha. The research presented in this paper is carried out in the Sulita hydrographic basin from Botosani County.
The main objective is represented by the spatial analysis of the processes that take place in the hydrological system and of the physical-geographical factors that determine their variability. This GIS system developed under ArcGIS 9.2 can be considered a basic research in structuring a hydrological GIS and in creating an appropriate geospatial database.
The approached method is based on the digital analysis of the terrain, determining the morphometric parameters and the hydrological parameters. Using the ArcGIS 9.2 software, the calculation of slopes and directions is done at the pixel level, in a 3x3 pixel window, on all 8 directions from the central pixel to the neighborhoods. The important part of the paper is the determination of the parameter called flow accumulation, which in the study of water erosion, that indicates the way in which the actual flow is carried out on the slopes.

Key words*: Database, water erosion, GIS, hydrological modelling.*

INTRODUCTION

The alluvial stream on the slopes as a result of the erosion processes carried out at the level of the slopes and of the riverbed network is a very complex process that depends, on the one hand, by natural factors, and on the other hand by a series of human activities.
Globally, erosion is one of the greatest problems of humanity, vital to the process and its economic stability, to the environment. Of the total fertile soil reserves of the Earth (approx. 3.5 trillion tons), 23 billion tons are eroded annually; at this rate, the soil reserve can be depleted in 152 years (Rusu et al., 2020).
According to U.S. Department of Agriculture (USDA) data, in recent decades, erosion of humus over its ability to form has affected 1/3 of the globe's arable land.
The volume of sediments with a high percentage of nutrients from eroded soils transported by rivers and oceans has increased globally from 9 billion t/year, before the intensive cultivation of soil and irrational overgrazing, to 24 billion t/year (Chiorascu et al., 2017; Cojocaru et al., 2016).
In Romania, out of the total agricultural area (approx. 15 million ha), 44% is located on slopes of over 5% (usually lands with a slope below 5% are considered without danger of erosion). If only arable land is mentioned, out of the 9.8 million ha, 35% are located on slopes of over 5% (Niacșu, 2015).
The most important problem facing agriculture in Romania is soil erosion. This process of degradation (pollution in modern ecological conception) is extended to almost half (47%) of the agricultural surface of the country, respectively on approx. 7 million ha, representing the lands affected by the degradation process, of which 6.75 million ha of eroded lands (including 0.25 million ha of active landslides) and 0.25 million ha are lands with wind erosion. Of the 7 million ha mentioned, 3.9 million are lands with appreciable erosion, but with the danger of erosion if no vigorous measures are taken to control them and 3.1 million ha of lands affected by moderate to very strong erosion processes. Water erosion predominates (95.7%). 150 million tons of soil are lost annually due to erosion, containing 1.5 million tons of humus, 0.45 million tons of soil with nitrogen, as well as significant amounts of phosphorus, potassium and other nutrients (calcium, magnesium, zinc, molybdenum,

boron, etc.). The specific annual soil losses due to erosion vary between 3.2 and 51.5 t/ha; the weighted average in Romania being 16.28 t/ha year, much higher than the maximum allowable tolerable losses of 3-6 t/ha year (Rosca et al., 2015).

The applicability of Geographic Information Systems (GIS) methods and techniques in the field of Hydrology is extremely diverse, ranging from determining the morphometric parameters of river basins, to the ability to solve deterministic, process-based models, or even distributed models.

Society's progress is also closely linked to the ability to store, process and interpret information based on mathematical algorithms used in spatial analysis, given the explosive growth of data and the need to make decisions in the shortest possible time. Geographic Information Systems emerged as a consequence of this progress, based on the simplification of the real world by its representation in the form of layers, which facilitated the analysis of spatial variables and the distribution of entities on the earth's surface.

The rapid development of this field (as well as all computer technologies) and the widespread use of computers and modern measurement techniques (automatic stations, radars, satellites, drones, etc.) have allowed the development of calculation methods and algorithms and, further on, mathematical models and applications in the GIS environment. All this has led to the use of GIS in the field of modelling and hydrological analysis, by expanding the spatial analysis and detailing the physical processes that take place in the hydrological system (Irimuș et al., 2017; Niacsu et al., 2015).

MATERIALS AND METHODS

Research area

This paper describes a research conducted on a land with an area of 370 ha, i.e. the V-Sulița perimeter in Botoșani County, Romania (Figure 1). From the administrative point of view, it is in the Sulița and Lunca communes. From the hydrographic point of view, the V-Sulița perimeter is located in the Sitna river basin, which is part of the Prut river basin. From the geomorphological point of view, the area studied is located in the Moldavian Plain, the Jijia-Bașeu depression.

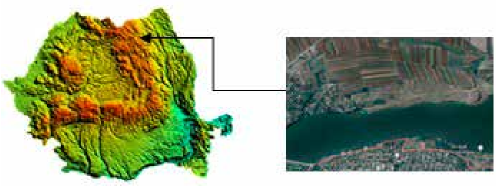


Figure 1. Location of investigated area
(https://earth.google.com)

The relief is represented by differently exposed slopes, plateaus and valleys. For the climatic characterization of the studied area, we used meteorological rainfall data from Sulița station located within the perimeter, while the other data were collected from Botoșani station, located about 25 km away. The land in the investigated perimeter is affected by surface erosion processes, the steep slopes are sometimes affected by deep erosion materialized in ditches, gullies and ravines. Also, where coastal springs are present and the solidification rock is represented by marl and/or clay, there are active and semi-stabilized landslides. For the pedological characterization of the analysed perimeter, the studies prepared at the Botoșani County Office of Pedological and Agrochemical Studies were used, based on which the pedo-amelioration sectioning was achieved depending on the intensity of the limitations of agricultural land use or the possible risk of degradation and subclasses depending on the nature and extent of limitations.

Research method

With the improvement of information technology, the performance and capabilities of GIS have expanded, evolving from simple software applications to crystallization, in the opinion of many specialists (Haidu et al., 2012), as an independent field (even if the tools they operate with are borrowed from other fields), (Moldovan et al., 2019).

The applicability of GIS methods and techniques in the field of Hydrology is extremely diverse, ranging from determining the morphometric parameters of river basins, to the ability to solve deterministic, process-based

models, or even distributed models (Cochrane et al., 1999).
For the evaluation and modelling of leakage, modern methods specific to GIS, but also those of aerial photography and remote sensing play an important role.
They complement the field of hydrology, allowing, on the one hand, the organization, visualization and, especially, the processing and analysis of spatial data, and on the other hand, the increase of the performances of hydrological models.
The most eloquent example is the topological modelling of the river basins and the translation, on a space scale, of the applicability limit between the systems with concentrated, semi-distributed or distributed parameters (Figure 2).
This type of approach takes into account the non-uniformity in space of the conditional factors of the flow (topography, lithology, vegetation, soils, etc.), as well as the non-uniformity in time and space of precipitation, and involves the division of the basin and the hydrographic network into homogeneous units, followed by the modelling of the rain-runoff process (Bilaşco et al., 2018; Teresneu et al., 2021).

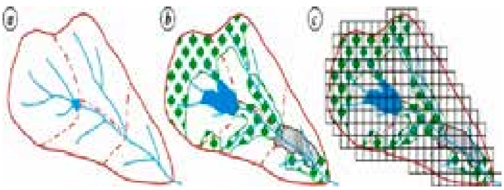


Figure 2. Topological modeling of river basins:
a) system with concentrated parameters; b) system with semi-distributed parameters; c) system with distributed parameters, (Bilaşco et al., 2018)

Both the input data in a GIS and the information resulting from the processing and analysis have as main characteristic the spatiality or georeferencing, which means that each element of the map is linked to a certain place, to other computer systems (Biali et al., 2020; Haidu et al., 2012; Moore et al., 1992).

Morphometric parameters of the terrain
The morphometric parameters of the terrain also called primary parameters are of particular importance in any study involving the modelling and assessment of erosion processes and phenomena on slopes.
In this project DEM’s has a spatial resolution of 25 m, it was created in 2020, by the Kriging interpolation method.

Slope
It is commonly perceived as the magnitude of the increase in altitude with the distance in the direction in which it is greatest, and is usually calculated by reference to a fixed distance, 100 meters, for example. If the distance in the plane is considered, the ratio between the altitude difference and the distance travelled is the tangent of the angle between the earth's surface and the horizontal of the place. If the distance on the earth's surface is considered, the slope becomes the sine of the same angle. The difference between the two is not significant for a slightly sloping surface, but it is very large for very sloping surfaces.
In the program developed under GIS application, the value of the tangent is used and expressed as such, the value of the ratio (calculated for a distance of 100 meters, and expressed as a percentage), or by the value of the angle of the surface with the horizontal.
For a continuous, analytic surface, S (X, Y) = Z slope represents the first-order derivative of the function S (eq.1), thus:

$$S=\sqrt{\left(\frac{\partial Z}{\partial X}\right)^2+\left(\frac{\partial Z}{\partial Y}\right)^2} \qquad (1)$$

This formula implies the possibility of determining the variation of the altitude on very small, infinitesimal distances. In a GIS, however, surfaces are not analytical but are modelled by irregular triangular grids or rectangular matrices with a finite resolution. That is why the calculation formulas implemented in various GIS applications are approximations of it, which are applied on grids (Cochrane et al., 1999).
In ArcGIS, the slope is calculated according to an algorithm that takes into account all 8 points in a 3 x 3 pixel neighbourhood (Figure 3), around the point where the calculation is desired. This is the finite difference method (FD) (eq. 2 and eq. 3). For example, for the pixel P in the adjacent figure, the slope will be calculated by applying eq. 1, but considering:

$$\frac{\partial Z}{\partial X}=\frac{(Z_{NV}+2Z_{V}+Z_{SV})-(Z_{NE}+2Z_{E}+Z_{SE})}{8\Delta X} \quad (2)$$

$$\frac{\partial Z}{\partial Y}=\frac{(Z_{NV}+2Z_{N}+Z_{NE})-(Z_{SE}+2Z_{E}+Z_{SV})}{8\Delta Y} \quad (3)$$

where Z is the altitude value, and ΔX and ΔY are the resolutions on the X and Y axes (in the case of the study equal to 25 m).

NW	N	NE
V	**P**	E
SW	S	SE

Figure 3. A neighborhood of 3 x 3 pixels for the central pixel P

Land exposure

The land exposure is an element of natural potential that can be used in various applications, for example:

- finding all the slopes with southern and western exposure to determine the best areas to cultivate but also which have high potential for erosion;
- finding all south-facing slopes to identify the places where snow is most likely to melt first, as part of a study to identify areas exposed to flooding.
- estimation of incident solar radiation, as part of a study to determine biodiversity in different sites;

In ArcGIS, the function for determining the exposure values is applied analogously to the one for determining the slope, also on the same neighborhood of 3 x 3 pixels, and the formula (eq. 4), which is applied for each pixel in part it is:

$$A=\frac{360}{2\pi}\cdot\arctan\left(\frac{\partial Z}{\partial Y},-\frac{\partial Z}{\partial X}\right] \quad (4)$$

Where the function $\arctan\left(\frac{\partial Z}{\partial Y},-\frac{\partial Z}{\partial X}\right]$ applies to both slope components determined by eq. 2 and eq. 3.

Hydrological parameters of the terrain

The distribution of the altitude in space directly determines the flow, and the water is the main modelling agent of the slopes. Hence, the concept of morpho-hydrographic basin as a basic unit of the natural geomorphological system. Extracting as much information as possible from an altitudinal numerical model, necessary for a hydrological analysis, has been an active concern in the scientific community, and the algorithms that have been developed for this are numerous and offer different results. The methods by which hydrological parameters are extracted from a Digital Elevation Model (DEM) fall into two broad classes: those that consider flow to and from pixel centres (also called flow-routing algorithms) and those that consider free flow to any direction (also called flow-tracing algorithms). The first methods are applied in the context of the D8 approach (all 8 pixels in the 3x3 neighbourhood of the pixel for which it is applied are considered) and are included as standard in most GIS applications and the latter are more elaborate, involve more complex functions and have some restrictions of use (Cojocaru et al., 2018). A distinction is also made between one-dimensional and two-dimensional flow.

RESULTS AND DISCUSSIONS

Digital terrain analysis

This stage involves deriving some parameters of the terrain from the numerical altitude model and analysing their distribution by cartographic methods (maps, profiles, block-diagrams) and statistics (frequency histograms). These are differentiated in (Bilasco et al., 2017): primary parameters, derived directly from the altitude values of the DEM, such as slope, exposure and curvature and secondary parameters, obtained by combining one or more primary parameters and which serve to describe geomorphological processes, such as stream power index (SPI), stream power deficit on basin slopes (DEBAS), Melton Ruggedness Number, (MRN) (Teresneu, 2019).

In the present study, we adopted the method that classifies the terrain parameters according to the purpose of the analysis in (Biali et al. 2021; Niacsu, 2012):

1) morphometric parameters, which describe the morphology of the surface,
2) hydrological parameters, which describe the leakage potential of the material, and therefore the risk of erosion, and

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

3) climatic parameters, climate variables adjusted to relief (Moţoc, 2002).
This is represented the hypsometric map in Figure 4 and Figure 5 (different perspective).

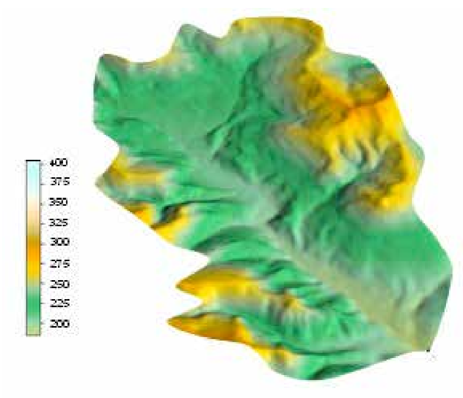


Figure 4. Representations of the Sitna basin, based on the numerical altitudinal model (DEM's) - perspective 1

The hypsometric map is performed by classifying the range of altitude values into classes that correspond to limits defined by the architect of the GIS system or limits to the development of natural processes

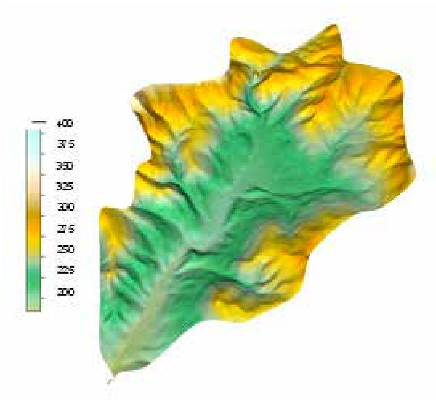


Figure 5. Representations of the hypsometric map in Sitna basin, perspective 2

Morphometric parameters of the terrain
Slope
The slope is the indicator that best estimates the action of gravity, being the means by which it controls the flow of water. It is therefore particularly important for geomorphological processes, which can accelerate or fade depending on certain threshold values of the slope. The slope also controls the hydraulic gradient, which can be decisive in the hydrogeological processes.
In ArcGIS, the slope is calculated according to an algorithm that takes into account all 8 points in a 3x3 pixel neighbourhood, around the point where the calculation is desired. This is the finite difference method (FD) (Biali et al., 2020).
Applying this algorithm with the Slope tool of ArcGIS 9.2. the map was obtained in Figure 4, in which the slope values, in sexagesimal degrees, are classified into five ranges and represented in different colours (Figure 6). An immediate application of a GIS is the possibility to generate the histogram for the respective slope classes (Biali et al., 2021).
This provides useful quantitative information in analysis.
For example, in the case of this paper, it is observed that the largest areas also have the largest slopes, over 10%, while the lowest values of the slope are concentrated in the depression areas.

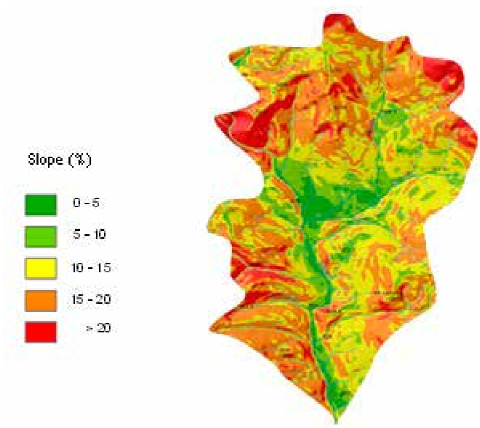


Figure 6. Map of the slopes in the studied river basin

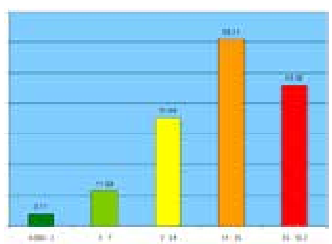


Figure 7. Histogram of the slopes in the studied river basin

In the resulting histogram (Figure 7) it can be determined that the surfaces with different slopes: slopes 15-20% predominate with 47% from area, slopes over 20% on 29% from area and slopes between 10 and 15 occupy 23% of the studied area.

Drain direction/Land exposure

Previously it was shown that the slope is elevation changing with distance. This variation is a vector because it is measured in a certain direction, namely the one in which it has the maximum value (Biali et al., 2018). The slope is the size component of the gradient vector, and the direction is expressed by the exposure of the slopes. This is the angle, in sexagesimal degrees to the north, of the slope line.

Usually, the resulting map is already classified by the algorithm that makes it, in the directions to the cardinal points: N, NE, E, SE, S, SW, W and NW (Figure 8).

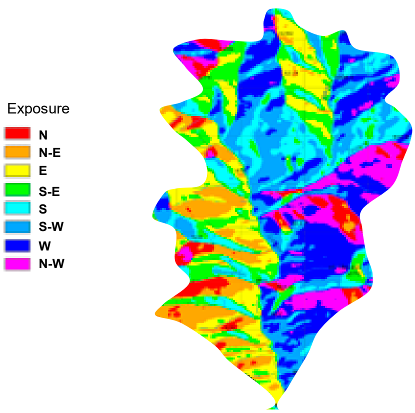


Figure 8. Slope exposure map

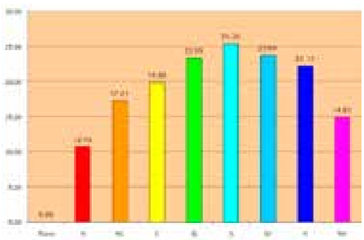


Figure 9. Histogram of slope exposure classes

In the resulting histogram (Figure 9) it can be determined that the surfaces with southern exposure predominate: S, SE and SW are predominant exposures of the slopes, which means that they are sunny slopes, with warm soils, so with agricultural potential. This fact can be important in the modelling of climatic parameters and vegetation.

Hydrological parameters of the terrain

The numerical altitude model is a rectangular matrix of altitude values. Each value is represented graphically by a pixel of a certain colour. Hydrological parameters are also represented by rectangular matrices of values, grids that overlap spatially on the altitude matrix. In other words, each pixel of altitude will correspond to the value of the calculated indicator. They are calculated based on the principle that flow always occurs from a higher altitude pixel to a lower altitude one. Basically, the problem is to determine, for each pixel separately, the number of all the other pixels that "pour" into it, which have higher altitude values and which is connected by this virtual flow of water (Figure 10).

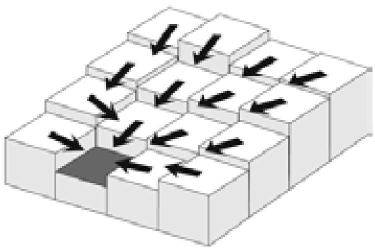


Figure 10. Drain calculation scheme
(Arc/Info Data Management, 1994)

Multiplying this number of pixels with the size of the surface of each of them (with the square of the resolution) an important hydrological indicator is obtained which has the size of a surface, but which must be associated with water flow: the surface of the basin upstream (upslope catchment area), also called the accumulation of flow (flow accumulation). If, for the respective basin, the precipitation values are known, either from concrete data, for example recorded after a rain, or entered as test values, expressed in mm, and multiplied by the surface of the basin upstream, a distribution of an indicator is obtained which has the unit of measurement of a volume of water, expressed in cubic meters.

If we consider the altitude values of the pixels that contribute to the flow towards a certain pixel are considered, two other hydrological indicators are obtained the average altitude of the basin (upslope catchment height), as an average of the altitude values of the contributing pixels and the average slope catchment slope, as the average of the slopes calculated for each contributing pixel (Figure 11). Values represent the average slope for the pixels that contribute to the flow, in degrees.

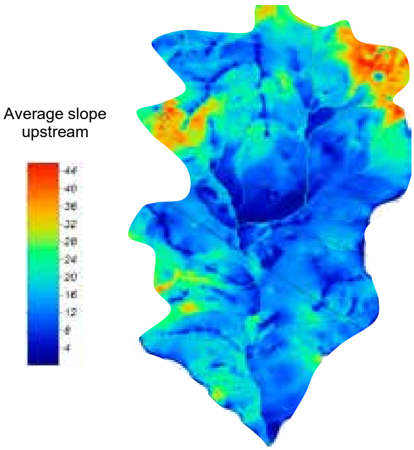


Figure 11. Average slope upstream

CONCLUSIONS

In this paper the aim was to present methods for calculating and representing the spatial distribution of some terrain indicators. The selected indicators are the most used in geo-morphometric studies, in hydrological and climatic models, and their distribution offers a broad picture of the natural potential of a region.
The spatial resolution is chosen depending on the size of the study area, the available data set. The results of the simulation and the study are directly influenced by the choice of resolution, the higher the resolution (i.e., small-sized pixels), the better and more accurate the results.
The morphometric parameters of the terrain are the slope, the exposure and the length of the slopes. These are the primary parameters that underlie the determination of all others, so their derivation is a very important operation.
The hydrological parameters are derived from the altitudinal numerical model also based on morphometric parameters: the slope and accumulation of flow (or the surface of the basin upstream), and describe the potential of the relief to influence the flow. Also, by including precipitation data and soil characteristics, they can be used to quantitatively estimate water erosion in the river basin during a rainfall (e.g., flow accumulation can provide the size of the water flow in each pixel of the model).
The GIS technique in this research made it possible to map surfaces with a risk of water erosion. This study showed that 43% of the surface of the river basin is with a very high to excessive erosion potential, 37% of the surface with a high to medium potential and 20% with minor erosion potential. If the current map of land use was to overlap with this mapping, we could determine the arable areas (or of any category of use) vulnerable to water erosion. If the soil map overlaps this mapping, we could make a connection between the accumulation of flow and the characteristics of the soils that can be subjected to water erosion.

REFERENCES

Biali Gabriela, Cojocaru Paula (2021). The influence of GIS technology in reclamation solutions for sloping land affected by erosion. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*. Vol. X, Print ISSN 2285-6064, Online ISSN 2393-5138, pp. 293-300.

Biali Gabriela, Cojocaru Paula (2020). Comparison of simulation models of water erosion using GIS. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*. Vol. IX, Print ISSN 2285-6064, pp. 161-168.

Biali Gabriela, Cojocaru Paula, Boboc V. (2018). Modeling erosion degradation on slopes using GIS. *Lucrări Ştiinţifice, Seria Horticultură*. Vol. 61, nr. 2, USAMV "Ion Ionescu de la Brad" Iaşi, ISSN–L=1454-7376 (Print)-ISSN 1454-7376 (Online)=ISSN 2069-8275, pp. 317-322.

Bilaşco Şt., Roşca Sanda, Păcurar I., Moldovan N., Vescan I., Fodorean I., Petrea D. (2018). Roads accesibility to agricultural crops using GIS technology methodological aproach. *Geographia Technica,* Vol. 13, Issue no. 2/2018, DOI: 10.21163/GT_2018.132.02, pp. 12-30.

Bilaşco Şt., Roşca Sanda, Fodorean I., Vescan I., Filip S., Petrea D. (2017). Quantitative evaluation of the risk induced by dominant geomorphological processes on different land uses, based on GIS spatial analysis models. *Journal Frontiers of Earth Science,* pp. 1-14.

Burrough P.A. (1988). Fuzzy mathematical methods for soil survey and land evaluation, *Journal of Soil Science*, 40, pp. 477-482.

Chiorescu Esmeralda, Chiorescu D., Filipov F. (2017). Hydraulic models for the infiltrations through a guard levee dyke during a high flood, *AgroLife Scientific Journal*, Volumul 6, Numărul 2, decembrie 2017, decembrie, ISSN 2285-5718, pp. 58-66.

Cochrane T.A., Flanagan D.C. (1999). Assessing water erosion in small watersheds using WEPP with GIS and digital elevation models, *Journal of Soil and Water Conservation*, 54, pp. 678-685.

Cojocaru Olesia, Chiorescu Esmeralda (2016). Erosion major problem in the efficient use of sloping lands, *Scientific Papers,Series A, Agronomy*, Vol. 59 , ISSN: 2285-5785, pp. 55-58.

Cojocaru Olesia, Cerbari V, Filipov F., Chiorescu Esmeralda, Rusu T., Bogdan Ileana, Moraru Paula, Pop A.. (2018). Statistical analysis of the sustainable agricultural lands use and fertile irreversible loss of soil which are washing from versants of rural area. *Scientific Papers. Series A. Agronomy*, Vol. LXI, No. 2, ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785, pp. 58-63.

Haidu I., Costea G. (2012). Remote Sensing and GIS for the forest structure assessment at the small basins level in the Apuseni Natural Park, *Studia Universitatis Babes-Bolyia Geographia*, 1, 98-112.

Irimuș I., Roșca Sanda, Rus Mădălina-Ioana, Marian Flavia Luana, Bilașco Șt. (2017). Landslide susceptibility assessment in Almas basin by means of the frequency rate and GIS techniques. *Geographia Technica*, 12, Issue no. 2/2017, DOI: 10.21163/GT_2017.122.09, pp. 97-109.

Moldovan Maria-Olivia, Dirja M., Gliga (Arion) Iulia-Diana, Voevod M. (2019). Making a digidal database regarding land antierosion organization works and its dissemination through the carry map extension. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*, Vol. VIII, Print ISSN 2285-6064, 142-147.

Moore I.D., Wilson J.P. (1992). Length-slope factors for the Revised Universal Soil Loss Equation-simplified method of estimation, *Journal of Soil and Water Conservation,* 47, pp. 423-428.

Moţoc M. (2002). Average erosion rate on the territory of Romania, *ASAS Newsletter*, 12, pp. 11-17.

Niacsu L. (2012), Geomorphologic and pedologic restrictive parameters for agricultural land in the Pereschiv catchment of Eastern Romania, *Carpathian Journal of Earth and Environmental Sciences*, 7, pp. 25 – 37.

Niacșu L., Ioniță I., Curea D. (2015). Optimum agricultural land use in the hilly area of Eastern Romania. Case study: Pereschiv catchment. *Carpathian Journal of Earth and Environmental Sciences,* 10 (1), pp. 195-204.

Roșca Sanda Maria, Bilaşco St., Păcurar I., Oncu M., Negruşier C., Petrea D. (2015). Land capability classification for crop and fruit product assessment using GIS technology. Case study: the Niraj River Basin (Transylvania Depression, Romania). *Journal Notulae Botanicae Horti Agrobotanici*, Cluj-Napoca, Volume 43, Issue 1, pp. 235-242.

Rusu A., Ursu A., Stoleriu C., Groza O., Niacșu L, Sfîcă L., Minea I., Stoleriu Oana Mihaela (2020). Structural changes in the Romanian economy reflected through Corine Land Cover Datasets, *Jurnal Remote Sensing*, Vol. 12, No. 8.

Teresneu C. (2021). GIS analysis of area determination methods in forestry. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*, Vol. X, Print ISSN 2285-6064, pp. 311-315.

Teresneu C., Vasilescu Maria Magdalena (2019). Analysis of the influence of orographical factors on the planimetric accuracy of points determined using GPS in forested areas. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*, Vol. VIII, Print ISSN 2285-6064, pp. 152-155.

***(1994). Arc/Info Data Management. (Concepts, data models, data base design, and storage) ESRI, Redland, California

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

PILOT MONITORING SERVICE FOR CULTURAL HERITAGE BASED ON SATELLITE DATA AND PRODUCTS

Iulia DANA NEGULA[1, 2], Cristian MOISE[1], Andi Mihai LAZĂR[2, 3], Cristina Elena MIHALACHE[1], Florina DEDIU[2], Alexandru BADEA[2]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, Faculty of Land Reclamation and Environmental Engineering, 59 Marasti Blvd, District 1, Bucharest, Romania
[2]Romanian Space Agency, 21-25 Mendeleev Street, District 1, Bucharest, Romania
[3]University of Bucharest, Faculty of Geography, Nicolae Bălcescu Blvd., District 1, Bucharest, Romania

Corresponding author email: iulia.dana@fifim.ro

Abstract

The potential of Earth Observation (EO) data for cultural heritage documentation and systematic monitoring is currently widely recognized. Considering the large spectrum of threats and the high importance of safeguarding, cultural heritage requires sustained monitoring that can efficiently be done based on a combination of satellite images having adequate spatial, spectral and temporal resolution, in-situ data and a broad-spectrum of ancillary data such as historical maps, digital elevation models and local knowledge. The present study showcases the features of a pilot cultural heritage monitoring service that was developed for several Romanian representative sites such as the Castle of Hunedoara, the Palace of Magna Curia, the Medieval Ensemble of Deva Fortress, the Alba Carolina Citadel, the archaeological sites of Micia and Germisara, etc., but can be upscaled at national or regional level. The monitoring service is composed of a Results Platform (based on open-source GeoServer and OpenLayers) and a near-real time Monitoring Platform (cloud computing through Google Earth Engine). The products that are ingested in the first platform are obtained using an approach tailored for each property type. Examples include old cartographic maps, historical satellite images, remote sensing radiometric indices, Copernicus products, displacement maps and many others. The products that are continuously generated within the second platform enable the early identification and assessment of natural and anthropogenic risks, thus representing a key element for cultural heritage protection. The pilot monitoring service was developed considering the requirements of the cultural heritage authorities that are administrating the above-mentioned sites, representing a reliable source of unparalleled knowledge regarding the potential threats and degradation risks.

***Key words**: Earth Observation, cultural heritage, pilot monitoring service, GeoServer, Google Earth Engine.*

INTRODUCTION

The importance of Earth Observation (EO) data for the different stages of the Cultural Heritage (CH) management process (e.g., inventory and documentation, condition assessment and monitoring, protection and promotion, etc.) is worldwide recognized.
Numerous studies demonstrated the benefits of using EO data for CH. It is a modern and non-destructive approach that enables efficient monitoring and mapping at multiple scales by using different spatial and spectral resolutions. The variety of the existing satellite sensors offers the possibility to combine different techniques in order to generate products tailored to the specific needs of each CH property. In addition, the free and open satellite data contribute to an accurate and rapid condition assessment and monitoring of CH. The capabilities of EO-based products for CH were demonstrated by various studies that included identification of architectural buried remains (Agapiou et al., 2012), the analysis and mapping of land use changes in cultural and archaeological landscapes (Tang et al., 2022), and the evaluation of the impact of climate change by measuring the air pollution, which constantly threatens the CH (Themistocleous et al., 2010). Furthermore, the current approaches allow a manifold CH monitoring by integrating radar and optical satellite data as well as additional data and technologies such as light detection and ranging (LiDAR) and data acquired by unmanned aerial vehicles (UAVs) and ground sensors that record essential

parameters. Nowadays, the information offered by the EO programs is increasingly used in various projects dedicated to the management of CH. A relevant example is the HERIPORT project, a digital heritage portal dedicated to preserving South African heritage, by using a collection of metadata from diverse heritage archives (https://heriport.cs.uct.ac.za). Another example is ARCH – Saving cultural heritage (https://savingculturalheritage.eu/). ARCH is an ongoing project dedicated to CH disaster risk management, by using an integrated approach that includes satellite, aerial and ground data. Other significant CH projects focused on the use of EO are: "SpaceToPlace - EO to Empower UNESCO Site Managers" (https://copernicus-masters.com/winner/spacetoplace-eo-empower-unesco-site-managers/) whose main objective is to train the United Nations Educational, Scientific and Cultural Organization (UNESCO) site managers to incorporate Copernicus Sentinel data for monitoring activities and HERACLES (http://www.heracles-project.eu/), a research project dedicated to resilience of CH against climate change effects.

The RO-CHER project is a multidisciplinary project for the monitoring, conservation, protection and promotion of Romanian cultural heritage (http://ro-cher.rosa.ro/). The project was composed of 4 complementary component projects, namely: Monitoring of cultural heritage based on space technologies, Nanotechnology - an innovative approach of developing materials and methods for cultural heritage safeguarding, Integrated cultural heritage management (conservation, restoration and protection) and Cultural heritage promotion based on modern digital reconstruction technologies. Several CH test sites were selected for the project, including: Sarmizegetusa Regia, Ulpia Traiana Augusta Dacica Sarmizegetusa, the Medieval Fortress of Deva, the Magna Curia Palace, the Corvin Castle, the Roman Fort of Cigmau, the Micia Roman Fort and the Alba Carolina Citadel. All of the above-mentioned sites are representative both at national and international level (for example, Sarmizegetusa Regia is part of the UNESCO World Heritage). The selected test sites are located in Transylvania, a historically significant region containing a large variety of CH properties. The project's main goal was represented by integrated research dedicated to the study of the mobile and immobile cultural and historical heritage using new space technologies and classical in situ and ex situ analysis methods. One of RO-CHER's specific objectives focused on the development of a pilot CH monitoring service based on satellite data and products.

MATERIALS AND METHODS

The Monitoring Service is based on open-source geospatial technologies and has two main components. With the goal of creating a sustainable flow of information to be provided by the service also after the completion of the RO-CHER project, the emphasis was put on the use of open access satellite data. Specifically, the project benefited by the free and open satellite data provided within the Copernicus Programme which is managed by the European Commission (https://www.copernicus.eu/).

Within the RO-CHER project, products derived from the data acquired by the Sentinel-1A/B satellites operating in the microwave portion of the electromagnetic spectrum were derived and integrated in the monitoring service. These satellites have a revisit period of 6 days at the equator. Using long series of synthetic aperture radar (SAR) images and specific acquisition and processing techniques (i.e., Persistent Scatterers Interferometry), the displacement along the line-of-sight (LOS) can be accurately derived.

Besides SAR data, satellite data in the visible, near-infrared, and short-wave infrared spectrum acquired by Sentinel-2A/B satellites was used. These satellites allow the monitoring of the areas of interest at a frequency of 5 days at the equator and 2-3 days at the latitude of Romania.

To the previously mentioned archive of multispectral satellite data, images acquired by the satellites of the Landsat Programme that has been operating since 1972, were added. Although having a lower spatial resolution of only 30 m compared to 10 m in the case of Sentinel-2 imagery, Landsat data offer unique and valuable information for the last 5 decades.

The Monitoring Service incorporates a Results Platform and a Monitoring Platform. The first platform is implemented on local infrastructure within the Romanian Space Agency (ROSA) and the second one is based on a cloud computing service. The first step towards the implementation of the Monitoring Service was to download and process satellite data. Sentinel-1 and Sentinel-2 data was downloaded from the Copernicus data distribution service by accessing the Open Access Hub available at the web address: https://scihub.copernicus.eu. Landsat images were downloaded from the Earth Explorer service provided by the United States Geological Survey (USGS) accessible at: https://earthexplorer.usgs.gov/.

The interferometric processing of Sentinel-1 data was performed using the ENVI software with the dedicated SARscape extension. The resulting data consisted of a vector dataset representing persistent scatterers which have as attributes the value of the vertical displacements (in mm/year) of the target points. The vertical displacements were computed in a subsequent phase based on the LOS displacements.

Landsat and Sentinel-2 multispectral imagery was processed using the SNAP (Sentinel Application Platform) open-source geospatial software. The processing resulted in a series of satellite products such as vegetation indices and false colour images for the test areas studied within the RO-CHER project. Some of these satellite products were used to extract thematic vector layers that show the progress of various aspects such as the urban evolution of the Alba Iulia city or the evolution of the Mureș riverbed.

The goal was to create an application that is easily accessible by the general public. For this purpose, a WebGIS application that offers the possibility to be accessed with any web browser was developed.

The Results Platform was created based on FOSS (Free and Open-Source Software) technologies that allow the easy management of geospatial data and their delivery to third parties, via the Internet. The development of such an application required a series of steps as illustrated in Figure 1. GeoServer is developed under open-source licence, enabling the users to share large geospatial datasets via standard protocols such as Web Map Service (WMS), Web Feature Service (WFS) and others, developed by the Open Geospatial Consortium (OGC). This software was used for the sharing of raster geospatial products developed within the RO-CHER project.

Displaying the data as a map required the use of the OpenLayers library, which allows the creation of interactive web maps. The web map was connected to the data stored in the GeoServer via WMS protocol.

Other vector layers were directly introduced in the web map by saving them as GeoJSON and directly linking them to the source code. An intermediate step was to connect the web application to the available WMS service at http://www.geo-spatial.org/geoserver/. Through this service, a collection of historical maps could be accessed and introduced as base maps in the Results Platform.

The advantage of the open-source technologies mentioned above offers administrators the opportunity to interact with the source code, allowing a wide customization of the final product.

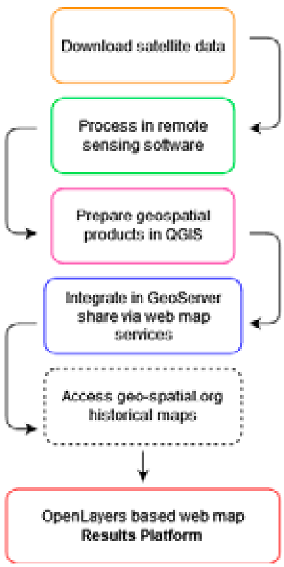


Figure 1. Implementation layout of The Results Platform

The second component of the Pilot Monitoring Service is designed for the continuous monitoring of the cultural heritage objectives through the use of satellite imagery. The Monitoring Platform allows users to access all images acquired by Sentinel-2 satellites over the areas of interest, starting from the beginning of the mission (i.e., 2015) until the current date. Users can observe the Earth's surface through both natural and false colour images, but also through spectral indices. The implementation of such a platform required a series of steps as shown in Figure 2. In order to provide this service, the technical solution relied on the Google Earth Engine cloud computing platform. This platform provides users with both a global archive of satellite and geospatial data, as well as the necessary geoprocessing tools. Accessing algorithms and data is done through JavaScript. The configuration of an application that addresses the specific needs of CH monitoring was performed through the Code Editor interface.

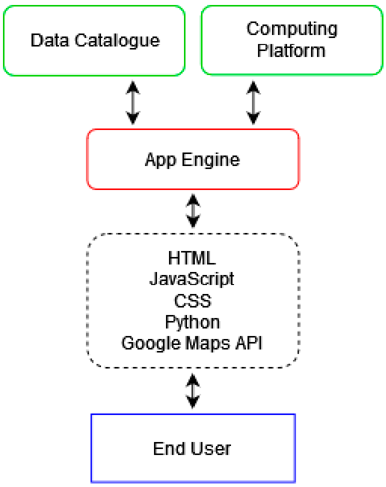


Figure 2. Functioning layout of The Monitoring Platform

RESULTS AND DISCUSSIONS

Each CH site included in the project presents different challenges for conservation, therefore multiple types of monitoring methods were applied resulting in a series of geospatial data which were stored and distributed to the general public through the Pilot Monitoring Service.
As mentioned before, the Results Platform was created using open-source solutions and is used for storing and viewing all the geospatial products obtained from the analysis carried out in the project on the 8 CH sites (Figure 3). The menu is structured according to the cultural objectives monitored within the project, each of these objectives having assigned a series of results that can be selected for display.
The platform stores vector and raster datasets, implemented in the form of thematic layers. Some examples are: satellite images, plans and maps, vegetation indices, evolutions of urban surfaces or riverbeds.

Figure 3. The Results Platform (base map: © OpenStreetMap contributors)

The vector datasets include: the administrative boundaries of the objectives (the approximate limits of the 8 analysed objectives), the Mureș riverbed evolution, vertical displacements (using Persistent Scatterers Interferometry - PSInSAR) for Corvin Castle, ancient constructions, and Alba-Iulia city surface area evolution. Specifically, the vector dataset contains the following products:

- The boundaries of the objectives which is a polygon vector layer representing the approximate limits of the CH properties, each polygon containing information about the name and the description of the CH;
- The Mureș riverbed evolution (Figure 4) is a polygon vector layer representing the Mureș riverbed in 3 different moments of time: year 1926, year 1968 and year 2018;
- The displacement map for Corvin Castle was obtained using the PSInSAR method and it is containing displacement velocities measured in mm/year. It is a point-type vector layer representing the vertical displacements of ground and / or buildings; the map was generated based on series of Sentinel-1A/B data acquired from ascending and descending orbits.
- Ancient constructions which are line and polygon vector layers containing information about 3 of the cultural heritage sites studied in the RO-CHER project, namely: Micia, Sarmizegetusa Regia and

Sarmizegetusa Ulpia Traiana. These layers represent the outline of ancient buildings and each polygon holds information about the respective building;
- Alba-Iulia's urban growth evolution (Figure 5) is a polygon vector layer that represents the limits of the city of Alba Iulia in 4 different moments of time (year 1926, year 1967, year 1988 and year 2018).

Figure 4. Mureș riverbed evolution (year 1926 is selected) (base map: © OpenStreetMap contributors)

Figure 5. Alba Iulia urban evolution (year 1926 is selected) (base map: © OpenStreetMap contributors)

The raster dataset includes general raster products, specific raster products and historic maps. The general raster products were generated for all 8 cultural heritage sites, such as Corine Land Cover (CLC) maps, CORONA and Landsat 5, 7 and 8 images and high-resolution images. In detail, the raster dataset contains the following products:
- Corine Land Cover or CLC, a raster file provided by the Copernicus program. It is a 1:100.000 scale map and it represents homogeneous landscape models and land cover classes that were extracted from satellite data. The RO-CHER project made use of CLC data for the years 1990, 2000, 2006, 2012 and 2018 for all 8 cultural heritage objectives;
- CORONA images are high-resolution images obtained between 1960 and 1972, during the United States of America (USA) espionage programme. These images have a high spatial resolution and are particularly useful for observing changes in built-up areas, street plots and the state of CH. The images for Micia, Germisara, Sarmizegetusa Ulpia Traiana, Corvin Castle and Sarmizegetusa Regia were acquired in 1968 and the image for Alba Iulia on June 5, 1967 (Figure 6);
- Landsat 5, 7 and 8, and Sentinel-2 images are displayed as natural colour images (representations of reality as perceived by the human eye). The images used within the project are acquired at different times, as follows: Landsat 5 images for years 1984 and 1995, Landsat 7 images for 2003 and Landsat 8 images for 2019, so that observations about changes over time can be made accordingly. All Landsat images have a spatial resolution of 30 m;
- High resolution images are represented by images acquired by the Planet satellites within the Planet satellite programme and which have a spatial resolution of 3 m. The Planet images used within the project were acquired for the year 2020.

Figure 6. CORONA image of the Alba Iulia city, June 5th, 1967 (© US Geological Survey)

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Beside these general raster datasets, a series of specific raster products were derived from satellite images, but only for some of the 8 CH sites analysed in the project. These are: land cover products, urban heat island products, false-colour imagery, Normalised Difference Water Index (NDWI), CH plans, runoff maps, Simple Ratio Vegetation Index (SR), Normalised Difference Vegetation Index (NDVI) (Figure 7) and an orthophoto image. As shown in Figure 7, the values of the NDVI allow the evaluation of the health state of the forest that overlaps with the limits of the Sarmizegetusa Regia archaeological site. Using a multitemporal series, the unhealthy trees which could endanger the integrity of the archaeological remains could be identified.

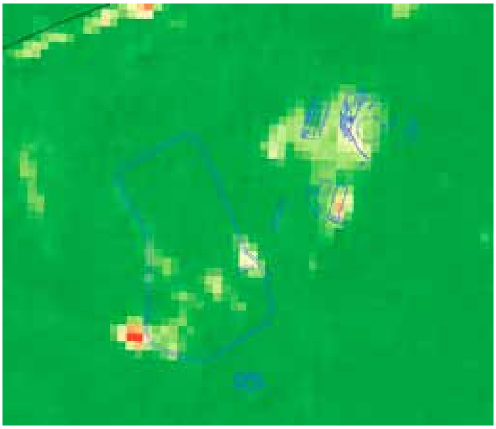


Figure 7. NDVI for Sarmizegetusa Regia objective - in blue: footprints of ancient structures (© Contains Modified Copernicus Sentinel data, 2021)

In addition to these two types of raster datasets (i.e., general and specific), two more products / maps can be viewed and analysed at national level within the Results Platform, namely: Romanian Lambert-Cholesky Map (Figure 8) and the 3rd Military Mapping Survey of Austria-Hungary (Figure 9). The Romanian Lambert-Cholesky Map (in Romanian language, the so-called *"Planurile Directoare de Tragere"*) are Romanian military maps at a scale of 1:20.000, in Lambert-Cholesky projection, developed between 1916 and 1959 (Crăciunescu, 2010), thus useful for viewing the monuments and landmarks as existing in the first half of the 20th century. The technical details of the cartographic projection are lost, hence there may be small differences between the Romanian Lambert-Cholesky Map and the other products of the platform. The 3rd Military Mapping Survey of Austria-Hungary (Figure 9) are topographic maps, at a scale of 1:200.000, made during the third topographic survey of the Habsburg Empire military, starting in 1869 (Crăciunescu, 2006). Like the Romanian Lambert-Cholesky Map, this set of maps is useful for viewing sights and performing comparisons with newer maps.

Figure 8. Romanian Lambert-Cholesky Map showing the city of Alba Iulia (source:geo-spatial.org)

Figure 9. The 3rd Military Mapping Survey of Austria-Hungary showing the city of Alba Iulia (source:geo-spatial.org)

As previously mentioned, the Monitoring Platform (Figures 10 and 11) is a web application built using Earth Engine Apps. The scope of this platform is to allow near-real-time monitoring of the CH objectives that were studied within the RO-CHER project.

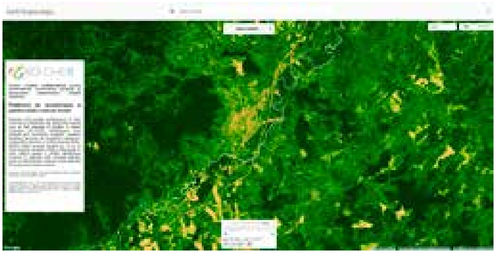


Figure 10. The Monitoring Platform - NDVI (© Contains Modified Copernicus Sentinel data, 2021)

Figure 11. The Monitoring Platform - NDWI (© Contains Modified Copernicus Sentinel data, 2021)

The monitoring is performed based on Sentinel-2 satellite imagery, using various spectral compositions and indices (NDVI, NDWI). This application can be extended to include other CH sites considering that the satellite images systematically provided by the Copernicus Programme are free, open and at a global scale.

Other results

During the final stage of the project, several online training sessions were organised. The training sessions were dedicated to the end users and partners of the project representing local authorities responsible for CH management. The goal of the training sessions was to explain how to access remote sensing data and products, and how to use these products for CH monitoring. The sessions strengthened the capacity of end users to learn about the state-of-the art remote sensing products and the software used to visualise these products. Users were trained to correctly interpret the geospatial products available on the platform. Subsequently, based on the feedback received during the sessions, the two platforms of the pilot monitoring service were updated in order to meet the end user needs and expectations.

CONCLUSIONS

The easily accessible pilot monitoring service developed in the framework of the RO-CHER project enabled the integration of a very wide range of geospatial products in a standardised and organised manner as well as the systematic monitoring of CH objectives even after the project's completion. This valuable tool is appreciated by archaeologists and the wider community of CH specialists as well as by the general public, considering that it is offering a broad perspective, over a long period of time on the evolution of the studied CH objectives. The service can be also used both for educational or research purposes and as a mean for promoting CH and its environment.

The use of open-source data and mostly open-source software guarantees sustainability by eliminating excessive costs that can accumulate over long periods of operation. Another aspect regarding the sustainability of the service was the integration within the Monitoring Platform of satellite data from missions that are planned to be extended for an indefinite period of time.

EO definitely offers sustainable means for the CH documentation, monitoring, planning of risk mitigation and preservation measures, and promotion. Especially in the current context in which CH is globally endangered by different threats (e.g., climate change, uncontrolled urban development, land conversion, severe weather events, sudden ecological and geological events, etc.), the continuous and many-sided monitoring is essential.

Another important aspect is the interdisciplinary character required for a robust approach in support of an efficient CH management. In the last years, the gap between the CH specialists and the EO community is steadily reducing due to the successful studies that demonstrated the unique potential of EO satellite imagery for producing useful and timely information for CH.

Some of the activities conducted in the frame of the RO-CHER project are continued within the "Artificial Intelligence & Earth Observation based services for cultural heritage monitoring (AIRFARE)" project that is funded through the "Transfer to the economic operator" programme. AIRFARE aims to advance the technology readiness level (TRL) of the solutions developed within RO-CHER.

ACKNOWLEDGEMENTS

This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI – UEFISCDI, project number PN–III–P1–1.2–PCCDI–2017–0413/contract number 50PCCDI/2018, within PNCDI III. This work was also partially supported by a grant of the Romanian Ministry of Education and Research, CCCDI - UEFISCDI, project number PN-III-P2-2.1-PTE-2019-0579, within PNCDI III.

REFERENCES

Agapiou, A.; Hadjimitsis, D.G.; Georgopoulos, A.; Sarris, A.; Alexakis, D.D. (2012). Towards an archaeological index: Identification of the spectral regions of stress vegetation due to buried archaeological remains, in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 7616, 129-138.

Crăciunescu, V. (2006). Hărțile austriece (1910) reproiectate în Stereo70. Retrieved from http://geo-spatial.org/vechi/download/harile-austriece-1910-reproiectate-in-stereo70 (accessed April 2022).

Crăciunescu, V. (2010). eHarta: Planurile Directoare de Tragere. Retrieved from http://geo-spatial.org/vechi/articole/eHarta-work-planurile-de-tragere (accessed April 2022).

Perdikou, S. (2010). Monitoring Air Pollution in the Vicinity of Cultural Heritage Sites in Cyprus Using Remote Sensing Techniques. *EuroMed*.

Tang, Y.; Chen, F.; Yang, W.; Ding, Y.; Wan, H.; Sun, Z.; Jing, L. (2022). Elaborate Monitoring of Land-Cover Changes in Cultural Landscapes at Heritage Sites Using Very High-Resolution Remote-Sensing Images. *Sustainability*, *14*, 1319.

Themistocleous, K.; Nisantzi, A.; Hadjimitsis, D.G.; Retalis, A.; Paronis, D.; Michaelides, S.C.; Chrysoulakis, N.; Agapiou, A.; Giorgousis, G.;

ARCH PROJECT. SAVING CULTURAL HERITAGE, retrieved from https://savingculturalheritage.eu/ (accessed April 2022).

COPERNICUS – Europe's Eyes on Earth, retrieved from https://www.copernicus.eu/ (accessed April 2022).

HERACLES PROJECT. Retrieved from www.heracles-project.eu/project/project-objectives (accessed April 2022).

HERIPORT PROJECT. HERIPORT WEB PORTAL, retrieved from https://heriport.cs.uct.ac.za (accessed April 2022).

RO-CHER PROJECT. Multidisciplinary complex project for the monitoring, conservation, protection and promotion of the Romanian cultural heritage, retrieved from http://ro-cher.rosa.ro/ (accessed April 2022).

SPACETOPLACE PROJECT. EO TO EMPOWER UNESCO SITE MANAGERS, retrieved from https://copernicus-masters.com/winner/spacetoplace-eo-empower-unesco-site-managers/ (accessed April 2022).

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ADVANTAGES OF USING GNSS TECHNOLOGY AND QGIS SOFTWARE IN INVENTORY STANDS EXPLOITERS

Adrian PICA[1], Florin BOJA[2], Ciprian FORA[3], Mihaela MOATAR[3], Nicusor BOJA[2,3]

[1]Transilvania University of Brasov, 1 Sirul Beethoven Street, Brasov, Romania
[2]"Vasile Goldiş" Western University of Arad, 91-93 Liviu Rebreanu Street, Arad, Romania
[3]Banat University of Agricultural Sciences and Veterinary Medicine "King Mihai I of Romania" from Timisoara, 119 Calea Aradului, Timisoara, Romania

Corresponding author email: bojanicu@yahoo.com

Abstract

The inventory of the production fund aims to determine its size, structure and growth, starting with the determination of the dendrometric characteristics of each component tree. This inventory is done both for the purpose of regulating the production and protection process and for controlling the production fund and its evolution. The inventory methodology is based on the application of the methods of mathematical statistics and especially on the application of selective methods, as well as by scientifically based dendrometric estimations. In the case of these inventories, will be determined: the average diameter, the average height, the specific composition, the number of trees per hectare (density), the density index, the current growth by species, classes of diameters and quality classes, the volume of the trees. The trees that have reached the age of exploitability must be inventoried to determine the volume. Stands with a consistency of more than 0.4 and a surface area greater than 4.0 ha will be inventoried by the 12.62 m radius of circle and a 500 m^2 area, uniformly located in the entire layout, and those with consistencies of less than 0.4 will be fully compiled by the forest district, as they will enter the first-ever decennial plan. The only condition is the existence of a digital layout map, which can be obtained from the parcel and parcel construction work with the redevelopment works in the Stereographic 70 projection, where the position of each circle can easily be materialized with Qgis software.

***Key words**: QGIS software, forests maps, topographic details, inventory stands.*

INTRODUCTION

Over the last decades, Geographic Information Systems (GIS) have proved to be a very useful and effective tool for the knowledge, description and analysis of the environment. In particular, studies performed since the 1990s have shown how the powerful capabilities of GIS in terms of data management and processing, spatial analysis and mapping could be successfully applied to environment analysis (Tebano et al., 2017).

In latest years, free and open source GIS software have been largely developed and applied with the aim to offer the users the possibility to customize functions and tools and sharing solutions with the scientific community. This approach allows a continuous improvement and updating of GIS platforms thanks to the contribution of different scientists and users. In particular, applications to watersheds and stream networks analysis are reported. Among them, (Dorillo, 2010; (Jasiewicz and Metz, 2011) proposed processing toolsets, based on raster analysis of Digital Elevation Models (DEMs), running under GRASSGIS (Neteler et al., 2012): the first estimates main geomorphic parameters, while the latter focuses on the extraction and analysis of stream network according to different criteria. Abera et al., 2014 presented a specialized toolset for topographic, hydrologic and geomorphic analysis running under the using application framework. A discussion on the application of open-source GIS to Earth and environmental sciences, including watershed analysis, can be found in (Noti, 2014).

QGIS is an open source Geographic Information System, released under the GNU general public license (QGIS 2016). Initially conceived as a simple GIS-GNSS RTK data viewer, QGIS experienced a very rapid growth over the last years, and its built-in functions, plugins and processing tools are nowadays widely used in many fields. Besides native algorithms, third-party processing tools and functionalities as GRASS (Neteler et al., 2012) and SAGA (Conrad et al., 2015) tools are also

integrated in QGIS current releases (Tebano et al., 2017).
It is a cross-platform, thus it works on different Operating Systems (OS) like Windows, Mac, Linux as well as Android. It provides noteworthy data viewing, editing and analysis capabilities. It facilitates users to create maps with multiple layers using different map projections. QGIS allows maps to be composed of raster and vector layers. The raster layer consists mainly of images (Google Hybrid), while the vector data is composed of points, lines and polygon features (*limite ua, limite parcela, borne, drum forestier, drum public*), as illustrated in Figure 4.
Satellite data or images consist of those images of Earth or other planets that are collected by the satellite. Satellite images are widely used in the field of cartography, geology, metrology, agriculture, electric power system, fishing, biodiversity, forestry and many others. QGIS can be used to create a composite image of the entire planet or of a desired region on the surface of the planet. This scheme aims to provide free and high quality satellite images to researchers and students for non-commercial usage (Khanet al., 2015).
Topographic details represent certain "natural" details on the terrestrial surface (e.g., oceans, rivers, continents, etc.) or certain "man-made" details (e.g., roads, constructions, parcels, compartments, etc.) (Boja et al., 2016).
Attributes describe the details in a GIS, for example the attributes of the forest fund can be all the information found in the parcel description sheet. A GIS-GNSS RTK is a computerized system used to accomplish various functions based on geographical information. The components of the system are: Software for making maps; The database that stores and links the field details and attributes; Tools for the analysis, editing and manipulation of geographic data.
The forests of the country, like other real estate, need to be studied in terms of geographic location, their analysis and representation accurately on plans and maps must be a topical concern both for the private and public entities.
The actual planning of the forest areas was done expeditiously, but the methods of planning involved some well-established topo-cadastral techniques. The use of terminals, toponyms, boundary boundaries of plots and sub-plots by painting trees and using a uniform system of conventional signs is the basis of a well-organized arrangement (Boja et al., 2013; 2016; 2018; 2020; 2021).

MATERIALS AND METHODS

GPS-GNSS RTK determinations have produced major changes in geodesy, topography and cartography. GPS-GNSS RTK (Global Positioning System) is a technology that uses a complex of satellites to help determine the location of any point on the Earth's surface in a single reference system with the help of specific devices.
For real-time centimeter accuracy of point coordinates, GPS-GNSS RTK is need to receive corrections from ground-based stations, this is possible either by UHF radio from one base (this requires 2 bases and rover devices), or they use GSM modems to connect to the Internet to receive RTK corrections from permanent fixed stations existing in Many countries (ROMPOS for Romania). GSM modules work with GSM internet cards from local mobile operators.
The condition of the GPS-RTK measurements is that the controller software has implemented the WGS 84 coordinate system transcaling algorithm in the national coordinate system of each country (in the case of Romania - Transdat - for the transition and the Stereographic Projection 1970 as a national system).
Another condition is that in the area where the measurement is carried out is a GSM data signal strong enough to make the Internet connection, otherwise, for the RTK measurements, at least two devices are needed (base and rover) and the possibility of establishing the UHF radio connection among them. A satellite navigation system with global coverage may be termed a global navigation satellite system (GNSS). As of September 2020, the United States' Global Positioning System (GPS), Russia's Global Navigation Satellite System (GLONASS), China's BeiDou Navigation Satellite System, and the European Union's Galileo are fully operational GNSSs. Japan's Quasi-Zenith Satellite System (QZSS) is a (US) GPS-GNSS RTK satellite-based augmentation system to enhance the accuracy

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

of GPS-GNSS RTK, with satellite navigation independent of GPS-GNSS RTK scheduled for 2023. The Indian Regional Navigation Satellite System (IRNSS) plans to expand to a global version in the long term.

The S8 GNSS Stonex® (Figure 1) receiver is a high-precision equipment typically used to determine the outline of the property, using equipment that can be used with higher efficiency indoors. S8 is able to receive both GPS signal frequency and satellite signals. The S8 general unit includes the GNSS antenna, the GNSS module, the UHF radio, the receiving radio antenna, the GSM/GPRS modem, the Bluetooth device and the battery. S8 is fully integrated, which makes the topographer just start the device for measurements.

The forest fund covered by the present study belongs to Forest District Codrii Cămării, Management Unit I Dobrești.

For exploitable stands that have a consistency of more than 0.4 and have an area of more than 4 hectares, their inventory is made in circles of 500 m^2 with a radius of 12.62 m.

Figure 1. S8 GNSS Stonex Receiver ®10

The number of circles and the distance between them are established with the help of Technical Norms V for Forest Management Planning (Table 1).

Table 1. Determining the number of circles and the distance between them (Technical Norms V for Forest Management Planning), Tolerance 10%, Coverage probability 90%, The size of the test site 500 m^2

Surface, ha	n	Coefficients of variation																			
	d	15	20	21	25	28	**30**	35	36	40	**41**	43	45	49	50	54	55	56	60	65	70
4	n	6	10	11	14	17	**19**	23	24	28	**29**	30	32	36	37	39	40	41	44	47	50
	d	84	65	63	54	49	**46**	41	40	38	**37**	36	35	33	33	31	31	31	30	29	28
5	n	6	10	11	14	18	**20**	25	26	30	**31**	33	35	39	40	44	45	46	49	53	57
	d	93	72	69	59	54	**51**	45	44	41	**40**	39	38	36	35	33	33	33	32	31	30
6	n	6	10	11	15	18	**20**	26	27	32	**33**	36	38	42	43	48	49	50	54	49	63
	d	102	78	75	64	58	**54**	48	47	43	**42**	41	40	38	37	35	35	35	33	32	32
7	n	6	10	11	15	19	**21**	27	28	33	**34**	37	39	45	46	51	52	53	57	63	68
	d	110	84	81	68	62	**58**	51	50	46	**45**	44	42	40	39	37	37	37	35	33	32
8	n	6	10	11	15	19	**21**	27	28	34	**35**	38	41	47	48	53	54	55	61	67	72
	d	117	89	86	72	66	**62**	54	53	48	**47**	46	44	42	41	39	38	38	36	35	33
9	n	6	10	11	15	19	**21**	28	29	35	**36**	39	42	48	49	55	56	57	63	70	76
	d	124	94	90	76	69	**65**	57	56	51	**50**	48	46	44	43	41	40	40	38	36	34
10	n	6	10	11	16	20	**22**	28	30	36	**37**	40	43	49	51	57	58	59	65	73	80
	d	130	99	95	80	73	**68**	59	58	53	**52**	50	48	45	44	42	42	41	39	37	35
15	n	6	10	11	16	20	**23**	30	32	38	**40**	43	46	53	55	62	64	66	73	83	92
	d	159	120	115	97	88	**82**	71	69	63	**62**	59	57	53	52	49	48	47	45	43	40
20	n	6	11	12	16	20	**23**	31	33	39	**41**	44	48	56	58	66	68	70	78	89	99
	d	183	138	133	111	100	**93**	81	79	72	**70**	67	64	60	59	55	54	53	51	47	45
25	n	6	11	12	16	20	**23**	31	33	40	**42**	45	49	58	60	68	70	72	81	93	105
	d	204	154	148	124	112	**104**	90	88	79	**77**	74	71	66	65	61	60	59	55	52	49
30	n	6	11	12	16	20	**23**	31	33	40	**42**	46	50	59	61	70	72	74	84	96	108
	d	223	168	161	135	122	**113**	98	96	86	**84**	81	77	71	70	66	65	64	60	56	53
35	n	6	11	12	16	21	**24**	32	34	41	**43**	47	51	60	62	71	73	75	85	98	111
	d	241	181	174	146	132	**122**	105	103	93	**91**	87	83	77	75	70	69	68	64	60	56
40	n	6	11	12	17	21	**24**	32	34	41	**43**	47	51	60	62	72	74	77	87	100	114
	d	257	194	186	155	140	**130**	112	109	99	**97**	92	88	82	80	74	73	72	68	63	59
50	n	6	11	12	17	21	**24**	32	34	41	**43**	48	52	61	63	73	76	79	89	102	117
	d	288	216	207	173	156	**145**	125	122	110	**108**	103	98	91	89	83	81	80	75	70	65

Crown density of the stand	Stand structure					
	Even-aged			Uneven-aged		
	Homogeneity class					
	I	**II**	III	I	**II**	III
>=0,8	21	**30**	41	25	**36**	49
0,5-0,7	28	**41**	54	30	**43**	56

By GPS-GNSS RTK measurements, the coordinates of the points used later were calculated as routing heads and orientations, the location of these points being chosen so that the measurements are possible. Precision topographic elevation in forest sector required for the cadastre can not only be done with GPS-GNSS RTK technology because this type of measurement can only take place in uncovered terrain or where the free horizon can be reached up to 15º without obstacles.
Also, the measurement area must have GSM coverage to receive ROMPOS corrections through data transfer. In the case of the study, it was necessary to use the rover base system. The base was installed in a GSM signal area, and the transmission between the base and the rover was possible by using an external radio.

RESULTS AND DISCUSSIONS

The operation of circulating in the field is quite expensive, thanks to the GPS-GNSS RTK technique and the QGIS software, this operation can be done very easily and with very high precision.
In order to begin this operation, we need to have a digital map, and for example we have chosen the Forest District Codrii Cămării, Management Unit I Dobrești (Figure 2).

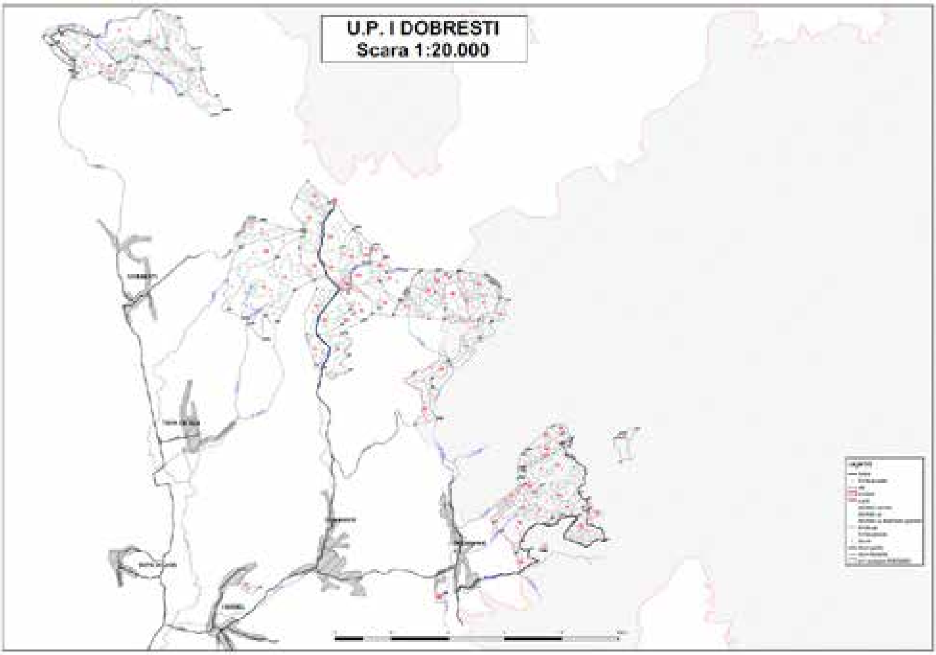


Figure 2. Forest District Codrii Cămării, Management Unit I Dobrești

In this management unit, the exploitable stands to be enumerated through the circles are: 10B, 14B, 15A, 19A, 34A, 40A and 41A. For example, we have chosen the forest compartments 41A, Figure 3.
To be able to materialize the position of each circle on the surface of the QGIS layout, it is necessary to install the Feature Grid Creator plug-in from the Plugins - Manage and Install Plugins menu.

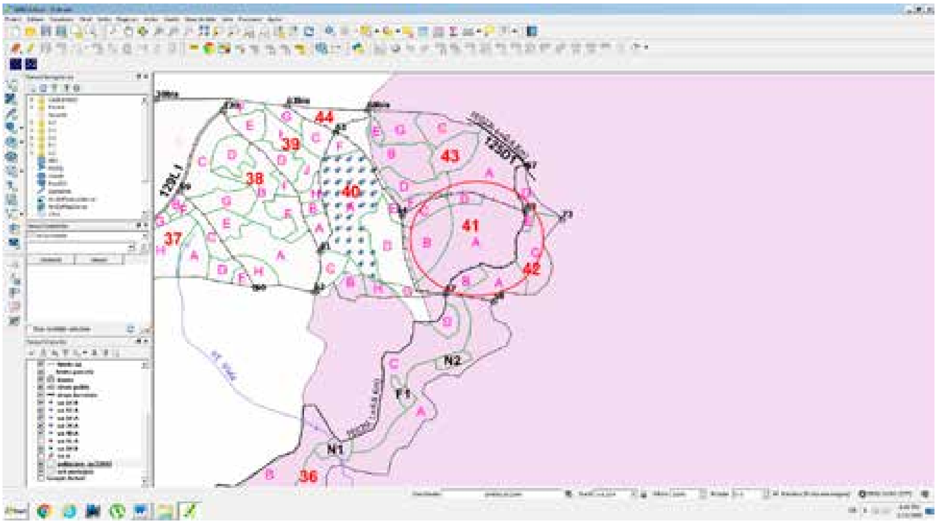


Figure 3. Forest compartments 41 A

The next step is to select the polygon layer that contains the forest compartment, select compartment in which the circles are to be created, and click the button created by the Feature Grid Creator plugging in to insert the distance between the circles (the same on x and y) according to the technical norms. In the case of the forest compartment 41 A the distance between the circles is **55** m and the number of circles is **37**, according to Figures 4-9.

The program creates a temporary layer called "holes" that contains the inventory circles but will be lost after closing QGIS so it must be saved with the username of forest compartment but it must be saved as a vector layer to which the forest compartment name will be entered because it will be inserted into the GPS-GNSS RTK along with the digital map. The advantage of using the QGIS software is that all the map elements, in our case the materialized circles (the vector layers that comprise the circles) are in Stereographic Coordinates 70.

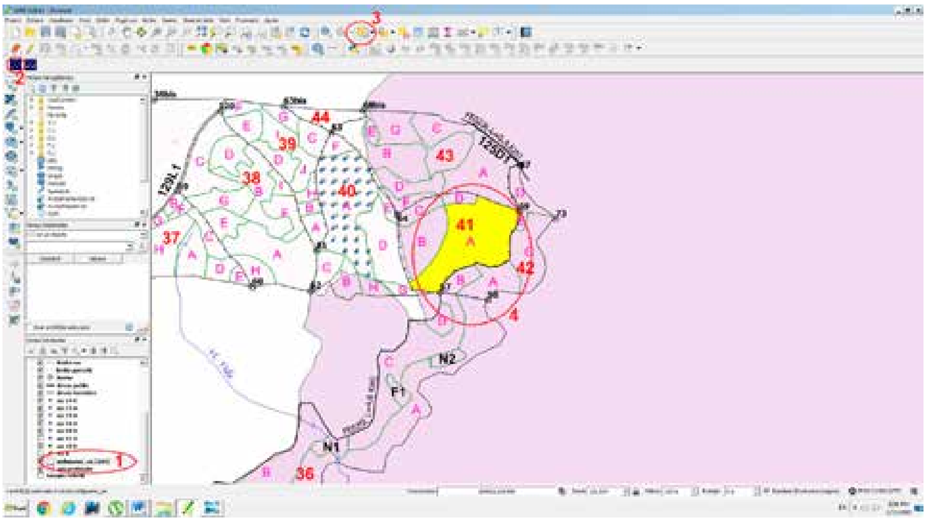


Figure 4. Selecting the forest compartment 41 A

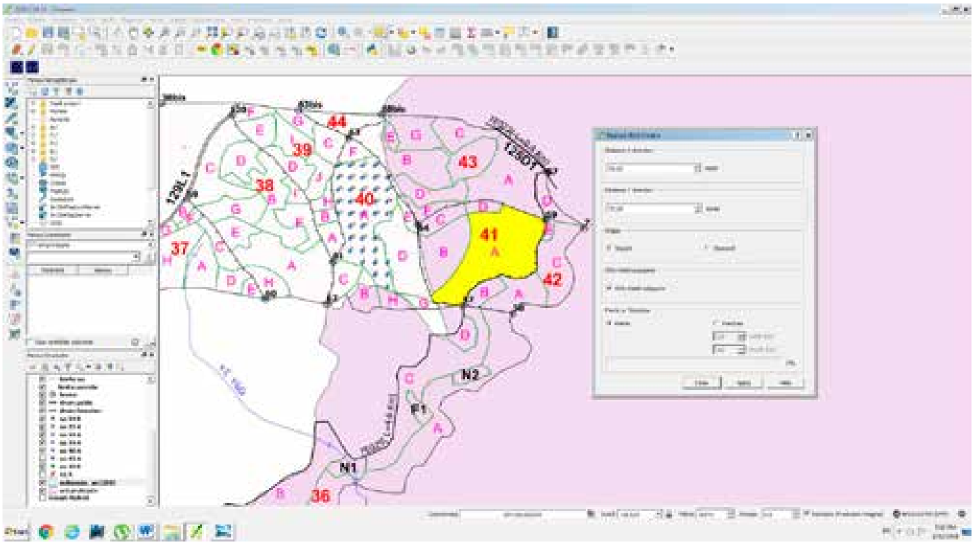


Figure 5. Entering the distances between circles

In the Layers panel, the new layer with the name of forest compartment will appear, and the following settings will be made: properties - labels - show labels for this layer - are tagged with - code, and then the attribute table and layer editing at code, enter the formula @row_number and then complete the update. At this point, the software assigns an automatic numbering to all circles, which is extremely important because the center of each circle must also materialize in the field, and the inventory of the trees must be done individually on each circle.

It is recommended that in the case of circles that fall very close to the compartment or parcel limits they are eliminated from the start because there is a risk that the radius of the circle will fall into another forest compartment or more severely in another parcel.

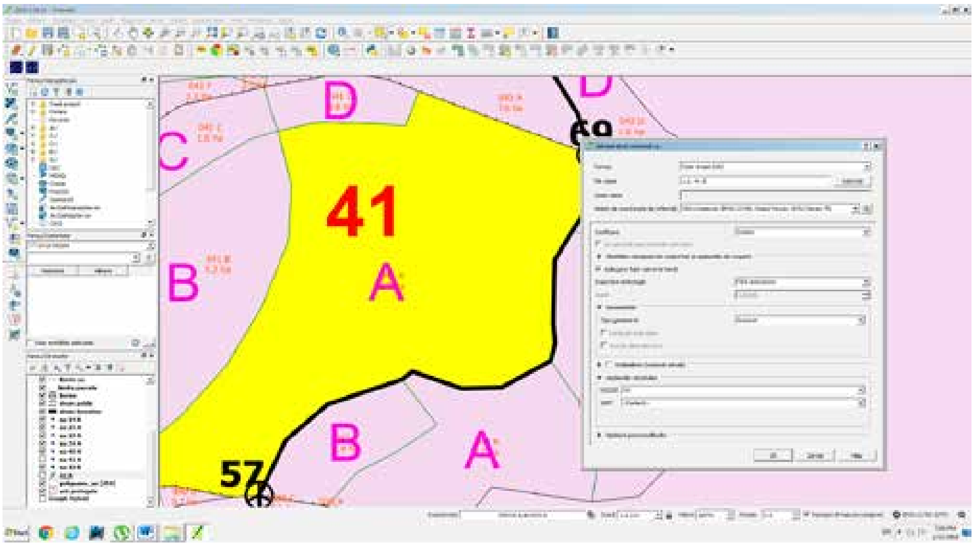


Figure 6. Saving circles as a vector layer

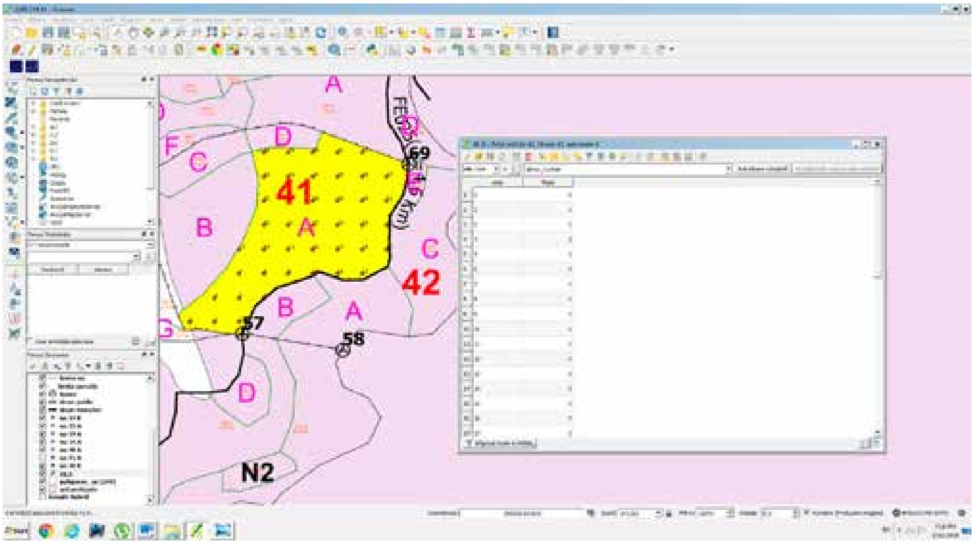


Figure 7. Numbering circles

After completing the QGIS drawing circle, this map can be loaded into the GPS-GNSS RTK, with each circle being found in the field based on GPS-GNSS RTK precision. The GPS-GNSS RTK identifies the Stereographic coordinates of the center of the circle, which is to be materialized on the nearest tree, and all trees falling within the range of 12.62 m are to be inventoried (mean species diameter and mean height). The following are the score sheets and the cubic sheet for the 41 A forest compartment. These records provide evidence of the species and average diameters and mean heights of all the trees in each inventory circle.

According to the interpretation of the cubic sheet, the composition of the tree stands: **5CA** (*Carpinus betulus*) **3FA** (*Fagus sylvatica*) **1CE** (*Quercus cerris*) **1ST** (*Quercus robur*) and the volume per hectare is 180 m^3, broken down by species: CA 84 m^3, FA 62 m^3, CE 18 m^3, ST 16 m^3, and the consistency of the tree is 0.51. A number of 371 trees with a total volume of 287.47 m^3 were inventoried in this forest compartment.

The average number of trees in the 37 circles is 8.83, even if there are circles without any tree.

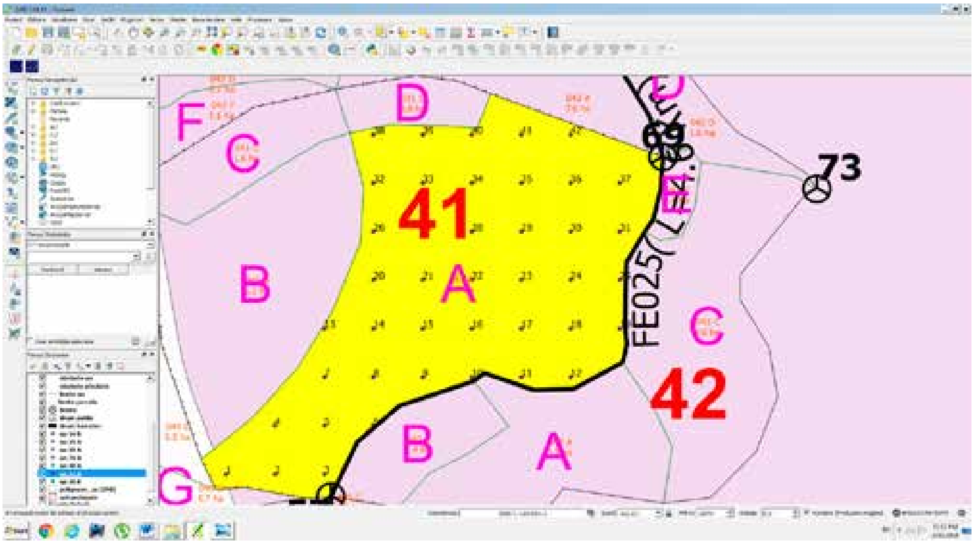


Figure 8. Finish placement of circles in forest compartment 41 A

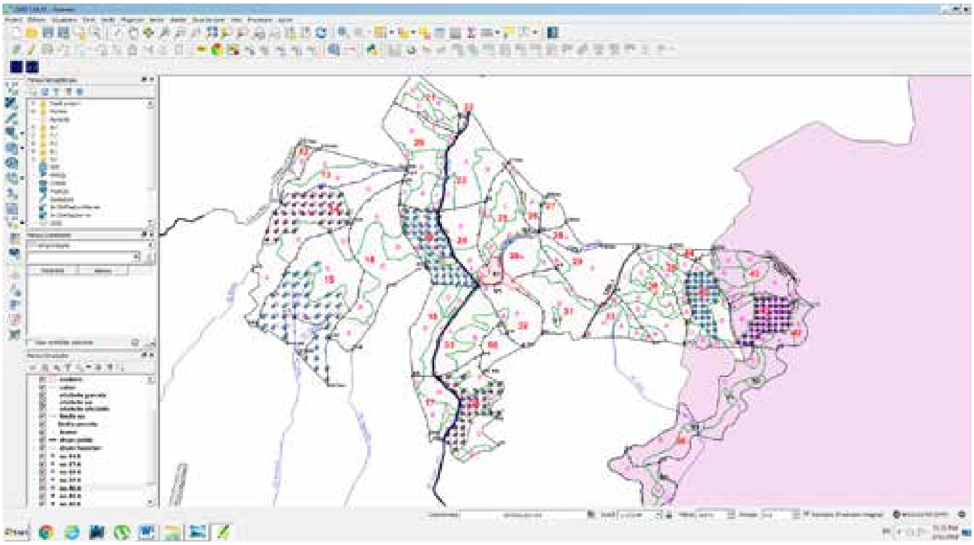


Figure 9. Location of circles in Management Unit I Dobrești

Table 2. Scoring sheet summary

Ocolul Silvic Codrii Cărăbii — Specia: mp
u.a. 041 A — Operator: [illegible]
Procedeu: cerc R dim(500 mp) — Suprafața u.a: 10,1 ha
U.P. I Dobrești — Panta medie: 15, cos 0,966
Nr. cercuri: 42 — Suprafața inventariată redusă: 1,594 ha

Centralizare fișelor de punctaj pentru specia: CA1

8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	Total
		17	75	53	38	28	6	10	1	2														230

Centralizare fișelor de punctaj pentru specia: FA1

8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	Total
		2	13	16	18	13	9	8	7	2	2	2	1											95

Centralizare fișelor de punctaj pentru specia: CE1

8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	Total
		1	3	1	7	2	5	4	4	2														29

Centralizare fișelor de punctaj pentru specia: ST1

8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	Total
			1	2	1	4	4	1	1	1		2												17

TOTAL NR. ARBORI INVENTARIATI IN U.A. 041 A: 371 arbori

TOTAL arbori inventariati in cerc 1: 15
TOTAL arbori inventariati in cerc 2: 14
TOTAL arbori inventariati in cerc 3: 13
TOTAL arbori inventariati in cerc 4: 11
TOTAL arbori inventariati in cerc 5: 12
TOTAL arbori inventariati in cerc 6: 14
TOTAL arbori inventariati in cerc 7: 11
TOTAL arbori inventariati in cerc 8: 13
TOTAL arbori inventariati in cerc 9: 14
TOTAL arbori inventariati in cerc 10: 13
TOTAL arbori inventariati in cerc 11: 10
TOTAL arbori inventariati in cerc 12: 10
TOTAL arbori inventariati in cerc 13: 10
TOTAL arbori inventariati in cerc 14: 7
TOTAL arbori inventariati in cerc 15: 9
TOTAL arbori inventariati in cerc 16: 10
TOTAL arbori inventariati in cerc 17: 13
TOTAL arbori inventariati in cerc 18: 11
TOTAL arbori inventariati in cerc 19: 8
TOTAL arbori inventariati in cerc 20: 7
TOTAL arbori inventariati in cerc 21: 12
TOTAL arbori inventariati in cerc 22: 13
TOTAL arbori inventariati in cerc 23: 11
TOTAL arbori inventariati in cerc 24: 8
TOTAL arbori inventariati in cerc 25: 16
TOTAL arbori inventariati in cerc 26: 11
TOTAL arbori inventariati in cerc 27: 14
TOTAL arbori inventariati in cerc 28: 9
TOTAL arbori inventariati in cerc 29: 9
TOTAL arbori inventariati in cerc 30: 12
TOTAL arbori inventariati in cerc 31: 11
TOTAL arbori inventariati in cerc 32: 11
TOTAL arbori inventariati in cerc 33: 12

Table 3. Log measurement sheet

Fișa de cubaj u.a. 41 A

Proprietar: Comuna Dobrești
Administrator: Ocolul Silvic Codrii Cărăbii — UP I Comuna Dobrești
Unitatea amenajistică: 041 A — Suprafața UA: 10,1 ha
NR Cercuri: 42 — Suprafața inventariată: 1,65 ha
Suprafața cercului: 500 mp — Panta medie: 15 g, COS 0,966
Suprafața inventariată redusă: 1,594 ha

D	CA		FA		CE		ST					
	D=28	h=21	D=36	h=27	D=40	h=24	D=40	h=27	D=..	h=..	D=..	h=..
	ds=VII; seria=32;		ds=IX; seria=37;		ds=IX; seria=28;		ds=IX; seria=39;		ds=; seria=;		ds=; seria=;	
	nr.arb	vol.	nr.arb	vol.	nr.arb	vol.	nr.arb	vol.	nr.arb	vol.	nr.arb	vol.
8	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-
16	17	3,060	2	0,398	1	0,131	-	-	-	-	-	-
20	75	25,023	13	4,483	3	0,762	1	0,231	-	-	-	-
24	53	28,129	16	7,776	1	0,399	2	1,012	-	-	-	-
28	38	28,366	18	12,388	7	4,116	1	0,744	-	-	-	-
32	28	28,376	13	12,353	2	1,684	4	4,136	-	-	-	-
36	6	7,234	9	11,880	5	5,420	4	5,492	-	-	-	-
40	10	15,070	8	13,896	4	5,540	1	1,734	-	-	-	-
44	1	1,807	7	14,200	4	6,700	1	2,151	-	-	-	-
48	2	4,396	2	4,852	2	3,984	1	2,222	-	-	-	-
52	-	-	2	5,692	-	-	-	-	-	-	-	-
56	-	-	2	6,396	-	-	2	6,862	-	-	-	-
60	-	-	1	3,787	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	-	-	-	-	-
68	-	-	-	-	-	-	-	-	-	-	-	-
72	-	-	-	-	-	-	-	-	-	-	-	-
76	-	-	-	-	-	-	-	-	-	-	-	-
80	-	-	-	-	-	-	-	-	-	-	-	-
84	-	-	-	-	-	-	-	-	-	-	-	-
88	-	-	-	-	-	-	-	-	-	-	-	-
92	-	-	-	-	-	-	-	-	-	-	-	-
96	-	-	-	-	-	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-	-	-
104	-	-	-	-	-	-	-	-	-	-	-	-
108	-	-	-	-	-	-	-	-	-	-	-	-
112	-	-	-	-	-	-	-	-	-	-	-	-
116	-	-	-	-	-	-	-	-	-	-	-	-
120	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	230	134,813	95	96,187	29	28,704	17	24,964	-	-	-	-
Volum/ha	84		62		18		16		-		-	
Vol. tabel	271		498		396		556		-		-	
Desimi	0,31		0,12		0,05		0,03		-		-	
Compoziție	4,38		3,41		1		0,87		-		-	
Volum total calculat= 287,47 mc												
Volum / ha = 180 mc/ha												
Număr total arbori= 371												
Consistența= 0,91												

CONCLUSIONS

For exploitable stands that have a consistency of more than 0.4 and have an area of more than 4 hectares, their inventory is made in circles of 500 m^2 with a radius of 12.62 m. The number of circles and the distance between them are established with the help of Technical Norms V for Forest Management Planning. This operation is carried out in the framework of the forest management planning.

With this method, the QGIS software and GPS-GNSS RTK technology, the center of the circles can be spotted very easily and in a very short time with the help of the GPS-GNSS RTK, and it is not necessary to measure the distances between circles in the field with the help of the forest ribbon, which is extremely expensive operation.

Thus obtaining a GIS, maps with all the information held can be easily generated: the parcels volumes, the consistency of the tree, the number of trees, etc.

The only condition is the existence of a digital layout map, which can be obtained from the parcel and forest compartment construction work with the redevelopment works in the Stereographic 70 projection, where the position of each circle can easily be materialized with QGIS software.

REFERENCES

Abera W, Antonello A, Franceschi S, Formetta G, Rigon R. (2014). The usig spatial toolbox for hydro-geomorphic analysis. *Geomorphological Techniques 2*, pp. 1–19.

Boja N., Boja F., Teusdea A., Dărău P. A., Maior C. (2013). Research regarding the uniformity of sprinkler irrigation, *Journal of Environmental Protection and Ecology (JEPE)*, vol. 14, no.4 / 2013, pp. 1661-1672.

Boja N., Boja F., Teusdea A., Vidrean D., Marcu M.V., Iordache E., Duţă C.I., Borz S.A. (2018). Resource Allocation, Pit Quality, and Early Survival of Seedlings Following Two Motor-Manual Pit-Drilling Options. *Forests*, 9, pp. 665.

Boja N., Boja F., Vidrean D., Jimon A., Denut R. (2016). Aspects regarding the use of Qgis software in the drawing of forests maps, *Engineering Sciences and Agroturism Series „StudiaUniversitatis”,* vol. 11, issue 2, University Press „VasileGoldiş” Arad, pp. 7-17.

Boja N., Borz S.A. (2020). Energy Inputs in Motor-Manual Release Cutting of Broadleaved Forests: Results of Twelve Options. *Energies*, 13, pp. 4597.

Boja N., Borz S.A. (2021). Seedling Growth Performance of Four Forest Species with Different Techniques of Soil Tillage Used in Romanian Nurseries. *Forests*,12, 782.

Carlo Tebano, Francesco Pasanisi, Sergio Grauso (2017). QMorphoStream: processing tools in QGIS environmentfor the quantitative geomorphic analysis of watersheds and river networks, *Earth Sci Inform* 10, pp. 257–268.

Crainic G. C. (2011). Research on the modernization of topo-geodetic works in the forestry sector, Brașov.

Dorillo I. (2010). A GIS algorithm for calculating quantitative geomorphic analysis parameters. An application to Fersinone creek (central Umbria). Dissertation, UniversitàdegliStudi di Perugia.

Jasiewicz J, Metz M. (2011). A new GRASS GIS toolkit for Hortonian analysis of drainage networks. *ComputGeosci 37*, pp. 1162–1173.

Khan A.P., Sangeeta Khare, Atirek Dandriyal. (2015). Employing Open Source GIS (QGIS) for Retrieving and Generating Satellite Image, Proceedings of National Conference on Open Source GIS: Opportunities and Challenges Department of Civil Engineering.

Neteler M, Bowman MH, Landa M, Metz M. (2012). GRASS GIS: a multi-purpose open source GIS. *Environ Model Softw* 31, pp. 124–130.

Noti V. (2014). GIS Open Source per geologia e ambiente. Dario FlaccovioEditore, Palermo, Italy

QGIS. A Free and Open Source Geographic Information System, 2016. http://www.qgis.org.

*** User Manual Stonex S8 GNSS Receiver, Stonex

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

OPEN-SOURCE GIS FOR TERRITORIAL PLANNING - SOLAR MAP OF TIMIȘ COUNTY, ROMANIA

Ovidiu Marcel SÎRBU, Clara-Beatrice VÎLCEANU, Anca Maria MOSCOVICI, Sorin HERBAN

Politehnica University Timisoara, 2 Traian Lalescu Street, Timisoara, Romania

Corresponding author email: beatrice.vilceanu@upt.ro

Abstract

The space regarded as land, as the primary support of mankind has undergone continuous evaluations as the source of raw materials, means of agricultural production, forestry source to the location of social and urban activities being thus an invaluable asset. The land's potential is invaluable, so that its efficient, correct, accurate management is a sine qua non condition for keeping it with all its benefits. In modern times, its management can best be done through the Geographical Information System. The territorial arrangement combines the balanced development of the exhaustible geophysical elements, respecting the cultural, social, traditional (historical) elements of the environment and helps to harmonize them and to avoid the negative evolutions. Territorial planning is the basis of sustainable development policies. The theoretical notions that support the realization of the case study - creating the solar map of Timiș county, Romania using open source GIS programs - are thoroughly documented, including aspects regarding solar energy mapping and the methodology of solar irradiation calculation as well as the current global context in which emphasis is put on the use of renewable energy.

***Key words**: Open-source GIS, planning, solar map, sustainable development.*

INTRODUCTION

The major problem of space today, more precisely in relation to its lack, its affectation, its exhaustion, is that it is necessary to maintain a balance in its use and identify the benefits of urban planning and controlled and sustainable urban development.
Urban planning is a complex process of effective use of greenfield and urban land, involving urban design, transport infrastructure and the harmonious integration of existing and future buildings (https://www.britannica.com/topic/urban-planning). Urban planning, although by name seems to refer only to urban localities (municipalities, cities and fairs) is much more comprehensive covering any human settlement, regardless of size.
Sophisticated phenomenon, urban planning involves fields such as architecture, construction engineering, research, analysis, financing, strategic planning, public consultation, neighbourhood planning, strategic thinking, recommendations and limitations, historical preservation, implementation, management and, finally, buildings, roads and structures construction.
The actual changes of a territory are the result of the decisions adopted by real estate developers, corporations, traders, bankers, politicians, urban planners, civil servants, roads, architects, nongovernmental organizations, prospective home builders, of the economic development, ecological balance, social balance etc.
In order to overcome this chaos, a single general oversight, accepted by all these actors, must be established to produce integrity at all levels.
In this context, nowadays, there is a constant preoccupation for finding directions of action in order to improve the cities competitiveness.
We can consider the following action strategies as being of fundamental importance in order to improve the cities competitiveness:

- Creating and providing good quality public spaces;
- Modernization of infrastructure networks and increasing energy efficiency;
- Pro-active innovation and educational policies;
- Paying special attention to the disadvantaged areas in the context of the city as a unitary whole;

- Strengthening the local economy and local politics related to the labour market;
- Proactive education and education policies for children and young people;
- Promoting efficient and cheap urban transport (A report of the Global Agenda Council on Competitiveness. The Competitiveness of Cities. World Economic Forum, 2014).

The present paper aims at presenting a cheap solution which implies using open-source GIS software for mapping the solar potential of Timis County, Romania. This preoccupation falls under the action strategies mentioned above, namely increasing energy efficiency and can represent a solution for local authorities in order to increase Romanian cities competitiveness. By implementing such an approach it also brings added value to the urban planning process, as optimal decisions can be adopted with regard to the most suitable areas for placing solar panels.

MATERIALS AND METHODS

Renewable energy can bring a number of benefits to humanity and the natural environment. These are reflected in:

1) social: health improvement, consumer choice, greater self-confidence, job opportunities and technological advances;
2) environment: reducing air pollution, reducing greenhouse gas emissions, lower impact on reception basins, reduced transport of energy resources and maintaining long-term natural resources;
3) economic: job creation, cost reduction and economic diversification.

Thus, countries generally tend to increase the exploitation of renewable energy sources. For example, according to the energy sector development strategy for the coming period, a short-term objective is to increase the existing share of renewable energy sources (Pereec, 2004) to reach the highest gross consumption in 2020. Recent cost reduction of solar technology has generated an increased interest in solar energy exploitation, in particular. It is the largest energy resource on Earth and the International Energy Agency estimates that the sun could also be the largest source of electricity in the world by 2050 (International Energy Agency, 2021). The potential of solar energy is very high. Every half hour, the Earth receives from the Sun an amount of energy equivalent to the energy consumption of mankind for a whole year. That is why solar energy represents the energy alternative of the future (Moscovici et al., 2020).

This approach has led to a series of studies on solar potential of certain special geographical areas (Pereec, 2010) and the mapping of suitable locations for the installation of solar panels. Of particular interest is obtaining information regarding solar potential in urban environments, due to the advantages of producing energy closer to consumers. Moreover, a number of research studies dealing with models and methodologies for estimating the solar potential of buildings and the degree of roofs adequacy for the installation of photovoltaic systems have been carried out (Pinker et al., 2005).

Solar radiation is a key driving force for many natural processes. At the Earth's surface, solar radiation is the result of the complex interaction between the atmosphere and the Earth's surface. Solar radiation is a major driving force for physical, biological, hydrological and agricultural processes. The study of solar radiation is particularly important recently in the context of climate change. An overall decrease in solar radiation of -0.51 ± 0.0 W/m^2 per year was recorded between 1950 and 1980, which is 2.7% per decade (Wilde, 2009). This decrease phenomenon is known as global blur. In contrast, the opposite trend has been observed since 1980, and is known as the worldwide brightness, which is characterized by an increase in overall solar radiation (Pons, Ninyerola, 2008).

It has been documented that anthropogenic activities have been the basis of the increase in atmospheric concentrations of aerosols which could be the reason for the decrease of solar radiation (Protic et al., 2012). On the other hand, specialists in the field have shown that the reduction of aerosol emissions from anthropogenic activities in recent decades has contributed to an increase in solar radiation (Raaflaub, Collins, 2006). Suggesting a degree of uncertainty in previous conclusions, experts have emphasized the importance of anthropogenic aerosols in relation to local and regional solar radiation.

The analysis of the spatial model of solar radiation and/or irradiation is also of great significance. The spatial variability of solar radiation can be a key tool in ecological and economic planning, as well as for the development of renewable energy strategies. The spatial heterogeneity of the received solar radiation is determined by many factors besides atmospheric vapours and clouds, including topography, the coefficient of water reflection and the crowning of trees in green areas. Topography, and in particular altitude, slope and environmental conditions are major factors that determine the amount of incident solar radiation on the Earth's surface (Ramanathan, 2001).

In recent years there have been a number of initiatives to bring solar power closer to citizens, business and public local communities, and many are using solar maps as a tool to achieve this goal. In this context, the term "solar map" refers to an interactive cartographic web tool that provides various information related to the solar potential of buildings or greenfield, as well as the benefits related to this potential exploitation. The information helps potential users plan their investments in solar technology or include solar energy in their future projects and plans (Ruiz-Arias et al., 2001).

There are a number of recently developed and published urban solar maps. They have been produced using different methods and are intended to provide different levels of information, from very basic (for example, irradiation levels) to advanced (for example, the production of solar systems, financial considerations, installers etc.). It is expected that many cities will develop their solar maps in the near future.

Solar irradiation calculation methodology

In this study, SAGA GIS - open source software was used, (Vilceanu, 2017) in particular the module called “Potential Incoming Solar Radiation” (Unkasevic, 1997). The detailed description of the implemented methodology has been previously published (Bohner, Antonic, 2009). The authors recognized three main factors that have an effect on the spatial variation of solar radiation:

1) the relative orientation of the Earth in relation to the sun;
2) clouds and other atmospheric inhomogeneities;
3) topography.

SAGA GIS offers the possibility to enter many input parameters to model the received solar radiation potential; however the best option is to use Digital Elevation Model instead of individual terrain features such as slope, appearance, clear sky factor, shadow or geographical coordinates (latitude and longitude).

These input parameters cover the influence of the first and third main factors that have an effect on the spatial variation of solar radiation, that is, the relative orientation of the Earth in relation to the sun and topography. In order to take into account the impact of the second group of factors, represented by clouds and other atmospheric in homogeneities, information such as cloud cover is required.

Direct irradiation is a function of the solar zenith angle, solar flux at the top of the atmosphere, atmospheric transmittance, the angle of solar illumination on the slope, and the elements obstructing the sky.

The zenith angle and the solar flux depend on the calendar date, while the atmospheric transmittance is a function of altitude since the substances that absorb the energy decrease in proportion to the altitude. The angle of solar illumination (the angle between an orthogonal plane to the sun's rays and the ground) is a function of surface altitude (slope and aspect of the ground) and the relative position of the sun in the sky (sun orientation and azimuth) (Watson et al., 2003).

Daily direct irradiation $S^*_{S(d)}$ can be calculated by using the following formula:

$$S^*_{S(d)} = \sum_{i=1}^{n} S^*_{S(h)i} = \sum_{i=1}^{n} z_i \frac{S_{S(h)i}}{\sin\theta_i} \cos\gamma_i \quad (1)$$

where:

- $S^*_{S(h)i}$ represent direct topographic radiation per hour;
- z is the binary mask of shadow (0 = shadow, 1 = non-shadow);

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

- θ - sun's orientation of the over the horizon;
- γ - sunlight's angle;
- n is the number of hours used to calculate daily radiation amounts.

In this study for n we have used 24 hours (time frame between 0a.m. to 24p.m.).

Diffuse irradiation $S(h)$ is the part of the total irradiation received from the sky hemisphere (Watson et al., 2003). It is a function of the solar geometry, the pressure (elevation) and the scattering and absorption properties of the atmosphere. It is necessary to calculate the sky view factor ψ_s to describe the portion of the sky that can be obstructed by the terrain topography for each individual location when modeling this solar irradiation partition:

$$\psi s = \frac{1}{2\pi}\int_0^{2\pi}[\cos\beta cos^2\pi + \sin\beta\cos(\Phi - \alpha)(90 - \varphi - \sin\varphi\cos\varphi)]df \qquad (2)$$

where:

- φ represents the zenith angle at the local horizon for the azimuthal direction Φ;
- β and α represent the slope, respectively the terrain's aspect.

ψs the sky view factor is a measure that quantifies the diffuse irradiation ratio at a certain point from that on an unobstructed horizontal surface. This parameter ranges from 1 (for the completely unobstructed terrain surface, such as the landscape of the plane horizon or peaks or ridges) to 0 for the completely obstructed terrain surface.

Topographic diffuse solar radiation S_h^* is calculated as:

$$S_h^* = S_h\,\psi s \qquad (3)$$

❖ Description of the study area

The geographical location of Timiş County gives it a privileged location, being the westernmost county in Romania.

It is bordered on the west by Csongrad County - Hungary and on the southwest by the province of Vojvodina - Serbia, the connection between the two counties being ensured by the border crossing points from Cenad, respectively those from Stamora Moravița and Jimbolia. The neighbouring Romanian counties with Timiş County are Arad to the North, Hunedoara to the East and Caras-Severin to the South-East.

Timiş, the largest county in the country ($8697 km^2$), benefits from a very varied relief: plain in the western and central part, hilly area continued with mountainous relief, in the eastern part.

The territory of the county is crossed by Timiş and Bega rivers, and the climate is pleasant, temperate-continental with Mediterranean influences.

Figure 1. Localization of Timiș County

From the point of view of urbanism and territorial planning, at present the entire territory of Timiş County is managed through the specialized GIS software, MapSys Internet Map Server, implemented within the County Council.

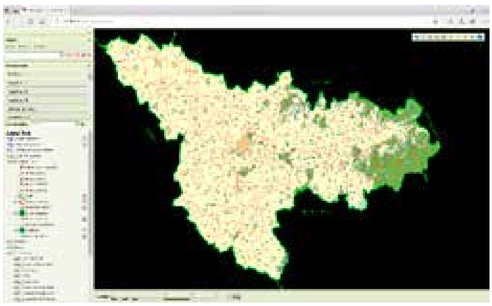


Figure 2. Overview of the Timiș County managed with MapSys software

The most important layers defined in the application include area town planning, detailed urban plan, electric wires network, territorial administrative boundaries, vegetation, roads, green spaces, ortophotoplans etc. which can be subject to geospatial analysis. The final product of the geospatial analysis consists of thematic maps.

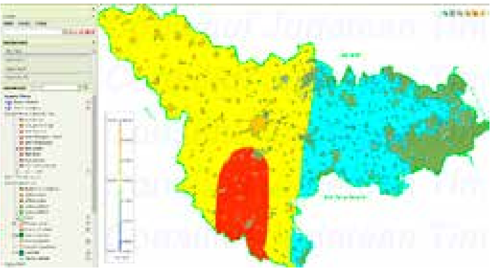


Figure 3. Thematic map with Timiș county seismic susceptibility

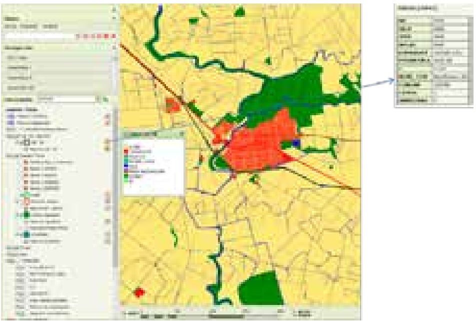


Figure 4. Thematic map with Timiș County land use

Sources of data

Creating the solar map for Timiș County, Romania using open-source GIS involved procuring, as initial geospatial data, the Digital Elevation Model - D.E.M., the administrative limits of the study area and the “sky clearness”.

D.E.M. was downloaded from http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp, being part of the Shuttle Radar Topography Mission, 90m resolution. The file that covers Timiș county and was used for the study is srtm_41_03.zip.

Timiș county map was downloaded from http://www.gadm.org/country, a site which contains a database with the administrative boundaries of the countries.

The file is structured on 3 levels of administrative boundaries: for country - (0), administrative territorial units - (1) and municipalities - (2). For this study, ROU_adm1.shp has been used.

D.E.M. and the digital map were imported into the specialized QGIS program. The Clip raster with polygon function from the toolbar was used to crop the “tiff” image of the Digital Elevation Model from SRTM by overlapping it with the digital map.

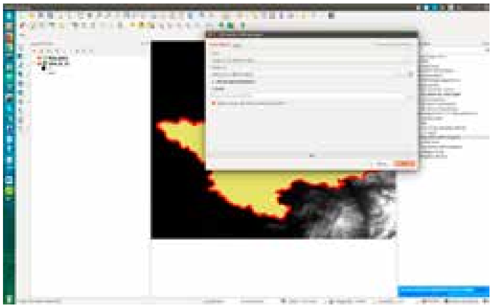


Figure 5. D.E.M. overlapped with administrative boundaries of Timiș County

But before executing the function it is necessary to select only the polygon that contains the region of Timiș County. When using the function, the user can choose to perform the processing including only the selected polygon, a possibility offered by the version QGIS 3.0. The goal is to get this D.E.M. which only covers the study area, then is saved for later use.

To download the “sky clearness index” we need to know the coordinates of the cell in the grid. These coordinates are in the WGS84 system and are found in the properties of the layer cut in the previous step, in the section "Metadata Properties". "Sky clearness index" is downloaded from the specialized site https://eosweb.larc.nasa.gov/cgi-bin/sse/subset.cgi based on the grid coordinates determined for D.E.M. cut only for Timiș County (Tables 1 and 2).

Table 1. The grid limits needed to be determined to download the “sky clearness index”

Limits	20.2637505219999987, 45.1937503549999988 22.5529170970000017, 46.1904169820000021

Limits	19,44 : 24,48

Table 2. “Sky clearness index” values for Timiș County

	44	45	46	47	48
24	0.68	0.68	0.68	0.68	0.69
23	0.67	0.68	0.68	0.69	0.70
22	0.69	0.69	0.69	0.70	0.70
21	0.69	0.70	0.70	0.71	0.70
20	0.69	0.71	0.71	0.71	0.71
19	0.68	0.72	0.72	0.72	0.72

RESULTS AND DISCUSSIONS

Solar radiation calculation involves having the data in a 2D projection system, so it is necessary to reproject the D.E.M. cut for Timiș County before the actual processing of the solar radiation. In this sense, the "warp (reproject)" function is used. Regarding the projection systems, we will select EPSG:4326 for the source and EPSG:31700 (equivalent of the Stereographic projection system 1970) as the target. Also during this stage, the user can select the type of interpolation to be bilinear or if the user types "0" the software does not use interpolation data in processing. The result of the reprojection is saved for use in subsequent stages.

In order to be able to create the solar map for Timiș County based on the geospatial data downloaded from the online environment, after the D.E.M. reprojection in the 2D system, it is necessary to create in QGIS a new layer in which to import the "sky clearness index" values. For this purpose, we used the Add Layer - Add Delimited Text Layer command.

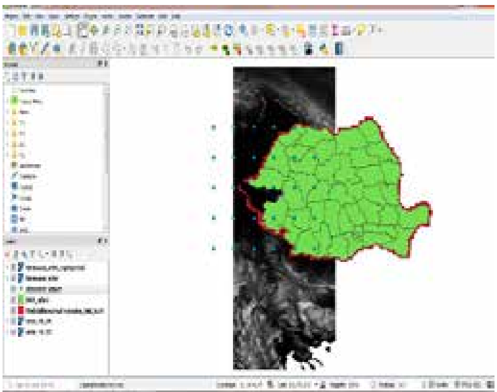


Figure 6. The result obtained after creating the layer with the "sky clearness index" values

After all the geospatial data has been introduced in the SAGA GIS software, the "Potential Incoming Solar Radiation" function is used (The European Solar Radiation Atlas, 2000). In the dialog box of this command, the user chooses the option "Total Insolation" and the time period for which we need to calculate the solar radiation.

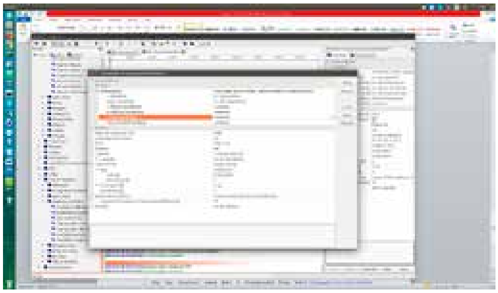


Figure 7. "Total Insolation" for a longer period of time

The actual calculation of the solar radiation is done from the menu Tools - Lighting Visibility - Potential Incoming Solar Radiation.

After the realization of the digital thematic solar map, through the open layers or qgis2web plugins available in GIS specialized programs such as QGIS and SAGA GIS (https://sagatutorials.wordpress.com/about-saga-gis/), we can position the solar map on Google Maps.

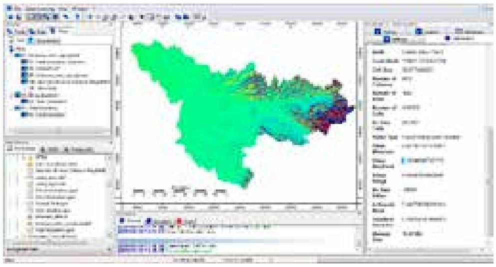


Figure 8. Solar map for Timis County, Romania

As it can be seen from the mapping of the Global Photovoltaic Power Potential (https://globalsolaratlas.info/global-pv-potential-study), Romania is suitable for developing strategies of implementing solutions based on green energy, in particular solar energy.

Being situated in a mostly plain area, Timis County has high solar potential high both for installing solar panels on residential houses and for developing projects for photovoltaic parks.

The map realized shows variability of the solar potential on the Timis County's territory, as follows: the eastern part of the county is less populated as the relief is hilly in contrast to the western part where the solar potential is at a high value (being represented with light green).

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

The solar map of Timis County is a high scale precision map which can be further used to be uploaded into a platform that should represent a pillar of the national strategy for energy. This platform would benefit from adding small producers of green energy, geospatial information regarding wind energy and heat pumps energy produced in Romania. Implementing such a GIS platform can be extended in the future with more capabilities in order to answer to the needs of different users: both energy companies and residential users.

CONCLUSIONS

The economic and demographic evolution have led to the current situation where we are facing the shortage of spaces that ensure - at the same time - all the necessary uses without creating a conflict situation between them (for example, housing - green spaces - traffic areas).

Adopting strategies such as creating and ensuring good quality public spaces, modernizing infrastructure networks and increasing energy efficiency, pro-active innovation and educational policies, paying special attention to disadvantaged areas in the context of the city as a whole, strengthening the local economy and of local politics related to the labour market, the promotion of pro-active education and education policies for children and young people and of an efficient and cheap urban transport lead to an efficient territorial arrangement.

The actual estimation of solar radiation is of considerable interest in the sustainable planning of the environment and resources. Increased greenhouse gas concentration has led many governments to explore renewable energy sources. By the Kyoto Protocol signed in 2007, 175 countries have approved the implementation of the protocol, thus assuming responsibility for increasing the amount of energy produced from renewable energy, which includes biomass, geothermal, solar and wind energy sources. So far, the use of renewable energy in Romania is mainly based on hydro-power plants, biomass and wind farms to a small extent. Although in the first years the scope of the use of solar panels in Romania has been quite limited, in recent years this phenomenon has taken hold, energy production being subsidized through different projects and initiatives, considering the country's potential for using solar energy.

The “Green House” program started timidly with the support of the installation of solar panels in 2012 and continues today with the “Green House 2019” - regarding the financing by the Romanian State of the citizens who install their photovoltaic panels at home, approved by Order number 1287/2018 and “Green House 2021”. In order for the citizens to make the most of this program, the authorities should implement a webGIS, freely available, with maps like the one created by the authors in order to find out if the region they live in is suitable for installing solar panels.

The methodology presented in this paper consists of a cheap solution which implies using open-source GIS software for mapping the solar potential, in particular for Timis County, Romania. The topicality of this research is given by the fact that it contributes in real time to increasing energy efficiency and can represent a solution for Romanian local authorities in order to increase cities competitiveness. By implementing such an approach it also brings added value to the urban planning process, as optimal decisions can be adopted with regard to the most suitable areas for placing solar panels.

REFERENCES

Bohner, J., Antonie, O. (2009). Land-Surface Parameters Specific to Topo-Climatology, in: Geomorphometry - Concepts, Software, Applications (Eds. T. Hengl, H. Reuter), Elsevier, Vol. 33, pp. 195-226.

Moscovici, A.-M., Vîlceanu, C.-B., Herban, S., Grecea, C. (2021). Solar cadastre in Timisoara, Romania, Scientific Papers-Series E-Land Reclamation Earth Observation & Surveying Environmental Engineering, Volume 10, pp. 272-277, WOS:000704605600037, ISSN 2285-6064.

Pereec Tadie, M. (2004). Digital Map of Average Annual Sum of Global Solar Radiation on Inclined Differently Oriented Surfaces, *Croatian Meteorological Journal*, 39, pp. 4l-49.

Pereec Tadie, M. (2010). Gridded Croatian Climatology for 1961-1990, *Theoretical and Applied Climatology*, 102, 1, pp. 87-103.

Pinker, R. T., Zhang, B., Dutton, E. G. (2005). Do Satellites Detect Trends in Surface Solar Radiation? *Science*, 308, 5723, pp. 850-854.

Pons, X., Ninyerola, M. (2008). Mapping a Topographic Global Solar Radiation Model Implemented in a GIS and Refined with Ground Data, *International Journal of Climatology*, 28, 13, pp. 1821-1834.

Protic, D., Kilibarda, M., Vucetic, I., Nestorov, I., (2012). 3D Roof Modeling for Accurate Assessment of Solar Potential, *EUROSUN2012, Proceedings, Opatija*, Croatia, ISBN 978-953-6886-20-3.

Ramanathan, V., Crutzen, P.J., Kiehland, J.T., Rosenfeld, D. (2001). Aerosols, Climate, and the Hydrological Cycle, *Science*, 294, 5549, pp. 2119-2124.

Raaflaub, L.D., Collins, M.J. (2006). The Effect of Error in Gridded Digital Elevation Models on the Estimation of Topographic Parameters, Environmental Modelling & Software, 21, 5, pp. 710-732.

Ruiz-Arias, J.A., Pescador, J.E., Pozo-Vazquez, D., Alsamamra, H. (2009). A Comparative Analysis of DEM-Based Models to Estimate the Solar Radiation in Mountainous Terrain, *International Journal of Geographical Information Science*, 23, 8, pp. 1049-1076.

Unkasevic, M. (1997). Characteristic Global and Diffuse Solar Radiation Values for Serbia, *Idojaras,* 101, 1, pp. 55-64.

Vîlceanu C.-B. (2017). *Sisteme Informatice Geografice, Concepte și Aplicații*, Editura Politehnica, Timișoara, ISBN 978-606-35-0125-8.

Wang, L., Wang, K. (2015). Impacts of DEM Uncertainty on Estimated Surface Solar Radiation and Extracted River Network, *Bulletin of the American Meteorological Society*, 96, 2, pp. 297-304.

Watson D., Plattus A., Shibley R. (2003). Time-saver Standards for Urban Design, McGraw-Hill Professional Cary Sullivan Publishing House, ISBN 0-07-068507-X.

Wilde M. (2009). Global dimming and brightening: A review. *Journal of Geophysical Research*, Vol. 114, D00D16, doi:10.1029/2008JD011470, 2009

***(2000). *The European Solar Radiation Atlas*, Vol. 2: Database and Exploitation Software (Eds. K. Scharmer, J. Greif), Presses de l'Ecole des Mines de Paris, Paris.

***(2014). A report of the Global Agenda Council on Competitiveness. The Competitiveness of Cities. World Economic Forum, Available online at https://www3.weforum.org/docs/GAC/2014/WEF_GAC_CompetitivenessOfCities_Report_2014.pdf

***(2021). International Energy Agency. Net Zero by 2050. A Roadmap for the Global Energy Sector. https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf

https://www.britannica.com/topic/urban-planning

https://sagatutorials.wordpress.com/about-saga-gis/

https://globalsolaratlas.info/global-pv-potential-study

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE USE OF GEOGRAPHICAL INFORMATION SYSTEMS FOR ISSUES OF FOREST LAND RETROCESSIONS

Cornel Cristian TEREŞNEU

Transilvania University of Brasov, 25 Eroilor Street, Brasov, Romania

Corresponding author email: cteresneu@unitbv.ro

Abstract

This paper aims to highlight the advantages of using Geographical Information Systems in the complicated problems of forest land retrocessions. The study is focused on an area of about 400 hectares in Poiana Mărului, Brașov county. This forested area has been identified on the appropriate forestry map, measured in the presence of landowners using two Trimble GPS receivers and parcel plans were created, in order to be sent to OCPI Brașov for approval. Sensible issues hindering the successful completion of this operation were evidenced, with four categories of problems being identified. Each category involves a number of situations which were individually analyzed. Besides the technical and judicial knowledge necessary in find the optimal solutions, the benefits offered by Geographical Information Systems are presented, benefits which give specialists significant opportunities to identify critical issues and make overall verifications. Therefore, the conclusion of this paper is that this modern instrument can be successfully used even in projects of this nature.

Key words*: mountainous forests, GPS, land retrocession, GIS.*

INTRODUCTION

This paper looks at one of the challenges the land surveyor meets in his activity, which is the technical and judicial issue of forest land retrocessions. It is a well-known fact that property laws propose the retrocession of land to the old owner, before the communist era expropriations. The study area is in the Poiana Mărului municipality of Brașov county (Figure 1) and is composed of a series of past forestry land parcels intermixed with arable land. For the mountainous area of Brașov county, numerous studies were conducted which looked at the factors influencing positioning accuracy using GPS equipment in the case of forested areas (Tereşneu et al., 2011; Tereşneu et al., 2014; Tereşneu and Vasilescu, 2015; Tereşneu and Vasilescu, 2019 a, b) and also correlating the influence this accuracy has on determining areas of forested land (Tereşneu, 2021). In this study the convenience offered by remote sensing techniques has been taken into account (Herbei et al., 2021; Vorovencii, 2014a; 2014b). A commission to analyse and validate all data collected has been established at the Poiana Mărului town hall. Point positions determined using GPS were classified in two categories: under the forest cover and at the edge of it. Taking into account the influence on point positioning accuracy (Ordonez Galan et al., 2011; 2013; Weilin et al., 2000; Zhang et al., 2014; Wang et al., 2014; Janez et al., 2004; Dogan et al., 2014; Sawaguchi et al., 2003) we found a horizontal precision of 0.75m for points under forest cover and 0.23m for points at the edge of the forest cover, respectively. Considering the realities of the study area, we can state that these values indicate a very good precision which can be successfully used in this kind of projects.

Figure 1. Study area

MATERIALS AND METHODS

The following materials were used for this study: topographical plans with forest parcel boundaries, ortophotoplan of the study area,

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

parcel description from the forest management projects, two *Trimble ProXT* and *Trimble ProXH* GPS receivers.

With regards to the research methods involved, these are: bibliographical study: by which all property titles issued by the land register commission, recordings of proceedings for land retrocession to owners, certificates of record issued by Poiana Mărului town hall; mathematical statistics methods, which were used for two purposes: the analysis of coordinate precision using GPS positioning and for data correlation (town hall data and forest administration office); direct measurement method with which over 2000 point coordinates were determined (specifically, by using the *Stop&Go* with post-processing method). A GIS project of the study area was created and point coordinates determined using GPS receivers were imported in the ArcMap software.

RESULTS AND DISCUSSIONS

Collected and correlated data was synthetized in Table 1, an extract of which is presented here.

Table 1. Collected and correlated data from Poiana Mărului town hall

No. crt.	GIS observation	UP	UA	Declared owner name	Measured area (ha)	Observation
1	397	XI	69	CORCA TEODORA	1.12	
2	398	XI	69	BOBEIU IOAN	2.27	
3	399	XI	69	TOGOE ALEXANDRU / COMANICI GHEORGHE	0.27	
4	400	XI	69	CORCA IOAN	0.08	
5	401	XI	69	LAZAROIU GHEORGHE	0.95	
6	402	XI	69	GUIMAN PARASCHIVA	0.43	
7	403	XI	68	GUIMAN PARASCHIVA	0.04	
8	404	XI	68	PISEU AUREL	0.70	
9	406	XI	68	PISEU AUREL	0.33	
10	407	XI	68	PISEU AUREL	3.23	
11	408	XI	68	PISEU AUREL / ADAM ION	0.26	
12	409	XI	68	TOGOE ION	0.10	
13	410	XI	68	PISEU AUREL / ADAM ION	0.13	
14	411	XI	70	PISEU MARIA	0.84	
15	412	XI	70	ENESCU ELVIRA	0.70	
16	413	XI	70	PASOIU (RASOIU) ANA	1.65	
17	414	XI	70	LIHACIU ANA (ANA STAN PERSOIU)	0.74	
18	415	XI	70	TITILINCU ARON	0.62	
19	416	XI	70	BALAU IOAN	2.28	SERVER OVERLAPPING
20	417	XI	70	TITILINCI ION	0.44	
21	418	XI	70	PERSOIU IANCU / PERSOIU EMIL	0.75	
22	420	XI	70	ORZAN ION	0.25	SERVER OVERLAPPING
23	422	XI	70	ORZAN GHEORGHE	0.53	SERVER OVERLAPPING
24	423	XI	71	TITILINCU ARON / GURAN ARON	0.40	
25	424	XI	71	POPA IOAN / DRAGOI MARIA	2.50	
26	434	XI	72 - 76	DOBRESCU ILIE	6.06	
27	435	XI	72A	CEAPA NECULAI	2.72	
28	436	XI	72A- 72C	NECULOIU GHEORGHE	3.33	(certificate)
29	437	XI	72	TICOI ANA (COFEI IOAN)	1.42	
30	438	XI	70	BRAGHESIU IOAN	2.02	
31	439	XI	70	BRAGHESIU VASILE	0.27	

No. crt.	GIS observation	UP	UA	Declared owner name	Measured area (ha)	Observation
32	440	XI	70	CODREANU ANA (FLANGEA MARIA)	2.66	
33	441	XI	70- 71	PASEU MARIA / PASEU GHEORGHE	5.06	(both claim the same surface)
34	442	XI	71	BOBEI ION	0.31	
…	…	…	…	………..	….	….
382	884	XI	82	UNKNOWN	0.38	
383	885	XI	80	UNKNOWN	2.06	
384	886	XI	80	UNKNOWN	0.42	
385	887	XI	85	UNKNOWN	0.97	
386	888	XI	86	UNKNOWN	0.57	
387	889	XI	89	UNKNOWN	1.90	
388	890	XI	89	STAT (O.S.)	0.60	
389	891	XI	113	UNKNOWN	0.65	
390	892	XI	137	STAT (O.S.)	0.53	
391	893	XI	132	UNKNOWN	0.85	
392	894	XI	125	MANECUTA ION	0.22	
393	895	XI	84	STAT (O.S.)	1.74	
394	900	XI	90	STAT (O.S.)	1.24	
TOTAL					**393.43**	

By analysing this data, a number of issues were identified:

a. More than one landowner claiming the same forest area;
b. Some of the landowners carried out works of cadastral data updating based on the old cadastral registers (which did not use forest as a land use category) which went over portions of forest areas. In this manner real property overlaps occurred;
c. Other landowners updated their cadastral data for agricultural areas bordering the forest and virtual overlaps with it are present because of incorrect positioning;
d. There are differences between surfaces for the parcels identified in the field and those recorded in documents;
e. There are forests areas with unknown owners.

Each case was analysed and the best solution was aimed for. For a proper management of these issues, a warning system in the GIS project was established, based on the code of each issue (Tereşneu et al., 2016) (Figure 2).

With regards to the first category of issues, which is likely the most difficulty, each case was individually considered. For each category several cases were identified. In some of them, the conflict was only formal.

Even if both landowner had a claim over the same area, their documents lead to the conclusion that they were claimed a larger surface than proven. The real issue was explained by mediation and the issue was thusly solved. This is the case for parcel no. 111, where two landowners were claiming the same boundary (Figure 3). Each of them had claims in the same forest parcel, but at a certain distance from this location. By adding up the measured surfaces of the two landowners, both in locations without issues and in this conjoined location, a surface very close to the claimed one was obtained. Therefore, a splitting-up of the surface in disputation was proposed and the conflict was resolved.

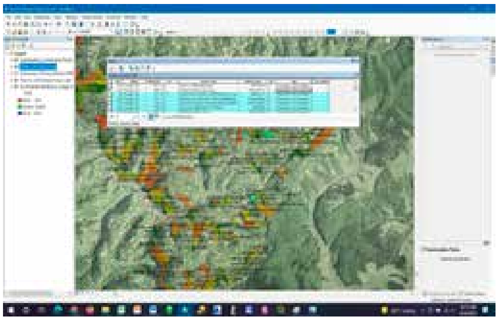


Figure 2. GIS warning system

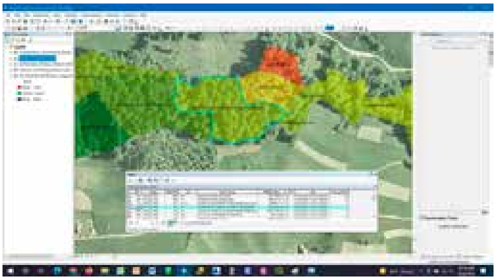


Figure 3. Resolved conflict

However, there are other issues of this nature, such as discrepancies between forest land administration and town hall records (Figure 4). In this case, all proving documents were searched and a recording mistake was identified. Specifically, the forest administration office did not subtract the corresponding surface retroceded to the previous owner from their records.

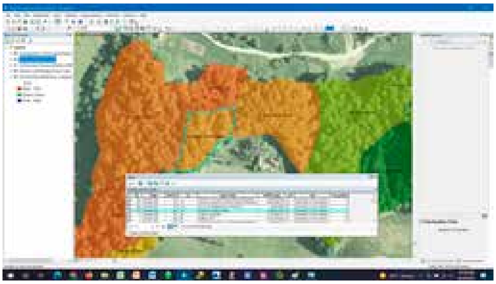


Figure 4. Artificial conflict due to lack of record updating

Another problem was identified in forest management unit no. 122 where another two owner had a claim over the same area. To solve this issue, the old cadastral register plans were consulted and the fact that one of the landowners had a claim outside his property's perimeter was established (Figure 5).

With regards to the second category of issues (real property overlaps), these are still to be resolved. Involved landowners were summoned and it was convened that the only solution is for the owners to carry out surface rectification works for the agricultural parcels overlapping forest areas. In this manner the owners would renounce their claims over the portions of their land overlapping the forest. With regards to the forest areas, a parcel plan will be created, as this is the only manner in which the landowners will be able to have noted, in the updated cadastral registers, forest as the land use category (Figure 6).

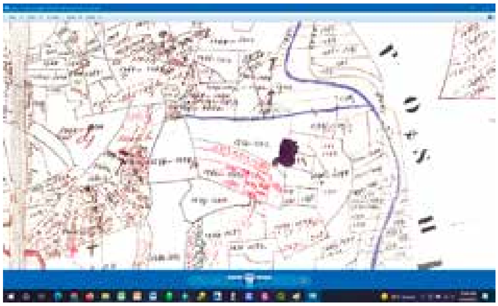


Figure 5. Solving a conflict issue by use of old cadastral register plans

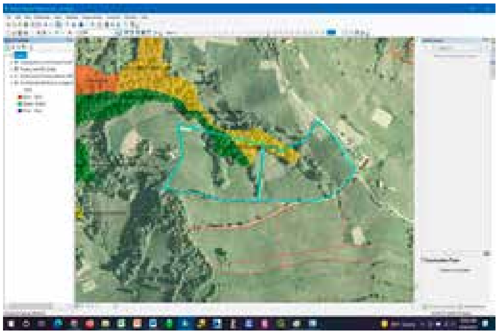


Figure 6. Real property overlap

For the third category of issues the solution is much simpler. Contact was made with land surveying experts which carried out cadastral data updates and they were asked to carry out repositioning works (Figure 7). No real parcel overlaps were identified for this issue, even if the problem of agricultural land-forest boundaries is not properly regulated.

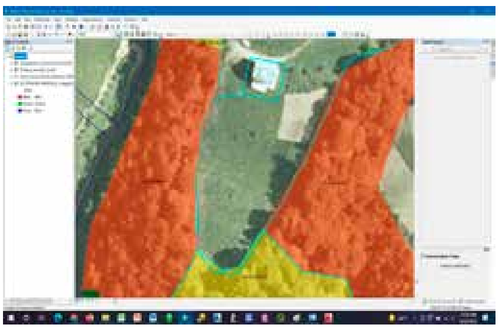


Figure 7. Solving virtual overlap issues

For issues in the fourth category no major problems were had, in the sense that surfaces did not have major differences in the field from the values validated in documents. Or, if high differences did occur, land surveys for the whole property in question were carried out and it was determined that the surface difference (for the most part) was located in the agricultural portion of the property (Figure 8).

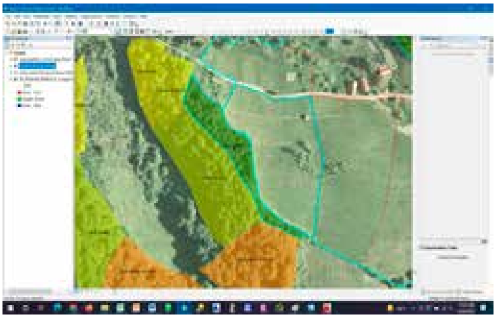


Figure 8. Surface-related issues

With respect to the category of issues, the fact that a lot of forest areas which have yet to be claimed show up as having an unknown owner was established (Figure 9). This issue does not hinder the creation of parcel plans, as all these surfaces are for the moment at the disposal of the local commission for the application of forest ownership laws.

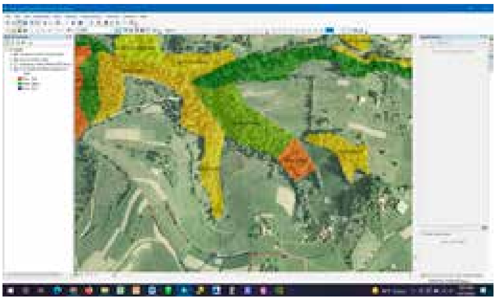


Figure 9. Surfaces with unknown owners

CONCLUSIONS

Issues caused by the application of land property rights require the existence of trained specialists involved in their handling. Furthermore, there is a need for adequate equipment and software to ease the finding of solutions. In this paper, a series of issues were identified and solutions were found for each of them. To find optimum solutions for each situation, Geographical Information Systems were used to create a complex system of notifications for each situation with issues. Then, using the same system and experts, the best solution was found for each case. For the almost 400 hectares of identified, validated and surveyed forest areas, 12 parcel plans were created and cadastral number attributed, which are currently in the approval phase at local commission for the application of land property laws. Therefore, it can concluded that, no matter how complicated cases can be with regards to the application of laws intended to fix the damage of communism on private property, if adequate specialists are assigned and appropriate methods and technical means are employed, solutions can be arrived at for all cases in a reasonable timeframe.

REFERENCES

Dogan, U., Uludag, M., Demir, D.O. (2014). Investigation of GPS positioning accuracy during the seasonal variation. *Measurement*, *53*, pp. 91–100.

Herbei, M.V., Bertici, R., Sala, F. (2021), Geomatic Methods for management planning of protected areas. Case study: Paniova forest, Timis County, Romania. In Scientific papers – series E – Land reclamation *Earth observation & surveying environmental engineering*, X, pp. 301-310.

Janez, G., Adrados, C., Joachim, J., Gendner, J.P., Pepin, D. (2004). Performance of differential GPS collars in temperate montain forest. *Comptes Rendus Biologies*, *327*, pp. 1143–1149.

Ordonez Galan, C., Rodriguez Perez, J. R., Garcia Cortez, S., Bernardo Sanchez, A. (2013). Analysis of the influence of forestry environments on the accuracy of GPS measurements by means of recurrent neural networks. *Mathematical and Computer Modelling*, *57*(7-8), pp. 2016–2023.

Ordonez Galan, C., Rodriguez Perez, J. R., Martinez Tores, J., Garcia Nieto, P. J. (2011). Analysis of the influence of forestry environments on the accuracy of GPS measurements by using genetic algorithms. *Mathematical and Computer Modelling*, *54* (7-8), pp. 1829–1834.

Sawaguchi, I., Nishida, K., Shishiuchi, M., Tatsukawa, S. (2003). Positioning precision and sampling number of DGPS under forest canopies. *Journal of Forest Research*, *8*, pp. 133–137.

Tachiki, Y., Yosimura, T., Hasegawa, H., Mita, T., Sakai, T., Nakamura, F. (2005). Effects of polyline simplification of dynamic GPS data under forest canopy on area and perimeter estimation, *Journal of Forest Research*, *10*, pp. 419 – 427.

Tereşneu, C.C. (2021). GIS analysis of area determination methods in forestry. In Scientific papers – series E – *Land reclamation Earth observation & surveying environmental engineering*. X, pp. 311-315

Tereşneu, C.C., Vasilescu, M.M. (2019). Anaysis of the influence of orographical factors on the planimetric accuracy of points determined using GPS in forested areas. In Scientific papers, series E *Land reclamation Earth observation & surveying environmental engineering, 8*, pp. 152-155.

Tereşneu, C.C., Vasilescu, M.M. (2019). The influence of orographic and tree stand factors on the precision of planimetric coordinates determined using GPS equipment in a forest environment. In *Forest and sustainable development*, pp. 177-184.

Tereşneu, C.C., Vasilescu, M.M. (2015). Testing the accuracy of the GPS locations as a pre-requisite of forest cadastre related bordering issues. În Lucrările sesiunii ştiinţifice naţionale *"Pădurea şi dezvoltarea durabilă",* Editura Universităţii Transilvania din Braşov, pp. 356-361.

Tereşneu, C.C., Clinciu, I., Vasilescu, M.M., Biali, G. (2016). Using the GIS Tools for a sustainable forest management. Environmental Engineering and Management Journal, *15(2),* pp. 461-472.

Tereşneu, C.C., Vorovencii, I., Vasilescu, M.M. (2014). Statistical study on the accuracy of determining points coordinates in mountain forests from Bran-Brasov, Romania. *In 14th SGEM Geoconference on Informatics, Geoinformatics and Remote Sensing, Conference Proceedings*, 3, pp. 893-900.

Tereşneu, C.C., Vasilescu, M.M, Hanganu, H., Vlad-Drăghici, H.G., Tamaş, Şt. (2011). A GIS analysis regarding the implications of redetermining forestry geodetic markers positions. *In GeoPreVi 2011, Geodesy present and future.* Bucharest, RO: Conspres Publishing House, pp. 355-364.

Vorovencii (2014 a). A change vector analysis technique for monitoring land cover changes in Copsa Mica, Romania, in the period 1985-2011. *Environmental Monitoring and Assessment, 186 (9),* pp. 5951-5968.

Vorovencii (2014 b). Detection on environmental changes due to windhrows using Landsat 7 ETM+ satellite images. *Environmental Engineering and Management Journal,* 13 (3), pp. 565-576.

Wang, H., Zhan, X., Zhang, Y. (2008). Geometric dilution of precision for GPS single-point positioning based on four satellites. *Journal of Systems Engineering and Electronics*, *19*(5), pp. 1058–1063.

Weilin, L., Buo, X., Yu, L. (2000). Applications of RS, GPS and GIS to Forest Management in China. *Journal of Forestry Research*, *11*, pp. 69–71.

Zhang, H., Zheng, J., Dorr, G., Zhou, H., Ge, Y. (2014). Testing of GPS Accuracy for Precision Forestry Applications. *Arabian Journal for Science and Engineering*, *39*(1), pp. 237–245.

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE IMPACT OF SHEEP WASTE WOOL ON THE ENVIRONMENT

Bianca-Denisa CHEREJI, Florentina-Daniela MUNTEANU

"Aurel Vlaicu" University of Arad, 2 Elena Dragoi Street, 310330, Arad, Romania

Corresponding author email: florentina.munteanu@uav.ro

Abstract

The present study focuses on the impact of sheeps' wool on the environment if it becomes waste. Wool is a keratin-rich by-product that is resistant to degradation, and appropriate management plans for this type of waste should be carefully considered. Some studies consider hydrolyzation of wool, but these processes are implying the use of harsh chemicals for the environment. Therefore, different methods for the valorization of wool waste refer to composting, obtaining fertilizers for using them in agriculture, producing cosmetics, or for thermally-isolating of houses. Special attention is paid to the extraction of keratin from wool, as this is the most valuable by-product resulting from the process of sheep shearing.

Key words: *waste wool, environmental pollution, valorisation, wool keratin, extraction.*

INTRODUCTION

The agricultural economy, today, includes a variety of applied fields, with considerable overlap with the conventional economy, and have an important role in the optimization of the production of food and fiber, as well as in their distribution.
Recently, this research area has registered substantial contributions in economics, econometrics, development economics, and environmental economics while influencing food policy, agricultural policy, and environmental policy.
Scientists in this field have shown that meat consumption is an important source of protein in the human diet, and the prefered is poultry and pig meats, followed by bovine and sheep meats (Montossi et al., 2013).
Compared to other animal species, the costs associated with raising sheep are not necessarily related to the price of fodder crops, such as maize, soybeans, and cereals.
Therefore, independent producers, including family businesses with limited resources, can focus on sheep production. These small businesses are advantageous for raising sheep, as the sheep industry is one of the few types of animal economic agriculture that has not been included in the vertical agro-industry (Montossi et al., 2013; Petek & Marinšek Logar, 2020).
From ancient times, all over the world, the sheep were grown for multiple resources, such as meat, milk, wool, as well as for the obtaining of leather goods. Therefore, it can be considered that the existing species of sheep are multipurpose animals (Erdogan, Seki & Selli, 2020). Sheep also play an important role in many local economies, some of which are focused on organic or sustainable agriculture (Erdogan et al., 2020; Väntsi & Kärki, 2013).
Domestic sheep are relatively small ruminants, which offer a wide range of raw materials, wool being the most widely used and widespread since old times. Especially in developing countries, such herds can become part of subsistence farming.
The life expectancy of a domestic sheep is about 12 years, but only about half of its life can be considered productive because a sheep's productivity usually reaches its peak between the ages of 3 and 6 and begins to decrease after the age of seven (Allafi et al., 2020; Väntsi & Kärki, 2013).
As mentioned previously, wool represents a resource that can be further exploited during the growth of the sheep. This is produced by the small cells located in the skin, called follicles. These cells are located in the upper layer of the skin called the epidermis and push down into the second layer of skin called the dermis, as the wool fibers grow.
Annually, a sheep produces 900 grams to 13.5 kilograms of wool, but this amount depends on breed, genetics, nutrition, and sheer range.

Globally, wool is collected from about 90% of raw wool-producing sheep.
Lambs produce less wool than mature animals. On the other hand, due to their larger size, the amount of wool produced by rams is higher than of the sheep of the same breed or type (Maier, Rajabinejad, & Buciscanu, 2019).
Merino sheep produce most of the world's wool and makeup about a third of the sheep population. Their wool is of high quality, whose fibers are so fine that five strands of them are equal to the width of a human hair.
Nowadays, wool is considered as a by-product of the sheep farm, not only because of its low quality but also because of low prices. As a consequence, wool is incinerated, dumped or sent to landfills. All these practices are impacting the environment and are not sustainable (Montossi et al., 2013).
Recently, several scientific studies are focusing on the improvement of the properties of wool (Assefi Pour et al., 2020; Wang, Shen, & Xu, 2012; Zhang, Millington, & Wang, 2009; Zhou et al., 2020), or on the valorization of this keratin-rich waste (Perta-Crisan, Ursachi, Gavrilas, Oancea, & Munteanu, 2021).
The present study has in attention the evaluation of the impact on the environment of wool, as a by-product, and to identify possibilities of valorization of wool waste.

MATERIALS AND METHODS

For the purpose of the paper, the collected data from the statistical program on the Knoema website (https://knoema.com/) was analysed for evaluating the impact of sheep waste wool on the environment.
The data refers to information on global, European, and Romanian sheep and wool production.
After data collection, the analysis was performed and the impact on the environment was evaluated.
The data analysis and graphs preparation were performed using Microsoft Excel software.

RESULTS AND DISCUSSIONS

European Union has the second-highest world population of sheep. According to the recent statistics collected, it is shown that in 2019 the global sheep production was 1,238,719,591 (Figure 1).

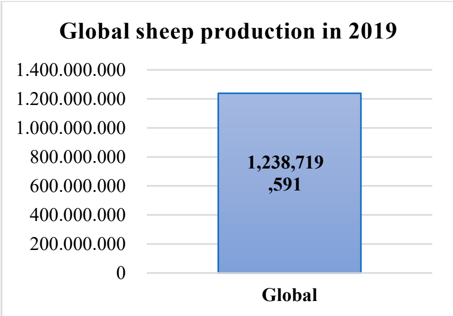


Figure 1. Global sheep production 2019

Table 1 presents the global sheep production from 2019 in comparison to the one in Europe. As observed from the data in Table 1, European sheep production is about 10% of the global sheep production.

Table 1. Global sheep production in 2019

Country	Unit	2019
Global	Global sheep production	1,238,719,591
Europe	Sheep production	127,912,209

Figure 2, presents the sheep production in 2019, and the percentage for European countries.
As shown in Table 2, it can be concluded that the Romanian sheep production stands for about 8% compared to the European one.
Besides the sheep production, the data for the production of wool were also collected and are shown in Table 3. The amount is expressed in tons and is representative for the year 2019, except for Romania, for which the latest reported information on wool is from 2012 (marked with an asterisk,*), in Table 3.

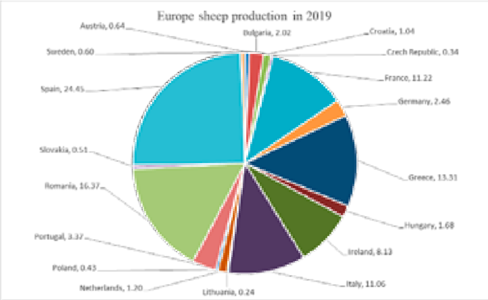


Figure 2. Europe sheep production in 2019

Table 2. Romania sheep production in 2019

Country	Unit	2019
Romania	Sheep production	10,358,700

Table 3. Global, European and Romanian wool production

Country	Amount, Tons
Global	1,719,876
Europe	138,161
Romania	19,713*

Figure 3 shows the percentage of wool produced in different European countries in 2019. Spain ranks first, with 22.87% of the wool produced, followed by Ireland with 14.48%, France 14.33%, Germany 12.45%, Greece 7.42%, Italy 7.28%.

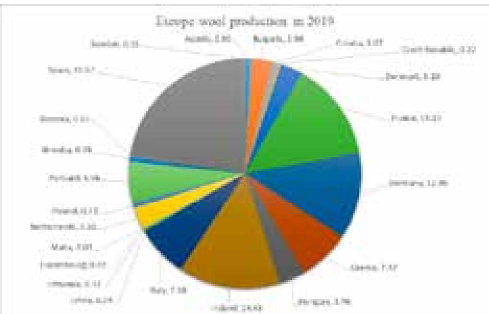


Figure 3. Europe wool production in 2019

As already mentioned, unfortunately, the latest statistics for wool production in Romania were recorded until 2012, because only until that year was the wool production in Romania registered on the Knoema website, but we are convinced that the wool production in the country remained almost unchanged and from 2012 to the present.

The sheep wool as waste

Wool waste management is a problem related to sheep farming, as the main role of sheep is meat production, sheep are cross-bred that are not classified for the production of fine wool (Petek & Marinšek Logar, 2020).

Every year, huge amounts of unused wool are thrown away, incinerated, or simply due to poor legislation, remains on the ground, becoming an environmental pollutant.

Among other solid wastes, wool waste is of growing concern due to the huge volumes accumulated and the difficulties in finding solutions for their efficient management.

Raw wool is sheared wool from sheep, which is the most problematic waste. World crude wool production can only be estimated based on the number of sheep.

Following the waste management terminology, some comments should be made on terms such as by-product, co-product, waste, all of them referring to sheared wool (Eslahi, Dadashian, & Nejad, 2013).

Recent studies on major agro-ecological areas have shown significant differences depending on sheep breed and wool grade.

Table 4. Relationships between the sheep and wool production, data for 2019

Country	Unit	2019
Global	Global sheep production	1,238,719,591
	Total wool produced	1,719,876
	Wool - used	1,032,000
	Wool - waste	688,000

For example, in 2019, the world sheep production was 1,238,719,591 pieces, and the world wool production was 1,719,876 tons, as shown in Table 4.

Huge amounts of organic waste and by-products are generated every year. Waste from the wool textile industry (poor quality raw wool, unsuitable for spinning), is rich in collagen, elastin, and keratin and must be properly managed.

From recent scientific studies, the world wool production annually records enormous amounts of wool fiber (Erdogan et al., 2020; Johnson, Wood, Ingham, McNeil, & McFarlane, 2003; Petek & Marinšek Logar, 2020; Väntsi & Kärki, 2013).

Of this total, between 50-60% is used in the textile industry, depending on the needs and requirements of each factory. The remaining wool is waste.

This problem has become more and more serious for the environment, as sheep wool has become an increasingly serious environmental pollutant (Johnson et al., 2003).

Figure 4. Produced, used and wasted wool, in 2019

This aspect must be taken into account by as many people as possible because the pollution of the environment with wool has become an increasingly worrying aspect, as it pollutes the water, the soil, and the natural decomposition of wool is very difficult to accomplish.

Taking action without consulting a legal basis can have considerable consequences, as in the absence of essential information on how to protect the environment from certain factors that pollute nature, the taken consequences can lead to very complicated situations.

To help minimize the degree of pollution of the three main components of the environment, soil, water, air, there are regulations of the European Commission, which specify in detail the procedures for disposal and use of Category 3 materials, wool being one of the materials of the category specified above.

The current situation is in the context of European regulations with EC Regulation 1069 (2009), ("Commission Regulation (EU) No 142/2011 of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council Laying Down Health Rules as Regards Animal by Products and Derived Products not Intended for Human Consumption and Implementing Council Directive 97/78/EC as Regards Certain Samples and Items Exempt from Veterinary Checks at the Border under that Directive Text with EEA relevance. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32011R0142," ; "European Commission. Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 Laying down Health Rules as Regards Animal by-Products and Derived Products not Intended for Human Consumption and Repealing Regulation (EC) No 1774/2002 (Animal by-Products Regulation); European Commission: Brussels, Belgium, 2009. Available online: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009R1069,").

According to EC Regulation 1069 (2009) Category 3 materials, including wool, must be disposed of as follows:

(a) considered for incineration;

(b) thrown away or renewed by co-incineration;

(c) dumped in an approved landfill after processing;

(d) processed, unless the Category 3 material has been altered by decomposition or deterioration to present an unacceptable risk to public or animal health, through the product concerned, and used:

(e) converted to compost or biogas;

(f) processing to make fertilizers;

(g) field application as fertilizer;

(h) cosmetics.

Following the regulations on safe disposal, wool can not be buried in a farm warehouse or incinerated without authorities' permission.

If unused wool does not become waste according to Regulation (EU) NO. Commission Regulation (EC) No 142/2011 ("Commission Regulation (EU) No 142/2011 of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council Laying Down Health Rules as Regards Animal by Products and Derived Products not Intended for Human Consumption and Implementing Council Directive 97/78/EC as Regards Certain Samples and Items Exempt from Veterinary Checks at the Border under that Directive Text with EEA relevance. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32011R0142,"), the wool may be transited under the following conditions:

(a) enclosed in safe and dry packaging and

(b) sent directly to a plant producing derived used outside the food chain, animal, or to a facility carrying out intermediate operations, under conditions that prevent the spread of pathogens.

If the necessary measures are not taken this situation is a significant problem for the environment because in the long-term affects the ecosystem, the animals, the air, the ground, and all the important structures (Allafi et al., 2020).

Our future studies will focus on the valorization of wool, for the extraction of the keratin. Keratin is the most valuable by-product of sheep shearing. According to the etymology, keratin comes from the Greek language, from the word, *"Keras"* (genitive *Keratos*) which means *"horn"* and the meaning of this word refers to the hard tissues in animals, and the first spelling and formulations were around in the 1850s (Chaitanya Reddy et al., 2021).

Regarding the structure of the wool fiber, the basic substance contained in defatted wool of about 95% keratin and 5% water (Perta-Crisan et al., 2021).

With such a high content of keratin, it is necessary to point out that the dumping of wool will finally lead to the dermatophytes development that has an impact on human health (Anbu, Hilda, & Gopinath, 2004).

Keratin is seen as three-dimensional polymers interconnected by the intermolecular bonds of the amino acid cysteine disulfide and the inter- and intramolecular bonds of nonpolar and polar amino acids, which are responsible for their high stability and distinctive physical properties.

Two main directions have been developed to add value to wool waste, in applications that exploit the properties of the native fiber and in applications that use the keratin biopolymer, extracted from fibers through different methods, but the most valuable should be considered the ones with minimal impact on the environment.

Protein waste, from by-products of the wool textile industry, agricultural sources, poor quality raw wool, hair, and feathers unsuitable for spinning, are important sustainable resources.

Due to their biodegradability and biocompatibility, the recovery of these extremely accessible and inexpensive protein sources, as well as the development of methods for extracting keratin from this waste have been the focus of many studies (Allafi et al., 2020).

Therefore, in recent years, there has been great interest in developing new applications of keratin extract in various fields such as innovative products, biomedical applications, getting and use of fertilizers, environmental applications, cosmetics, biodegradable composites, compostable packaging, medical membranes, and agricultural films, etc.

CONCLUSIONS

Every year, the amount of unused wool is very high, resulting in it being dumped, burned, buried or simply left on the ground, water or landfills, polluting the environment due to inefficient legislation.

Among other solid waste, wool waste has attracted more and more attention due to the accumulation and difficulties in finding efficient management solutions. As it is impossible to avoid waste and is improbable to be minimized considering the population growth, reuse and recycling are still the most viable options for keratinous waste management.

Wool waste will inevitably be produced, which demands the search for a reasonable and cost-effective solution for the management and recycling of solid waste, with social and environmental benefits.

A promising alternative for the valorization of wool is keratin extraction, but of major importance is the use of eco-friendly methods for its extraction. The development of such methods for the valorisation of keratin might open new perspectives for the obtaining of new materials with applications in different industries.

ACKNOWLEDGEMENTS

This work was supported by the Romanian National Authority for Scientific Research MEN–UEFISCDI (grant number PN-III-P1-1.2-PCCDI2017-0569, no. 10PCCDI/2018).

REFERENCES

Allafi, F., Hossain, M.S., Lalung, J., Shaah, M., Salehabadi, A., Ahmad, M.I., & Shadi, A. (2020). Advancements in Applications of Natural Wool

Fiber: Review. *Journal of Natural Fibers, 19*(2), 497-512. doi:10.1080/15440478.2020.1745128

Anbu, P., Hilda, A., & Gopinath, S.C.B. (2004). Keratinophilic fungi of poultry farm and feather dumping soil in Tamil Nadu, India. *Mycopathologia, 158*, 303–309. doi:10.1007/s11046-004-3465-1

Assefi Pour, R., Bagheri, R., Naveed, T., Ali, N., Rehman, F., & He, J. (2020). Surface functionalization of wool via microbial-transglutaminase and bentonite as bio-nano-mordant to achieve multi objective wool and improve dyeability with madder. *Heliyon, 6*(9), e04911-e04911. doi:10.1016/j.heliyon.2020.e04911

Chaitanya Reddy, C., Khilji, I.A., Gupta, A., Bhuyar, P., Mahmood, S., Saeed Al-Japairai, K.A., & Chua, G.K. (2021). Valorization of keratin waste biomass and its potential applications. *Journal of Water Process Engineering, 40*, 101707. doi:10.1016/j.jwpe.2020.101707

Commission Regulation (EU) No 142/2011 of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council Laying Down Health Rules as Regards Animal by Products and Derived Products not Intended for Human Consumption and Implementing Council Directive 97/78/EC as Regards Certain Samples and Items Exempt from Veterinary Checks at the Border under that Directive Text with EEA relevance. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32011R0142.

Erdogan, U.H., Seki, Y., & Selli, F. (2020). Wool fibres. In Ryszard M. Kozlowski & M. Mackiewicz-Talarczyk (Eds.), *Handbook of natural fibres. Volume 1: types, properties and factors affecting breeding and cultivation* (pp. 257-278). Cambridge: Elsevier.

Eslahi, N., Dadashian, F., & Nejad, N.H. (2013). An investigation on keratin extraction from wool and feather waste by enzymatic hydrolysis. *Preparative Biochemistry & Biotechnology, 43*(7), 624-648. doi:10.1080/10826068.2013.763826

European Commission. Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 Laying down Health Rules as Regards Animal by-Products and Derived Products not Intended for Human Consumption and Repealing Regulation (EC) No 1774/2002 (Animal by-Products Regulation); European Commission: Brussels, Belgium, 2009. Available online: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009R1069.

Johnson, N.A.G., Wood, E.J., Ingham, P.E., McNeil, S.J., & McFarlane, I.D. (2003). Wool as a Technical Fibre. *Journal of the Textile Institute, 94*(3-4), 26-41. doi:10.1080/00405000308630626

Maier, S.S., Rajabinejad, H., & Buciscanu, I.-I. (2019). Current Approaches for Raw Wool Waste Management and Unconventional Valorization: A Review. *Environmental Engineering and Management Journal, 18*(7), 1439-1456. doi:10.30638/eemj.2019.136

Montossi, F., Font-i-Furnols, M., del Campo, M., San Julian, R., Brito, G., & Sanudo, C. (2013). Sustainable sheep production and consumer preference trends: compatibilities, contradictions, and unresolved dilemmas. *Meat Science, 95*(4), 772-789. doi:10.1016/j.meatsci.2013.04.048

Perta-Crisan, S., Ursachi, C.S., Gavrilas, S., Oancea, F., & Munteanu, F.D. (2021). Closing the Loop with Keratin-Rich Fibrous Materials. *Polymers (Basel), 13*(11). doi:10.3390/polym13111896

Petek, B., & Marinšek Logar, R. (2020). Management of waste sheep wool as valuable organic substrate in European Union countries. *Journal of Material Cycles and Waste Management, 23*(1), 44-54. doi:10.1007/s10163-020-01121-3

Väntsi, O., & Kärki, T. (2013). Mineral wool waste in Europe: a review of mineral wool waste quantity, quality, and current recycling methods. *Journal of Material Cycles and Waste Management, 16*(1), 62-72. doi:10.1007/s10163-013-0170-5

Wang, X., Shen, X., & Xu, W. (2012). Effect of hydrogen peroxide treatment on the properties of wool fabric. *Applied Surface Science, 258*(24), 10012-10016. doi:10.1016/j.apsusc.2012.06.065

Zhang, H., Millington, K.R., & Wang, X. (2009). The photostability of wool doped with photocatalytic titanium dioxide nanoparticles. *Polymer Degradation and Stability, 94*(2), 278-283. doi:10.1016/j.polymdegradstab.2008.10.009

Zhou, Q., Rather, L.J., Ali, A., Wang, W., Zhang, Y., Rizwanul Haque, Q.M., & Li, Q. (2020). Environmental friendly bioactive finishing of wool textiles using the tannin-rich extracts of Chinese tallow (*Sapium sebiferum* L.) waste/fallen leaves. *Dyes and Pigments, 176*, 108230. doi:10.1016/j.dyepig.2020.108230

https://knoema.com/data/stocks+sheep

https://knoema.com/FAOPRDSLS2020/production-statistics-live-animals-live-stocks-primary-live-stocks-process

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

YEAST - SUSTAINABLE NUTRIENT SOURCE FOR FISH FEED - REVIEW

Corina DUMITRACHE, Constanta MIHAI, Mihai FRINCU

University of Agronomic Sciences and Veterinary Medicine of Bucharest,
59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: mihai_tania@yahoo.com

Abstract

Traditionally, when growing fish, their protein and fat requirements are provided by fishmeal, fish oil, soybeans, etc. More recently, to protect biodiversity and the environment, but also to use sustainable natural resources, researchers in the field are looking for alternative ingredients that can meet the requirements of fish feed. Utilizing the nutritional potential of yeast strains creates sustainable opportunities for new sources of high-quality protein. Thus, the use of yeasts is a solution to improve the economic profitability of aquaculture, as well as to reduce the impact on the environment. This paper focuses on those studies and scientific findings on the use of yeast biomass as a source of quality protein as an alternative to fishmeal and fish oil, as well as soy derivatives in fish feed. Studies have shown that the yeast biomass used in fish feed in various rations has been shown to improve immunity, resistance to bacterial infections, and increase growth rate.

Key words: *yeast, fish feed, aquaculture, sustainable.*

INTRODUCTION

The current trend of human consumption has undergone a huge increase in line with population growth and high living standards. Also, the latest technological advances have increased the accessibility of the population to a wide variety of foods and processed products from all over the world. This also brings disadvantages due to the negative effect brought by the ever-expanding food chain (large transport routes with huge quantities of food to be transported by water, road and air). Thus, the need to shorten the food chain and increase the accessibility of local products is more than obvious. At the same time, due to climate change, the processes of obtaining food must be aligned with the legislative requirements in force at the moment and with the trend imposed by the circular economy promoted by the European Union. The circular economy is a model of production and consumption that involves sharing, reusing, repairing, renovating and recycling existing materials and products as much as possible. In this way, the life cycle of the products is extended. In practice, this involves minimizing waste. When a product reaches the end of its life, the materials from which it is made are kept in the economy whenever possible. They can be used again and again, thus creating additional value.

The coming years will bring great challenges in terms of feeding the growing population with the least possible impact on the environment, especially for areas where major environmental changes are expected - areas prone to drought, forest fires, floods or landslides (FAO, 2017; Suweis, S. et al., 2015; United Nations, 2018).

Yeast is a eukaryotic organism with high nutritional value, which makes it suitable for animal feed (Shurson G.C., 2018).

The manufacturing process of many products depends on the processes triggered and supported by microorganisms. Wine, beer, and bread are just a few examples of yeast-dependent products (Rocio G-P et al., 2011). Studies on the possibility of using bacteria, fungi and algae have been conducted since 1996. Following these studies, quality protein was obtained from microbial sources and was named "Single Cell Protein" - SCP (Anamika Malav et al., 2017). Globally, a total production of approximately 0.4 million metric tons of yeast biomass is estimated, half of which is from the bakery industry (Rocio Gomez-Pastor, 2011).

Yeasts have a beneficial effect on health due to their vitamin content (especially in group B), and have a role in the production of microbial proteins, β-glucans and mannans. Also, due to their high protein content and probiotic properties, yeasts are an option in animal feed, especially if used yeast from different industries is used (Jach M.E. et al., 2015).

In nature, yeasts appear in the form of area-specific communities (in vineyards - wine yeasts; in barley fields appear yeasts that are used in the beer industry, etc.). Due to this fact, there are about 60 types of yeasts, with about 500 of different species, the differences being at the variation in cell morphology, metabolism of different substrates, and different reproduction (Lachance & Starmer, 1998; Stone, 2006).

In aquaculture, fish feed can represent over 50% of the operational cost. As the cost of feed remains high, finding quality feed at a reasonable price becomes a challenge for many commercial farmers. From the perspective of the impact on the aquatic environment, ways are being studied to reduce the number of fish needed for fishmeal and fish oil, as a food source for aquaculture, through feed alternatives such as biomass ingredients from yeast, microalgae or plants.

Sustainability concerns associated with the sources of protein and fishmeal currently in use and herbal flour have necessitated the search for new sustainable ingredients for use in aquatic food. Yeasts have been proposed as sustainable ingredients, mainly due to their potential to capitalize on non-food lignocellulosic biomass as valuable protein resources. Previously, there were extensive studies on the role of yeast cell wall components in modulating fish health responses. However, research on its use as a major source of protein in fish diets is still in its infancy. Yeast cells contain appreciable crude protein (approximately 40-55%) and other bioactive components beneficial to fish growth and development *(*Øverland M. et al., 2013; Hansen et al., 2019; Rawling et al., 2019; Vidakovic et al., 2020).

Yeats have been proposed as sustainable ingredients, especially for their potential to capitalize on non-food lignocellulosic biomass in protein resources. Studies on the role of yeast cell wall components in modulating fish health responses have been performed, however, further research on its use as a major source of protein in fish diets is needed.

MATERIALS AND METHODS

To accomplish this article, a literature review was conducted to investigate new research studies that have been conducted in recent years on the possibility of integrating residual yeast into fish feed. The content analysis of the revised studies aimed at defining the scope of the analysis, the evaluation of the content, in order to finally classify the content in order to highlight the shortcomings in this field and to give a direction for future research. In order to obtain the necessary information, research articles and reviews on topics such as "fish feed with added yeast" and "fish grow rate" were targeted. The databases used were: Web of science, Elsevier, Springer, Scopus and Google Scholar, etc.

RESULTS AND DISCUSSIONS

Studies have been performed on several yeast species (*Saccharomyces cerevisiae, Cyberlindnera jadinii, Kluyveromyces marxianus, Blastobotrys adeninivorans* and *Wickerhamomyces anomalus*, etc.) to determine their protein quality in order to replace fishmeal and soybean meal. It is true that the crude protein content of yeast (40-55%) is lower than that of fishmeal, but it is comparable to soybean meal. It is also known that, compared to fishmeal, there are species of yeasts with amino acid profiles that are limiting factors for different species of fish, such as Atlantic salmon and rainbow trout (Agboola O.J., 2020).

Studies on the replacement of fish feed elements with yeast have been performed. Thus, in 2019 Jingping Guo et al. studied the effect of using a yeast instead of fishmeal and soy flour in shrimp. Different food chains were used in which fishmeal and soy were replaced with yeast in different quantities. It was found that, compared to batches of shrimp fed with conventional feed, batches fed with feed with added yeast showed similar or better values in terms of final biomass, survival, protein retention efficiency and feed conversion ratio. Thus, the results indicated that 180-240 g of yeast/kg of feed can be used effectively in shrimp diets as a substitute for fishmeal or up to 240 g of yeast/kg of feed when replacing soybean meal (Guo J., 2019).

Another study was conducted by A. Estévez et al. in 2021. They performed two experiments to test the effect of partially replacing fishmeal with two by-products from the brewing, yeast and waste grain industry, included in the isoprotein and isolipid diets for gold rush (*Sparus aurata*). They concluded that the addition of up to 30% brewers' spent yeast and 15% spent grain in the feed for fish gave similar results in terms of growth, food conversion and fillet final composition to a feed with fish meal as the main protein source and show a protein digestibility of 89-95%.

In 2020, Hardy Joël Timothée Andriamialinirina et al. studied the effect of yeast hydrolyzate addition on growth, hematology, antioxidant enzyme activities and non-specific immunity of juvenile Nile tilapia (*Oreochromis niloticus)*. They had 3 experiments in which they fed the fish, twice a day, with 3 food recipes (control, with 1% and 3% addition of yeast hydrolysate) during 8 weeks. Their results showed no significant difference in survival among all treatments. The fish fed 1% and 3% yeast hydrolyzate had significantly higher glutathione peroxidase, superoxide dismutase, catalase activity and a significantly lower malondialdehyde level in the liver than the control group, indicating enhancement of the anti-oxidant status.

In 2018, Reda M. R. et al. studied the effect of yeast nucleotide addition on antioxidant activity, non-specific immunity, intestinal cytokines, and disease resistance in Nile Tilapia. They fed the fish with 4 types of food (control, addition of 0.05%, 0.15% and 0.25% yeast nucleotides). From the actual determinations, significantly higher serum protein, albumin, total serum globulin, total WBC counts, and lymphocyte and granulocyte contents were observed in the feed with the addition of yeast nucleotides compared to the control feed. Regarding the survival rate upon exposure to sober Aeromonas, the fish in the fodder groups fed with the addition of yeast nucleotides the percentage of survivals was significantly higher than in the control group. They concluded that the administration of feed with 0.25% addition of yeast nucleotide improved blood proteins, leukocytes, antioxidant activity, non-specific immunity, cytokine gene expression, and disease resistance of Nile Tilapia.

Rosale et al., (2017) in a study of *Sciaenops ocellatus* red road fish, evaluated the effectiveness of dry yeast with different amounts of yeast in feed distributed differently (20-50%) as a partial substitute for fishmeal. After eight weeks, they concluded based on the results obtained that the dry yeast could replace up to 30% and 50% of the fishmeal protein, respectively, and at the end of the test period there were no negative effects on the fish growth performance.

Omar et al., in 2012, tried to highlight the benefits of using a product that contains wheat as a raw material and yeast in different concentrations for protein intake, for mirror carp fish carp *Cyprinus carpio*. At the end of the test period, the yeast-fed fish developed better than the control-fed fish, and no microbial analysis showed any changes between the two variants.

Replacing/supplementing a fraction of fish feed with yeast is a topic that has begun to gain increasing interest. Thus, the growth performance fish on different diets containing some levels of yeast from research trials recent is presented in Table 1.

To determine the effects of adding yeast hydrolyzate, Xiang-Yang et al. conducted a study in 2017 that looked at the growth performance and resistance to stress of juvenile carp Jian (*Cyprinus carpio* var. *Jian*). The researchers formed three variants: one control, one with food with the addition of 3% and 5% hydrolyzed yeast. The fish of the 3 variants were fed for 10 weeks. After the feeding period, it was observed that the addition of yeast hydrolyzate positively influenced weight gain and immunity, the highest values of weight gain were observed in the version with the addition of 3% yeast hydrolyzate than fish fed without yeast. Also, higher values were observed in the protein and albumin content of the fish fed with 3% hydrolyzed yeast compared to the control group. The observations of this study suggest a positive contribution of the addition of yeast

hydrolyzate on growth performance and immunity (Xiang-Yang et al., 2017).
A larger study was performed on the Nile tilapia, *Oreochromis niloticus*. The effects of different ratios of brewer's yeast additives, *Saccharomyces cerevisiae*, on growth performance, body composition and nutrient utilization were investigated. The fish were fed for 51 days, with food with different yeast content (0%, 10%, 15%, 20%, 30% or 40%) instead of fishmeal. The results showed that the body weight tripled for the fed fish up to 20% yeast incorporation. Fish fed with 40% yeast showed lower values, the best option for fish feed was the one with the addition of 15% yeast to promote the growth and efficient use of the diet, without negative effect (Ozório et al., 2012).

Table 1. Effect of different diets containing some levels of yeast on fish growth performance

Yeast	Yeast supplemented (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Daily growth coefficent (% day^{-1})	References
Saccharomyces cerevisiae	0÷5	34.37÷37.78	5.21÷5.39	7.26÷7.52	1.9÷3.75	Xiang et al., 2017
Saccharomyces cerevisiae	0÷40	26.3÷27.4	10.3÷11.9	8.5÷10.2	1.02÷2.08	Ozório et al., 2012
Saccharomyces cerevisiae	0÷100	34.5÷37.07	3.48÷6.2	9.36÷9.89	1.81÷5.64	Solomon et al., 2017
Saccharomyces cerevisiae + Wickerhamomyces anomalus	40÷60	46÷53	1÷6	5÷10	1.1÷1.3	Huyben, 2017
Saccharomyces cerevisiae	0÷2	31÷31.18	-	8.72÷8.86	3.75÷5.16	Essa et al., 2011
Saccharomyces cerevisiae	0÷45	37.31÷37.49	7.92÷7.99	2.93÷3.44	3.08÷4.96	Gumus et al., 2016
Saccharomyces cerevisiae	0÷15	30.28÷31.13	7.55÷7.98	10.46÷11.56	1.08÷2.23	Banu et al., 2020
Saccharomyces cerevisiae	0÷24	37.46÷38.92	8.3÷8.6	6.1÷7.4	3.5÷4.5	Guo et al., 2019
Saccharomyces cerevisiae	20÷50	41.5÷43.1	11.4÷13.0	7.9÷9.9	-	Rosale et al., 2017
Saccharomyces cerevisiae	7.5÷50	35.21÷35.82	6.47÷7.20	9.05÷10.60	2.21÷2.46	Omar et al., 2012

The performance of African catfish *Clarias gariepinus* with dry brewer's yeast food was tested by five diets of increasing soybean meal replacement with 25%, 50%, 75% and 100% dry brewer's yeast and a control without dry brewer's yeast. After 8 weeks of testing, it was found that the protein efficiency ratio and the specific growth rate differed significantly between the groups tested, the specific growth rate decreased with increasing substitution, while the efficiency and utilization of the protein decreased with increasing levels of protein yeast. They concluded that the optimal range of inclusion and replacement of soy flour with brewer's yeast in *C. gariepinus* feed is between 1% and 14% of the dry matter (Solomon et al., 2017).
In a 214-day experiment on the African, Egyptean and hibrid between these catfish *Clarias gariepinus* fed a diet containing about 31% crude protein, they were tested with four diets with dry brewer's yeast, *Saccharomyces cerevisiae*, at levels of 0.0, 1, 0, 1.5 and 2.0%. The results show that the diet with 2% yeast had the highest final body weight, with a growth rate (4.72 g/fish/day), also, demonstrated the benefits of using brewer's yeast as feed additives in hybrid African catfish diets (Essa et al., 2011).
A feeding study was carried out to examine the potential of replacing fish meal with brewer's yeast in the diet of goldfish (*Carassius auratus*). 5 diets were tested, in which the protein from fish meal was replaced with 0%, 15%, 25%, 35% and 45% of yeast, for 84 days. At the end of the experiment, according to results obtained, the weight growth of the fish fed the diet in which the fish meal was replaced by 35% yeast was better than that of the fish fed the other diets. However, the addition of brewer's yeast over 35% of fish meal, this replacement has led to a slight decrease in the growth performance of goldfish (Gumus et al., 2016).
Rubia Banu et al. (2020) studied the effects of baking yeast as an additive in animal feed, to evaluate the growth performance, feed use and disease resistance to freshwater catfish *Mystus*

cavasius. The fish were fed an experimental recipe containing 0.5 to 1.5 g of yeast/kg of food for 75 days. The results indicated that the yeast supplement is a promoter, with a role in improving feed intake, with a promising increase and could be an alternative method to antibiotics for the prevention of *M. cavasius* disease. In addition, significantly higher amounts of crude protein and carbohydrates were obtained, and the feed conversion ratio was also significantly improved in yeast-fed fish.

Yeast is a protein alternative for farmed fish, replacing fish meal without producing major effects on their development. Fish meal has been replaced in different percentages by the yeasts *Saccharomyces cerevisiae* and *Wickerhamomyces anomalus*. Following the study to observe the effects of feeding different species of fish, with different amounts of yeast, it was concluded that the use of yeast can successfully replace between 40 and 60% protein in fish meal, without reducing the growth performance of fish (Huyben D., 2017).

To assess the effects of brewer's yeast, two growth trials were conducted of Pacific white shrimp post larvae and nursed inan indoor recirculating system using diets were different brewer's yeast levels (0, 6, 12, 18, 24%) to replace fish meal and soy flour, in practical shrimp feed. Results indicate that at least 18% yeast can be used to replace fishmeal without reduced growth performance. The results showed that shrimp fed the 0% diet had a significantly higher average final weight and weight gain than those offered with the 24% diet and indicated that 18-24% yeast can be used effectively in diets with shrimp as a replacement for fish meal (Guo et al., 2019).

CONCLUSIONS

The stage of knowledge in the use of yeast in animal feed is increasing. It is obvious that the use of yeast (especially spent yeast) in animal feed is a win-win situation. Globally, there are record productions of spent yeast, which would have a place in fish feed with positive effects on the environment: used yeast will gain added value, it will no longer pollute the environment, and fish are no longer used in the manufacture of fishmeal so necessary in their food. If we also turn our attention to the huge demand for fish products (especially culture products) it is obvious that yeast has its place in fish food.

One of the ultimate goals of protein nutrition is formulation of high quality and yet cost-effective feed with efficient utilization of alternative protein sources.

This review also presents future area of research and emphasize the need for large-scale production of yeast at competitive price to constitute a feasible replacement for fishmeal and soy protein in aquaculture.

ACKNOWLEDGEMENTS

The present work was funded by the University of Agronomic Sciences and Veterinary Medicine of Bucharest – Romania, Research Project 1262/30.07.2021, acronym Feed4fish in the competition IPC 2021.

REFERENCES

Agboola, J.O., Øverland, M., Skrede, A., & Hansen, J.Ø. (2020). Yeast as major proteinrich ingredient in Aquafeeds: A review of the implications for aquaculture production. *Reviews in Aquaculture*, *13*(2), pp.949–970. https://doi.org/10.1111/raq.12507

Banu, M.R., Akter, S., Islam, M.R., Mondol, M.N., & Hossain, M.A. (2020). Probiotic yeast enhanced growth performance and disease resistance in Freshwater Catfish Gulsa Tengra, Mystus Cavasius. *Aquaculture Reports*, *16*, 100237. https://doi.org/10.1016/j.aqrep.2019.100237

Effects of feeding yeasts on blood physiology and gut microbiota of ... (n.d.). Retrieved May 22, 2022, from https://www.researchgate.net/publication/319276232_Effects_of_feeding_yeasts_on_blood_physiology_and_gut_microbiota_of_rainbow_trout

Essa, M.A., Mabrouk, H.A., Mohamed, R.A., & Michael, F.R. (2011). Evaluating different additive levels of yeast, saccharomyces cerevisiae, on the growth and production performances of a hybrid of two populations of Egyptian African catfish, Clarias gariepinus. *Aquaculture*, *320*(1-2), pp. 137–141. https://doi.org/10.1016/j.aquaculture.2011.08.015

Estévez, A., Padrell, L., Iñarra, B., Orive, M., & Martin, D.S. (2021). Brewery by-products (yeast and spent grain) as protein sources in Gilthead Seabream (sparus aurata) feeds. *Aquaculture*, *543*, 736921. https://doi.org/10.1016/j.aquaculture.2021.736921

Gause, B., & Trushenski, J. (2011). Replacement of fish meal with ethanol yeast in the diets of Sunshine Bass. *North American Journal of Aquaculture*, *73*(2), pp. 97–103.

Gomez-Pastor, R., Perez-Torrado, R., Garre, E., & Matall, E. (2011). Recent advances in yeast biomass production. *Biomass - Detection, Production and Usage*. https://doi.org/10.5772/19458

Growth and feed utilization of goldfish (Carassius auratus) fed graded ... (n.d.). Retrieved May 22, 2022, from https://www.researchgate.net/publication/305770363_Growth_and_feed_utilization_of_goldfish_Carassius_auratus_fed_graded_levels_of_brewers_yeast_Saccharomyces_cerevisiae

Guo, J., Qiu, X., Salze, G., & Davis, D.A. (2019). Use of high-protein brewer's yeast products in practical diets for the Pacific white shrimp *Litopenaeus vannamei*. *Aquaculture Nutrition*, *25*(3), pp. 680–690. https://doi.org/10.1111/anu.12889

Guo, J., Qiu, X., Salze, G., & Davis, D.A. (2019). Use of high protein brewer's yeast products in practical diets for the Pacific white shrimp *Litopenaeus vannamei*. *Aquaculture Nutrition*, *25*(3), pp. 680–690.

Jach, M. E., Serefko A., Sajnaga E., Kozak E., Poleszak E., Malm A. Dietary supplements based on the yeast biomass. Current topics in nutraceutical research 2015, 13(2), 83-88, ISSN 1540–7535. (10) (PDF) Dietary supplements based on the yeast biomass (researchgate.net) https://www.journalijdr.com/sites/default/files/issue-pdf/10488.pdf

Kurtzman, C. P., & Fell, J. W. (1998). *The yeasts, a taxonomic study*. Elsevier.

Malav, A., Meena, S., Dube, P., Sharma, M., & Sharma, M. (2017). *A critical review on singl cell protein production using different substrates*. Retrieved from https://www.journalijdr.com/critical-review-singl-cell-protein-production-using-different-substrates

Omar, S. S., Merrifield, D. L., Kühlwein, H., Williams, P. E. V., & Davies, S. J. (2012). Biofuel derived yeast protein concentrate (YPC) as a novel feed ingredient in carp diets. *Aquaculture*, *330-333*, pp. 54–62. https://doi.org/10.1016/j.aquaculture.2011.12.004

Øverland, M., Karlsson, A., Mydland, L.T., Romarheim, O.H., & Skrede, A. (2013). Evaluation of *Candida utilis, Kluyveromyces marxianus* and *Saccharomyces cerevisiae* yeasts as protein sources in diets for Atlantic salmon (*Salmo salar*). *Aquaculture*, *402-403*, pp. 1–7.

Øvrum Hansen, J., Hofossæter, M., Sahlmann, C., Ånestad, R., Reveco-Urzua, F. E., Press, C. M. L., Mydland, L. T., & Øverland, M. (2019). Effect of candida utilis on growth and intestinal health of Atlantic salmon (*Salmo salar*) Parr. *Aquaculture*, *511*, 734239. https://doi.org/10.1016/ j.aquaculture.2019.734239

Ozório, R. O. A., Portz, L., Borghesi, R., & Cyrino, J. E. P. (2012, January 13). *Effects of dietary yeast (Saccharomyces cerevisiae) supplementation in practical diets of tilapia (Oreochromis niloticus)*. Animals: an open access journal from MDPI. Retrieved May 22, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4494266/

Rawling, M.D., Pontefract, N., Rodiles, A., Anagnostara, I., Leclercq, E., Schiavone, M., Castex, M., & Merrifield, D. L. (2019). The effect of feeding a novel multistrain yeast fraction on European seabass dicentrachus labrax intestinal health and growth performance. *Journal of the World Aquaculture Society*, *50*(6), pp. 1108–1122.

Reda, R. M., Selim, K. M., Mahmoud, R., & El-Araby, I. E. (2018). Effect of dietary yeast nucleotide on antioxidant activity, non-specific immunity, intestinal cytokines, and disease resistance in Nile tilapia. *Fish & Shellfish Immunology*, *80*, pp. 281–290. https://doi.org/10.1016/j.fsi.2018.06.016

Rosales, M., Castillo, S., Pohlenz, C., & Gatlin, D. M. (2017). Evaluation of dried yeast and threonine fermentation biomass as partial fish meal replacements in the diet of red drum Sciaenops ocellatus. *Animal Feed Science and Technology*, *232*, pp. 190–197. https://doi.org/10.1016/j.anifeedsci.2017.08.014

Shurson, G. C. (2018). Yeast and yeast derivatives in feed additives and ingredients: Sources, characteristics, animal responses, and quantification methods. *Animal Feed Science and Technology*, *235*, pp. 60–76. https://doi.org/10.1016/j.anifeedsci.2017.11.010

Solomon, S. G., Ataguba, G. A., & Itodo, G. E. (2017). Performance of *Clarias gariepinus* fed dried brewer's yeast *(Saccharomyces cerevisiae)* slurry in replacement for soybean meal. *Journal of Nutrition and Metabolism*, *2017*, pp. 1–8. https://doi.org/10.1155/2017/8936060

Stone, C. W. Yeast products in the feed industry: a practical guide for feed professionals. Yeast Products in the Feed Industry. 2006.

Suweis, S., Carr, J. A., Maritan, A., Rinaldo, A., & D'Odorico, P. (2015). Resilience and reactivity of Global Food Security. *Proceedings of the National Academy of Sciences*, *112*(22), pp. 6902–6907.

Future of Food and Agriculture – Trends and challenges. (n.d.). Retrieved 2022, from https://www.fao.org/3/i6583e/i6583e.pdf

Timothée Andriamialinirina, H. J., Irm, M., Taj, S., Lou, J. H., Jin, M., & Zhou, Q. (2020). The effects of dietary yeast hydrolysate on growth, hematology, antioxidant enzyme activities and non-specific immunity of juvenile Nile tilapia, *Oreochromis niloticus. Fish & Shellfish Immunology*, *101*, pp. 168–175. https://doi.org/10.1016/j.fsi.2020.03.037

UN. The Sustainable Development Goals Report.United Nations, New York, 2018. pp. 40 https://unstats.un.org/sdgs/files/report/2018/TheSustainableDevelopmentGoalsReport2018-EN.pdf

Vidakovic, A., Huyben, D., Sundh, H., Nyman, A., Vielma, J., Passoth, V., Kiessling, A., & Lundh, T. (2019). Growth performance, nutrient digestibility and intestinal morphology of rainbow trout (*Oncorhynchus mykiss*) fed graded levels of the yeasts *Saccharomyces cerevisiae* and *Wickerhamomyces anomalus*. *Aquaculture Nutrition*, *26*(2), pp. 275–286. https://doi.org/10.1111/anu.12988

Yuan, X.-Y., Liu, W.-B., Liang, C., Sun, C.-X., Xue, Y.-F., Wan, Z.-D., & Jiang, G.-Z. (2017). Effects of partial replacement of fish meal by yeast hydrolysate on complement system and stress resistance in juvenile jian carp (*Cyprinus carpio* var. *Jian*). *Fish & Shellfish Immunology*, *67*, pp. 312–321.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

COMBINE HEADER ACTIVE SIDE DIVIDER

Kukhmaz KUHMAZOV, Igor KARASEV, Babken MELOYAN, Navruz NAVRUZOV, Maxim KIRIN

Penza State Agrarian University, 30 Botanicheskaya Street, 440014, Penza, Russia

Corresponding author email: kuhmazov.kz@pgau.ru

Abstract

The headers of modern combine harvesters are mainly equipped with passive side dividers. When harvesting lodged and tangled crops (for example, peas), plant mass accumulates on passive side dividers, the harvested strip is poorly separated from the rest of the field, which leads to a decrease in combine productivity and an increase in losses of the grown crop. To eliminate these shortcomings, the design of an active field divider is proposed, the main working body of which is a disk cutter. The article describes the design of the active side divider, provides a laboratory setup and describes the methodology for laboratory research to justify the optimal design and operating parameters of the proposed divider. The studies were carried out using the theory of multifactorial experiment. The optimization criteria are the completeness of separation of tangled stems and the amount of losses of the grown crop. The completeness of the separation of tangled stems is determined visually and by photographing, and the losses are determined by the method of collecting and weighing crumbled grains. As the results of laboratory studies show, the smallest losses are provided with the number of teeth of the disk cutter z=8 pieces, the frequency of rotation of the disk cutter n=125 min^{-1} and the operating speed of the feed conveyor vp=2.0 m/s. At the same time, the active side divider works stably, the completeness of separation of tangled stems is 100%. the smallest losses are provided with the number of teeth of the disk cutter z=8 pieces, the frequency of rotation of the disk cutter n=125 min^{-1} and the operating speed of the feed conveyor vp=2.0 m/s. At the same time, the active side divider works stably, the completeness of separation of tangled stems is 100%. the smallest losses are provided with the number of teeth of the disk cutter z=8 pieces, the frequency of rotation of the disk cutter n=125 min^{-1} and the operating speed of the feed conveyor vp=2.0 m/s. At the same time, the active side divider works stably, the completeness of separation of tangled stems is 100%.

Key words: *legumes, peas, harvesting, combine harvester header, active side divider, disk cutter, laboratory tests, significant factors.*

INTRODUCTION

When harvesting lodged and tangled leguminous crops, in particular peas, plant mass accumulates on the passive side dividers of the header of the combine harvester, the harvested strip is poorly separated from the main field mass, which leads to a decrease in the productivity of the combine and an increase in losses of the grown crop (Kuhmazov et al., 2019; Meloyan et al., 2021; Meloyan et al., 2019; Shumaev et al., 2020; Shumaev et al., 2021; Yadin, 2009; Patent, 1983).

MATERIALS AND METHODS

To solve this problem, it is proposed to install on the sidewall 1 (Figure 1) with the toe 2 of the combine harvester an active side divider, consisting of a disk cutter 3 mounted on the shaft of the hydraulic motor 4 and an anti-cutting plate 5. The hydraulic motor 4 is fixed with screws 6 to the bracket 7, welded to sidewall of 1 combine harvester.

To substantiate the optimal values of the design and operating parameters of the active side divider, laboratory studies were carried out on an experimental setup consisting of a frame 1 (Figure 2), on which a feed belt conveyor 2, a side frame 3 of a combine harvester with a bar divider 4 and an active side divider are installed, consisting of a disk cutter 5 and a counter-cutting plate 6.

The infeed belt conveyor 2 is driven by a gear motor (ZG1 KMR 71G4) 7 by a chain drive 8. The speed of the infeed belt conveyor 2 is controlled by a frequency converter 9 (DELTA VED-B7).

The drive of the disk cutter 5 of the active side divider is carried out from the motor-reducer (SEV-EVRODRIVE) 10 and V-belt transmission 11. The rotational speed of the disk cutter 5 is controlled by the frequency converter 12 (FCV 103). Switching on and off of the drive mechanisms is carried out from the control panel 13. To the belt of the supply belt conveyor 2 are attached lodged and tangled stems of leguminous crops (peas) 14 with a given lodging. The height of the sidewall 1 of the combine harvester relative to the supply belt conveyor 2 is set in accordance with the requirements for harvesting lodged and tangled grain. To collect lodged and tangled stems and losses, a collection box 15 is located behind the supply conveyor 2.

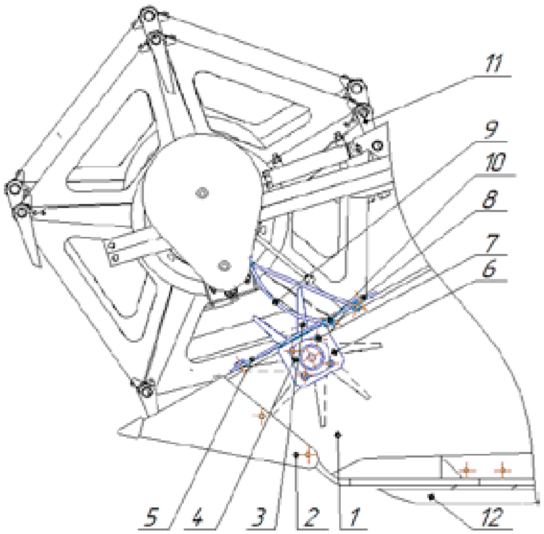


Figure 1. General view of the active header side divider

The counter-cutting plate 5 is fixed to the inclined surface of the sidewall 1 with bolted connections 8. To feed long stems into the cutting zone of the active side divider, a bar divider 9 is provided, fixed to the sidewall 1 of the header with bolted connections 10. Based on the geometric parameters of the sidewall 1 of the combine harvester, the outer diameter of the disc cutter 3 taken equal to 300 mm.

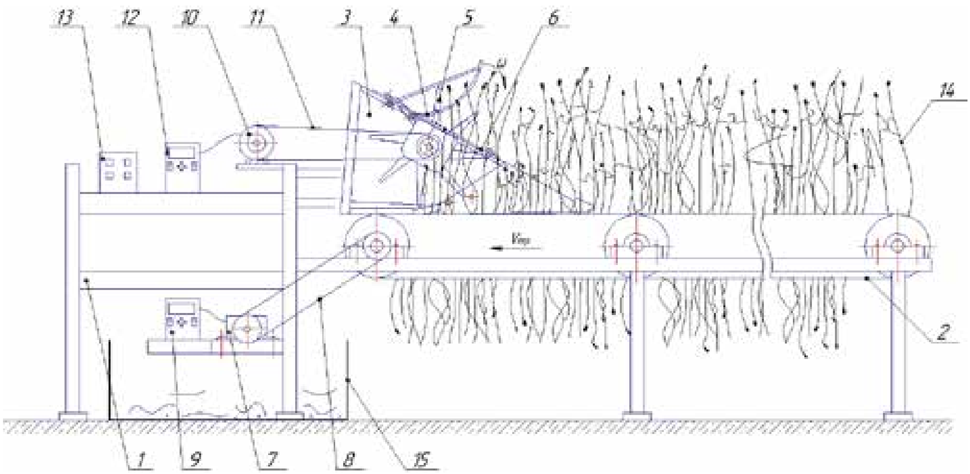


Figure 2. General view of the laboratory setup

The experimental procedure is as follows. On the feed conveyor belt 2, we fix the lodged and tangled stalks of leguminous crops 14 with a given lodging, and on the active side divider we install the tested disk cutter 5. We select the required rotational speed of the disk cutter 5 and the supply belt conveyor 2 with frequency converters. Sequentially, from the control panel 13, we turn on the drive of the disk cutter 5 and the supply belt conveyor 2. When the conveyor belt 2 moves, the lodged and tangled stems with the front part of the sidewall 3 rise and are fed into the cutting zone of the disk cutter 5 of the active side divider. Thus, the harvested mass is clearly separated from the rest of the array. The lost grains are sent by the belt conveyor 2 to the collection box 15.

RESULTS AND DISCUSSIONS

The studies were carried out using the theory of multivariate experiment. As an optimization criterion, the completeness of separation of tangled stems (N, %) and grain loss (G, %) were taken. The completeness of the separation of tangled stems was determined visually and by photographing, and the grains that fell into the collection box 15 are considered losses.

$$G = \frac{m_n}{m_o + m_n} \cdot 100, \% \qquad (1)$$

where:

- m_n is the mass of lost grains, g;
- m_o is the mass of grains remaining in the pods, g.

Based on a priori information and previous studies, three most significant factors were identified that affect the quality indicators of the active field divider: the number of teeth of the disk cutter z, pcs., the rotational speed of the disk cutter n, min^{-1} and the speed of the feed belt conveyor Vt, m /from.

Intervals and levels of variation of significant factors are shown in Table 1.

Table 1. Regulated factors, intervals and levels of their variation

Factors	Designation	Levels of variation			Variation intervals
		+1	0	-1	
Number of cutter teeth, pcs	x_1	12	8	4	4
Disc cutter speed n, min^{-1}	x_2	175	125	75	50
Feeding conveyor speed, m/s	x_3	2.2	1.7	1.2	0.5

After processing the results of the experiments in the Statistica 6.0 program, an adequate mathematical dependence of grain losses behind the header on the design and kinematic parameters of the active side divider of the combine harvester was obtained in coded form:

$$y = 1{,}528 - 0{,}073x_2 + 0{,}142x_3 + 0{,}043x_1x_2 - 0{,}047x_1x_3 + 0{,}397x_1^2 + 0{,}307x_2^2 + 0{,}292x_3^2 \qquad (2)$$

In this case, the multiple correlation coefficient is R = 0.99, which is more than the confidence probability P = 0.95, and F-test = 0.99, showing the degree of density (scatter) of experimental and calculated values, then the adequacy of the obtained mathematical dependence is 99% .

To determine the optimal design and kinematic parameters of the active side divider of a combine header in terms of grain loss, it is necessary to investigate the mathematical dependence (2) for an extremum, that is, to determine the possible maximum or minimum of this dependence as a function of three variables x_1, x_2, x_3.

The MathCAD program was used to determine the extremum and construct the response surface. The mathematical model (2) was differentiated separately for each variable x_1, x_2, x_3.

As a result of further calculations, the grain loss response surfaces behind the header were built when using the active side divider of the combine harvester and their two-dimensional sections (Figures 3, 4 and 5).

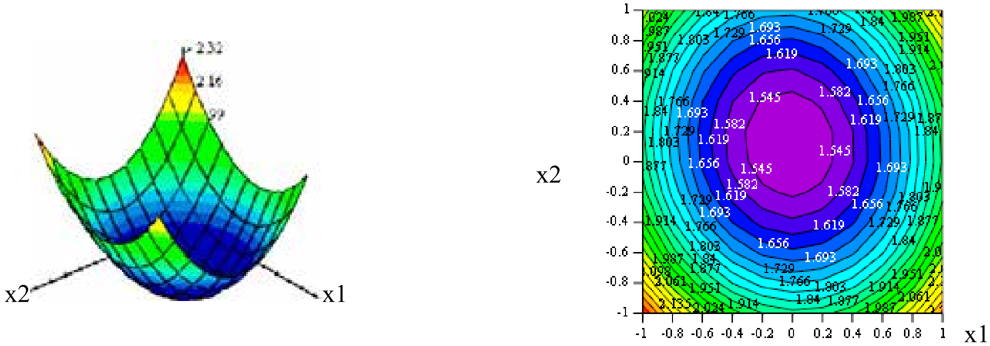


Figure 3. The surface of the grain loss response behind the header and its two-dimensional cross section on the rotational speed of the disc cutter x1 and the number of teeth of the disc cutter x2 at the optimal value of the feed conveyor speed x3

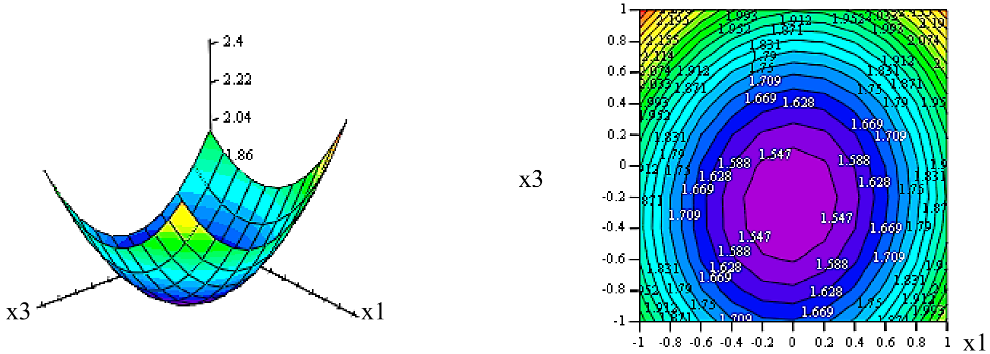


Figure 4. Response surface of grain loss behind the header and its two-dimensional cross-section on the speed of the disc cutter x1 and the speed of the feed conveyor x3 at the optimal value of the number of teeth of the disc cutter x2

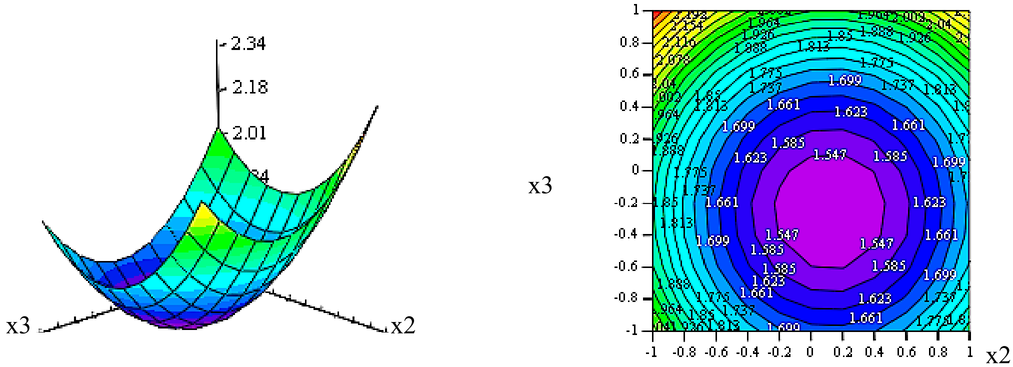


Figure 5. The surface of the grain loss response behind the header and its two-dimensional cross section on the number of teeth of the disc cutter x2 and the speed of the feed conveyor x3 at the optimal value of the speed of the disc cutter x1

CONCLUSIONS

Analyzing the graphical representation of two-dimensional sections, we can conclude that the optimal values of the studied factors are: the rotational speed of the disk cutter n=125.6 min^{-1}; number of teeth of the disc cutter z=8 pcs.; feed conveyor speed (combine working speed) Vtr=2 m/s. At the same time, the side divider works stably, the completeness of separation of tangled stems is 100%.

REFERENCES

Kukhmazov, K.Z. (2019). Side divider of roller and combine headers / K.Z. Kukhmazov, B.M. Meloyan, M.A. Alderbekov // *Agro-industrial complex: state, problems, prospects: collection of articles of the XIV International Scientific and Practical Conference*. - Part II. - Penza: RIO PGAU. 252, pp. 62-64.

Meloyan, B.M. (2021). Methods of laboratory studies of the active side divider of a combine harvester / M.B. Meloyan, M.A. Alderbekov, K.Z. Kukhmazov // *The contribution of young scientists to the innovative development of the agro-industrial complex of Russia*. Penza: RIO PGAU, pp. 112-116.

Meloyan, B.M. (2019). Upgraded side divider for harvesting peas / B.M. Meloyan, M.A. Alderbekov, K.Z. Kukhmazov // *The contribution of young scientists to the innovative development of the agro-industrial complex of Russia: a collection of articles of the All-Russian Scientific and Practical Conference of Young Scientists*. Volume II / Penza State Agrarian University. - Penza: RIO PGAU, pp. 231-232.

Patent No. 1007596 SU, IPC A01D 63/02. *Header field divider*: No. 2925599 Appl. 1980.05.14: publ. 30.03.1983/ Vozovik I.S., Nurullin R.G., Zimagulov A.Kh. - 2 s.: ill. - 4.

Shumaev V., Kulikova J., Kalabushev A., Gubanova A. (2021). Theoretical research on technological process of a stud seed with a furrow-forming working body. *Scientific paper Series A. Agronomy*. LXIV. 1, pp. 154-160

Shumaev V., Kulikova J., Orekhov A., Polikanov A. (2020). Investigation of the grain seeder opener operation for environmental friendly technologies of crop production. *Scientific paper Series A. Agronomy*. 63. 1, pp. 527-532.

Yudin, M.I. (2009). *Experiment planning and processing of its results: monograph* / M.I. Yudin. Krasnodar: KubGAU, 239.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

BIOTRANSFORMATION OF EXPANDED PERLITE IN ORGANIC-LIKE SUBSTRATE BY CHEMOTROPHIC CONSORTIA

Sorin MATEI[1], Gabi-Mirela MATEI[1], Elena Maria DRĂGHICI[2]

[1]National Research-Development Institute for Soil Science, Agrochemistry and Environment Bucharest, 61 Marasti Blvd, District 1, Bucharest, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: so_matei602003@yahoo.com

Abstract

Expanded perlite, resulted by in heating process of a naturally occurring perlite ore, make it an versatile and law-impact material for greenhouse, soil amendment, hydroponics, and which offers advantages such as aeration, drainage, water retention, resistance, reuse. By bioaugmentation with chemotrophic microorganisms that decompose natural / manufactured rocks, expanded perlite can be biotransformed into an organic-like substrate. In the present study, the microorganisms responsible for the biotransformation of expanded perlite into organic-like substrates were analized for compatibility, interspecific synergy (bacteria, fungi, diazotrophs), the organic content by chromatography, humic-like fractions, siderophores, enzyme complex, seed germination and the growing of plantlets. The results reflected the effect of living organisms synergism in the ascendent evolution of organic compounds accumulation. The secondary exomethabolites are involved in humic-like acids fractions formation and biotransformation of the rock, increasing polyphenoloxidase activity, in conversion towards organic-like substrate and in association with colloids. Also, increse in time the siderophores and IAA content in substrate, intensity of physiological and biochemical processess, the seed germination and the plantlets's biomass.

Key words: *expanded perlite, bioaugmentation, biotransformation, organic-like substrate, consortia.*

INTRODUCTION

Bioweathering of natural rocks and biological processes in the rhizosphere improve dissolution due to the intensity of the interactions between bacteria, fungi, diazotrophs, plants and minerals, resulting macro and micronutrients, which are released and accumulate in the substrate solution. Cultivated plants can be important in this dissolution process, acting directly by rooting excretions on the dissolution of minerals in the rock component of the substrate or by supporting in the rhizosphere a biodiversity of microorganisms active in the weathering. These microorganisms act by producing siderophores and organic acids (complexing ligands), exoenzymes, inorganic and organic acids that influence the pH and producing redox reactions, in order to prioritize the process of dissolving minerals in the inorganic substrate. The relatively diverse rhizosphere microflora can also directly promote the weathering activity performed by plants, through a synergistic contribution ensured by their involvement. By using inoculation with bioweathering-specific microbiome, in combination with an inorganic material of natural expanded rocks, used as a substrate, it could favorably influence the fertility, by accumulations of organic and mineral material. The following biological transformations, could improve the quality of the substrate and rhizosphere. Also, the biotransformations can promote the evolution of the initial anorganic substrate chemically fertilized towards generation of an organic-like substrate and cause increasing of the plants.

Expanded perlite has a number of advantages when used in cultures, such as non-toxicity, inert and sterile material, availability of air and moisture, different sizes, availability in different quantities, adaptability to many cultures and culture media, excellent support for immobilization of biocatalysts. Generally, the natural rocks used include a single nutrient with high solubility or slow nutrient release and with multiple nutrients such as expanded perlite, a silicatic rock (Fayiga & Nwoke, 2016). Because not all nutrients are readily available to the plants, the microorganisms in the consortium intervene to increase solubilization and the effectiveness, both depend on the chemical and mineralogical composition of the rocks, characteristics of the substrate, plants requirements and management.

The chemical composition and physical structure of rock from which the substrate is formed, influences the composition of the initial microbial consortium, where C or N-based compounds are missing (Schulz et al., 2013). The ecto- and endolytic microorganisms attach to the rock and promote a greater dissolution of the elements from the mineral particles (Ahmed & Holmström, 2015). The establishment and activity of the consortium on natural rocks require the formation of microbial biofilm. Humic precursors, organic components derived from the secondary metabolism of the inoculated microbiota, increase water availability and improve the decomposition of rocks. The activity of extracellular enzymes associated with mineral or organic colloids emphasizes the biological ability to convert to an organic substrate and to associate with mineral/organic colloids.

Plants grown on anorganic substrate promote the degradation by improving its basic properties, influencing the water dynamics and the cation cycle, in the fertilization solution. Through roots exudates, plants promote the solubilization of minerals, increase the content of organic acids and chemical ligands. In the rhizosphere, microbiome promotes secretion of siderophores and phytohormones which increase absorption/availability of macro-, micronutrients and plant tolerance to stress conditions (Lopez & Bacilio, 2020).

Research has been carried out to bioaugmentating expanded perlite with a complex microbiome capable of inducing the humification of exometabolized organic matter and the forming of sustainable organo-mineral ligands in the anorganic substrate. Also, compared to conventional fertilization practices, the results can positivelly influence the reducing fertilizer dependence.

MATERIALS AND METHODS

Bioweathering and biotransformation of expanded perlite experiment. The bioweathering of expanded perlite and biotransformation processes were analyzed in laboratory experiment, in controled conditions. The bioassay pots with bioaugmented expanded perlite were maintained at constant humidity, temperature 27°C, constant photoperiodic lighting (10 hours of light:14 hours of dark), for 61 days. Further, the bioaugmented perlite was sown with 7 cucumbers seeds/pot, in successive series of 30-45days, for 210days, maintaining constant the parameters. The samplings for assessing the evolution of anorganic substrate, the biotransformations /accumulations level of organic matter were made in 4 phases, respectivelly after bioaugmentation and at 61 days after that, and 2 phases after the succesiv sowing, at 136 and 210 days. Microbial activity developed on the surfaces of expanded perlite were observed under microscope and the evolution of the substrate and plants growth was assess by biochemical and biometrics parameters.

Characteristics of expanded perlite. The general characteristics include the appearance of granular product with porous structure, free of impurities, white-gray color, loose and dry density 80-110 Kg/m^3, water absorption 20-35% by volume, granularity 3-5mm, delivery humidity max 1%, neutral pH, free of organic matter. The chemical composition of perlite contains amorphous silicon dioxide, in the proportion of about 74-77% SiO_2, Al_2O_3 12-15%, Fe_2O_3 1.1-1.6%, CaO 1.3-1.7%, MgO 0.1 0.7%, Na_2O, K_2O 5-8%, product manufactured by PROCEMA PERLIT S.R.L.

Consortium preparation. The compatible isolates of bacteria, fungi and diazotrophes were selected, on the basis of their characteristics, for preparation of consortium. The consortium with selected isolates grown on liquid medium was used for bioaugmentating expanded perlite.

Bioaugmentation of expanded perlite. The sterilized perlite granules, with dimensions between 3-5mm, were inoculated with the microbial consortium in the special growth medium, kept under pressure and placed in 250 g bioassay pots. The constant humidity was maintained by watering with a special water/medium mixture in a ratio of 3:1 and a constant temperature of 27ºC.

Quantification of exopolysaccharides. The amount of exopolysaccharides produced by the microorganisms in the consortium was performed using mixed cultures of 24 hours at 28^0C on a special medium. The samples were centrifuged and the exopolysaccharides precipitated from the supernatant with ethanol. These were kept overnight at 4^0C, centrifuged and the precipitate was collected and dried in a Petri dish at 60^0C. The total amount of exopolysaccharide produced was determined gravimetrically. The dry weight of the polymer was reported in one liter, the results obtained represent the average of 3 replicates for each sample. The comparison of the amounts of EPS was performed by statistical analysis.

Siderophores test. In the chrome azurol S reagent (CAS), the iron is bound to hexadecyltrimethylammonium bromide (HDTMA), the ligand extracts the iron from the dye complex, forms a complex and by releasing the dye, the color changes. Thus, 0.5 ml of supernatant was dispersed on blue agar CAS. Non-inoculated medium was used as reference. The positive test was indicated by changing the color of the microbial colonies from blue to orange.

Indole-3-acetic acid (IAA) test. Plate test with JNFb-agar containing 100μg/mL of tryptophan was used to determine IAA production. Samples containing the culture mixture were collected from the perlite substrate after inoculation and at intervals of 61, 136 and 210 days, introduced into the agar wells, grown in culture at 30ºC, for 24 h. The cultures were removed from the wells and 200 μL of IAA reagent was added to the wells. A pink halo area appeared around the wells, which was measured to include the entire well. The halo-zone diameter was measured at the time of testing. The diffusion potential of IAA is directly proportional to the concentration, and the diameter of the halo-zone is representative for the amount of IAA produced. A larger size of the halo-zone diameter, in a given time, corresponds to a larger amount of IAA.

Polyphenol oxidase test. Samples extracted from bioaugmented expanded perlite were used to make 30 μl aqueous suspensions which were inoculated into 0.5 mm wells in agar containing bromophenol blue (BFB).

Germination test. The filter paper (Ø15 cm) was used for germination, in the clear glass Petri plate (Ø15 cm) containing distilled water to keep the paper moist. The seeds were placed on the germination paper and introduced in the germination plate. The germination process was performed at 27^0C with a circadian rhythm of 8h light and 16h dark. Each variant had three replicates with 15 seeds per plate. The germination test lasted 7 days.

Plantlets biomass. The 14-days plantlets, with true leaves, were harvested and measured for fresh weight, placed in sachets in an oven at 105^0C for 30 min, then dried at 80^0C for 40h, until a constant weight was reached.

Specific circular chromatogram. The chromatogram involves impregnating a cellulosic support with a heavy metal salt ($AgNO_3$), drying and migrating the extracted supernatant in a basic solution, developing after 24 hours.

RESULTS AND DISCUSSIONS

The use in consortium of pioneering organisms, adhering to perlite, allows the penetration of the rock surface and the fragmentation of minerals.

Also, the microorganisms in the consortium involved in the initial weathering of perlite directly or indirectly cause the disintegration of the primary minerals from which plant nutrients result, except for nitrogen compounds biosynthesized by the action of free diazotrophs, followed by dissolution, hydration and formation of secondary minerals, plant growth and development.

The poikilohydric forms of the consortium form a thin layer of biological activity that takes place on or in the first few centimeters of the surface of the perlite rock.

Although considered of little ecological importance, recent studies (Adhikari et al., 2018) have shown species richness, spread in the most extreme climates, with role in important ecosystem functions, in all biomes, so they can highlight the importance of microbial interactions and disturbances in case of efficient management (Figure 1).

Figure 1. Surface penetration, disintegration and initiation of perlite rock fragmentation by consortium microorganisms

The establishment and activity of the bioweathering consortium on perlite requires, as an essential stage, the formation of the microbial biofilm. The growing biofilm contains an extracellular matrix, represented by a hydrated gel that envelops microorganisms, promotes their adhesion to the surface of perlite granules, supports and protects their activity against drying and external factors, allows the concentration of organic acids, siderophores, of chelating compounds and other weathering agents at the mineral / microorganism interface.
The ecto- and endolytic microorganisms in the consortium attach to the perlite and promote a greater dissolution of the elements in the mineral particles. Also, the biofilm formed in the perlite substrate allows the manifestation of the synergistic effect, regarding the dissolution of minerals, of the different microorganisms in the consortium, of the biological processes, favoring the microbial interactions and the intercellular communication. Biofilms are considered important in the geochemistry of rock bioweathering, and due to recent research indicating their protective roles, highlighted by maintaining the integrity of damaged rock surfaces, by forming rock cover structures (Jackson, 2015; Goswami et al., 2016; Zaharescu et al., 2020). The attachment of microorganisms and the promotion of the dissolution of mineral elements were evidenced in the research studies conducted by Ahmed & Holmström (2015).
The carbon produced is supplied by the exometabolites of the microorganisms in the consortium, by the photosynthetic symbiote and through it the development of microorganisms is promoted but also the secretion of many organic acids, which initiate the intense process of bioweathering.
Generally, biodegradation of rock substrate directly influence water infiltration capacity, substrate moisture, depletion of nutrients, and will determine the availability of water for plants, for optimal growth.
Therefore, the efforts of bioweathering and biotransformation, conservation of the microbiome, use of microorganisms in the perlite substrate and rhizosphere, to stimulate plant roots, could improve the structure of the substrate by aggregating it by microorganisms producing exopolysaccharides in the consortium.
Aggregation involves, in the basic concept, the incorporation of mineral particles with organic and inorganic materials, for the formation of secondary particles.
The dynamics of the process can be influenced by factors such as substrate type, plants, mineral composition, organic carbon concentration, activity of microorganisms, ion exchange, nutrient reserves in the inorganic substrate, humidity and management.
Exopolysaccharides protect the microorganisms in the consortium from a variety of stressors, protect cells from antimicrobial compounds, antibodies, bacteriophages, or ensure the adhesion of other microorganisms or plant tissues.
The mechanism of interaction of microorganisms in the substrate associated with the stability of aggregates and the supply of nutrients to crops is little known.
By using exopolysaccharide-producing microorganisms to aggregate perlite particles, intense activity in the plant rhizosphere is ensured to obtain exopolysaccharide biofilms (Figures 2 and 3).
EPS produced by consortium microorganisms can help to achieve high cell densities, useful in bioweathering and biotransformation, cell-cell recognition and resistance, in case of non-specific and specific host defense.
The presence of the EPS layer around the colonies has an effect on intra-, intercellular diffusion, prevents the access of toxic compounds (toxic metal ions) due to flocculation and their ability to bind metal ions in solution.

Figure 2. EPS layer around the microbial colonies

Figure 3. Microbial biofilm on expanded perlite granules, under the action of the consortium

Thus, through it, increase the immobilization of Pb^{2+} and Cu^{2+} ions, with ecological implications, help organisms to adhere to rock surfaces, can be flocculants that protect hydrophobic membrane areas but also the transitions between hydrophobic and hydrophilic areas.

Consortium biosynthesized EPSs can also act as extracellular storage polymers, in substrate where no other organic source has been identified, such as those encountered in the early stages of expanded perlite. The role of EPS in cellular protection is extensive and could includes bacteriophages, protozoa, phagocytosis processes, anti-cytotoxic activity and plant infection.

The microbial cells in the consortium produce EPS, respectively homo- and hetero-EPS, depending on the monosaccharide content, which they secrete in the rock substrate, through the action of extracellular enzymes. Biosynthesized EPS ensures resistance to various stressors and bacteriophage attack, toxic metal action, dehydration, the role of coating agents, conjugation, but also, matrix for microflora (Grosu-Tudor & Zamfir, 2014).

The screening performed at intervals of 61, 136 and 210 days after the bioaugmentation of the expanded perlite showed the presence of polysaccharide material, in different quantities, which increase progressively, until the end of the experiment.

These results are supported by data from the literature, which showed dependence of the amount of EPS produced by a number of selected microorganisms, on the composition of the substrate, the microbial strain, the nature of the source and the growing conditions, respectivelly temperature, pH, oxygen. (Patel et al., 2013).

The experiment examined the ability of the selected consortium to produce exopolysaccharides in the perlite substrate at certain time periods.

Under the influence of controlled experimental parameters at 61 days after expanded perlite inoculation, EPS yield of consortium strains was 47.5 mg/l EPS (Figure 4 b).

EPS production increased under second cucumber culture at 136 days after bioaugmenting expanded perlite, to 84.7 mg/l EPS and respectivelly, at 144.3 mg/l EPS, at the end of the experiment (Figure 4 c and d).

Figure 4. a) EPS in bioaugmented expanded perlite, b) EPS produced at 61 days, (c) EPS at 136 days under plants culture (d) EPS at 210 days under plants culture

The data are consistent with the observations of other authors who point out that the production of EPS is dependent on the microorganisms tested, but also on environmental factors. Thus, Madhuri & Prabhakar (2014) highlighted the dependence of the amount of EPS on the microorganism species. Vamanu et al. (2007) highlighted the influence of pH, carbon source and temperature on the formation of EPS in probiotic strains and the biosynthesis of EPS could be considered a mechanism of microbial self-protection against unfavorable conditions. (Lin & Chang Chien, 2007).

Living microorganisms from the expanded perlite need iron for vital processes and for cell growth.

They receive iron by direct diffusion through cell membranes or by the synthesis/secretion of siderophores, avoiding its lack of bioavailability, manifested in low concentrations of Fe (III), below 10^{-18} M.

Basically, the role of siderophores biosynthesized by the consortium is bringing insoluble iron from the inorganic substrate into the cell.

Siderophores, in addition to affinity for Fe (III), also form complexes with other metal ions, such as Fe^{2+}, Mg^{2+}, Ca^{2+} and Al^{3+}, which can be bioweathered from the expanded perlite substrate by the microorganisms from the consortium. In the competitive medium of bioaugmented expanded perlite, there is initially a deficiency in soluble iron and, to ensure the survival and growth of plants and of the microbial isolates from the consortium, iron increases its availability in the substrate and in the roots zone of cultivated plants. The intensity of siderophores biosynthesis increased over time, starting from their absence in the inorganic substrate of expanded perlite, after inoculation of the consortium (Figure 5a) and until the evidence of a generalized biosynthesis of siderophores by the microbiome developed in the substrate, at the end of the experimental period (Figure 5d).

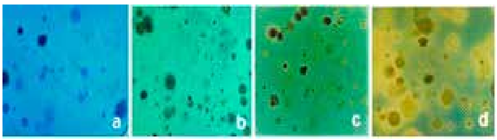


Figure 5. a) Siderophores presence in bioaugmented expanded perlite, (b) siderophores after 61 days, (c) siderophores after 136 days under culture, (d) siderophores after 210 days under culture

Iron is essential for the processes of respiration and DNA synthesis, which is why most microbial species have developed a high-affinity iron (Fe^{3+}) transport system, based on siderophores, to avoid the very low solubility of these ions at neutral pH.

Soluble Fe^{3+} complexes can be taken up by active transport mechanisms by microorganisms/plants, become available to microbial cells by dissolving these ions, by siderophore. Also, the siderophores produced inhibit the colonization of roots by plant/ pathogens (Alexander & Zuberer, 1991; Khan et al., 2006).

In the substrate, siderophore functional groups have interacted with iron through negatively charged oxygen atoms, but sometimes distortions can occur when they can be replaced with nitrogen, potassium or magnesium from bioweathering of the substrate, which reduces the affinity for Fe(III).

The natural siderophores in the substrate can be arranged in a superior chelating structure, highlighted over time by the generalization and intensification of their biosynthesis (Figure 5c and 5d).

Possibly, over time, hexadentate and tetradentate structures become predominant, more stable, and less labile, as the iron-bound ligand causes the entropy to change. In addition, in the substrate, the aqueous solution causes the siderophores to surround the natural complex $Fe(H_2O)_6^{3+}$, and the water to be completely replaced in a favorable manner, from an entropic point of view. Also, for the formation of the iron complex, siderophores could donate more oxygen atoms, so they form weak field donors (σ and π). The combination of complex geometry and configuration it possible may not generate enough energy to stabilize the ligand field, either due to ligand dentition or multiple interactions between strong acids and bases. A negative charge corresponds to the accumulation of bases such as catecholates/carboxylates which, due to negatively charged oxygen atoms/functional group, can perform closer interactions with Fe (III) in the perlite substrate or can achieve a higher negative charge density, respectively a higher affinity for iron, shown in Figure 5c-5d.

Also, the Fe(III)-siderophore complexes that form in the inorganic substrate could be sensitive to pH values, so that in a substrate with a low pH, intense competition for siderophores can be triggered, due to the increase of the proton concentration solvates or free iron.

Immediately after the inoculation of the consortium in the substrate, it was observed that the test applied to the samples collected from the bioaugmented expanded perlite did not allow the highlighting of a pink area around the well, which suggested the absence of IAA in the substrate. Over time, the samplings carried out at different time intervals, revealed changes in the diameter of the area with pink halo.

Thus, 61 days after inoculation of the expanded perlite, the diameter of the pink halo was 2 mm. In the case of the other samples (at 136 and, respectively 210 days), the additional influences mediated by the succesiv cultivated plants intervene, also. After the evaluation of the IAA synthesis capacity of the consortium, pink areas around the cavity were highlighted, with various diameters, respectively by 4mm and 7mm, probably due to the higher amounts of IAA produced by the consortium in the perlite substrate (Figure 6).

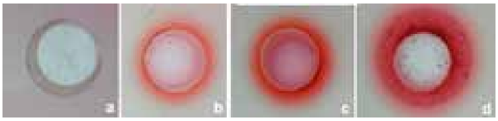


Figure 6. IAA diffusion in plate assay. a) no IAA synthesis in bioaugmented expanded perlite, b) IAA halo-zone after 61 days to the bioaugmented expanded perlite, c) IAA halo-zone after 136 days under plants culture, d) IAA halo-zone after 210 days under plants culture

Selected consortium produce indole-3-acetic acid (IAA) to solubilize different toxic metal (Al) containing minerals and for metal tolerance. In addition, the metal tolerance /solubilizing activities of consortium, vary for different minerals/microbial species in a inverse report between solubilization and the concentration of metal. În experiment, the highest IAA concentration was obtained after 210 days from the perlit bioaugmentation, under plants culture.

The germination index, determined at the established time intervals, was 23.7% higher at 61 days than at the control, after germination. In particular, the germination rate at the end of the experimental period (210 days) was 66.2% higher than that obtained in the perlite substrate before the introduction of the cultures (61 days), and respectively by 25.7% higher than that obtained in the bioaugmented perlite substrate, for perlite under the second culture (136 days).

IAA production varies between different species and is influenced by growing conditions, growth stage and substrate availability. Many plant-associated organisms produce related auxin and indole compounds. Microorganisms living in the substrate and rhizosphere of plants use rich sources, from the substrate and from root exudates, biosynthesize and release auxins, as secondary metabolites.

Silicon (Si) is abundant in the perlite substrate, in the form of insoluble silicates, and is a quasi-essential element for plants, which can be absorbed only in the soluble form of monosilicic acid. Due to the bio-weather of silicate rocks, its production depends on temperature, pH, redox potential, water content and the level of microbial activities. Numerous studies have shown the role of indole-3-acetic acid (IAA) and organic acids produced by silicate solubilizing microorganisms. IAA, a product of L-tryptophan metabolism, is produced by the consorțium microorganisms, not only by plants (Apine & Jadhav, 2011).

In the experiment, it was observed that priming with IAA, derived from microbial biosynthesis and root exudation, improves seed germination, by regulating the content of IAA, and growing seedlings. The favorable response of these parameters depends on the species and the optimal concentration of IAA present in the substrate. The results also showed that by showing with IAA, germination can be regulated positively, by the synthesis of favorable phytohormones and negatively, by inhibiting unfavorable phytohormones (ABA).

During the germination stage, the IAA priming caused an increase in weight and water absorption, but the dry weight remained constant. After analyzing the effect of seed priming on seedling growth, it was concluded that different chemicals can induce seedling growth through different mechanisms. Thus, as in melatonin initiation, IAA increased the weight of the plant root under stress, possibly by counteracting the effects on metabolites and by increasing the antioxidant capacity (Bahcesular et al., 2020).

Researches showed that the germination rate improves significantly after initiation with IAA. Our results are in line with previous researches on seed priming with chemicals and promoting germination. Thus, the priming of

Cuminum syminum L. seeds with polyethylene glycol favors the germination of seeds in conditions of temperature and water stress, and the priming of *Nigella sativa* L. seeds with KH_2PO_4 increased the vigor of the seeds (Min et al., 2014; Seyyedi et. al., 2015; Espanany et al., 2016).

In addition, additional silicon priming could improve biomass and plant yield by reducing oxidative stress (Hussain et al., 2019). Also, results were obtained regarding the priming with melatonin in corn, in order to improve the germination of the seeds under low thermal stress. The selected consortium which can produce indole-3-acetic acid (IAA) could solubilize and different toxic metal (Co, Cd, Cu, Pb, Zn) containing minerals, or induce metal tolerance.

Microorganisms are able to produce IAA in the liquid medium, from the expanded perlite substrate, obtaining the highest IAA yield after 210 days, under plants culture. So that, by the biological activity of consortium, IAA produced can stimulate increase seed germination, hypocotile elongation and root length of plants.

Also, the metal tolerance/solubilizing activities of consortium possibly vary, for the different minerals or microbial species, in a inverse report between solubilization and concentration of metal, aspect that could sugest a low tolerance to metals.

Different types of microorganisms, according to recent studies, are involved in the solubilization of the unavailable form of Si (Li et al., 2018). Mineral and rock bioweathering are some of the beneficial processes in which microorganisms play an important role in promoting dissolution. Different types of rocks are susceptible to bioweathering and may also include siliceous rocks (silicates, silica, aluminosilicates). So that, microorganisms form geochemical agents and act on insoluble forms of Si, transforming them into soluble orthosilicic acid, usable and available to plants (Sheng et al., 2008).

Phenotypes of *Cucumis sativus* L. seedlings, after the germination test of IAA-treated seeds, were investigated 14 days after emergence. The characteristics of *Cucumis sativus* L. seedlings, determined at the beginning of each established time interval, according to Table 1, allowed the evaluation of some biometric parameters, of plant growth and development under experimental conditions, following the analysis which found that some parameters such as hypocotyl length, roots length, fresh biomass and dry biomass of plants increased.

Table 1. Biometric parameters of *Cucumis sativus* L. plants, under experimental conditions

Time periods	Hypocotyls length (cm)	Root Length (cm)	Biomass Fresh weight (g/plant)	Biomass Dry weight (g/plant)
Initial	1.46 ± 0.21 d	2.28 ± 1.07 d	0.328 ± 0.025 d	0.085 ± 0.004 d
61days	2.76 ± 0.32 c	3.12 ± 1.32 c	0.512 ± 0.032 c	0.102 ± 0.006 c
136 days	3.28 ± 0.33 b	6.48 ± 1.44 b	1.057 ± 0.045 b	0.135 ± 0.006 b
226 days	5.37 ± 0.39 a	9.12 ± 1.52 a	1.262 ± 0.052 a	0.147 ± 0.007 a

Values are mean ± standard deviation (SD), Letters behind the values in the same column indicate significant difference at different periods of times, $p < 0.05$.

Based on the direct and indirect action of microbial biosynthesized IAA and IAA from roots exudates, some plants parameters have improved, which over time have induced significant differences between the values determined for the same parameters. The direct /indirect action of microbial biosynthesized IAA and from roots exudates, improves the level of microbial activity and the organic content of the perlite substrate. It is possible that *Cucumis sativus* roots exudates released in expanded perlite have the ability to restructure microbial communities, reduce substrate infestation, significantly reduce phytopathogen favorability and improve microbial activity.

IAA priming could have a positive impact on seedling germination and growth. Compared to germination, biomass, including fresh and dried weight, accumulated significantly compared to the control, especially at the end of the experiment, because the initiation of IAA activated photosynthesis, also.

Given the multitude of processes in which biosynthesized exoenzymes by microorganisms consortium and plants may be involved, the assessment of the presence and activity of these exoenzymes, respectivelly of the polyphenol oxidases in the substrate is important because it allow microorganisms to interact effectively with the expanded perlite substrate, on direct contact level with the anorganic substrate.

Also, polyphenol oxidases as exoenzymes, causes degradation of the plant organic matter, that begins to accumulate after the first culture, catalyzes fragmentation of high molecular

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

weight biopolymers from the environment into simpler forms that can then be easily assimilated and used, helps the microorganisms în metabolisation/using the fractions and subfractions of organic matter, intervene in the processes of stimulating the growth/microbial activity in the substrate.

Qualitative tests on the presence and activity of polyphenol oxidase were performed at the same time intervals established for the initial phase, respectively 61 days after the bioaugmentation of the expanded perlite, when the diameter of the halo was Ø=0.92mm. Under successive cultures, the level of enzyme activity increases and determines at 136 days a halo diameter of Ø=1.24cm and at the end of the experiment Ø=2.3cm (Figure 7).

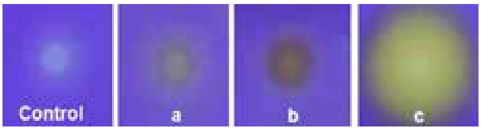


Figure 7. a) Polyphenol oxidase activity in bioaugmented expanded perlite, after 61 days, b) polyphenol oxidase activity after 136 days under plants culture, c) polyphenol oxidase activity after 226 days under plants culture.

The yellow halo indicates the presence of polyphenol oxidases in the substrate, highlighted by the change from blue to yellow. The diameter of the yellow halo could be a semi-quantitative measure of the level of enzyme activity. Also, due to the directly proportional relationship between the amount of enzyme present in the sample and the size of the halo, could determine the biosynthesis and presence level in substrate. The ever-increasing level of polyphenol oxidase activity also reflects the fact that there are favorable conditions for the accumulation and intensification in the perlite substrate of enzyme-mediated biochemical processes.

The microorganisms in the consortium and the plants used released extracellular polyphenol oxidases into the perlite substrate, which possible are involved in the formation of organic compounds, secondary metabolites, melanic protective compounds. The exoenzymes intervene in the biosynthesis/ degradation of organic matter and humus, in obtaining carbon and nutrients, in attenuation of the toxicity of phenolic molecules and metal ions from the anorganic substrate and in antimicrobial defense. Also, the exoenzymes biosynthesized and released into substrate are involved in the oxidation of a wide range of small molecules, including prehumic or humic, in the formation of stable radicals, in the polymerization of soluble phenols and in humification, function as proteolytic/ chitinolytic enzymes or are able to extract nitrogen from humic complexes.

The specific circular chromatograms highlight the evolution and structure of the organic matter biosynthesized by the microbial consortium and by the root exudates of the seedlings in the expanded perlite.

Specific chromatography also provided the opportunity to distinguish different characteristics, from the point of view of expanded perlite or from the point of view of the consortium, as well as indications of the progress of humification, the likely effect of bioweathering and biotransformation induced by the consortium on the substrate.

Biosynthesis and biotransformation of organic matter can also be considered effective in retaining carbon, because it, in dissolved form, will react rapidly with minerals in the substrate for stabilization. Thus, the high values of pH in the substrate, associated with those of ammonium, potassium, sodium, bring the necessary solubility to the synthesized organic matter.

The specific circular chromatograms made it possible to obtain information on the evolution of the biological quality of the bioaugmented and cultured substrate, through analytical separations and the formation of images whose pattern of uniformity, shape, size, color, texture indicates soil health, vitality, fertility, intensity of biotic activity, substrate conditions, complexity of organic matter and the presence of stable humus (Figure 8).

The images of bioaugmented expanded perlite assay pots, correspond to a-d chromatograms images, showed in Figure 9 a-d.

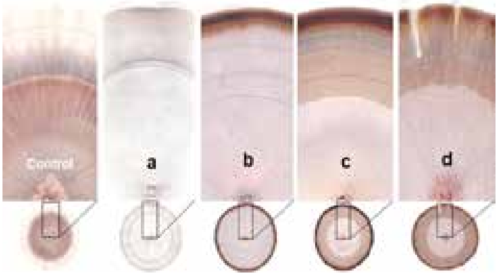


Figure 8. Control-standard humic acid chromatogram and a) organic matter in bioaugmentated expanded perlite, b) organic matter accumulation în expanded perlite after 61 days of consorțium influence, c) organic matter accumulation în expanded perlite, after 136 days of consorțium and plants influence, d) organic matter evolution în expanded perlite, under consorțium and plants influence, at 210 days

In the peripheral area, chromatogram a highlights organic matter content under bioaugmentated expanded perlite with consortium. Enzymatic activity is reduced to 61 days (chromatogram b) since the introduction of the consortium, without a nutritional variety, without stable structures over time, and relatively weak microbial activity, not diversified compared to 136 days (chromatogram c), where the activity appears more diversified and the enzymatic activity becomes more intense, the nutritional variety is constantly growing and humic structures begin to stand out. At 210 days (chromatogram d) enzymatic processes appear relatively diversified and more intense, there is nutritional variety and the tendency to accumulate organic melanic structures, more intense microbial activity, but insufficiently diversified.

The external area is of particular importance in the analysis of chromatograms. The standard humic acid chromatogram was used as a control for highlighting the main fractions of structured humic compounds, condensed, highly mobile, migrating compounds.

The strong coloration and thickness of the outer area suggest an intense biosynthesis of mobile organic precursors. At the same time, through the processes of biotransformation, after a period of time, the changes can be observed on the chromatogram by the loss of mobile compounds, which indicates an association with other compounds, the formation of complexes with inorganic constituents and therefore more insoluble.

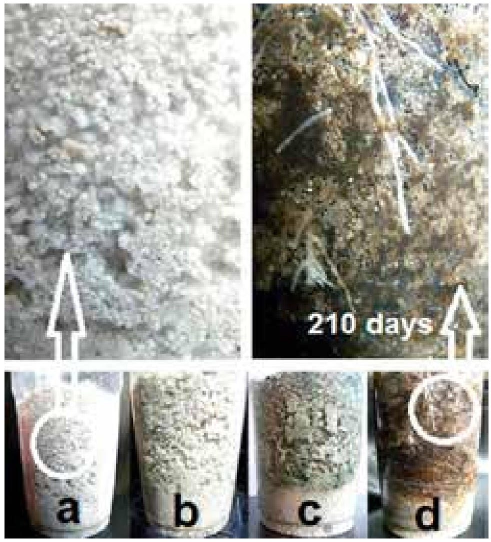


Figure 9. Bioassay pots with (a) bioaugmented expanded perlite; b) bioaugmented expanded perlite, after 61 days; c) bioaugmented expanded perlite and plants influence, after 136 days, and d) after 210 days

If the relative concentration of fulvic compounds is high in the extract, a thick front of motion appears, forming a dark outer zone, as seen in chromatograms b and c. Due to the biotransformation processes, the proportion of these mobile compounds changes. It becomes considerably lighter, more fragmented, or may disappear altogether if the mobile compounds are missing. Also, few humic substances are formed, mainly acidic; nutrient content and low organic content, colloidal substances are present (chromatogram a). Complex humic substances are formed, mainly in chromate-gram d, more than in chromatograms b and c. More intense accumulations of humic sub-stances appear in chromatogram d. The presence of colloidal substances increases, the acidic character of the organic material is progressively reduced from chromatogram b-d.

The intermediate zone of the chromatograms progressively shows an increase of the mineral diversity relatively integrated in the organic material, a rich content of protein material, their structural complexity increases, and the level of microbial activity is highest in the chromatogram d. Intermediate development processes are observed with tendencies of accumulation and integration in the substrate of the little organized material. There is a good connection between the different components, aggregates are present in the solution. There are still unfavorable conditions and deficiencies. Accumulations of humic compounds appear in chromatograms c and d but are not sufficiently integrated (chromatogram c). The microbial activity increases in intensity, the tendencies of accumulation and integration of the organic material synthesized in the substrate are maintained (chromatogram d). There are no differences between chromatograms c and d regarding the presence of aggregates in the solution, and from the analysis of the uniformity model and the chromatogram texture, the existence of unfavorable conditions is observed. The model appears more evolved in chromatogram d, without major separations or sub-average parameters of the soil processes. In the expanded perlite substrate, intermediate development processes are highlighted, a weakly structured organic material appears, characteristics of a healthy evolution state, more intense releases of molecular aggregates in chromatogram c. Unlike the situation in chromatogram b, in chromatograms c and d no more signs of such intense mineralization appear, so that the equilibrium can be considered to be in favor of organicization. The interactions of organic carbon are more intense with polysaccharide complexes and with the diversified mineral component in chromate-gram d. In the inner and central area, biotic conditions become predominant in chromatograms c and d, and small non-flocculating inorganic molecules appear in the solution. There are increased amounts of accessible salts, of nitrogenous compounds, which, in comparison, have a higher weight in the chromatogram d over time.

CONCLUSIONS

The ecto- and endolytic microorganisms from consortium attach to the perlite and promote surface penetration, disintegration and initiation of perlite rock fragmentation.

The biofilm formed in the perlite substrate allows the manifestation of the synergistic effect and favoring the microbial interactions and the intercellular communication.

The selected consortium produced exopoly-saccharides in the perlite substrate, under controlled experimental conditions, from 47.5 mg/l EPS at 61 days after bioaugmentation to the 144.3 mg/l EPS under plants culture.

Siderophores biosynthesis increased in intensity all over the time, starting from a low presence after inoculation of the consortium, to a high presence, after succesive plants cultures, at the end of the experiment.

Substrate bioaugmention produced IAA, so that at 61 days after inoculation, the diameter of the pink halo was at 2 mm and under additional influences mediated by plants, the higher amounts of IAA produced a pink halo of 7 mm diameter.

The germination index was 23.7% higher at 61 days than at the control and at the end of the experiment was 25.7% higher than that obtained in the perlite substrate, under the second succesion of plants culture.

IAA priming had a positive impact on plants growth, so that the biomass (fresh and dried) accumulation increased significantly compared to the control, especially at the end of the experiment.

The presence and activity of polyphenol oxidase tested at 61 days after the bioaugmen-tation of perlite, was highlight by the yellow halo with Ø 0.92 mm and under the successive plants cultures, the level of enzyme activity increased to Ø 2.3 cm, at the end of experiment.

The chromatograms highlights organic matter content evolution under bioaugmentated expan-ded perlite, a nutritional variety in a constantly growing, the accumulation of organic structures, intensification of microbial activity but insufficiently diversified and prehumic and humic structures begin to stand out.

ACKNOWLEDGEMENTS

This research work was supported by the Romanian National Authority for Scientific Research and Inovation by Research Programme NUCLEU, the Project PN 19 34 04 01 /2019.

REFERENCES

Adhikari, P., Shin, M.S., Jeon, J.Y., Kim, H.W., Hong S., & Seo C. (2018). Potential impact of climate change on the species richness of subalpine plant species in the mountain national parks of South

Korea. *Journal of ecology and environment, 42*, 36. *Retrieved from https://doi.org/10.1186/s41610-018-0095-y*

Ahmed, E., & Holmström, S.J.M. (2014). Minireview: Siderophores in environmental research: roles and applications. *Microbial Biotechnology*, *7*, pp. 196–208.

Alexander, B. & Zuberer, D.A. (1991). Use of chrome azurol S reagents to evaluate siderophore production by rhizosphere bacteria. *Biology and Fertility of Soils*, *12*, pp. 39–45.

Apine, O.A, & Jadhav, J.P. (2011). Optimization of medium for indole-3-acetic acid production using Pantoea agglomerans strain PVM. *Journmal of Applied Microbiology, 110*, pp. 1235–1244.

Bahcesular, B., Yildirim, E.D., Karaçocuk, M., Kulak, M., & Karaman, S. (2020). Seed priming with melatonin effects on growth, essential oil compounds andantioxidant activity of basil (*Ocimum basilicum* L.) under salinity stress. *Industrial Crop Prouction., 146,* 112165.

Espanany, A., Fallah, S., & Tadayyon, A. (2016). Seed priming improves seed germination and reduces oxidative stress in black cumin (*Nigella sativa*) in presence of cadmium. *Industrial Crop Production*, *79,* pp. 195–204.

Fayiga, A.O., & Nwoke, O.C. (2016). Phosphate rock: origin, importance, environmental impacts, and future roles. *Environment Review. 24*, pp. 403–415.

Goswami, D., Thakker, J.N., & Dhandhukia, P.C. (2016). Portraying mechanics of plant growth promoting rhizobacteria (PGPR): a review. *Cogent Food & Agriculture* 2:1, 127500. *Retrieved from https://doi.org/10.1080/23311932.2015.1127500*

Grosu-Tudor, S.S., Stancu, M.M., Pelinescu, D., & Zamfir, M., (2014). Characterization of some bactericins produced by lactic acid bacteria isolated from fermented foods, *World Journal of Microbiology and Biotechnology*, *30*, pp. 2459–2469.

Hussain, A., Rizwan, M., & Ali, Q. (2019). Seed priming with silicon nanoparticles improved the biomass and yield while reduced the oxidative stress and cadmium concentration in wheat grains. *Environmental Science and Pollution Research, 26,* pp. 7579–7588.

Jackson, T.A. (2015). Weathering, secondary mineral genesis, and soil formation caused by lichens and mosses growing on granitic gneiss in a boreal forest environment. *Geoderma, 25,* pp. 78–91.

Khan, A, Geetha, R, Akolkar, A, Pandya A, Archana G, & Desai A. (2006). Differential cross-utilization of heterologous siderophores by nodule bacteria of CajanusCajanand its possible role in growth under iron-limited conditions. *Applied Soil Ecology*, *34*(1), pp. 19–26.

Li, Z.C., Song, X.Z., Yang, M., Song, A., Yu, C., Shaopan, W., Tao, X., & Liang Y.C. (2018). Impacts of silicon on biogeochemical cycles of carbon and nutrients in croplands *Journal of Integrative Agriculture, 17*, pp. 2182–2195.

Lin, T.Y., & Chang Chien, M.F. (2007). Exopolysaccharide production as affected by lactic acid bacteria and fermentation time, *Food Chemistry, 100*, pp. 1419–1423.

Lopez, B.R., & Bacilio, M. (2020). Weathering and soil formation in hot, dry environments mediated by plant–microbe interactions. *Biology and Fertility of Soils, 56,* pp. 447–459.

Madhuri, K.V., & Prabhakar, K.V. (2014). Recent trends in the characterization of microbial exopolysaccharides, *Oriental Journal of Chemistry*, *Retrieved from* http://www.orientjchem.org/pdf/vol30no2/OJCV030I02P895-904.pdf

Min, L., Li, Y., Hu, Q., Zhu, L., Gao, W., Wu, Y., Ding, Y., Liu, S., Yang, X., & Zhang X. (2014). Sugar and auxin signaling pathways respond to high-temperature stress during anther development as revealed by transcript profiling analysis in cotton. *Plant Physiology*, *164*(3), pp. 1293–308.

Patel, S., Majumder, A., Goyal, A. (2012). Potentials of exopolysaccharides from lactic acid bacteria, Indian *Journal of Microbiology, 52*(1), pp. 3–12.

Schulz, S., Brankatschk, R., Dümig, A., Kögel-Knabner, I., Schloter, M., & Zeyer, J. (2013). The role of microorganisms at different stages of ecosystem development for soil formation. *Biogeosciences 10,* pp. 3983–3996.

Seyyedi, S.M., Khajeh-Hosseini, M., Moghaddam, P.R., & ShahandehH. (2015). Effects of phosphorus and seed priming on seed vigor, fatty acids composition and heterotrophic seedling growth of black seed (*Nigella sativa* L.) grown in a calcareous soil. *Industrial Crop Production*, 74, pp. 939–949.

Sheng, X.F., Zhao, F., He, L.Y., Qiu, G., & Chen, L. (2008). Isolation and characterization of silicate mineral-solubilizing *Bacillus globisporus* Q12 from the surfaces of weathered feldspar. *Canadian Journal of Microbiology*, *54*, pp. 1064–1068.

Vamanu, A., Vamanu, E., Popa, O., Câmpeanu, G., & Drăgulescu M. (2007). Biotechnological studies on the production of exopolysaccharides by lactic bacteria in batch system, *Romanian Biotechnological Letters*, *12*(2), pp. 3149–3156.

Zaharescu, D.G., Burghelea, C.I., Dontsova, K., Presler, J.K., Maier, R.M., & Domanik, K.J. (2019). Ecosystem bedrock interaction changes nutrient compartmentalization during early oxidative weathering. *Nature Scientific Reports*, *Retrieved from* https://doi.org/10.1038/s4159801951274x.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE ROLE OF BIOSYNTHESIS HUMIC-LIKE PRECURSORS IN SOIL PROCESSES DYNAMICS

Sorin MATEI[1], Gabi-Mirela MATEI[1], Elena Maria DRĂGHICI[2]

[1]National Research-Development Institute for Soil Science, Agrochemistry and Environment Bucharest, 61 Marasti Blvd, District 1, Bucharest, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: so_matei602003@yahoo.com

Abstract

Microorganisms are involved in biosynthesis of the exogenous compounds with role in the dynamics of edaphic processes. A variety of such biosynthesized exometabolites, such as enzymes, phenols, carbohydrates, proteins, can be released into the soil, where they undergo biochemical interactions, form precursors involved in the synthesis of complex polymers and in determining a priming effect of biogeochemical processes. The research focused on the influence induced by humic precursors, extracted from the previously selected C1-C4 consortia, on the dynamics of bioprocesses in two soil types (Albic Luvisol and Fluvisols), respectively on enzymatic activities, biomass evolution, soil respiration and nitrifying microflora. Exometabolites from the C4 consortium showed the greatest diversity and complexity as humic-like precursors, followed by those the C3 consortium. In Albic Luvisol, the qualitative differences induced by precursors from consortia are well highlighted in the fulvic acid (FA) chromatograms. Enzymatic activity, DNA content, biomass and potential respiration level were influenced differently by the precursors in the C1-C4 consortia. Qualitative and quantitative analyzes for phenols and polysaccharides showed the influence of precursors on edaphic bioprocesses, in close correlation with soil type.

Key words: *chromatograms, exometabolites, humic-like precursors, microbial consortia, soil processes.*

INTRODUCTION

Several ways in which humic substances are formed are based on published theories based on lignin modification, amino acid-quinone interaction, microbial synthesis of aromatic compounds (Picart et al., 2017; Schutyser et al., 2018; Xu et al., 2018; Wang et al., 2020; Yang & Antonietti, 2021).
Each theory describes complicated biotic and abiotic reactions in which a variety of organic compounds, such as phenolic compounds, carbohydrates, and nitrogenous protein substances, are resynthesized to form large complex polymers (Zhang & Wang, 2020).
The variability of the molecular characteristics of humic substances is mainly due to humic precursors and the environmental conditions in which humic substances are formed (Madsen, 2011).
The biochemical processes in the cells of microorganisms active in the soil produce a mixture of metabolites that reflects the level and complexity of their metabolic activity. Exometabolites represent the set of metabolites released by microorganisms inoculated into the soil under the form of microbial consortia and which express a specific imprint, depending on their own composition (Romano et al., 2014; Fiore et al., 2015; Johnson et al., 2016). The diversity of exometabolites is much higher than theoretically anticipated, the results highlighting the possibility of biosynthesis of thousands of molecular masses (Matei et al., 2016a; Dickey et al., 2021). Thus, in addition to the anticipated exometabolites, new compounds appear in a large proportion in metabolic pathways, with molecular masses and unknown elemental composition.
These exometabolites are thought to form and may be released due to excess metabolic rate caused by the growth of microorganisms in the presence of abundant sources of carbon.
However, under normal conditions, in addition to signaling exometabolites (Hartmann & Schikora, 2012), vitamin and vitamin precursors (Sañudo-Wilhelmy et al., 2014; Johnson et al., 2016), siderophores (Linnik,

2020), 3-acetic acid indole plant hormones (IAA) (Wienhausen et al., 2017) and many other metabolites are released as humic-like precursors in the adjacent environment. Between soil microorganisms, the exchange of exometabolites and precursors is a common pathway due to extensive auxotrophy, with the growth of organisms themselves depending on the concomitant supply of exometabolites and mutualistic interactions between microorganisms (Li et al., 2019).

Also, the loss of some genes and the division of the ecological niche can be important factors in the co-evolution of auxotrophs but also the exchange of precursors can have profound implications.

Simplifying or adapting the genome of the selected microbiome correlates / includes the presence of several exometabolites and beneficial precursors for other microorganisms in the ecological niche, which promote the growth of auxotrophs and prototrophs, possibly because it does not involve providing energy for their synthesis (Mas et al., 2016; Estrela et al., 2016).

The idea of using microbial consortia is developing because such consortia through their exometabolites can fulfill / influence the performance of functions in the soil, more complicated than native populations, can be more resistant to environmental fluctuations and can intervene in the dynamics of soil processes (Tang et al., 2021).

In general, setting up consortia for the production of specific compounds remains a challenge.

We are looking for models and methods that allow the realization of consortia that produce various exogenous compounds involved in modifying edaphic processes and that influence the dynamics of humification, by integrating carbon from humic precursors, by determining a priming effect of biogeochemical processes, which can control C dynamics in soils.

The research aimed at the biostimulatory/ inhibitory influence induced by humic-like precursors, biosynthesized by the consortia of C1-C4 microorganisms previously selected, on the dynamics of bioprocesses in two soil types, respectively on enzymatic activities, humification, biomass and soil respiration, microflora, the content of phenols and polysaccharides.

MATERIALS AND METHODS

The Soils - Albic Luvisol and Fluvisols, type diagnosis in agreement with World Reference Base for Soil Resources (2014), had as agrochemical characteristics: pH 5.86, Humus (%) 1.74, Nt(%) 0.060, C/N 19.6, P_{AL} 35 ppm, K_{AL} 70ppm for Albic Luvisol and pH 8.36, Humus (%) 1.26, Nt(%) 0.106, C/N 8, P_{AL} 78.6 ppm, K_{AL} 126.6 ppm for Fluvisols.

Humic-like precursors biosynthesized by the C1-C4 consortia (Matei et al., 2016b), were extracted according to the IHSS methodology (Swift, 1996), treated with fluorochrome and their distribution was highlighted, by specific ascending chromatography. Thus, photographic images were obtained at 350 nm UV illumination, through which a qualitative analysis was performed on some aspects related to the density of the biochemical composition, molecular complexity and weight distribution.

In the experiment, the influence of the composition of humic-like precursors, extracted from the C1-C4 consortia, on the dynamics of soil processes, was analyzed after a period of 90 days from the application of 20 ml of humic precursors/pot.

The bioassay pots contained two types of agricultural soils (Albic Luvisol and Fluvisols). Each pot with 300g soil/pot was incubated at 27^0C, at a constant humidity of 60% of the soil field capacity and maintained for a period of 90 days, under the same controlled conditions.

At the end of this period, soil samples were collected for analysis. Five replicates were used for each experimental variant.

Phenol oxidases (PO) activity was determined by using 0.1 g of soil, MUB solution, pH 2.0 and 200 µl of a 0.1 M ABTS solution. After incubation at 30°C for 5 min, the mixture was centrifuged at 12000 rpm at 4°C for 2 min and the oxidation rate of ABTS to $ABTS^{+\cdot}$ released in the supernatant was measured at 420 nm. Enzyme assays were performed in three replicates for each soil sample, and statistically analyzed, according to the Student test.

FTIR analysis was performed to identify the structural and functional groups present in the fraction of fulvic acid extracted from Luvosol Albic, under the influence of humic precursors from the C4 consortium. The fulvic acid fraction was mixed well with 200 mg dry KBr and pellets were obtained for further investigation in region 4000-500 cm^{-1}.

DNA extraction from soils was based on lysis with a high-salt extraction buffer (1.5 M NaCl), extended heating of the soil suspension in the presence of sodium dodecyl sulfate (SDS), hexadecyltrimethylammonium bromide, and proteinase K.

Soil microbial biomass (SMB-C) was determined under Romanian National Standard - SR-ER-ISO-14240-1-(2012)-Soil quality - Determination of soil microbial biomass.

Soil respiration was determined by the method of respiration induced by the addition of a substrate. The method measures the amount of CO_2 released by the microflora due to the use of the substrate and the results were expressed in mg CO_2 x100 g^{-1} dry soil (Ştefanic, 1991)

Nitrobacter count in the soil sample was estimated using MPN. The enriched soil is transferred to a liquid medium containing $NaNO_2$, incubated and shaken at 25°C. The culture was transferred to a fresh medium using a 1% inoculum, after eight passages, filtered through a membrane to trap the cells. There were washed, transferred on a fresh medium, again six passages on fresh medium, followed by filtration.

The tubes medium contain salts of potassium, magnesium, trace elements, iron and bromothymol blue as indicators.

The change in color of the tubes from blue-green to yellow indicates the oxidation, dilutions indicated by the presence of NO_2 and the population estimation, according to the tables.

The Phenolic content of the samples collected from the two soil types were analyzed by passing on liquid media, incubated at 35^0C for 48 hours, centrifuged at 10,000 rpm for 30 minutes.

The supernatant was filtered through microfilters and applied in quantities of 30 μl for wells from the agarized medium, used to highlight the phenolic compounds in the soils. Petri dishes with extracts were incubated, analyzed, photographed and semi-quantitatively evaluated for phenolic content by determining the diameter of the stained area.

The Polysaccharidic content was determined for evaluation of the biosynthetic capacities of the polysaccharide-type by soils microflora under the influence of precursors from C1-C4 consortia, on Petri dishes with a culture medium having an accessible carbon source. Petri dishes inoculated with extracts belonging to microbial consortia were incubated at 30°C for 24 hours.

Polysaccharide biosynthesis by capable soils microbiota, around the discs, was observed and photographed.

Quantitative determinations of polysaccharide content in the two soil types, under the influence of humic-like precursors, synthesized by microbial consortia were made by the procedure of Lowe (1993) with modifications.

The absorbance reading at 490 nm on the spectrophotometer was performed using distilled water instead of standard, as the control.

The evaluation of the hydrolyzed samples was performed according to the standard procedure, by performing the calibration curve and calculating the regression.

The results were expressed as total polysaccharide and statistically analyzed, according to the Student test.

RESULTS AND DISCUSSIONS

The entry of additional carbon from humic-like precursors, biosynthesized by the previously selected C1-C4 consortia, results in changes in soil organic matter dynamics and induces a priming / intensifying effect of biogeochemical processes by which C dynamics can be controlled in soils.

Significant taxonomic differences of the C1-C4 consortia, even when selected for effectively control of some processes in the soil, may induce performing different carbohydrate fermentation, have profoundly different biosynthetic capabilities, increasing the level of only certain activities (e.g. proteolytic), as well as producing harmful metabolites or amino acids.

The compositional and metabolic changes of the consortium microbiota are strongly associated with the predominant functions they perform, which may suggest links between normal / altered microbial metabolism and the level of functioning and health of the environment on which they will act biochemically as a product.

Taxonomic changes and quantitative increases in exometabolites may be associated with functional influences or disturbances of edaphic processes.

The result of the interspecific interactions of the microorganisms in the consortia and those dependent on the composition of the culture medium determines the spectrum of the consortium's own composition.

Systemic detection of the evolution of favorable / harmful microbial metabolites may also suggest the existence of mechanisms by which the biosis / dysbiosis of the consortium microbiota directly contributes to the cause of the impact on the dynamics of soil processes. Thus, the exometabolites biosynthesized by the C4 consortium had the greatest diversity and complexity of humic-like precursors, close to that of the C3 consortium. In the case of consortia C2 and C1, chromatograms (a and b) show slow trends of complexation, possibly due to the inability to biosynthesize intermediate compounds or due to the self-generation of biochemical incompatibilities (Figure 1).

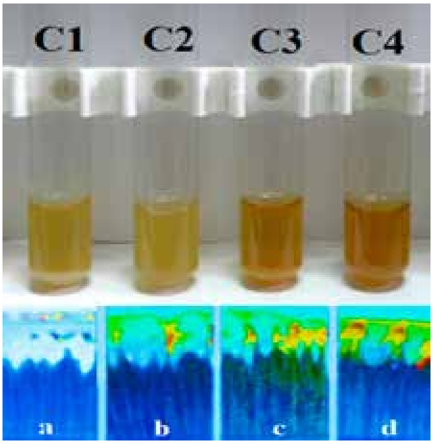


Figure 1. Humic-like precursors in aqeous solution, extracted from consortia C1-C4 and coresponded ascendant specific chromatograms
a) C1, b) C2, c) C3, d) C4

In Albic Luvisol, the fulvic acid (FA) content was 102 mg FA L^{-1} in the control soil, untreated with humic-like precursors and 134 mg FA L^{-1} in the same soil influenced by the application of precursors from C4 consortium, at the end of the experimentation period (90 days).

The qualitative differences between the precursors from the C1-C4 consortia, in terms of the influences induced by the FA content of the same soil type, were also significant in the case of the C3 consortium (128 mg FA L^{-1}). The influences induced by the FA content of Albic Luvisol by humic-like precursors from the C1 and C2 consortia were not significant compared to the control at the end of the experimental period.

The qualitative differences, induced by precursors from the C1-C4 consortia appear well highlighted in the specific ascending chromatograms of FA from Albic Luvisol, at the end of the 90 days.

They reveal accumulation areas with different densities, different concentrations and distributions of the compounds, specific influences of the precursors through which the direct contribution of each consortium is highlighted (Figure 2).

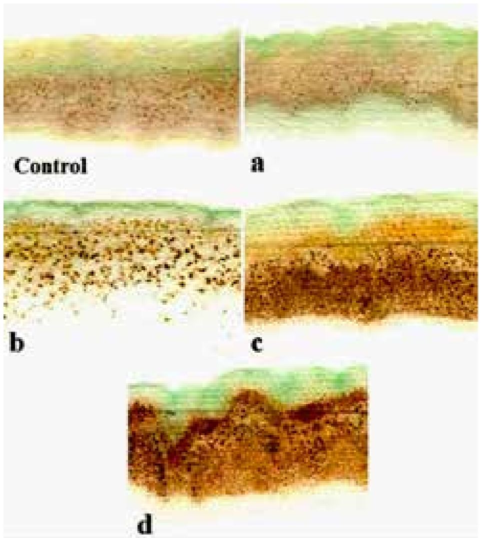


Figure 2. Chromatograms show qualitative differences in fulvic acid (FA) content due to the influence of humic-like precursors from a) C1, b) C2; c) C3; d) C4 and introduced into Albic Luvisol

In Fluvisols, FA content, determined under similar conditions, was 92 mg FA L^{-1} in control soil and 97 mg FA L^{-1} in humic-like precursors from the C4 consortium, determined at the end. In terms of changes induced to the content of FA by precursors from the consortia, the

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

differences were not significant compared to the control.

However, there are qualitative differences, well highlighted in the chromatograms, in the variants in which the compositions of the alcoholic subfractions of FA are analyzed. Thus, these qualitative differences were highlighted between humic-like precursors from the consortia compared to the untreated control.

The chromatograms show the organic accumulations, after 90 days from the treatment, induced in the composition of the alcoholic subfraction of FA, by introducing the precursors from the C4 consortium (Figure 3).

Figure 3. Qualitative differences between the alcoholic subfractions of FA in the humic-like precursors treated variant derived from C4 (a), compared to the untreated control in Fluvisols

The level of phenol oxidase activity determined in Albic Luvisol and in Fluvisols reflects the influence of humic-like precursors, coming from the C1-C4 consortia, on the evolution of the enzyme activity.

In Albic Luvisol, at the end of the experiment, the phenol oxidase activity in the control not treated with precursors was 0.19 Ug^{-1}DM and in the variant treated with humic-like precursors from the C4 consortium it was 0.51 Ug^{-1}DM.

The level of enzymatic activity determined in the soil differs significantly between the variants treated with precursors from C2, C3 and C4 as well as in relation to the control variant. The enzymatic activity does not differ significantly from the control in the case of the influence exerted by the precursors from the C1 consortium.

In Fluvisols, the phenol oxidase activity in the control not treated with precursors was 0.16 Ug^{-1}DM and in the variant treated with humic-like precursors from the C4 consortium it was 0.42 Ug^{-1}DM at the end of the experiment.

In this soil, the level of enzymatic activity differs significantly between the variants treated with precursors from C2, C3 and C4 and in relation to the control, as in Albic Luvisol but its level of activity was lower.

The influence exerted by the precursors of the C1 consortium is not significant compared to the enzyme level reached in the control.

The activity of phenol oxidase (PO) in the two soils, under the influence of precursors biosynthesized by C1-C4 consortia, was determined because these enzymes also catalyze the oxidation of recalcitrant aromatic compounds such as lignin (Cullen & Kersten, 1996).

The PO activity also releases free radicals / quinones that can be involved in the synthesis of humic polymers, in the biodegradation processes but also in the evaluation of the dynamics of the edaphic processes, as sensitive indicators regarding their evolution. (Dec et al., 2003; Farnet et al., 2004).

Because the PO enzyme is particularly sensitive, it can also be used as a bioindicator of soil quality, health and the degree of adaptation of soil microbial communities to variations induced in the composition of soil organic matter (Taylor et al., 2002).

Generally, edaphic enzymes mediate the processes of synthesis / degradation of soil organic matter and their activity have been well studied (Bło´nska & Lasota, 2013; Dove et al., 2020; Piotrowska-Długosz et al., 2021; 2022). Phenol oxidases reach the soil by excretion or lysis, and through their activity mediate the functions of humification and mineralization of carbon, as well as the export of dissolved organic carbon. In soils, these enzymes are less stable, associate with organic particles or interact with mineral surfaces.

Their level of activity increases depending on the pH, the content of particles of organic matter and recalcitrant compounds, the presence of secondary metabolites.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Also, changes in nitrogen content in soils influence the expression of phenol oxidases, and in turn, they correlate with the content of organic matter in soils.
Thus, favorable changes in the organic matter content lead to an increase in oxidative activity because the changed content requires a correlation with the average potential activities of the enzyme.
In addition, the potential activity of phenol oxidase, according to the multiple regressions that takes into account the evolution of pH, temperature, precipitation, is considered to represent up to 37% of the variation of soil organic matter (SOM) content.
In addition, these factors interact and create positive / negative feedback on the dynamics of organic matter in the soil (Sinsabaugh et al., 2008). (Figure 4)

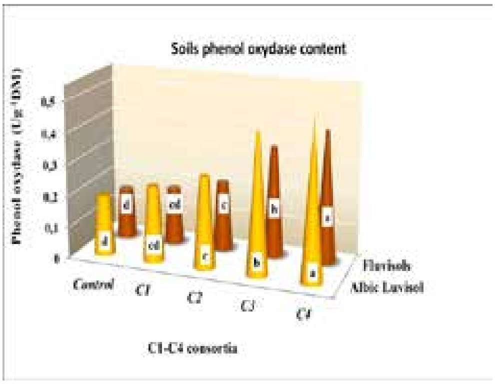


Figure 4. Soils phenol oxydase content under the influence of humic-like precursors from C1-C4 consortia

DNA extracted from Albic Luvisol and experimental variants treated with humic-like precursors from the four consortia was evaluated for purity and yield based on absorption ratios at 260/230 nm (DNA/humic acids) and 260/280 nm (DNA / protein).
The high absorption ratio of 1.234 at 260/230 nm indicated the purity of the DNA extracted from Albic Luvisol, in terms of humic acid contamination.
The value of the reports remained high (1.368 at C4) proportional to the level of microbial growth reached by each variant, at the end of the experimental period.
The ratio of 0.893, for absorption at 260/280 nm, indicates the purity in terms of protein contamination of DNA samples from Albic Luvisol.
The purity of the extracted DNA for protein contamination, extracted at the end of the experiment, with C4 precursors was 0.976.
To determine the nucleic acids in the soil sample, the DNA extract was exposed to ultraviolet light of 260 nm.
By spectrophotometric analysis, the DNA concentration in the soil was estimated at 13.2 µg g^{-1}, and under the application of microbial precursors, the DNA concentration was 14.06 µg g^{-1} at the application of C1 precursors and 16.75 µg g^{-1}, at the application of C4 precursors, at the end of the experiment.
The absorption ratio of 1.084 at 260/230nm indicated the level of purity of the DNA extracted from Fluvisols, in terms of humic acid contamination.
The value of the ratios was 1.102 for C1 precursors, 1.122-1.131 for C3, and C4, respectively.
To determine the concentration of nucleic acids present in the soil samples, the DNA from the Fluvisols was also quantified.
After exposure to 260 nm of the DNA extract from the soil, its concentration in the soil was estimated at 9.3 µg g^{-1}, and under humic-like precursors, the DNA concentration was 9.7 µg g^{-1} at the application of C1 precursors and 10.8 µg g^{-1} at the precursors from C4.
Under experimental conditions, at the end of the experiment, the influence of humic-like precursors on the dynamics of microbial reproduction, respectively on biomass accumulations was evaluated.
Thus, following the analyses, quantitative increases between 11-21% were found.
The biomass produced under the influence of the precursors of the selected consortium (C4), reached an average value of 262 mg C kg^{-1} soil, after 90 days from the treatment with humic-like precursors and represents the experimental variant with a 20.8% increase in the amount of microbial biomass relative to untreated Albic Luvisol biomass.
The biomass produced under the influence of the precursors of the selected consortium (C1) reached an average value of 226 mg C kg^{-1} soil, after 90 days from the treatment and represents the experimental variant with an increase of

only 3.6% of the amount of microbial biomass, in relative to untreated soil.

In the case of Fluvisols, the inoculation of the C4 consortium had a reduced influence through the biosynthesized precursors on the evolution of the microbial biomass content, an increase of only 11.25% (212 mg C kg^{-1} soil) compared to the control (190.5mg C kg^{-1} sol).

Also, the precursors of the C1-C3 consortia had a small influence on the evolution of the microbial biomass content, causing increases between 2.62-8.25%, compared to the control variant.

The physiological activity of the analyzed soil biota is reflected in the potential level of soil respiration.

Thus, in Albic Luvisol, the potential level of soil respiration determined 90 days after the introduction of the C4 consortium precursors was 128.85 mg CO_2x100 g^{-1} dry soil, compared to 94.32 mg CO_2x100 g^{-1} dry soil at the untreated control.

In Fluvisols, the potential respiration level determined under similar experimental conditions was 98.85 mg CO_2x100 g^{-1} dry soil, at the introduction of C4 consortium precursors, compared to 74.32 mg CO_2x100 g^{-1} dry soil, at the untreated control.

The FTIR analyzed the efficiency of the precursors from microbial consortia, in relation to the change in the qualitative and quantitative content of organic compounds in the composition of the fulvic fraction of Albic Luvisol.

Thus, the fraction of fulvic acids, under the influence of humic-like precursors of the C4 consortium, was analyzed by FTIR. In this case, the effect on carbon humification was monitored and changes in the functional groups in its composition were analyzed.

Generally, standard fulvic acids have peaks at 3497 cm^{-1} (OH bound to H), at 2925-2855 cm^{-1} (aliphatic CH stretch), at 2415 cm^{-1} (extended aliphatic CH stretch), at 1648 cm^{-1} (COO-, C=O of carbonyl and quinone), 1158 cm^{-1} (aliphatic CH).

In the case of FA from Albic Luvisol, the FTIR spectrum showed peaks at 3367 cm^{-1} (OH bound to H), at 2519 cm^{-1} (extended aliphatic CH range), at 1680 cm^{-1} (COO-, C=O of carbonyl and quinone), at 1578 cm^{-1} (NO, nitrogen compounds), at 1035 cm^{-1} (S=O, sulfoxides), at 966 cm^{-1} (OH deformation of COOH).

Thus, 90 days after the introduction of the precursors, the spectrum showed a strong absorption band at 3435 cm^{-1}.

Functional groups appear in addition to the untreated soil at 2309 cm^{-1} (O=C=O), 2218 cm^{-1} (C=C), 2047 cm^{-1} (N=C=S, carbodiimides), at 1941 cm^{-1} (C=C=C, alkene), at 1174 cm^{-1} (CO, ethers).

The weak band at 1725 cm^{-1} in the untreated and treated soil indicates a smaller number of COOH groups (Figure 5).

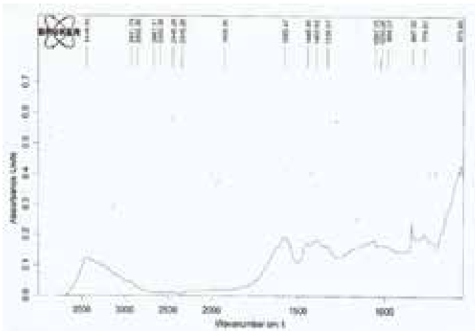


Figure 5. FTIR analysis of the influence of humic-like precursors from the C4 consortium on fulvic acids in Albic Luvisol

The influence of humic precursors on the activity and growth of chemoautotrophic microflora has been investigated *in vivo and in vitro*.

In vivo, Nitrobacter sp. multiplied after treatment with humic precursors from the C1-C4 consortia, reaching at the end of the period analyzed in Albic Luvisol at densities of 7.3 × 10^3 and 5.8 × 10^3 cells g^{-1} dry soil in Fluvisols under the influence of the precursors from the C4 consortium.

The lowest density of 2.6 × 10^3 cells g^{-1} dry soil was determined in Albic Luvisol, and 1.8 × 10^3 cells g^{-1} dry soil in Fluvisols, respectively, under the influence of the precursors from the consortium C1.

At the end of the analyzed period, the density values of the chemoautotrophic microflora were intermediate, in relation to the density values reached by the C4 and C1 consortia, in the two soil types, for the C2 and C3 consortia.

Research on the evolution of the growth and development of this microorganism, considered mandatory chemoautotroph, under the influence of precursors biosynthesized by C1-C4 consortia, was performed because it can be inhibited by the presence of organic matter, and the results allowed a better assessment of the direct influence of such organic compounds, defined as humic-like precursors, on it.

Also, as a nitrifying microorganism and biofertilizer, convert ammonia, reduce the forms of nitrogen present in the soil, into the most oxidized forms of the nitrogen, respectively nitrate.

Through its activity it ensures the functioning of the proceses, the control of nitrogen losses by leaching/denitrification of nitrates from the soil.

In vitro cultures with other edaphic microorganisms isolated from Albic Luvisol (*Bacillus* sp., *Pseudomonas* sp., *Trichoderma* sp.), treated with humic-like precursors from the C1-C4 consortia, showed for each, significant improvement in growth, compared to untreated control.

Biosynthesized humic-like precursors have influenced the growth of autotrophic nitrifiers, most of the precursors used have stimulated bacterial and fungal populations in natural soils (Albic Luvisol, Fluvisols).

It was also observed that there were no microbial growths dependent on the humic-like concentration of the applied precursors, which may suggest that they are not mainly used as a source of carbon and nutrients by the microorganism.

The results complete the absence of information on the response of autotrophic nitrifying bacteria to the presence of prehumic compounds in the soil, under axenic conditions, with representative strains.

In fact, biosynthesized humic-like precursors possibly improve the soil, allowing nitrifiers to grow in a better aerobic environment, compared to humus obtained from leonardite or other sources, which causes the microaggregates in the soil to collapse (Kaya et al., 2020; Akimbekov et al., 2021).

The differences induced in the soil by biosynthesized organic compounds compared to those extracted from different organic materials can be attributed to the divergent effects induced by their composition on some physico-chemical characteristics of the soil.

It can be considered that the influence of humic-like precursors in the soil depends more on their superficial characteristics, through which they can modify the permeability of cell membranes, causing a better absorption of both mineral nutrients and oxidizing substrates that produce energy. Microbial consortia, by excreting humic-like precursors, could control the decomposition rate of organic matter in the respective soil, or can intervene in the stabilization of organic carbon and in the dynamics of the circuit of the elements.

Phenols, as secondary metabolites that decompose slowly in soils compared to organic matter, show useful recalcitrance in protecting carbon stocks. Also, the microorganisms from soils can influence the form in which phenols can exist in the soil, starting from the reduction of dissolved forms (free in soil solution and exposed to degradation), to stimulating the involvement of phenols in the adsorbed forms in soil/proteins, or in polymerized forms (present in the composition of humic substances).

The phenolic content of the two soils, depending on the influence of humic-like precursors from C1-C4 consortia was directly proportional to the halo diameter and the intensity of the colored area, around the well. Thus, the highest phenols content in Albic Luvisol was synthesized under the influence of precursors from C4 consortium (ø28.5 mm), followed by those from C3 consortium (ø 17.5mm), by the C2 consortium (ø14.5mm), and the lowest phenols content obtained in this type of soil was obtained from the influence of humic-like precursors from C1 consortium (ø8.5mm). The phenolic content of Albic Luvisol synthesized under the different influence of the precursors from C1-C4 consortia and the halo of diffusion of the phenolic content can be observed from the soil samples analysis (Figure 6).

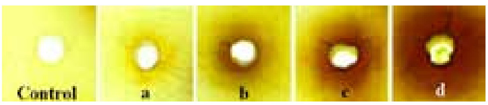


Figure 6 The content of phenolics of Albic Luvisol, under the influence of humic-like precursors from control and consortia a) C1, b) C2, c) C3, d) C4

The content of phenols in Fluvisols synthesized under the influence of humic-like precursors of the C1-C4 consortia followed the evolution of the content from the Albic Luvisol, but smaller diameters were obtained for the diffusion halos, in the analyzed soil samples, possible due to the reduced quantities of synthesized phenolic content. To evaluate the influence of precursors from C1-C4 consortia on the polysaccharide content of the two soils, soil extracts were inoculated on sterile filter discs arranged in Petri dishes to a semi-quantitatively evaluation of specific evolution of edaphic microflora capable of such biosynthesis in Albic Luvisol.
The chemical and biological synthesis processes in soils were strongly influenced by humic-like precursors from the C1-C4 consortia, possibly due to better adaptation or higher compatibility with the biochemical composition or with endemic microbial structure of the soil.
The precursors from C4, present in Albic Luvisol, stimulate endemic microbiom to biosynthesize a higher polysaccharides quantity (Figure 7).

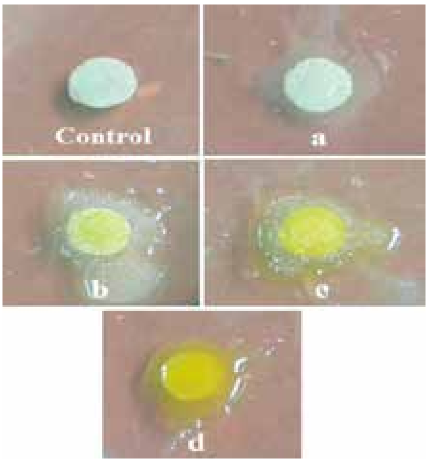


Figure 7. Semi-quantitative evaluation of the specific evolution of the edaphic microflora capable of polysaccharide biosynthesis, in Albic Luvisol, under the influence of humic-like precursors from consortia a) C1, b) C2, c) C3, d) C4

In Albic Luvisol were higher amounts of polysaccharides than those of Fluvisols, but the quantities differ depending on the type of consortium.

The polysaccharide content, in the two soil types, under the influence of humic-like precursors, from C1-C4 consortia was analyzed.
Quantitative analyses allowed to be determined the highest content of polysaccharide compounds in Albic Luvisol, under the influence of humic-like precursors from the C4 consortium (63.7 mg g^{-1} polysaccharides).
The differences are significant compared to the polysaccharides level in the control, and were significant differences between C4 and C1 consortia.
The quantitative differences, induced by the C2 and C3 consortia are not significant, in terms of the evolution of the polysaccharide content. In the Fluvisols under the influence of humic-like precursors from C4 consortium, the determined polysaccharide content was 48.5 mg g^{-1} polysaccharides.
The differences are significant compared to the level of control for the C2, C3 and C4 consortia.
The polysaccharide content determined in Fluvisols was the least influenced by the C1 consortium (36.5 mg g^{-1} polysaccharides), the differences being not significant in compare with control (Figure 8).

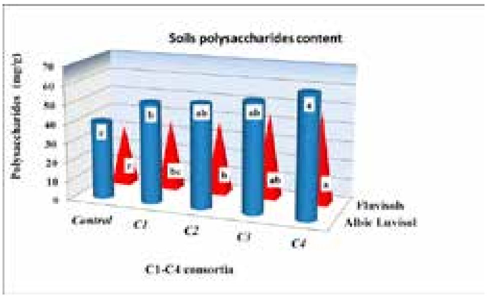


Figure 8. The polysaccharides content in two soil types, under the influence of humic-like precursors, from consortia C1-C4

CONCLUSIONS

Exometabolites biosynthesized by the C4 consortium show the greatest diversity and complexity of humic-like precursors, followed by the C3 consortium, and C1 and C2 show low diversity due to reduced biosynthetic capacity or incompatibilities.

In Albic Luvisol, the fulvic acid (FA) content was significantly influenced by the application of humic-like precursors from the C3 and C4 consortia.

The qualitative differences induced by humic-like precursors from the C1-C4 consortia are well highlighted in the FA chromatograms of Albic Luvisol by accumulation areas with different densities, concentrations and different distributions of specific compounds, highlighting the direct contribution of each consortium.

Qualitative differences are highlighted in the chromatograms, in the comparative analysis with the control for the composition of the alcoholic subfractions of FA, more obvious in the case of the C4 consortium.

The phenol oxidase activity determined in Albic Luvisol and in Fluvisols reflected the level of influence of humic-like precursors, from the C1-C4 consortia, on the intensity and evolution of the enzyme activity.

The DNA concentrations in Albic Luvisol and Fluvisols were 13.2 μg g^{-1} and 9.3 μg g^{-1}, respectively, and by applying precursors, the concentrations increased in all variants, and in the case of C4 precursors up to 16.75 μg g^{-1} and 10.8 μg g^{-1}, respectively.

The biomass produced under the influence of humic-like precursors of the selected consortium (C4), reached an average value of 262mg C kg^{-1} soil, representing the variant with increases of 21% and respectively 11%, compared to the biomass from Albic Luvisol and respectively Fluvisols, both untreated.

The potential level of respiration, determined 90 days after the introduction of the C4 consortium precursors in Albic Luvisol, was 128.85 mg CO_2 x 100 g^{-1} dry soil, compared to 98.85 mg CO_2 x 100 g^{-1} dry soil in Fluvisols, untreated.

The phenolic semi-quantitative content from two soils, under the influence of humic-like precursors from C1-C4 consortia was the highest under precursors from C4, and the lowest from C1 consortium.

In Albic Luvisol, the polysaccharide content under the influence of humic precursors differs significantly between the consortium variants, between them and the control and in Fluvisols the differences are not significant compared to the control, for the C1 consortium.

ACKNOWLEDGEMENTS

This work was supported by two grants of the Romanian Ministry of Research, Innovation and Digitization, project number PN 19 34 04 01/2019. **(**Development of smart tools for quantifying soil microbiota biodiversity as a provider of ecosystem services to secure natural soil resources in the context of climate change**)** and project number 44 PFE /2021, Program 1 – Development of national research-development system, Subprogramme 1.2 – Institutional performance – RDI Excellence Financing Projects.

REFERENCES

Akimbekov, N.S., Digel, I.,Tastambek, K.T., Sherelkhan, D.K., Jussupova, D.B. & Altynbay, N.P. (2021). Low-Rank Coal as a Source of HumicSubstances for Soil Amendment and Fertility Management. *Agriculture, 11,* 1261. Retrived March 15, from https://doi.org/10.3390/agriculture11121261

Bło´nska, E. & Lasota, J. (2013). Enzymatic activity of forest Luvisols. *Electronic Journal of Polish Agricultural Universities, 16,* 1. Retrived March 15, 2022, from http://www.ejpau.media.pl/volume16/ issue1/art-01.html

Brenner, K., Lingchong, Y. & Arnold, F.H. (2008). Engineering microbial consortia: a new frontier in synthetic biology. *Trends in Biotechnology, 26* (9), pp. 483–489.

Cullen, D., & Kersten, P.J. (1996). Enzymology and molecular biology of lignin degradation. In: R. Brambl, G.A. Marzluf (Eds.), *The Mycota III, Biochemistry and Molecular Biology*, pp. 295–306, Berlin, D:Springer-Verlag Publishing house.

Dec, J., Haider, K. & Bollag, J.M. (2003). Release of substituents from phenolic compounds during oxidative coupling reactions, *Chemosphere, 52*, pp. 549–556.

Dickey, R.M., Forti, A.M. & Kunjapur, A.M. (2021). Advances in engineering microbial biosynthesis of aromatic compounds and related compounds. *Bioresources and Bioprocess, 8,* 91. Retrived March 15, from https://doi.org/10.1186/s40643-021-00434-x

Dove, N.C., Arogyaswamy, K., Billings, S.A., Botthoff, J.K., Carey, C.J., Cisco, C., De Forest, J.L., Fairbanks, D., Fierer, N. & Gallery, R.E. (2020). Continental-scale patterns of extracellular enzyme activity in the subsoil: An overlooked reservoir of microbial activity. *Enviromental Research Letters, 15*, 1040a1. Retrived March 15, 2022, from https://iopscience.iop.org/article/10.1088/1748-9326/abb0b3

Estrela, S., Moris, J.J., & Kerr, B. (2016). Private benefits and metabolic conflicts shape the emergence of microbial interdependencies. *Environment Microbiology*, 18, pp. 1415–1427.

Farnet, A.M., Criquet, S., Cigna, M., Gil, G. & Ferre, E. (2004). Purification of a laccase from Marasmius quercophilus induced with ferulic acid: reactivity towards natural and xenobiotic aromatic compounds. *Enzyme and Microbial Technology, 34*, pp. 549–554.

Fiore, C.L., Longnecker, K., Kido Soule, M.C. & Kujawinski, E.B. (2015). Release of ecologically relevant metabolites by the cyanobacterium Synechococcus elongatus CCMP 1631. *Environment Microbiology. 17,* pp. 3949–3963.

Guggenberger G. (2005). Humification and Mineralization in Soils. In: Varma, A., Buscot, F. (eds) *Microorganisms in Soils: Roles in Genesis and Functions*. *Soil Biology, vol 3*. Berlin, Heidelberg, D: Springer Publishing house. Retrived from https://doi.org/10.1007/3-540-26609-7_4.

Hartmann, A. & Schikora, A. (2012). Quorum sensing of bacteria and trans-kingdom interactions of N-acyl homoserine lactones with eukaryotes. *The Journal of Chemical Ecology, 38,* pp. 704–713.

IUSS-FAO: World Reference Base for Soil Resources 2014. International Soil ClassificationSystem for Naming Soils and Creating Legends for Soil Maps. World Soil Resources ReportsNo 106. FAO, Roma, 2074.

Johnson, W. M., Kido Soule, M.C. & Kujawinski, E.B. (2016). Evidence for quorum sensing and differential metabolite production by a marine bacterium in response to DMSP. *Multidisciplinary Journal of Microbial Ecology 10*, pp. 2304–2316.

Kaya, C., Senbayram, M., Akram, N.A., Ashraf, M., Alyemeni, M.N. & Ahmad, P. (2020). Sulfur-enriched leonardite and humic acid soil amendments enhance tolerance to drought and phosphorus deficiency stress in maize *(Zea mays* L.). *Scientific Reports, 10*, pp. 1–13.

Kuzyakov, Y., (1997). The role of amino acids and nucleic bases in turnover of nitrogen and carbon in soil humic fractions. *European Journal of Soil Science, 48,* pp. 121–130.

Li, P., Liu, J., Jiang, C., Wu, M., Liu, M., & Li, Z. (2019). Distinct successions of common and rare bacteria in soil under humic acid amendment-a microcosm study. *Frontiers in Microbiology, 10,* 2271. Retrived March 15, from https://doi.org/10.3389/fmicb.2019.02271

Linnik, P. (2020). Role of Organic Substances-Exometabolites in Migration and Detoxification of Metals in Surface Waters (a Review). *Hydrobiological Journal, 56*(5), pp. 92–109.

Lowe, L.E. (1993). Soil Sampling and Methods of Analysis, Eds. Martin Carter, Lewis.

Mas, A., Jamshidi, S., van Lagadeuc, Y., Eveillard, D. & Vandenkoornhuyse, P. (2016). Beyond the black queen hypothesis. *Multidisciplinary Journal of Microbial Ecology 10*, pp. 2085–2091.

Madsen, E.L. (2011). Microorganisms and their roles in fundamental biogeochemical cycles. *Current Opinion in Biotechnology, 22*(3), pp. 456–464.

Matei, S., Matei G.M. & Anghel A. (2016a). Assessment of exometabolites biosynthesized by soil microorganisms as the main source of humic precursors. *Soil Forming Factors and Processes from the Temperate Zone, 15* (1), pp. 11–19.

Matei, S., Matei G.M., Dumitru S. & Ignat P. (2016b). Research on the role of microbial consortium on humic precursors based on secondary exometabolites. *Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series., 46*(1), pp. 348–356.

Picart, P., Liu, H., Grande, P.M., Anders, N., Zhu, L., Klankermayer, J., Leitner, W., Domínguez de María, P., Schwaneberg, U., & Schallmey, A. (2017). Multi-step biocatalytic depolymerization of lignin. *Applied Microbiology and Biotechnology, 101*, pp. 6277–6287.

Piotrowska-Dlugosz, A.; Kobierski, M.; Długosz, J. (2021). Enzymatic activity and physicochemical properties of soil profiles of Luvisols. *Materials 2021, 14*, 6364. Retrived March 15, 2022, from https://www.mdpi.com/1996-1944/14/21/6364

Piotrowska-Długosz, A., Długosz, J., Gryta, A., & Fr ąc, M. (2022). Responses of N-Cycling Enzyme Activities and Functional Diversity of Soil Microorganisms to Soil Depth. Pedogenic Processes and Cultivated Plants. *Agronomy, 12,* 264. Retrived March 15, 2022, from https://doi.org/10.3390/ agronomy12020264

Romano, S., Dittmar, T., Bondarev, V., Weber, R. J. M., Viant, M. R., & Schulz-Vogt, H. N. (2014). Exo-metabolome of Pseudovibrio sp. FO-BEG1 analyzed by ultra-high resolution mass spectrometry and the effect of phosphate limitation. PLoS ONE 9:e96038. Retrived March 15, 2022, from https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0096038

Sañudo-Wilhelmy, S. A., Gómez-Consarnau, L., Suffridge, C., & Webb, E.A. (2014). The role of B vitamins in marine biogeochemistry. *Annual Review of Marine Science, 6,* pp. 339–367.

Schutyser, W., Renders, T., Van den Bosch, S., Koelewijn, S.F. Beckham, G.T., & Sels, B.F. (2018). Chemicals from lignin: an interplay of lignocellulose fractionation, depolymerisation, and upgrading. *Chememical Society Reviews, 47*, pp. 852–908.

Sinsabaugh, R.L., Lauber, C.L., Weintraub, M.N., Ahmed, B., Allison, S.D., Crenshaw, C.L., Contosta, A.R., Cusack, D., Frey, S., Gallo, M.E., Gartner, T.B., Hobbie, S.E., Holland, K., Keeler, B.L., Powers, J.S., Stursova, M., Takacs-Vesbach, C., Waldrop, M., Wallenstein, M., Zak, D.R., & Zeglin, L.H. (2008). Stoichiometry of soil enzyme activity at global scale. *Ecology Letters, 11,* pp. 1252–1264.

Stefanic, G. (1991). Assay of the potential level of soil respiration with an oxygen-generating respirometer, *Journal of Academy of Agricultural and Forestry Sciences, 21*, pp. 87–91.

Swift, R.S. (1996). Organic matter characterization (chap 35). pp. 1018-1020. In: D.L. Sparks et al. (eds) *Methods of soil analysis. Part 3. Chemical methods.* Soil Sci. Soc. Am. Book Series: 5. *Soil Science Society of America, Madison, WI* Retrived from https://humic-substances.org/isolation-of-ihss-soil-fulvic-and-humic-acids.

Tang, C., Li, Y., Song, J., Antonietti, M. & Yang, F. (2021). Artificial humic substances improve microbial activity for binding CO_2. *iScience, 24(6)*, article 102647. Retrived March 15, from https://www.sciencedirect.com/science/article/pii/S2589004221006155

Taylor, J.P., Wilson, B., Mills, M.S., & Burns, R.G., (2002). Comparison of microbial numbers and enzymatic activities in surface soils and subsoils using various techniques, *Soil Biolology and Biochemistry, 34*, pp. 387–401.

Wang, X., Muhmood, A., Dong, R., & Wu, S. (2020). Synthesis of humic-like acid from biomass pretreatment liquor: quantitative appraisal of electron transferring capacity and metal-binding potential. *Journal of Cleaner Production, 255,* article 120243. Retrived March 15, from https://www.sciencedirect.com/science/article/pii/S0959652620302900

Wienhausen, G., Noriega-Ortega, B.E., Niggemann, J., Dittmar, T., & Simon, M. (2017). The Exometabolome of Two Model Strains of the Roseobacter Group: A Marketplace of Microbial Metabolites. *Frontiers in Microbiology, 8*, 1985.

Xu, R., Zhang, K., Liu, P., Han, H., Zhao, S., Kakade, A., Khan, A., Du, D. & Li, X. (2018). Lignin depolymerization and utilization by bacteria. *Bioresources Technology, 269*, pp. 557–566.

Yang, F. & Antonietti, T.C. (2021). Natural and artificial humic substances to manage minerals, ions, water, and soil microorganisms. *Chemical Society Reviews, 50(10),* pp. 6221–6239.

Young, I.M, Crawford J.W. (2004). Interactions and self-organization in the soil-microbe complex. *Science 304*, pp. 1634–1637.

Zhang, C. & Wang, F. (2020). Catalytic lignin depolymerization to aromatic chemicals. *Accounts of Chemical Research, 53*, pp. 470–484.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ISOLATION AND CHARACTERIZATION OF NEW YEASTS STRAINS FROM BARLEY SAMPLES

Constanta MIHAI, Mihai FRINCU, Corina DUMITRACHE

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: corina_dumitrache17@yahoo.com

Abstract

Due to their diversity and versatility, yeasts are considered of current industrial interest, as they can easily cover a wide range of industrial applications such as baker`s yeast, brewer`s yeast, nutritional yeast, distillation yeast, wine yeast or probiotic yeast. The purpose of this article is to isolate and characterize new barley yeast strains to obtain yeast biomass for the development of new fish feed recipes. Using the technique of decimal dilutions and inoculation by the "lawn" technique on DRBC Agar medium, the isolated strains were tested specifically to identify they're taxonomically. Colonies considered representative of a particular species or genus were isolated in pure culture and maintained on YPD Agar culture medium and cryopreserved in 20% glycerol at -20°C. 11 yeast strains belonging to the genera Saccharomyces, Candida, Cryptococcus, Torulaspora, Metschnikowia pulcherrima, Pichia, etc. were isolated. Further research will focus on the use of isolated strains of Saccharomyces cerevisiae mixed with strains of other non-Saccharmomyces to obtain yeast biomass as a potential source for fish feed.

Key words: *biomass, barley, isolation, yeasts strains.*

INTRODUCTION

The studies undertaken on yeasts, intensified in recent decades, are justified not only by the importance of these microorganisms as an experimental model, to which researchers in various specialties have turned their attention: cytology, microbiology, cell biology, genetics, but also by their applications in industry.
Yeats are without a doubt the most important group of microorganisms used by man since the beginning of his history as a social being.
From this point of view, biotechnology has always been contemporary with human history, first through its aspects - now called traditional - of making bread or wine, until today when the development of genetics and molecular biology led to the development of modern biotechnology (Banu C., 2000). Today, based on selection activities, we are witnessing worldwide the development of a special industry that produces yeasts in dry and granulated form.
These yeasts from different parts of the globe cannot always be successfully applied in other areas, which is why we believe it would be beneficial for the yeasts used to be based on the yeasts in the areas where they are to be used

Saccharomyces cerevisiae is undeniably the most studied and one of the most widely used eukaryotes in a wide variety of industrial processes, such as wine, food and ethanol production. Despite of the efficient adaptation of the various *S. cerevisiae* strains used in those processes, there is still a great potential of either optimizing existing strains, or exploiting the immense natural reservoir of environmental isolates (Parapouli et al., 2020).
Many researchers found yeasts in large numbers in a wide variety of natural habitats as different as leaves, flowers, sweet fruits, tree exudates, grains, roots fleshy fungi, insects, dung, soil. In assessing yeast strain for industrial use, specific physiological properties are required (Tikka et al., 2014).
Of all kinds of yeast, only a few species are used commercially. Typical commercial yeast applications include alcoholic beverages (beer, wine and spirits), soft drinks (root beer, kvass, kombucha, kefir, mauby), bread and food baking, bioremediation (to generate carbon dioxide for plant growth in the aquarium), food additives and flavoring agents, scientific research, and genetic engineering prophecies (Shurson, 2018). *Saccharomyces cerevisiae* is traditionally used in the food industry for the

production of alcoholic beverages, such as beer, wine, and sake, as well as for bread fermentation. More recently, *Saccharomyces cerevisiae* has also been used in the bioethanol industry and for the production of heterologous compounds, such as human insulin, hepatitis vaccines, and human papillomavirus vaccines (Hou et al., 2012).

Notwithstanding the fact that *S. cerevisiae* remains by far the most widely used industrial yeast species to date, other, so-called nonconventional yeasts, such as *Pichia, Torulospora*, have also claimed their stake as valuable contributors to industrial fermentation processes. Within non-Saccharomyces species, some cultures showed features of technological interest. Strains of *M. pulcherrima* showed the highest β-glucosidase activity and proved to be able to produce high concentrations of succinic acid. Strains of *M. pulcherrima* and *H. uvarum* showed a low fermentation power (about 4%), while *L. thermotolerans*, *Star. Bacillaris*, and *P. kudriavzevii* of about 10% (Aponte & Blaiotta, 2016).

Additionally, demands for increased productivity, wider substrate range utilization, and production of nonconventional compounds in industry, as well as changing in consumer preferences, led to a great interest in further improving the currently used industrial strains and the selection or development of strains with novel properties. It is also noteworthy that some *S. cerevisiae* strains lack the α-galactosidase enzyme and therefore cannot utilize melibiose, a disaccharide accumulated after the breakdown of raffinose when molasses are used for biomass production (Zhou et al., 2021).

The purpose of this research was to isolate and characterize new barley yeast strains to obtain yeast biomass for the development of new fish feed recipes and represents a preliminary stage for characterizing the microbial communities from barley, necessary for the improvement of biotechnological processes associated with food industry.

MATERIALS AND METHODS

The yeast was isolated from barley samples from Moara Domnească Farm (Belciugatele-Ilfov) with the following substrates: barley seed, bran, and barley cultivated soil. The used culture media are: **DRBC Agar** (agar-15 g/L, dextrose-10 g/L, dichloran - 0,002 g/L, magnesium sulphate -0,5 g/L, monopotassium phosphate-1 g/L and Bengal rose dye, 0,025 g/), **YPD Agar** (dextrose-20 g/L, peptone-20 g/L, yeast extract-10 g/L and agar-20g/L) and **YPG** (glucose-20 g/L, peptone-20 g/L, yeast extract-10 g/L and agar-20g/L).

Using the decimal dilution technique and seeding with the "In the lawn" technique on the DRBC Agar media, the isolated strains have been subjected to specific tests, for the purpose of their taxonomic identification. For each dilution in the interval $10^{-1} \div 10^{-3}$ was obtained 1 ml of suspension (by display) on 3 Petri plates and then a mean was made for the developed colonies. The determinations were performed in three repetitions.

The selected yeast strains were inoculated on liquid and solid media YPD Agar at 28°C for 72 h and identificated based on macroscopic observations (the appearance of a colony) and microscopic observations, according to the Lodder (1974), Barnett, Payne and Yarrow (1990), Pitt and Hocking (2009) classification criteria. For the identification of microorganisms through the microscopic analysis, fresh samples were prepared between slides for the identification of the cellular form of the type of microorganism. The Siemens microscope was used, and the smears were observed with the lens of 100x magnification, in a drop of cedar oil, using immersion oil (Vassu et al., 2001).

Physiological and biochemical characteristics of the yeast isolates were determined according to Kraepelin (1984) and Kurtzman (2011). To determine the physiological properties - assimilation / fermentation of various carbon sources and azote, we used classic lab techniques and quick identification kits - API tests. API tests allow the simultaneous highlighting of several biochemical characters, by associating several individual tests, which lead to the identification of a species with a high probability coefficient. The results obtained were compared with a reference strain of *Saccharomyces cerevisiae* Lalvin EC1118.

The colonies considered representative of a particular species or gender were isolated in pure culture and maintained on culture medium

YPD Agar and cryopreserved in glycerol 20% at -20°C.

RESULTS AND DISCUSSIONS

The shape and size of the cells have the peculiarities of growth depending on their morphological and physiological characteristics and can be observed under a microscope the size and shape of cells from young cultures in full activity in the standard liquid medium (Figure 1). Wet preparations in which the cells are suspended in a 0.1% agar solution are preferably used for the measurement, in order to avoid the movement of the cells. It is also noted the mode of vegetative propagation (budding, possibly splitting), the type of budding (polar, multipolar), the angle that the daughter cell makes with the mother cell giving different tree chains.

Colony characters were used for preliminary identification. Yeast strains produced different types of colonies on DRBCA medium such as raised, creamy white color colonies. After 48 hours of growth on YPGA medium our strains formed white colonies, elevated and convex with slightly different surfaces. Microphotographs of morphological diversity of isolates (Figure 2) and different colonies from different samples are shown in (Figure 3). Strains were observed for *Saccharomyces* characteristic oval cell shape and budding characters. Out of seven isolates, three isolates showed oval cell shape with budding character and classified as *Saccharomyces* yeast strain.

The yeast strains, *Saccharomyces cerevisiae* identificated after the macroscopic aspect, formed convex colonies with a glossy surface, cream-white colored with a diameter of 1-2 mm. Examined under a microscope, yeast cells were spherical or oval in shape, with diameters ranging from 5 to 20μm (Figure 1).

Following the results obtained at the macro and microscopic characterization of the isolated strains (Table 1) it turns out that the isolated yeast strains showed colonies with diameters between 2 and 4 mm, with lenticular or convex profile, having a circular perimeter with a creamy appearance, smooth and matte, and other colonies had a glossy surface, cream-white colored, with a diameter of 1-2 mm.

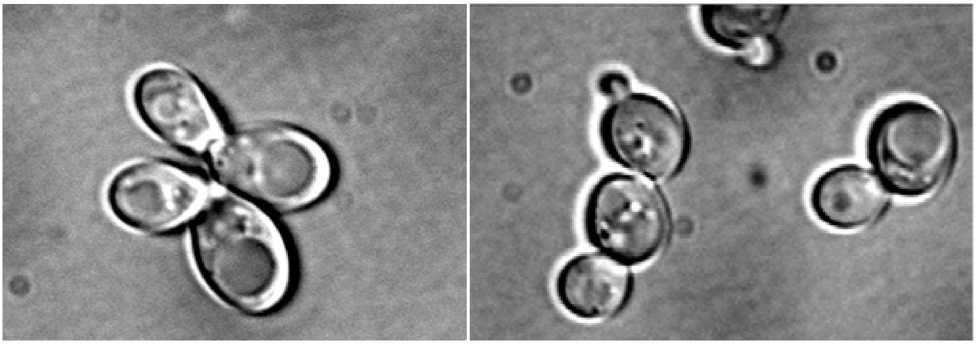


Figure 1. The shape of *Saccharomyces cerevisiae* cells in young cultures

Figure 2. Morphological diversity of isolates

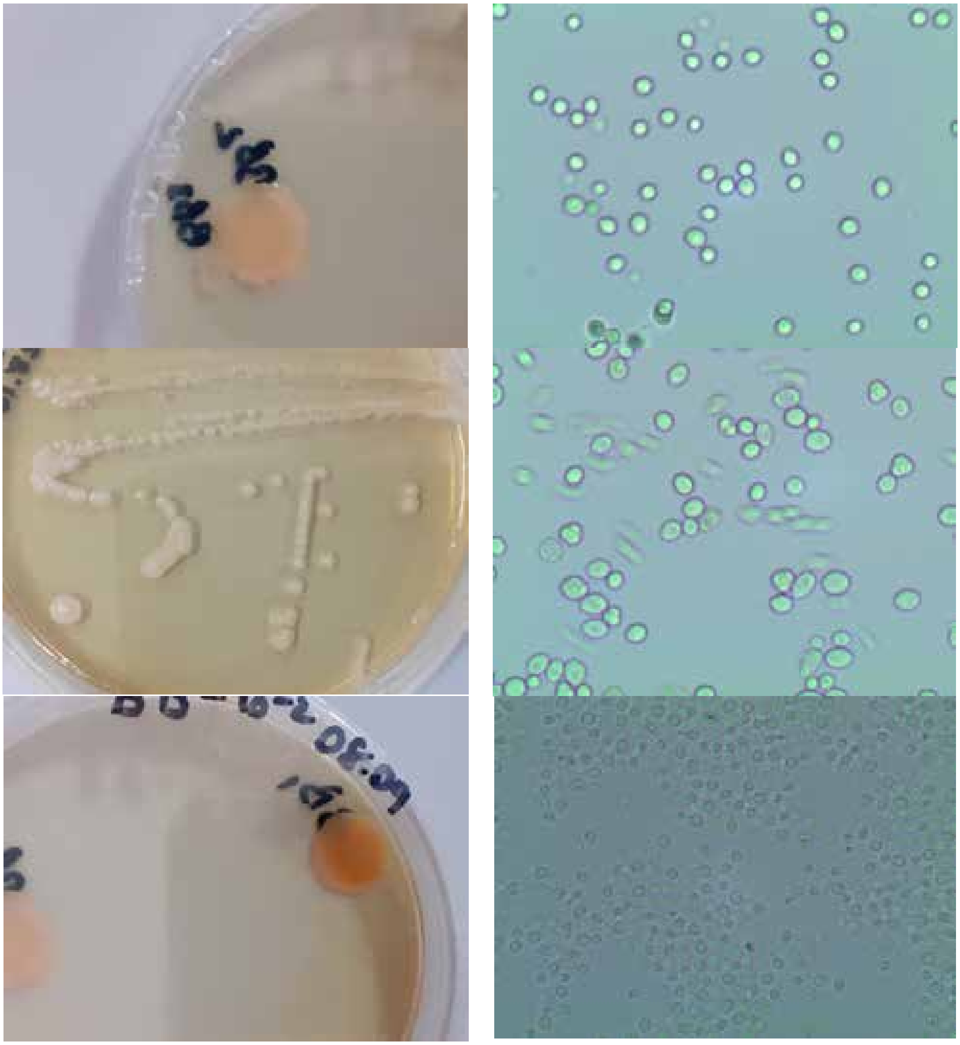


Figure 3. Aspect of the colonies and cells (40x) formed by isolated yeast strains

Table 1. Characteristics macro and microscopic of yeasts isolated from barley

Nr.crt.	Isolated strains (code)	Source	Character of the colony	Microscopic observations
1	OB1	Barley seeds	Smooth, glossy colonies with round edges	Small cells of round shape, isolated or grouped in pairs
2	OB2	Barley seeds	Irregular colonies, light cream-colored, smooth, buttery	Elliptical cells, isolated or grouped in small chains
3	OB3	Barley seeds	Umbonate colonies with scalloped edges, light cream-colored	Oval or elliptical cells, isolated or grouped in pairs
4	OB5	Barley bran	Umbonate colonies with scalloped edges, light cream-colored	Oval or elliptical cells, isolated or grouped in pairs
5	OB6.1	Barley bran	Colonies round, white to cream, glossy, smooth, buttery	Cells round to ovoid, isolated or grouped in pairs
6	OS1.1	Soil	Colonies round, white to cream, glossy, smooth, buttery	Cells round to ovoid, isolated or grouped in pairs
7	OS2	Soil	Smooth, glossy colonies with round edges	Cells round to ovoid, isolated or grouped in pairs

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

Table 2. Assimilation reactions/fermentation and other characteristics biochemical identification

Carbohydrates	**Yeast strain**						
	OB1	OB2	OB3	OB5	OB6.1	OS1.1	OS2
Gram reaction	+	+	+	+	+	+	+
Glucose	+	+	+	+	+	+	+
Galactose	+	+	-	+	+	+	+
Sucrose	+	+	+	-	+	+	-
Maltose	+	-	-	-	-	+	-
Lactose	+	-	-	+	v	-	+
Raffinose	+	+	-	-	-	+	+
Trehalose	-	+	+	-	+	+	-
Fructose	+	+	+	+	+	+	+
Arabinose	-	-	-	-	-	-	-
Urease	-	-	+	v	-	-	-

Code in table: +, positive=Present; −, negative=absent; v=variable

The fermentation capacity of the main sugars by the yeast strains isolated represents a stable character of the alcoholic yeasts. Following the tests, we found that there are differences between the yeast strains isolated regarding the nature of fermentable sugars and the ability of yeasts to ferment some monosaccharides, disaccharides and trisaccharide's.

All analyzed strains were found to ferment D-glucose, sucrose and fructose, except for the strains OB5 and OS2 which did not ferment the sucrose. No yeast fermented L- arabinose (the yeasts lack the proper enzymes), and D-galactose was not fermented by the yeast strain OB3. Maltose and raffinose were weakly fermented by isolated yeast strains (Table 2).

The colonies considered representative of a particular species or gender were isolated in pure culture and maintained on culture medium YPD Agar and cryopreserved in glycerol 20% at -20°C (Figure 4).

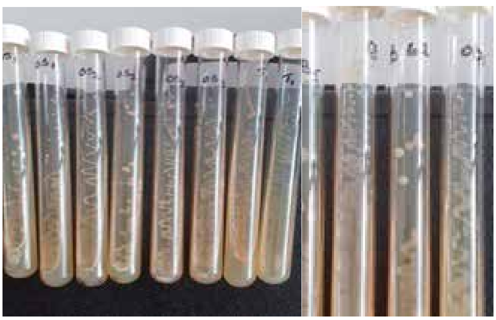


Figure 4. Yeast strains isolated in pure culture

Yeasts have the ability to assimilate urea, which is a good source especially if the culture medium contains biotin in sufficient quantity. Isolated yeast strains do not have the ability to hydrolyze high concentrations of urea in complex environments that contain peptone as the only source of nitrogen because they do not produce urease.

CONCLUSIONS

At this stage, we isolated and identified in the barley samples 7 strains of genera belonging to the classes: *Ascomycetes* (sporogenic yeasts with the species *Aureobasidium pullulans*), *Deuteromycetes* (imperfect fungi- non-sporogenic yeasts) and the genus *Candida* (with the species *Candida mycoderma*). Most of the yeasts identified turned out to be yeasts of the genus *Saccharomyces*, but a number of yeasts belonging to other gene have been recorded non-*Saccharomyces* (*Candida, Cryptococcus, Torulaspora, Metschnikowia pulcherrima, Pichia*), and a number of results were inconclusive. The *Saccharomyces* genus has the highest share in the analyzed microbiota with the species *Saccharomyces cerevisiae*, followed by non-*Saccharomyces* species, like: *Aureobasidium pullulans, Torulaspora delbruckiib* and *Metschnikowia pulcherrima*.

Based on the results obtained, it can be concluded that the highest incidence in the studied microflora is held by sporogenic species. Future research will focus on the molecular identification of selected yeasts and use of isolated strains of *Saccharomyces cerevisiae* mixed with *Metschnikowia pulcherrima* strains and other non-Saccharmomyces strains (like *Torulaspora* delbruckii) to obtain biomass as a potential source for fish nutrients.

ACKNOWLEDGEMENTS

The present work was funded by the University of Agronomic Sciences and Veterinary Medicine of Bucharest – Romania, Research Project 1262/30.07.2021, acronym Feed4fish in the competition IPC 2021.

REFERENCES

Aponte, M., & Blaiotta, G. (2016). Potential Role of Yeast Strains Isolated from Grapes in the Production of Taurasi DOCG. *Frontiers in Microbiology*, 7.

Banu, C.P., Vasu, S.-S., & Stoicescu, A. (1987). *Biotehnologii în Industria alimentară: Folosirea Enzimelor Şi microorganismelor în Industria alimentară*. Editura Tehnică.

Hou, J., Tyo, K.E.J., Liu, Z., Petranovic, D., & Nielsen, J. (2012). Metabolic engineering of recombinant protein secretion by Saccharomyces cerevisiae. *FEMS Yeast Research*, *12*(5), pp. 491–510.

Kraepelin, G., Barnett, J.A., Payne, R.W., & Yarrow, D. (1984). Yeasts: Characteristics and identification. *Zeitschrift Für Allgemeine Mikrobiologie*, *24*(7).

Kurtzman, C.P., Fell, J.W., Boekhout, T., & Robert, V. (2011). Methods for isolation, phenotypic characterization and maintenance of yeasts. *The Yeasts,* pp. 87-110.

Parapouli, M., Vasileiadi, A., Afendra, A.-S., & Hatziloukas, E. (2020). Saccharomyces cerevisiae and its industrial applications. *AIMS Microbiology*, *6*(1), pp. 1–32.

Shurson, G. C. (2018). Yeast and yeast derivatives in feed additives and ingredients: Sources, characteristics, animal responses, and quantification methods. *Animal Feed Science and Technology*, *235*, pp. 60–76.

Tikka, C., Osuru, H.P., Atluri, N., Raghavulu, P., yellapu, N. K., Mannur, I. S., Prasad, U. V., Aluru, S., K, N. V., & Bhaskar, M. (2013). Isolation and characterization of ethanol tolerant yeast strains. *Bioinformation*, *9*(8), pp. 421–425.

Vassu, T., Csutak, O., Stoica, I., Musat, F. (2001). *Genetica microorganismelor si inginerie genetica microbiana.* Editura Petrion.

Zhou, N., Semumu, T., & Gamero, A. (2021). Non-Conventional Yeasts as Alternatives in Modern Baking for Improved Performance and Aroma Enhancement. *Fermentation*, *7*(3), pp. 102.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

P-ADIC NUMBERS AND APPLICATIONS IN AND OUTSIDE MATHEMATICS – AN OVERVIEW

Cosmin-Constantin NIȚU

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: cosmin.nitu@fifim.ro

Abstract

The concept of p-adic number was first introduced by Hensel in 1897, but it can be found in some previous works of Kummer. The main motivation for their introduction was the use of some techniques of mathematical analysis in number theory. For example, they play a keyrole in proving Fermat's Last Theorem. The p-adic numbers have important applications in physics (quantum physics, string theory), but in the recent years they have been used in other domains such: computer sciences, cognitive sciences, psychology, sociology, biology and genetics. In this paper we explain the notion of p-adic number and we briefly present some applications with references.

***Key words**: p-adic numbers, applications, string theory, quantum physics, biology.*

INTRODUCTION

In this article, I intend to present the notion of p-adic number and the philosophy behind it. I do not intend to show applications in detail in different areas, because it would be time-consuming and very technical, but I give representative references that the interested reader may follow. The paper is written in a way it can be read both by mathematicians and non-mathematicians.

p-Adic numbers were introduced for the first time by Hensel in 1897, but the concept can be found found, without being explicitly named so in some of Kummer's earlier works. The main motivation for their introduction was the use of some mathematical analysis techniques (especially series theory) in number theory. The closer two p-adic numbers are, the more their difference is divisible by a greater power of the prime number p.

In 1918, Ostrowski proved that any norm on the field of rational numbers $\mathbb{Q}$ is topologically equivalent either with the usual real module, or with the p-adic module for a certain prime number p. Topologically completing the set $\mathbb{Q}$ in relation to the usual module we obtain $\mathbb{R}$, and in relation to the p-adic we obtain $\mathbb{Q}_p$, the field of the numbers.

The complex analysis techniques mentioned above were aimed at local development of an analytical function in a power series. The first attempt came in 1930 with Schobe's PhD thesis, but the most successful was Krasner in the 1950's, inspired by Runge's theorem from the classical analysis of approximation of analytical functions by rational functions, using a simplified method of Weierstrass's for the analytical continuation. Subsequently, in 1961, the study of p-analysis triumphed by the works of Tate who used Gröthendieck's ideas, giving a rigid topological structure of the analytic spaces over the p-adic fields.

CONSTRUCTION OF REAL NUMBERS

First, I briefly recall the process of construction of real numbers in mathematics. One starts by constructing the set of natural numbers:

$$\mathbb{N} = \{0,1,2, \dots\},$$

then the set of integer numbers:

$$\mathbb{Z} = \{\dots -2, -1,0,1,2, \dots\},$$

then the set of rational numbers:

$$\mathbb{Q} = \left\{\frac{m}{n} \mid m \in \mathbb{Z}, n \in \mathbb{N}^*\right\}$$

Definition 1. The usual *module* (or *absolute value*) on $\mathbb{Q}$ is "the positive part of a number"

$$|x| = \begin{cases} x, & x \geq 0 \\ -x, & x < 0 \end{cases}$$

Definition 2. *A Cauchy sequence (or a fundamental sequence)* is a sequence (a_n) with the following property:
For all $\varepsilon > 0$, there exists $n_\varepsilon \in \mathbb{N}$, such that for any $m, n \in \mathbb{N}$, $m, n \geq n_\varepsilon$, one has

$$|a_m - a_n| < \varepsilon$$

One may find Cauchy sequences on $\mathbb{Q}$ that have the limits outside $\mathbb{Q}$ (for example with the limit $\sqrt{2}$), and this fact shows that $\mathbb{Q}$ is not a complete space with respect to the usual module, which intuitively means that the set of rational numbers $\mathbb{Q}$ cannot be geometrically represented on a straight line, because there would be gaps. Thus, one has to complete $\mathbb{Q}$ with respect to the usual module, by considering the classes of Cauchy sequences, and obtains the set of real numbers $\mathbb{R}$, which can be intuitively represented on a whole straight line.

CONSTRUCTION OF P-ADIC NUMBERS

I recall the intuitive definition of the notion of *commutative field* in mathematics, which means a set $(K, +, \cdot)$ in which the arithmetic happens in the usual way.

Definition 3. Let *K* be commutative field. We define by *norm* (or *absolute value*) on *K* a function $\|\cdot\|: K \to \mathbb{R}_+$ a function with the properties (Nițu, C.C., 2017):

1) $\|x\| = 0 \Leftrightarrow x = 0$;
2) $\|xy\| = \|x\| \cdot \|y\|$;
3) $\|x + y\| \leq \|x\| + \|y\|$, for all $x, y \in K$.

Definition 4. *The p-adic norm* (or *p-adic module*)

$$|x|_p = \begin{cases} p^{-v_p(x)}, & x \neq 0 \\ 0, & x = 0 \end{cases}$$

where $v_p(x)$ represents the *p*-adic exponent.

Example. For $x = \frac{63}{2} = 2^{-1} \cdot 3^2 \cdot 7$, we have $|x|_2 = 2, |x|_3 = 3^2, |x|_7 = \frac{1}{7}$ .and $|x|_p = 1$, for every prime number $p \neq 2,3,7$.

Definition 5. Let *K* be a commutative field. We define by *valuation* on *K* a function $v: K \to \mathbb{R}$ with the properties:

1) $v(0) = \infty$;
2) $v(xy) = v(x) + v(y)$;
3) $v(x + y) \geq \min\{v(x), v(y)\}$,

for all $x, y \in K$.

Definition 6. Let *M* be a non-empty set. By a *distance (or a metric)* on *M* we mean a function $d: M \times M \to \mathbb{R}_+$ whith the properties:

1) Separability:

$$d(x, y) \geq 0, d(x, y) = 0 \Leftrightarrow x = y.$$

2) Symmetry: $d(x, y) = d(y, x)$
3) Triangle's inequality:

$$d(x, y) \leq d(x, z) + d(z, y),$$

for all $x, y \in M$.
The pair (M, d) is called a *metric space.*

Definition 7. Let (M, d) be a metric space. We define the open ball centered at *a* and of radius $\varepsilon > 0$:

$$B(a, \varepsilon) = \{x \in M |\ d(x, a) < \varepsilon\}$$

and the closed ball cantered at *a* and of radius $\varepsilon > 0$:

$$B[a, \varepsilon] = \{x \in M |\ d(x, a) \leq \varepsilon\}$$

Remark 1. These balls are the correspondents of the real open and closed intervals centred at the point a, $(a - \varepsilon, a + \varepsilon)$ and $[a - \varepsilon, a + \varepsilon]$.

Definition 8. A norm on *K* is called *non-archimedian* if $\|x + y\| \leq \max\{\|x\|, \|y\|\}$, for all $x, y \in K$, and *archimedean* otherwise. Also, a distance is called non-archimedean if $d(x, y) \leq \max\{d(x, z), d(y, z)\}$, for all $x, y, z \in K$ and archimedean otherwise. In particular, the distance induced by a the non-archimedean norm is non-archimedean. A non-archimedean metric space is also called an *ultrametric space*.

Remark 2. If $v: K \to \mathbb{R}$ is a valuation on *K* and $c \in (0,1)$, then $\|\cdot\|: K \to \mathbb{R}_+$, defined by $\|x\| = c^{v(x)}$ is a non-archimedian norm on *K*.

Definition 9. Let *X* be a set and τ a family of subsets of X. τ is called a *topology* (from the greek words "topos" (place) and "logos" (study)) if it has the following properties:

1) $\phi, X \in \tau$;
2) $(A_i)_i \in I \in \tau \Rightarrow \bigcup_{i \in I} A_i \in \tau$;
3) $A, B \in \tau \Rightarrow A \cap B \in \tau$.

A set $A \in \tau$ is called an *open* set, and its complement is called a *closed* set. A pair (X, τ) is called a *topological space*. It is easy to show that every metric space has a natural structure of a topological space, the topology being generated by the open balls.
Topological spaces are used to define continuous functions in the most general way.

Definition 10. Let (X, τ_X) and (Y, τ_Y) be two topological spaces. A function $f: X \to Y$ is named *continuous* if for all $U \in \tau_Y$, the preimage $f^{-1}(U) \in \tau_X$.

Definition 11. We say that two metrics (or norms) defined on the same field *K* are *equivalent* if they generate the same topology on *K*.

Theorem 1. (Ostrowski (born in Kiev), 1918)
A nontrivial norm defined on the the field of rational numbers $\mathbb{Q}$ is either equivalent with the usual module, or with the p-adic module, for a certain prime number *p*.

Remark 3. This is a very important theorem which establishes the **philosophy** behind the *p*-adic numbers: **there are only two possible ways in which one phenomenon can be analysed: the real way, or the *p*-adic way**. Therefore, it is natural to investigate *p*-adic mathematical modelling in different areas and to compare them with the models in real numbers.

Definition 12. Two sequences of rational numbers (a_n) and (b_n) are called *equivalent* and we write $(a_n) \sim (a_n)$ if for every $\varepsilon > 0$, there exists $n_\varepsilon \in \mathbb{N}$ with the property

$$|a_n - b_n|_p < \varepsilon, \text{ for all } n \geq n_\varepsilon .$$

It easy to show that "~" defined above is an equivalence relation. We denote by $\overline{(a_n)}$ the equivalence class of the sequence (a_n).

Definition 13. *The field of p-adic numbers* is the topological closure of $\mathbb{Q}$ with respect to the *p*-adic norm:

$$\mathbb{Q}_\mathrm{p} = \left\{\overline{(a_n)} \mid (a_n) \subset \mathbb{Q}, \text{Cauchy sequence}\right\}$$

We also denote by $\mathbb{Z}_\mathrm{p} = \left\{x \in \mathbb{Q}_\mathrm{p} \middle| \, |x|_p \leq 1\right\}$ *the ring of p-adic integers*.

Proposition 1. If $a = \overline{(a_n)} \in \mathbb{Z}_\mathrm{p}$, then there exists a unique sequence $(c_n), c_n \in \mathbb{N}, 0 \leq c_n < p$, such that

$$a_n = \sum_{k=0}^{n-1} c_k p^k, \ \ for\ all\ n \in \mathbb{N}$$

Thus, one can write

$$a = c_0 + c_1 p + c_2 p^2 + \cdots$$

Furthermore, if $a \in \mathbb{Q}_\mathrm{p} \backslash \mathbb{Z}_\mathrm{p}$, then $\frac{a}{|a|_p} = ap^m \in \mathbb{Z}_\mathrm{p}$ and we can write

$$a = \frac{c_{-m}}{p^m} + \frac{c_{-m+1}}{p^{m-1}} + \cdots + c_0 + c_1 p + c_2 p^2 + \cdots$$

Remark 4. The arithmetic in $\mathbb{Q}_\mathrm{p}$ resembles the one from the *p* base of natural numbers, but the computation is done from "left to write".

Example. If $p = 5$, in $\mathbb{Q}_5$, for

$$a = 2 + p + 4p^2 + \cdots$$
$$b = 3 + 2p + 4p^2 + \cdots$$

then

$$a + b = 4p + 3p^2 + \cdots$$
$$a - b = 4 + 3p + 4p^2 + \cdots$$
$$ab = 1 + 3p + 3p^2 + \cdots$$
$$\frac{a}{b} = 4 + 2p + 4p^2 + \cdots$$

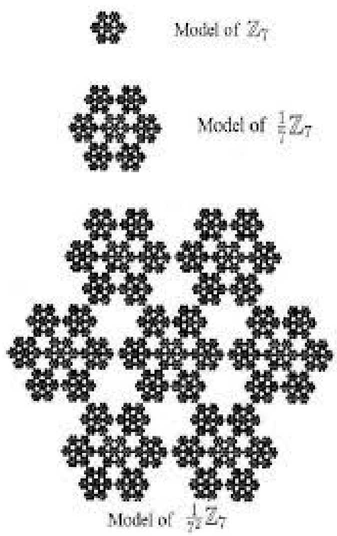


Figure 1. The p-adic balls can be represented in a fractal way (Robert A.M., 2000)

Theorem 2. The algebraic closure $\overline{\mathbb{Q}}_p$ is not a complete metric space with respect to the p-adic module. Let $\mathbb{C}_p = \widetilde{\overline{\mathbb{Q}}_p}$ be the topological closure of $\overline{\mathbb{Q}}_p$. Then $\mathbb{C}_p$ (also named the Tate field), is algebraically closed.

Remark 5. An algebraic closure of a field K is an extension denoted by $\overline{K}$ in which any polynomial from $K[X]$ has all his roots. All algebraic closures of a field are isomorphic.

Similarities between $\mathbb{R}$ and $\mathbb{Q}_p$

- both are fields, completions of $\mathbb{Q}$;
- $\mathbb{Q}$ is dense in each of them;
- they are locally compact spaces;
- they are not algebraically closed;
- we can use analysis techniques that have many similarities.

Differences between $\mathbb{R}$ and $\mathbb{Q}_p$

- $\mathbb{R}$ is an ordered field, the order relation being compatible with algebraic operations "+" and "·";
- $\mathbb{R}$ is archimedean, and $\mathbb{Q}_p$ is non-archimedean;
- $\mathbb{R}$ is a connected topological space, while $\mathbb{Q}_p$ is completely disconnected;
- On $\mathbb{Q}_p$ we cannot clearly define the notions of interval or curve.

General principles of ultrametric calculus

- The strongest wins:
$$|x| > |y| \Rightarrow |x + y| = |x|;$$
- Equilibrum: Every triangle is isoscel (or equilateral):
$$a + b + c = 0,\ |c| < |b| \Rightarrow |a| = |b|;$$
- Competition:
$$a_1 + a_2 + \cdots + a_n = 0 \Rightarrow \text{there exist } i \neq j \text{ such that } |a_i| = |a_j| = \max_{k=1,n} |a_k|;$$
- A dream came true: (a_n) is a Cauchy sequence $\Leftrightarrow |a_{n+1} - a_n| \to 0$;
- A first-year student's dream: the series $\sum_{n\geq 1} a_n$ is convergent $\Leftrightarrow a_n \to 0$;
- Stability of the absolute value:
$$a_n \to a \Rightarrow there\ exists\ N \in \mathbb{N} \text{ such that } |a_n| = |a|, for\ all\ n \geq N.$$

Elements of *p*-adic topology

- in a non-archimedean field the balls and spheres are open sets and closed sets; any two balls of the same kind are either disjoint or one contains the other. A set that is open and closed it is called a *clopen*;
- any point on a ball can be considered the center of that ball;
- any non-archimedean field K is totally disconnected, that is, the only connected subsets are those of the form $\{a\}$, $a \in K$;
- $\mathbb{Z}$ is dense in $\mathbb{Z}_p$. $\mathbb{Q}$ is dense in $\mathbb{Q}_p$;
- $\mathbb{Z}_p$ is compact and $\mathbb{Q}_p$ is locally compact;
- Any finite extension of $\mathbb{Q}_p$ is locally compact;
- $\mathbb{C}_p$ is not locally compact. In fact, it can be shown that
$$\mathrm{B}[0,1] = \{x \in \mathbb{C}_p \mid |x|_p \leq 1\}$$
is not compact.

APPLICATIONS

When they were first introduced, *p*-adic numbers where considered an exotic part of pure mathematics, without practical applications.

Soon after that, their property of being closer when their difference is divisible by a greater power of *p*, showed they were very useful in encoding properties of modulo *p* congruences and allowed the use of new analytical methods in number theory (for applications to mathematics see Koblitz N., 1977; Manin Yu & Panchishkin A.A., 2007). Thus, they turned out to have important applications in number theory, for example in the proof of Fermat's Last Theorem (Wiles, A.J., 1995).

Remark 6. Fermat's Last Theorem (FLT), was conjecture by the French mathematician Pierre de Fermat in 1637 and states that the equation
$$x^n + y^n = z^n$$
has no strictly positive natural solutions if $n \geq 3$.

The efforts of proving it by generations of mathematicians led to the development of modern algebra.

Since the 1960's physicist became interested in creating new models of space-time for the description of the very small Plank distances. There are evidences that the standard model based on real numbers is not correct, and that the p-adic numbers may give a better description due to some of their properties, such the fact that they are not ordered.

Thus, p-adics are an important tool for mathematical modelling in string theory and quantum mechanics (Rozikov, U.A., 2013; Araf'eva, L.Ya. et al., 1991; Freund P.G.O. & Witten E, 1987; Khamraev M. et al., 2004; Vladimirov V.S et al., 1994). This interest in physics gave rise to the development of new mathematical branches such as: theory of p-adic distributions (Albeverio, S. et al., 2010; Khrennikov, A.Yu., 1994) p-adic differential equations (Khrennikov, A.Yu., 1990; Vladimirov, V.S. et al., 1990), p-adic probability theory (Khrennikov, A.Yu., 1994; Vladimirov, V.S. et al., 1990) and p-adic spectral theory (Albeverio, S. & Khrennikov, A.Yu, 1996; Albeverio, S. et al., 1997; Khrennikov, A.Yu., 1997).

The representation of p-adic numbers as a sequence of digits allowed the use of this number system for encoding information. In particular, they can be used in cognitive sciences, psychology and sociology.

Such models are based on p-adic dynamical systems (Albeverio, S. et al., 2013; Albeverio, S. et al., 1999; Albeverio, S.A. et al., 1998; Anashin, V. & Khrennikov, A., 2009; Silverman, J., 2007).

For example, the human process of thinking can be modelled by a dynamical system that works with ideas or sets of ideas, of the form

$$x_{n+1} = f(x_n), \qquad x_n \epsilon X$$

where $X = \mathbb{Z}_p$ is the configuration space of dynamical system, the "space of ideas", and f is an analytic function on X (a function that can be developed locally at the point x_0 as a Taylor series: $f(x) = \sum_{n\geq 0} a_n (x - x_0)^n$).

There also exist effective results in areas such: computer science (straight line programs, cryptography, automata theory, formal languages), numerical analysis and simulations (Anashin, V. & Khrennikov, A, 2009; Anashin, V.S., 2011; Anashin, V., 2010; Anashin, V., 2012; Fan, A.H. & Liao, L.M., 2011; Kingsbery, J. 2009; Kingsbery, J., 2011; Lin, D. et al., 2012; Pin, J.E., 2009; Shi, T. et al., 2012).

An automaton is a relatively self-operating machine, or control mechanism designed to automatically follow a sequence of operations, or respond to predetermined instructions. For example, a finitness criteria for automata presented in an article mentioned above states that: Given a Lipschitz function $f: \mathbb{Z}_p \to \mathbb{Z}_p$ represented by the van der Put series

$$\sum_{n\geq 0} b_n p^{[\log_p n]} X(m, x)$$

then the function f is the automaton function of a finite automaton if and only if the following conditions are satisfied:

i) $B_f = \{b_n | \; n \geq 0\}$ is a finite subset of $\mathbb{Q} \cap \mathbb{Z}_\mathrm{p}$;

ii) the p-kernel of the sequence (b_n) is finite.

Remark 7. A function $f: (X, d_1) \to (Y, d_2)$ defined between two metric space is called Lipschitz if there exists $\lambda > 0$ such that

$$d_1\big(f(x), f(y)\big) \leq \lambda \, d_2(x, y) \, .$$

Remark 8. $X(n, x) = \begin{cases} 1, & if \; |x - n| \leq p^{-m} \\ 0, & otherwise \end{cases}$

Remark 9. The p-kernel of the sequence $b = (b_n)$ is the set $\ker(b)$ of all subsets $(b_{kp^m+t})_{\; k\geq 0}$, where $0 \leq t < p^m$ is fixed.

Remark 10. $\left[\log_p n\right]$ (the lower integer part) represents the number of digits of the representation of *n* in the *p* base.

Also, some applications of p-adic numbers to biology and genetics have been proposed (see Albeverio, S. et al., 2013;
Albeverio, S., 1999; Albeverio S., 1998; Khrennikov, A. Yu. Et al., 1997). It is considered that p-adic numbers can be used to model biological systems and phenomena with a hierarchical structure.

REFERENCES

Albeverio, S. and Khrennikov A.Yu. (1996). Representation of the Weyl group in spaces of square integrable functions with respect to p-adic valued Gaussian distributions, *J. Phys. A*, 29, pp. 5515–5527.

Albeverio, S., Cianci, R. and Khrennikov, A.Yu. (1997). A representation of quantum field Hamiltonians in a p-adic Hilbert space, *Theor. Math. Phys.*,112(3), pp. 355–374.

Albeverio, S., Khrennikov A.Y. and Shelkovich V.M. (2010). Theory of p-Adic Distributions: Linear and Nonlinear Models (Cambridge University Press).

Albeverio, S., Khrennikov, A. and Kloeden, P.E. (1999). Memory retrieval as a p-adic dynamical system, *BioSys.,* 49, pp. 105–115.

Albeverio, S., Khrennikov, A., Tirozzi, B. and De Smedt, S. (1998). p-adic dynamical systems, *Theor. Math. Phys.*, 114, pp. 276–287.

Albeverio, S., Rozikov U.A. and Sattarov I.A. (2013). p-adic (2, 1)-rational dynamical systems, *J. Math. Anal. Appl.*, 398(2), pp. 553–566.

Anashin, V. (2010). Non - Archimedean ergodic theory and pseudorandom generators, *The Computer J.,* 53(4), pp. 370–392.

Anashin, V. (2012). Automata finiteness criterion in terms of van der Put series of automata functions, p-Adic Numbers, *Ultrametric Anal. Appl.* 4(2), 151–160.

Anashin, V. and Khrennikov, A. (2009). Applied Algebraic Dynamics, de Gruyter Expositions in Mathematics, Vol. 49 (Walter de Gruyter, Berlin, New York).

Anashin, V.S., Khrennikov, A.Yu. and Yurova, E.I. (2011). Characterization of ergodicity of p-adic dynamical systems by using van der Put basis, *Doklady Math.* 83(3), pp. 306–308.

Araf'eva, L.Ya., Dragovich, B., Frampton, P.H. and Volovich, I.V. (1991). Wave function of the universe and p-adic gravity, *Mod. Phys. Lett. A,* 6, pp. 4341–4358.

Dragovich, B., Khrennikov, A.Yu., Kozyrev, S.V. and Volovich, I.V. (2009). On p-adic mathematical physics, p-Adic Numbers, *Ultrametric Anal. Appl.,* 1(1), pp. 1–17.

Dubischer, D., Gundlach, V.M., Khrennikov, A. and Steinkamp, O. (1999). Attractors of random dynamical system over p-adic numbers and a model of 'noisy' cognitive process, *Phys. D*, 130, pp. 1–12.

Fan, A.-H. and Liao, L.M., (2011). On minimal decomposition of p-adic polynomial dynamical systems, *Adv. Math*. 228, pp. 2116–2144.

Freund, P.G.O. and Witten, E. (1987). Adelic string amplitudes, *Phys. Lett.*, B 199, pp. 191–194.

Khrennikov, A.Yu. (1990), Mathematical methods of the non-Archimedean physics, *Uspekhi Mat. Nauk* 45(4), pp. 79–110.

Khrennikov, A.Yu. (1994). p-Adic Valued Distributions in Mathematical Physics (Kluwer, Dordrecht).

Khrennikov, A.Yu. (1997). Non-Archimedean Analysis: Quantum Paradoxes, Dynamical Systems and Biological Models (Kluwer Academic Publishers, Dordrecht, The Netherlands).

Khrennikov, A.Yu. (1997). The description of Brain's functioning by the p-adic dynamical system, preprint No. 355 (SFB-237), Ruhr Univ. Bochum, Bochum.

Kingsbery, J., Levin, A., Preygel A. and Silva, C.E. (2009). On measure-preserving c1 transformations of compact-open subsets of non-archimedean local fields, *Trans. Amer. Math. Soc.* 361(1), pp. 61–85.

Kingsbery, J., Levin, A., Preygel, A. and Silva, C. E. (2011). Dynamics of the p-adic shift and applications, *Disc. Contin. Dyn. Syst*. 30(1), pp. 209–218.

Koblitz, N. (1977). p-Adic Numbers, p-Adic Analysis, and Zeta-Functions (Springer, Berlin).

Lin, D., Shi, T. and Yang, Z. (2012). Ergodic theory over F2[[X]], Finite Fields Appl. 18, pp. 473–491.

Manin, Yu.I. and Panchishkin, A.A. (2007). Introduction to Modern Number Theory (Springer, Berlin).

Nițu, C.C. (2017). p-adic Distributions, Krasner analitic functions and applications (PhD thesis), Institute of Mathematics "Simion Stoilow" of the Romanian Academy.

Pin, J.-E. (2009). Profinite methods in automata theory, in Symposium on Theoretical Aspects of Computer Science — STACS 2009, (Freiburg), pp. 31–50.

Robert, A.M. (2000). p-adic Numbers. In: A Course in p-adic Analysis. Graduate Texts in Mathematics, vol 198. Springer, New York, NY. https://doi.org/10.1007/978-1-4757-3254-2_1

Rozikov, U.A. (2013), What are p-Adic Numbers? What are They Used for? Asia Pacific Math. Newsletter, 4(3), pp. 1-6.

Schikhof, W. (1984). Ultrametric Calculas (Cambridge University, Cambridge).

Shi, T., Anashin, V. and Lin, D. (2012). Linear weaknesses in T-functions, in SETA 2012, eds. T. Helleseth and J. Jedwab, *Lecture Notes Comp. Sci.*, Vol. 7280 (Springer-Verlag, Berlin, Heidelberg), pp. 279–290.

Thiran, E., Verstegen, D., and Weters, J. (1989), p-adic dynamics, *J. Stat. Phys.*, 54(3/4), pp. 893–913.

Vladimirov, V.S., Volovich, I.V. and Zelenov, E.I. (1990). The spectral theory in the p-adic quantum mechanics, Izvestia Akad. Nauk SSSR, Ser. Mat. 54(2) 275–302.peri-urban areas in Burkina Faso. *African Journal of Agricultural Research*, *3*(3), pp. 215–224.

Vladimirov, V.S., Volovich, I.V. and Zelenov, E.I. (1994). p-Adic Analysis and Mathematical Physics [in Russian], Nauka, Moscow English transl., World Scientific, Singapore.

Volovich, I. V., p-adic strings (1987), *Class. Quantum Grav.,* 4 pp. L83–L87.

Wiles, A.J. (1995). Modular elliptic curves and Fermat's Last Theorem, *Annals of Mathematics*, 141 (1995), pp. 443-55.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

OPPORTUNITIES TO APPLY NATURE-BASED SOLUTIONS IN ROMANIA IN THE CONTEXT OF EUROPEAN COMMON AGRICULTURE POLICY

Adriana-Magdalena PIENARU[1], Dan RĂDULESCU[2]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania
[2]Independent Consultant, Bucharest, Romania

Corresponding author email: apienaru@gmail.com

Abstract

The agriculture is facing different pressures linked to diffuse pollution from nutrients and chemicals, water abstraction and hydromorphological changes. According to information reported under the Water Framework Directive, around one third of surface water bodies fail to achieve good status because of one or several of these pressures. Using sustainable management practices based on agroecological principles, organic farming, and nature-based solutions, with multiple sustainability benefits, can contribute to reducing the magnitudes of pressures on water, enhancing the long-term resilience of agriculture to climate changes and benefit biodiversity. Investing in treatment plants, pipes, and conveyance schemes, is often the most trusted solution, but conventional engineered methods represent end-of-pipe solutions that do not address pollution at the source. The paper is presenting opportunities for green infrastructure and nature-based solutions application in Romania to aid in addressing some of the situations mentioned above.

Key words*: agriculture, green infrastructure, nature-based solutions, diffuse pollution, Romania.*

INTRODUCTION

According to the data included in the National Management Plan - Danube International River Basin Segment in Romania - Update 2021, agricultural activities are a major source of diffuse pollution, mainly due to nitrogen and phosphorus releases (MMAP-ANAR, 2021). According to the same document, agricultural activities contribute with approximatively 22.5% of the loads from nitrogen and 55.2% of the loads from phosphorus to the receiving waters. Although a significant reduction of releases from these compounds have been noticed since the last National Management Plan 2015, agricultural sector remains a significant source of diffuse pollution that puts pressure on achieving the good water status outlined in the European Union's Water Framework Directive. It is undeniable that water resources worldwide are under tremendous stress, especially due to the population migration from rural to urban areas and the spectre of climate changes.

In 2018, based on United Nations data, approximately 55% of the world's population lived in urban areas, and by 2050 this percentage is expected to reach 68% ("68% of the world population", 2018).

While this migration from rural to urban areas poses significant pressures on water resources in and around urban areas, at the same time, it increases the demands on agricultural yields and therefore the needs for water resources and production lands while there is a substantial conversion of land use. In addition, structural works constructed to protect agricultural production lands from flooding add to the hydromorphological changes pressures on the watercourses by limiting their continuity and disturbing the riverine and fluvial ecosystems. Climate change also intensifies the desertification phenomenon, disturbs the weather patterns, and increases the frequency of extreme rain events, in addition to the other challenges.

In this context, the paper describes an analysis of the opportunities available to apply nature-based solutions in the agricultural context where conventional structural engineering methods may not be as suitable under the new circumstances. In addition, at the international level there is a serious change of paradigm, from intensive agriculture to more nature friendly, ecological methods.

MATERIALS AND METHODS

To determine the range of measures and methods available to support the shift in paradigm toward sustainable, green infrastructure and eco-friendly nature-based solutions, several resources have been investigated. The focus was mainly on European Union strategies and available guidance; however, other international resources have been investigated.

The research relied on resources that increased in number and depth of detail in the recent period. While green infrastructure and nature-based solutions are not new concepts, they emerged in the 2000s to promote nature as a source of answers to challenges associated with climate change. The European Commission issued a Green Infrastructure Strategy in 2013 that declares: “Green Infrastructure is based on the principle that protecting and enhancing nature and natural processes, and the many benefits human society gets from nature, are consciously integrated into spatial planning and territorial development. Compared to single-purpose, grey infrastructure, GI has many benefits. It is not a constraint on territorial development but promotes natural solutions if they are the best option. It can sometimes offer an alternative, or be complementary, to standard grey solutions” (European Commission, 2013).

In addition, the European Union launched a nature-based solutions research policy to “support major EU policy priorities, in particular the European Green Deal, biodiversity strategy and climate adaptation strategy, as a way to foster biodiversity and make Europe more climate-resilient” (“Nature-based solutions research policy”, 2022).

RESULTS AND DISCUSSIONS

Undoubtedly, in the current era of climate changes, agricultural production depends on the impacts of unpredictability due to changes in patterns for precipitation and temperatures. Also, many reports and studies identify the increase of frequency and severity of extreme events as a major concern for the future of agriculture. The desertification phenomenon is also of serious concern, the Romanian authorities estimated in their Sixth National Communication on Climate Change and First Biennial Report (December 2013) that the area subject to desertification, characterised by an arid, semi-arid or subhumid-dry climate, is approximately 30% of the total area of Romania, being largely situated in Dobrogea, Moldavia, the south of the Romanian Plain and the Western Plain (European Court of Auditors, 2018). The demands on water resources are increasing and the agricultural activities, especially the intensive ones, apply themselves significant pressures on the environment. According to a recent European Environmental Agency’s report, the main pressures from agriculture to the receiving waters are linked to diffuse pollution from nutrients and chemicals (pesticides and some metals with predilection), to water abstraction and to hydromorphological changes (EEA, 2021a, Figure 1).

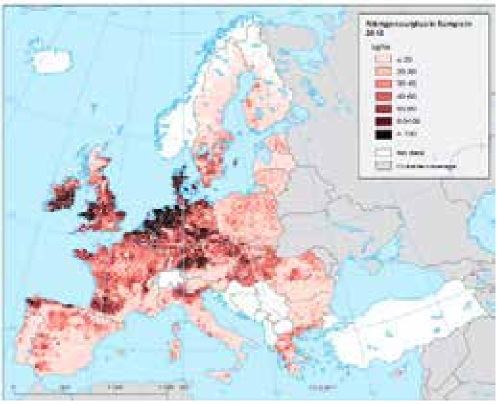


Figure 1. Nitrogen surplus in Europe in 2012

As a response to these challenges several international initiatives encourage the use of nature-based solutions as a way forward toward sustainable agricultural practices. Multiple global frameworks and policy initiatives – including the UN Framework Convention on Climate Change (UNFCCC), UN Convention for Combating Desertification (UNCCD), the Convention on Biological Diversity (CBD) and the Sustainable Development Goals (SDGs) – support the use of natural or ecosystem approaches to slow climate change and enhance the environment.

The Food and Agriculture Organization of the United Nations (FAO) emphasizes that healthy soils lay at the foundations of agricultural development, healthy and nutritious food production, and essential ecosystem services, which are crucial to our basic survival as well as our planet's sustainable future (FAO - Soils Portal, 2022). The soil's function of supporting food and agriculture worldwide is fundamental for the preservation and advancement of human life on this planet. Soil is increasingly recognized as playing a fundamental role in the quality and availability of our water supply. The soil, coupled with the landscape and its vegetation is responsible for the distribution of all rainwater falling upon it and thus plays a key role with respect to the water cycle and supply as now recognised by hydrologists. Related to how water moves through the soil and the absorption properties of soils is the soil's ability to perform an important function in pollution control (pesticides, nitrates, etc).

Furthermore, the EU Common Agricultural Policy (CAP) reform proposed by the European Commission in 2018 has common goals with the Green Deal in the environmental area by promoting climate change action, environmental care and landscape and biodiversity preservation ("Key policy objectives of the new CAP", 2022). The new CAP has introduced an enhanced conditionality for environmental protection. In support of the new CAP and other EU initiatives, the EU Soil Strategy sets the baseline for more ambitious and sustainable agricultural commitments through environment- and climate-friendly farming practices under eco-schemes and rural development interventions. Member States should better integrate soil and land use management in their river basin and flood risk management plans where possible by deploying nature-based solutions such as protective natural features, landscape features, river restoration, floodplains, etc. One of the main actions contained in the EU Soil Strategy for 2030 is making sustainable soil management the new normal, by proposing a scheme for landowners to get their soils tested for free, promoting sustainable soil management through the CAP and sharing best practices (European Commission, 2021). Emphasis is put on activities that are sustained by good environmental approaches that can achieve a sustainable system of agriculture. As an example, the CAP preserves both the quantity and quality of water used in agriculture by establishing buffer strips along watercourses, and by supporting more efficient irrigation systems, among other measures. In addition, rural development policy encourages actions that conserve and enhance biodiversity, such as providing funds for the establishment and maintenance of landscape features and "wildlife corridors", and supporting high nature value farming systems and nature management plans that nurture wildlife-friendly areas ("An environmental sustainable CAP", 2022).

Moreover, a suite of natural water retention measures (NWRMs), that are identified as multifunctional measures that aim to protect and manage water resources using natural means and processes, can be implemented in areas where agricultural activities occur. Typically, NWRMs can deliver multiple benefits, including reduced greenhouse gas emissions, habitat improvement, flood risk reduction, water quality improvement, groundwater recharge and drought management (EEA, 2020). Several NWRMs suitable for agriculture are outlined in Figure 2.

In a key document on the topic, three issues are emphasised: 1) Nature-based solutions (NbS) are cost-effective interventions that can enhance resilience in agriculture and food production, while mitigating climate change and enhancing the environment; 2) Agricultural producers have a critical role in implementing NbS in their operations and can help to shape wider landscape scale approaches to nature-based solutions; 3) Policy makers can enable the implementation of nature-based approaches through a variety of means including by law and regulation, economic incentives, capacity building, and communications (Iseman & Miralles-Wilhelm, 2021).

It is estimated that nature-based solutions implemented across all ecosystems can deliver emission reductions under the scenarios outlined by the Intergovernmental Panel on Climate Change (IPCC): "approximately 62% of this contribution is estimated to come from nature-based solutions related to forests, about 24% from solutions in grasslands and croplands, and 10% from additional solutions in peatlands.

The remaining 4% will come from solutions implemented in coastal and marine ecosystems" (UNEP, 2021).

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

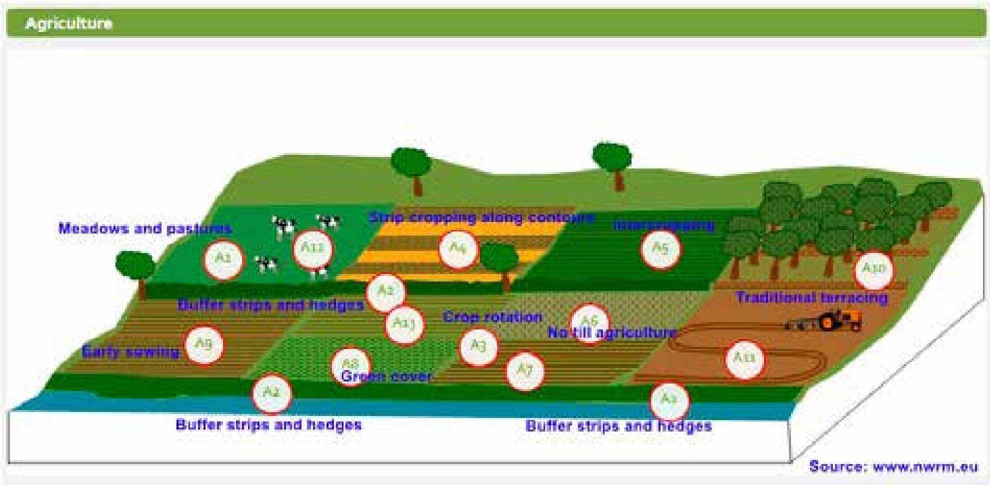


Figure 2. Suite of NWRMs for agriculture

Based on another study, natural climate solutions (NCS), another term for nature-based solutions, can provide 37% of cost-effective CO_2 mitigation needed through 2030 for a > 66% chance of holding warming to below 2°C, as shown in Figure 3 (Griscom, 2017).

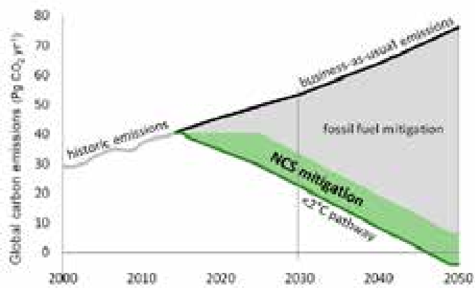


Figure 3. Contribution of natural climate solutions (NCS) to stabilizing warming to below 2°C

The research evaluated the importance of 20 conservation restoration, and improved land management actions that increase carbon storage and/or avoid greenhouse gas emissions across global forests, wetlands, grasslands, and agricultural lands. These NCS were chosen because they offer multiple benefits through water filtration, flood buffering, soil health, biodiversity habitat, and enhanced climate resilience.

The United Nations Development Programme, through its Climate and Forests Programme, also emphasizes the importance of taking into consideration the integration of nature-based solutions in the Agriculture, Forestry and Other Land-Use sector (AFOLU). It is suggested that NbS could provide a cost-effective solution for climate mitigation, adaptation and slowing of biodiversity loss (UNDP, 2021).

On the other hand, the implementation of nature-based solutions can be a viable approach to coping with environmental issues related to diffuse water pollution from agriculture. NbS use natural processes to remove pollutants from agricultural wastewater and they can also enable the recovery of otherwise lost resource, such as, nutrients (Mancuso G. et al., 2021). The benefits of NbS are shown in Figure 4.

An important case for supporting the new paradigm in Romania is represented by the approval of the first standard for ecological agriculture “SR 13595:2022 - Organic farming. Requirements and recommendations for environmentally sustainable products”. This original standard highlight that the purpose of organic farming is to produce cleaner food, to put on the market fresh and authentic agri-food products that respect natural and environmental factors, in full correlation with the conservation and development of a sustainable environment. The standard can be used as a reference for certification and is applicable to ecologically certified organizations that want to apply the principles of agroecology. The standard can also be applied by organizations in the process of ecological certification that want to apply the principles of agro-ecology.

"Organic farming" is a protected term, assigned by the European Union to Romania for the definition of this farming system, and is like the terms of "ecological farming" or "biological farming" used in other Member States.

Nature-based solutions in agriculture are also methods that enable climate change adaptation and disaster risk reduction. A key principle is that ecologically based diversification reduces vulnerability to hazards, while at the same time it can increase productivity (EEA, 2021). The EU Biodiversity Strategy for 2030 aims to increase biodiversity features on agricultural land, referring to agro-ecology as an option.

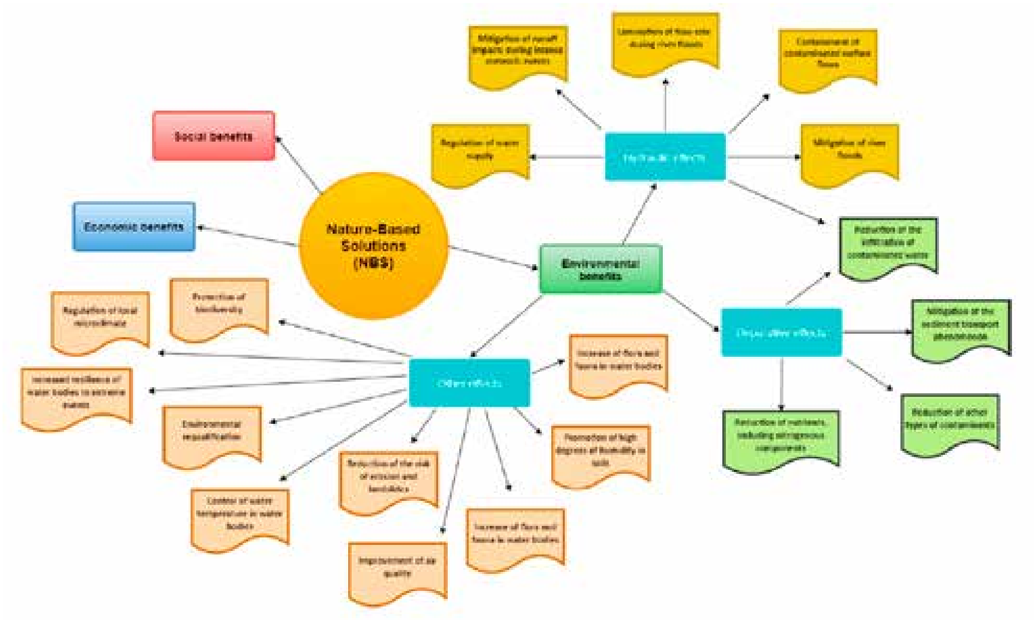


Figure 4. NbS implementation benefits (Mancuso G. et al., 2021)

CONCLUSIONS

Green infrastructure and nature-based solutions in agriculture are multi-functional and serve multiple benefits.

The projects already implemented at different scales and in different regions prove that these measures can be successful and economically valuable.

As far as benefits that can support the integration of EU's CAP with other strategies, such as climate change mitigation, sustainable soil and water management and soil protection, biodiversity, they are essential to establishing synergies and integration across various programs proposed for implementation.

As a member of the European Union, Romania may benefit from adopting these measures in its national programmes and allow for an integrated approach, since NbS can achieve multiple goals and can be implemented across various sectors.

Together we must commit to accelerating the role of NbS, not only in agriculture, but in many areas of our society, since they play an essential role in a sustainable future that addresses the multiple challenges we are facing today.

REFERENCES

European Commission (europa.eu). An environmentally sustainable CAP accessed on February 23, 2022.

European Commission (europa.eu). Key policy objectives of the new CAP accessed on February 22, 2022

European Commission (europa.eu). Nature-based solutions research policy accessed on February 22, 2022

European Commission, EU Soil Strategy for 2030 – COM (2021) 699 final

European Commission, Green Infrastructure (GI). Enhancing Europe's Natural Capital (2013). COM (2013) 249 final

European Court of Auditors (2018). Special Report No 33, Combating desertification in the EU: a growing threat in need of more action

European Environment Agency (2020). Water and agriculture: towards sustainable solutions, EEA Report No 17/2020. ISSN 1977-8449

European Environment Agency (2021). Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction, EEA Report No 01/2021. ISBN 978-92-9480-362-7

FAO – Soils Portal https://www.fao.org/soils-portal/en/ accessed on February 23, 2022

Griscom, B. W. et al. (2017). Natural Climate Solutions. *Proceedings of the National Academies of Sciences of the United States of America, 144*(44), 11645-11650.

Iseman, T. and Miralles-Wilhelm, F. (2021). Nature-based solutions in agriculture – The case and pathway for adoption. Virginia. FAO and The Nature Conservancy. https://doi.org/10.4060/cb3141en

Mancuso, G. et al. (2021). Diffuse Water Pollution from Agriculture: A Review of Nature-Based Solutions for Nitrogen Removal and Recovery. *Water*, 13, 1893. https://doi.org/10.3390/w13141893

Ministry of Environment, Water and Forests, National Administration "Romanian Waters" (2021). Updated national management plan for the part of the international river basin of the Danube River that is included in the territory of Romania

National Standardisation Body - ASRO. SR 13595:2022. Organic farming. Requirements and recommendations for environmentally sustainable products

UN DESA - United Nations Department of Economic and Social Affairs accessed on January 20, 2022

United Nations Development Programme (2021). Considerations for integrating Nature-based Solutions into Nationally Determined Contributions: Illustrating the potential through REDD+. New York, USA: UNDP

United Nations Environment Programme and International Union for Conservation of Nature (2021). Nature-based solutions for climate change mitigation. Nairobi and Gland. ISBN: 978-92-807-3897-1

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

DIGITAL APPLICATION FOR REMOTE CONTROL OF BACTERIAL ENDOPHYTES GROWTH IN BIOREACTOR VIA INTERNET AS A DESIGN SOLUTION TO A VIRTUAL LABORATORY

Radu Cristian TOMA, Camelia Filofteia DIGUȚĂ, Oana Alina BOIU-SICUIA, Mihai FRÎNCU, Călina Petruța CORNEA

University of Agronomic Sciences and Veterinary Medicine of Bucharest,
59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: *sicuia.oana@yahoo.com*

Abstract

Defining and delimiting the notion of biotechnology is becoming increasingly complicated, as this field is connecting various branches of science and technology. Biotechnology advances are inextricably linked to the successes of bioengineering, as well as the development and implementation of equipment and means to control these processes.
The present paper aims to create a real time monitoring system for bacteral endophytes production carried out in the bioreactor. The advantage of this application allows not only locally monitoring of the process but also via INTERNET. The practical applicability of this system should be mentioned due to the effective possibility of using the bioreactor monitoring program in the educational process. Therefore, developing a software application for remote and real-time monitoring the technological process at bioreactor level is a central point of a virtual laboratory, an important element in achieving a quality educational process in the current pandemic context, a framework that has led to an increased need of digitization processes in all sectors of society.

Key words: *bioreactor, digitalisation, endophytes, INTERNET monitoring, virtual learning.*

INTRODUCTION

Biotechnology means the directed obtaining of compounds useful both in the national economy and medicine, through biological agents, such as microorganisms, animal, or plant cells, through extracellular substances and cellular components.
Defining and delimiting the notion of biotechnology is becoming increasingly complicated, this field integrating with various branches of science and technology, such as: microbiology and biosynthesis processes, molecular biology, genetics, and genetic engineering (to improve biological agents), biochemistry, physical chemistry and electrochemistry (creating biosensors), engineered technology (creating bioreactors and other equipment) (Larroche, 2016).
The main directions of biotechnology development are conditioned by two aspects: on one hand, by the demand in certain products and energy, simultaneously with the quantitative accumulations of unusable raw materials, including wastes, and on the other hand, by the appearance of new discoveries in fundamental research.
Emphasis is placed on developing technical solutions for biotechnological processes, by: (1) bioreactors design for the intensive growth of microorganisms and cell cultures, with strict observance of the homogenization in the regime of biological agent management, elaboration and choice of special materials for the construction of internal components of bioreactors; (2) elaboration of new bioreactor constructions, with incorporated membranes for the fractionation of synthetic products, for tissues cultures growth on supports, in suspensions and in films etc., in general, the necessary devices are of reduced volume; (3) development of bio-catalytic reactors, necessary due to the fact that many substrate-product transformations are achieved through immobilized biological agents; (4) a processing of fermentation products will be carried out in a manner analogous to those of the food and chemical industries, providing for the use of transducers, information processing systems and execution mechanisms (taking into account

the particularities of biotechnology); (5) the mathematical modelling of some technological processes, and especially of the fermentation process (bio-catalysis), will be directed towards the optimization of their current stage, as well as of the integral technological scheme; (6) a highly development must know the devices for measuring primary information; thus, cloud biosensors (e.g. enzymatic transducers) will be necessary and will be used to determine the concentration of substrates, semi-finished products, and, respectively, products of the new biotechnology; (7) as in other industries, the evaluation and registration of raw material and final product flows, as well as the control of technological processes are provided by computers.

The development of biotechnology is inextricably linked to the successes of bioengineering, and therefore of improved equipment and means to control these processes.

Exploring beneficial endophytes as bio-fertilizers represent a promising strategy to reduce dependency on agrochemicals (fertilizers and pesticides) in developing sustainable agriculture (Adeleke and Babalola, 2021).

We choose to cultivate endophytes in bioreactor due to their significant roles in promoting growth such as phytostimulation, biotic/abiotic stres resistance (Shen et al., 2019), their ability to secrete bioactive metabolites to control plant pathogens (Fadiji and Babalola, 2020).

There is an important aspect to translate microbial endophyte process technology from the laboratory scale to a manufacturing process (pilot) providing optimal controllable growth conditions (e.g., temperature, pH, oxygen transfer, mixing) for massive production of bio-fertilizers (Ganeshan et al., 2021).

Here, we focus our discussion on the development of a digital application to monitor, adjust, and securely control bacterial endophytes cultivation in bioreactors from anywhere at any time via internet. Also, the virtual biotech laboratory can help the students to learn and understand more easily the experiments to improve their laboratory skills for remote access without affecting the quality of learning.

MATERIALS AND METHODS

The bioreactor is a plant in which biological reactions and transformations take place, usually a fermentation or biotransformation. Our study was directed for the growth of bacterial endophytes widely used as inoculants in agriculture. Such endophytes are plant associated microorganisms adapted to live inside plant tissues without causing harms to their hosts. Due to the intimate-beneficial relationship between these microorganisms and plants, it is considered that endophytes are valuable agro-inoculants. The endophyte used as microbial model to design the bioreactor application is a *Bacillus amyloliquefaciens* strain wisely selected to meet the requirements of organic farming and agro-inoculants production.

Before enlarging inoculants production to bioreactor scale, endophytic bacteria were selected based on their beneficial effect on economically important plant species and various agronomic and technical qualities. Among the agronomic traits the selected endophytic strain meets various biostimulant abilities that improve plant growth and development. It solubilize and increase the uptake of important organic and anorganic nutrients, is favorize plan nutrition with macronutrients, micronutrients and oligoelements, and it produces organic acids, enzymes and plant hormones. This strain also revealed good biocontrol activity against important phytopatogens and microbial contaminants. Moreover, this train is having good technical qualities, and can easily adapt to be multiplied in controlled condition.

The growth medium conventionallyused for *B. amyloliquefaciens* is Luria-Bertani. This substrate contains tryptone1%, yeast extract 0.5%, sodium chloride 0.5 to 1%, and a pH of 7.0±0.2. The optimal temperature is 30°C but can tolerate a wide thermal range. As *B. amyloliquefaciens* is an aerobic bacterium, to reduce flocculation, a proper stirring is recommended for the liquid culture.

The bioreactor, fermentation and biotransformation are the bases in biotechnology, from the manufacture of bread to the production of interferon with the help of genetic engineering, all represent fermentation processes produced in the bioreactor (Schugerl, 2001).

Although the classification categories of bioreactors are multiple, conventionally, bioreactors are classified into 3 groups, according to capacity: (1) Laboratory bioreactors, with a capacity of up to 50 L, are used in the laboratory, for research, for starting and optimizing the fermentation process on an industrial scale; (2) The bioreactors in the pilot stations, with a capacity between 50 and 1000 L, are used as an intermediate and optimization phase in the process of raising the fermentation process to industrial scale (Komives, 2003).

Bioreactors in pilot stations require a high degree of technological flexibility to allow the optimization of the bioprocess; (3) Industrial bioreactors can have any capacity, but usually have a volume of over 1000 L and can reach 1000000 L. In general, industrial bioreactors are much more specialized than pilot station bioreactors, they are designed to be able to operate a certain process with maximum efficiency (Mandenius, 2016).

Researchers aim to create a real-time culture control system. This requires two premises: high-performance computer systems as well as the existence of adequate software, and the possibility of on-line measurement of intracellular activities. Currently, not all parameter measurements can be made on-line, some being done off-line.

On-line measurements can be made for: temperature, pH, dissolved oxygen, determined gases. The values of pH and dissolved oxygen provide extremely useful data to the system, representing practically the alarm signal of the process, any deviation in these values must be corrected on the spot.

The analysis of gases emitted by microorganisms can be done on-line and provides information on the respiration coefficient and the rate of oxygen uptake.

Monitoring and regulation systems can be grouped into three basic categories: in-line, on-line, and off-line.

Off-line systems involve collecting samples at regular intervals for further treatment and analysis. These techniques involve standard chemical analyses which, although they can be optimized using automated laboratory analysers, take too long to achieve effective feedback regulation.

On-line systems use techniques that allow the continuous collection of samples on the flow, with their rapid analysis, so that the response time is within the time required to make decisions to regulate the process (Mitra, 2021). Examples of such systems include continuous gas extraction for analysis performed with a mass spectrophotometer or gas chromatograph, continuous dialysis of a culture medium for analysis with a high-performance liquid chromatograph (Schael, 2002).

In-line systems, electrodes and sensors are in direct contact with the environment, giving a fast, continuous signal. These include temperature, pH, dissolved oxygen, pressure sensors. In-line sensors must be sterilizable.

One of the main limiting factors in the processes carried out in bioreactors with a capacity of more than a few litres is the availability of oxygen and its speed of distribution to cells.

Oxygen is slightly soluble in water and is therefore found in small amounts in the culture medium, so that at a high density of microorganisms in the environment, they deplete it in a few minutes.

In general, the distribution of gas in the culture medium is done by aeration through a bubbler. As bubbles are smaller in diameter, faster and more efficient is oxygen transferred to the cells (Chopda, 2020).

One way to reduce the size of the bubbles is to introduce air through perforated pipes, instead of using a bubbler. Another way is to stir the culture with a stirring mechanism, a stirrer that can be of several types and sizes, depending on the nature of the process and the result sought.

Agitation and aeration of the culture medium can produce foaming especially in environments with a high cell density or with the addition of nutrients such as yeast, soy extract, etc. Foaming can be detected by attaching a sensor above the culture medium. When the foam produced touches the sensor, an electrical circuit closes that activates a pump connected to a source of antifoaming agent.

In addition to these aeration and agitation devices, bioreactors must have sensors to control and maintain oxygen, temperature, pH. Temperature control, for example, is important

for many fermentation processes that occur with the release of heat into the system, and the participating microorganisms may not tolerate this excess heat as the system needs to be cooled (excess heat dissipated).
It is recommended to monitor the intracellular activities and to achieve an optimal standardized technological profile of the fermentation in the bioreactor so that if deviations from it are observed to intervene by modifying the environmental conditions to correct them (Ferrero, 2012).
The equipment descripted above is contained in the reactor tank (Figure 1). The material of manufacture is stainless steel, and it must be of a high degree of purity in order not to corrode and to prevent the leakage of toxic metal salts into the growing medium.

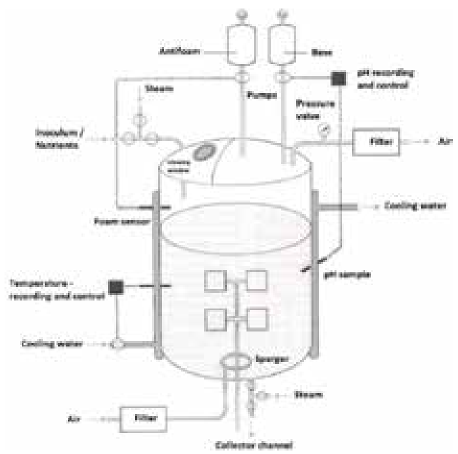


Figure 1. Schematic representation of a bioreactor

The autoclavable bioreactor used in this paper (Figure 2), for real-time monitoring of the main culture parameters, is of a benchtop type.

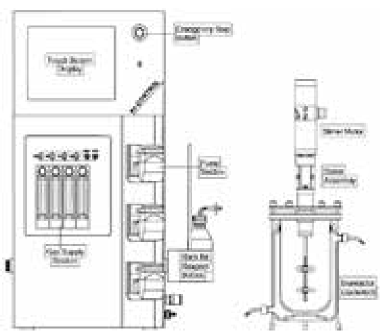


Figure 2. Diagram of Applikon autoclavable bioreactor

The bioreactor has a digital control and measurement system typeez Control, produced by Applikon Biotechnology B.V., the Netherlands (Figure 3).

Figure 3. EzControl interface of the bioreactor

The bioreactor has the connection with the sensors necessary for the proper functioning of the internal processes, as previously described. We refer to the sensor for temperature, pH, aeration, foaming, stirring (Figure 4).

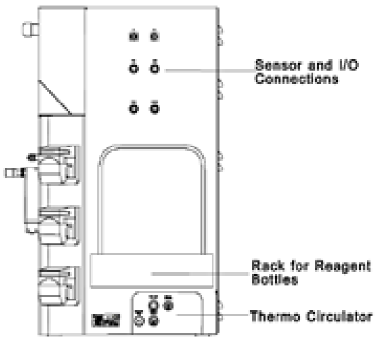


Figure 4. Sensor connectors

It offers the possibility to connect both through the ETHERNET interface and through USB type connectors, USB-Print port and RS232 (Figure 5).

Figure 5. Control panel with inputs/outputs

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

For an efficient use all the main routes relate to the bioreactor and with its sensors, according to the following scheme for connecting the gasses output of the ezControl to an air inlet sparger (Figure 6).

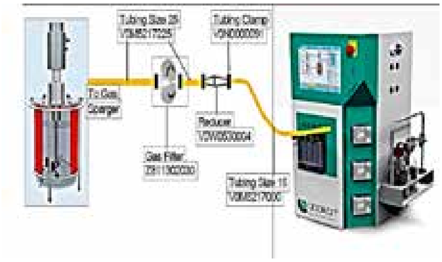


Figure 6. Connecting the gasses output of the ezControl to an air inlet sparger

Also, there is an Adding liquids scheme through a pump and the medium inlet triple (Figure 7).

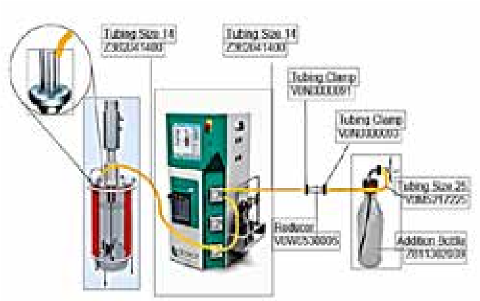


Figure 7. Adding liquids via a pump and the medium inlet triple

Connecting a PC to the bioreactor control system, ezController, allows on-line monitoring and control of on-going fermentation, and any unexpected events can be detected and corrected.

The working protocol includes the following elements: (1) date and time of registration; (2) the values of the monitored parameters; (3) alarm messages.

The connection of the computer to the command-and-control system of the bioreactor is made either through the ETHERNET interface or through the RS 232 serial interface.

After connecting the peripheral (computer) to the automated bioreactor unit, it can take over the monitoring and control functions of ezController.

The advantage of this control switch (taking control through another device) is that the monitoring of the process can be done outside the room where the bioreactor is located and implicitly the ezController system.

Thus, the monitoring can be done, through the computer, in another room (office), another building within the institution (via INTRANET) or even another city, country, continent (via INTERNET) (Lisci, 2021).

The practical applicability of this system should be mentioned due to the possibility of effective use of the bioreactor process monitoring program in the educational process by developing a software application for remote, real-time monitoring of the technological process at bioreactor level, as a central point of a virtual laboratory, an important element in achieving a quality educational process in the current pandemic context, a context that has determined an accentuation of the digitization processes in all sectors of society.

RESULTS AND DISCUSSIONS

INTRANET monitoring of the bioreactor requires, in addition to the existence of an adequate part of hardware (both high-performance computers, digital sensors and its own automated bioreactor control system) an adequate software component (Alford, 2006).

This element is an essential component in the bioreactor monitoring process. Through the software component the computer can. “Understands” and can tell us what is happening in the bioreactor (can “read” the fermentation parameters). The non-existence of this component makes unusable the constructions and hardware connections made to integrate the computer in the monitoring process.

To create the software necessary to "read" the information coming directly from the bioreactor - via its control and command system, ezController - several programming languages can be used, as well as several presentation variants both as a graphical aspect (interface) and as a system presentation of information: on-line or off-line or as a complexity of the data (setting the number and type of parameters read).

Both ways of presenting information (on-line or off-line) have advantages. Thus, the on-line model allows direct monitoring of the process carried out in the bioreactor both for the purpose of verifying the smooth running of the process and for teaching purposes, the possibility of tracking processes via INTRANET, anywhere inside the University, allows virtual presentation of fermentation via computer, at various laboratories, where the result of such a process is monitored, without the need to travel to the bioreactor. The offline model allows the storage of process parameters in the archive, thus making it possible to post-evaluate the process, compare various batches, and find solutions to improve the whole process by evaluating different data archived in the computer belonging to different batches obtained in the bioreactor.

In addition, this can be done in any department interested in the respective fermentation process, it is not necessary to "walk" the observation sheets from one laboratory to another or from one building to another, the INTRANET system allows searching all this data in the archives of the system.

The software made in this paper is written in the language of JAVA, one of the most modern object programming languages (Bloch, 2017). The monitoring program is called BioMon.BioMon is a client-server type application. Both the server component and the client component have a modular structure (Figure 8).

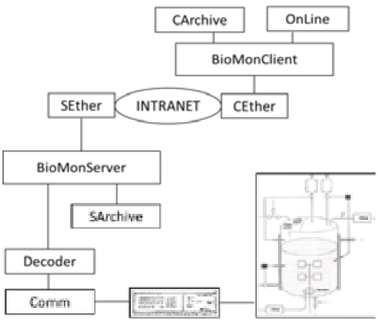


Figure 8. Modular structure of BioMon software

BioMonServer is a servlet program and was designed to run on the computer connected to the bioreactor via the RS232 serial interface. The Comm module provides the connection, setting the parameters of the serial interface and controlling the data flow from the bioreactor to the computer.

The Decoder module extracts useful information from the data stream: values of temperature, pH, pO_2, stirring speed, etc. This information can be stored locally in files using the S Module Archive or can be sent to clients, the connection with potential clients is provided by the SEther Module which implements the TCP/IP protocol using the 8060 ports for communication.

BioMonClient is an applet program and can be run from any computer in the laboratory's INTRANET network. If this network is connected to the INTERNET, the BioMonClient applet can be launched from any computer connected to the INTERNET using a browser.

The client program has two ways of working: on-line and off-line.

The On-line module performs a real-time monitoring of the processes carried out in the bioreactor. The monitored parameters are: pH, temperature, pO_2, stirring speed, amounts of antifoam, base and acid added.

The CArchive module allows access to the database stored on the server, which contains information about previous experiments (Figure 9).

Figure 9. BioMon - CArchive module

The snapshot image of the main window (HOME) is shown in Figure 10. As can be seen, this is the “gateway” in the BioMon program. It allows the selection of the mode of work desired by the user, who can opt for the on-line or off-line (archive) variant depending on needs.

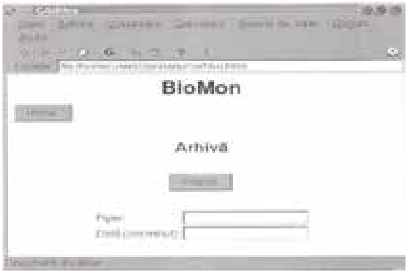


Figure 10. BioMonMaind window

The on-line monitoring program of the bioreactor is shown in figure 10 in the form of a snapshot image captured at the time of using the program.
The image shows the monitoring of a fermentation of *B. amyloliquefaciens*. The process takes place in optimal conditions, the process parameters (temperature, pO_2, pH, etc.) being within the limits provided in the working protocol.
In case of a problem (increase/decrease pH value, foaming, etc.) a warning message is displayed in the rectangle at the bottom of the image, in parallel with changing the values of the parameters that measure the amount of acid/ base/antifoam added automatically, to rectify the course of the process, in the upper right corner is monitored the time at which the reading is made.
The program is designed to read the parameters tracked at 60-second intervals.

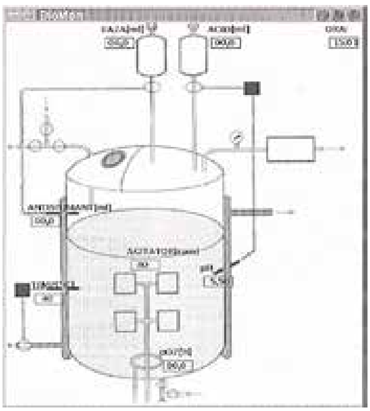


Figure 11. BioMon Server

The BioMon Server program has an extra window. It is shown in Figure 11 and is addressed exclusively to the Server because the Server is the one that directly monitors the bioreactor, receiving data from its control unit and at the same time being the place of storage of the information recorded during the monitoring process.
As can be seen in Figure 12, the Server window is basically the trigger/switch for the computerized monitoring of the bioreactor process and at the same time being the place of storage of the information recorded during the monitoring.

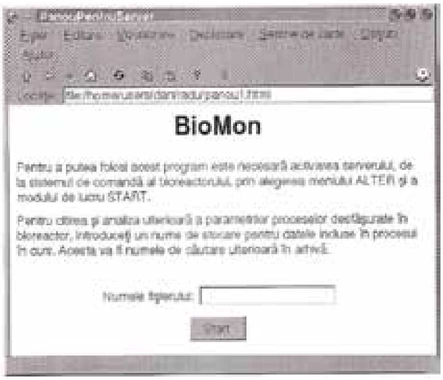


Figure 12. BioMon Server Interface

For the BioMon program to run, it is necessary to activate the server, from the bioreactor control system, by choosing the ALTER menu and the START operating mode.
For further reading and analysis of the parameters of the processes carried out in the bioreactor, a storage name must be entered for the data included in the on-going process. This will also be the name of the next search in the archive.

CONCLUSIONS

Both ways of presenting the information obtained by monitoring the industrial bioreactor (on-line or off-line) have advantages. Thus, the on-line model (direct, real-time monitoring interface of the bioreactor) allows direct monitoring of the process carried out in the bioreactor both in order to verify the smooth running of the process and for teaching purposes, the possibility of tracking processes via INTRANET, anywhere inside the University, it allows the virtual presentation of the fermentation through the computer, at various laboratories, where the result of such a process is followed, without the need to travel to the bioreactor.

The off-line model allows the storage of process parameters in the archive, thus making it possible to post-evaluate the process, compare various batches, and find solutions to improve the whole process by evaluating different data archived in the computer belonging to different batches obtained in the bioreactor.

In addition, this electronic monitoring system allows collaboration between universities in various fields of research through the INTERNET.

Thus, collaboration and research programs can be carried out between virtual teams located in different universities and even in different countries, the distance handicap being recovered through virtual access in the laboratories of teammates, through the computer. In this way, remote monitoring can be done, off-line re-verifications of the process can be done, or data can be taken from the working archive of the bioreactor, the collaboration between specialists being much easier in the current pandemic context, a context that has determined an accentuation of the digitization processes in all sectors of society.

A variant of this monitoring software specially adapted for the Android system is also being considered and is being prepared.

ACKNOWLEDGEMENTS

This research was funded by the University of Agronomic Sciences and Veterinary Medicine of Bucharest, project number 2021-0005/13.07.2021 - Developing a microbial bio-fertilizer technology [Dezvoltarea unei tehnologii de obținere de biofertilizanți de origine microbiană].

REFERENCES

Adeleke, B.S. and Babalola, O.O. (2021). The endosphere microbial communities, a great promise in agriculture. *Internetional Microbiology, 24*, 1–17.

Alford, J.S. (2006). Bioprocess control: advances and challenges. *Computers & Chemical Engineering, 30*,1464–1475.

Bloch, J. (2017). Effective Java. *Addison-Wesley Professional*; 3rd edition, ISBN: 9780134686097.

Chopda, V. R., Holzberg, T., Ge, X., Folio, B., Tolosa, M., Kostov, Y., Tolosa, L. and Rao, G. (2020). Real-time dissolved carbon dioxide monitoring I: Application of a novel in situ sensor for CO_2 monitoring and control, *Biotechnology and Bioengineering, 117*, 981-991.

Fadiji, A. E. and Babalola, O. O. (2020). Elucidating mechanisms of endophytes used in plant protection and other bioactivities with multifunctional prospects. *Frontiers in Bioengineering and Biotechnology*, *8*, 467.

Ferrero, G, Rodríguez-Roda, I. and Comas, J. (2012). Automatic control systems for submerged membrane bioreactors: a state-of-the-art review. *Water Research, 46*, 3421–3433.

Ganeshan S, Kim SH, Vujanovic V. (2021). Scaling-up production of plant endophytes in bioreactors: concepts, challenges and perspectives. *Bioresour Bioprocess*, *8*(1):63.

Komives, C. and Parker, R. S. (2003). Bioreactor state estimation and control. *Current Opinion in Biotechnology, 14*, 468–474.

Larroche, C., Sanromán, M. A., Du, G. and Pandey, A. (2016). *Current developments in biotechnology and bioengineering: bioprocesses bioreactors and controls*. Amsterdam: Elsevier.

Lisci, S., Grosso, M., Tronci, S. (2021). Different control strategies for a yeast fermentation bioreactor, *IFAC-PapersOnline*, *54*(3), 306-311.

Mandenius, C.F. (2016). Bioreactors: Design, Operation and Novel Applications. *Wiley Press*. ISBN: 978-3-527-33768-2.

Matei F. and Zirra D. (2019). *Introduction to Biotech Entrepreneurship: From Idea to Business*. Springer Press. ISBN: 978-3-030-22140-9.

Singh L., Yousuf A. and Mahapatra D. M. (2020). *Bioreactors: Sustainable Design and Industrial Applications in Mitigation of GHG Emissions*. Elsevier. ISBN-10: 0128212640.

Sagnik M. and Ganti S. (2021). Bioreactor control systems in the biopharmaceutical industry: a critical perspective, *Systems Microbiology and Biomanufacturing*, 10.1007/s43393-021-00048-6.

Schael F., Reich O., Engelhard S. (2002). Spectroscopy in heterogenous media and applications for bioprocess and environmental monitoring. *International Journal of Photoenergy, 4*, 21–26.

Shen,F.-T., Yen, J.-H., Liao, C.-S., Chen, W.-C., Chao, Y.-T. (2019). Screening of rice endophytic biofertilizers with fungicide tolerance and plant growth-promotingcharacteristics. Sustainability*, 11*, 1133.

Schugerl, K. (2001) Progress in monitoring, modeling and control of bioprocesses during the last 20 years. *Journal of Biotechnology, 85*, 149–173.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE USE OF LOW-COST SENSORS IN INDUSTRIAL HVAC AND AIR QUALITY MEASUREMENT APPLICATIONS

Emil DIACONU

Valahia University of Targoviste, 13 Aleea Sinaia Street, 130004 Targoviste, Romania

Corresponding author email: emy_diaconu@yahoo.com

Abstract

The air quality applications and also the industrial ones require a series of strict characteristics when we talk about the precision and endurance of the hardware and software elements involved in the work processes. A series of big firms have asserted in time on this section of market, clutching the industrial parks in their technological facilities. But, as the technologies developed, it has emerged a series of advanced possibilities of professional manufacturing regarding electrical assembly and boxes for the packaging of the hardware devices. This allows small producers or even amateurs, to benefit from the advantages of PCB technologies, which can aid in the innovation and forthcoming of super-performant gadgets on the market. These can compete with similar products developed by the big firms previously mentioned. In the gadget category have come in sight a series of very precise sensors which can rise to the industrial quality level, and, in this case, a normal question arises: why not integrate these low-cost sensors in the industrial applications? For that purpose, I have suggested a comparative analysis between two sensors of air, useful in the HVAC (heating, ventilation and air conditioning) and air quality field, one of them being manufactured by a specialized producer and the other one a gadget manufactured by a small firm which has build-up its own device for measuring the speed of the air and integrated it in its own portfolio of clients with notable results. The sensor of the specialized producer is approximately nine times bigger than the gadget category, which is why it has turned to a profound comparative analysis.

Key words*: Arduino, gadget, HVAC; low-cost, PCB, sensors.*

INTRODUCTION

The surrounding atmosphere is the easiest way for pollution and pollutants to spread in the environment. More precisely, the air favours this process of spreading pollution with serious effects on the health of both people and flora and fauna.

For these reasons, we pay special attention to air quality monitoring, maintenance and improvement activities.

The air quality in the surrounding atmosphere is directly and critically influenced by the emissions of pollution sources, especially in urban agglomerations. Detecting the pollution in the air is still a thorny issue, but with the development of more and more sensors expensive and low-cost also, the process is becoming easier to perform.

The number of the users of the Arduino hobby controller is about dozens of millions. The open-source system used by the ones who have imposed the Arduino brand, allows a huge flexibility regarding the integration of new projects, a series of hardware elements which keep up with the ultimate sensorial technologies. The software practices are accurately worked by the professionals in order to accompany the hardware acquisitions, so that, for example, a person who wishes to integrate a new sensor in his own application, has also available the necessary code to technically manipulate it.

The amateurs become professionals and the pressure on the technical profile markets is real. The HVAC field is a very large domain at a global level, like the idea of air conditioner which is spread at the same geographic scale. The diffusion and air quality measurement through the HVAC installations require control and the control require air sensors to measure and detect even small particles that are found in the polluted atmosphere (Rusca et al., 2022). The profile market offers customers various sensors for various applications including for measuring air speed, for various size ranges with various accuracies. For sure is that a sensor for the measurement mentioned before can achieve in the case of higher performances or characteristics even values over 1000 USD/EURO. In these circumstances, certain manufacturers of similar equipment or even HVAC are seriously blocked to integrate in their own products this kind of expensive sensors. That is why the gadget-sensors are becoming a serious alternative to the sensors produced by the industry from this field (Ardeleanu et al. 2019), if the "core" of the physical phenomenon function as precise and readable and the final boxing assure industrial protection.

The application on which the author has oriented is to verify comparatively the characteristics of two sensors intended for reading the speed of the air through a pipe; the first sensor is manufactured by the specialized HVAC firm Thermokon, and the second sensor is from the gadget category, manufactured by the American company Modern Device. The analogical data acquisition will be performed with an Arduino Mega 2560 controller, for physical situations reproduced identically. The values obtained will be compared with a set of benchmark data, obtained using a professional measurement equipment of air speed, which function based on the same physical principal as the analysed sensors.

The comparative analysis will decide the best approach of the benchmark sensor, which is why the system has been conceived to verify just the "core" of the physical phenomenon, not also the other aspects regarding the performance of other connected elements, such as the processor and /or the software filtration of the obtained data. The acquisition program is the same for both sensors.

The characteristics of the sensors and measurement equipment

The first one (Sensor 1) is AVT-D-R, an air velocity and temperature sensor, produced by Thermokon. AVT-D-R is a measurement and air speed sensor with three selectable measurement ranges. It is also capable of monitoring the speed of the air flowing through the ventilation system and controlling it by operating the control flaps. As an option, it can be delivered with an integrated LCD screen and relays that can be used to control the air volume. (https://www.thermokon.de/direct/en-gb/categories/avt). It is mainly used in the industry in the processes of monitoring and measuring air speed in HVAC installations, ventilation tubes, regulating valves and electro-valves.

Figure 1. The Thermokon AVT-D-R air velocity and temperature sensor

Its technical specifications are listed in Table 1.

Table 1. Technical specification of Sensor 1

Measured values	air speed and temperature
Type of gas	air or other non-flammable/non-aggressive gases
Output voltage	2x 0…10 V min. load 1 kΩ
Output electrical current	2x 4…20 mA max. load 400 Ω
Output switch contact optional	AVT LCD relay with change-over contact (volt free contact), 250 V ~ / 6 A, 30 V = / 6 A
Power supply	15..24 V = (±10%) or 24 V ~ (±10%) SELV
Power consumption	max. 2 W AVT-R LCD: max. 2,4 W
Temperature range	0…+50 °C
Air velocity range	0..2 m/s 0…10 m/s 0…20 m/s selectable at the device
Temperature accuracy	<0.5 K (v> 0,5 m/s) ± 0,5 K (typ. at 21°C)
Air speed accuracy (max time stabilization 10 min at 22°C)	0..2 m/s: < 0.2 m/s + 5% of measuring value 0..10 m/s: < 0.5 m/s + 5% of measuring value 0..20 m/s: < 1.0 m/s + 5% of measuring value
Sensor	calorimetric measuring principle
Display	LCD 3.5", 45.7 x 12.7 mm optional for indication of measured values
Enclosure	ABS cover PC
Protection	IP54 according to EN 60529
Cable entry	M16 for wire max. Ø=8 mm

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

The second sensor, Sensor 2 (the "low-cost" one), is manufactured by the American company Modern Device (https://moderndevice.com/products/wind-sensor-rev-p) and its technical specifications are listed in table 2.

As can be seen on the manufacturer's official website (https://moderndevice.com/), the air sensor Rev. P is the newest solution offered by Modern Device, having much improved precision and stability compared to its predecessors. Also, it has incorporated in its design a high-precision potentiometer that eases the calibration process, which is very important for the experimental setup and results.

The principle of operation of the air sensor Rev. P is that of a hot wire anemometer, similar to the old Rev. C air sensor (https://moderndevice.com/products/wind-sensor), but which additionally comes with the hardware compensation solution for the ambient temperature.

The positive temperature coefficient thermistors that are incorporated into this sensor require a higher voltage to heat the element up to the optimal operating temperature (9-12V). The advantage of needing to use a higher voltage source is that it will be able to provide enough power to heat the thermistor, leading to an improved ability of the sensor to capture wind speeds up to hurricane level without getting stuck at a maximum threshold (saturation).

Due to these properties, the author chose the air sensor Rev. P for the experiment presented in this work at the expense of the cheaper solution Rev. C, the cost difference between the two being insignificant compared to the price of Sensor 1.

Figure 2. The Modern Device Rev. P wind and temperature sensor

Table 2. Technical specification of Sensor 2

Powe supply	10-12 volts
Output current	~40 mA – increases a bit with higher wind speeds
Wind speed measured	0-150 mph
Ambient temperature compensation	

EXPERIMENTAL SETUP

The experimental setup is a classical HVAC system, with an industrial ventilator, a plastic pipe of 200 mm diameter, an electric three-phase motor speed variator of the frequency converter type produced by the NIDEC company, an ARDUINO MEGA 2560 controller, a PC to visualize the data and a DC supply source. In Figure 3 is shown the schematic of the experimental setup described above and in Figure 4 it is shown the actual experimental assembly.

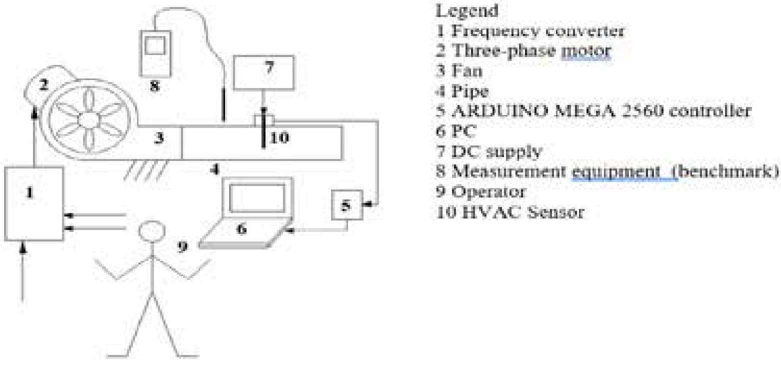


Figure 3. Schematic of the experimental setup

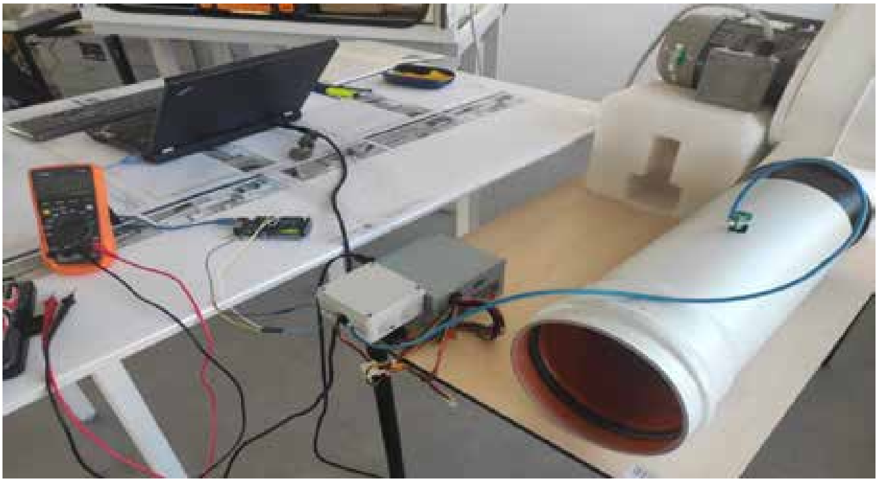


Figure 4. Experimental assembly

The mathematics of the data processing for the analogical signals

The sensors intercept the flow of the air from the pipe and generate analogical signals such as:

- Sensor 1 generates a proportional signal 0÷10 V c.c.
- Sensor 2 generates a proportional signal 0÷5 V c.c.

The digitalization of the analogical signals is accomplished by the ARDUINO MEGA 2560 controller, which has a transfer resolution in digital data of 10 bits.

The mathematics of signals

Sensor 1 is produced by the Thermokon company with a resolution of 0,1 (m/s).

$$f_1(S_1) = S_1, \text{ where } S_1 \in [a_1, b_1] \quad (1)$$

Sensor 2, low cost, measures both speed of the air and its temperature. Sensor 2 was calibrated through a series of statistical data, at different temperatures, so that there is a correction of the speed values depending on the temperature.

$$T = \left(\left((ADC(S_2) * 5) * \frac{1}{1023}\right) - 0.4\right) * \frac{1}{0.0195} \quad \text{..........(2)}$$

where:
- $S_2 \in [a_2, b_2]$;
- $V_0 = 1.355$;
- V_0 represents the value measured at the signal port for the state "no air flow" or "air speed equal to 0".

$$V(S_3) = \frac{ADC(S_3) * \frac{5}{1023} - V_0}{3.038517 * T^{0.115157}} * \frac{1}{0.087288} * 3.00013, \quad (3)$$

where:
- $S_3 \in [a_2, b_2]$

This speed of air is measured in american measurements, which is miles per hour.

$$f_2(S_3) = V(S_3) * 0.44704 \quad (4)$$

The S_k signals are limited as it is presented in Table 3.

Table 3. Technical specification of Sensor 2

$S_k \in [a_k, b_k]$, k=1:3		
$a_1=0$	$b_1=10$	k=1
$a_2=0$	$b_2=5$	k=2
$a_3=0$	$b_3=5$	k=3

The finished experiment, the obtained data, and the processing of the results

Sensor 1 is calibrated from the factory and represents the guaranty of a field producer, although the mathematics of the processing of the signals S_2 and S_3 is very rigorous as can be seen in relations (2), (3) and (4).
These formulas are obtained through statistical processing using exponentially regressive

functions (power), the speed of the air taking into account also the temperature correction.
The results of the measurements obtained with the help of the setup from figure 1 indicate three different situations:

a) Measurement with Sensor 1;
b) Measurement with Sensor 2;
c) Measurement with standard measurement equippment.

The converter will be based on the frequency value interval $f \in [5,50]$ Hz, with a step of 5 Hz. Therefore it will be obtained a set of 10 distinctive measurements. Each measurement, regardless of the sensor, will pe extended during a minute, and the value written in the table will be the average between the maximum value and the minimum value, obtaining this way the average values of the speed of the air. It will be obtained 3 sets of data d_{ij}, where i=1:3 and j=1:10.
The d_{3j} data are those of the standard and related to those data it will be determined the relative errors ε_{mj}, where m=1:2.

$$\varepsilon_{mj} = \frac{|d_{mj} - d_{3j}|}{d_{3j}} * 100 \quad (5)$$

RESULTS AND DISCUSSIONS

In Table 4 are shown the experimental results obtained, where S_1 is the sensor manufactured by Thermokon company of the HVAC field and S_2 is the “low-cost” sensor.
The measurement of the “Calibre” domain with the precise measurement equipment, has been accomplished through the averaging of the medium values on a minimum time of 1 minute with the medium values on a maximum time for the next minute.

Table 4. The experimental results obtained

Freqency	Calibre	S_1	S_2	ε_1	ε_2
Hertz	m/s	m/s	m/s	%	%
1	0.33	0.307	0.326	7.1	1.3
2	0.66	0.673	0.669	-2	-1.3
3	1.04	1.050	1.047	-1	-0.7
4	1.46	1.436	1.466	1.4	-0.7
5	4.90	1.832	1.921	3.3	-1.3
6	2.35	2.282	2.314	2.7	1.3
7	2.79	2.806	2.792	-0.5	0
8	3.2	3.213	3.266	0.3	-1.3
9	3.62	3.628	3.624	-0.1	0
10	3.98	4.016	4.063	-0.8	2

These values were taken by reference measuring the relative deviations of the values obtained from the two sensors. The data acquisition from the sensors has been made after the same method as that from the measurement equipment.

CONCLUSIONS

Without any other speculative affirmations, it is shown very clear that the “low-cost” sensor approaches very much to the real values measured with the precise professional equipment for measuring the speed of air. The errors from this sensor are bigger than those from the specialized sensor.
Nevertheless, if we consider that for a microbiological safety laboratory the standard the standard provides that the accepted value margin is a tolerance band of about 20% from the nominal values, the sensor becomes a sufficiently precise element to consider.
The economic argument is decisive, regarding that it has a ten times smaller price than the professional sensor from this field. In this case the Thermokon AVT-D-R sensor is valued at 244.50 euros while the Modern Device Rev. P sensor is valued at 24.95 dollars with the option of purchasing even a cheaper Rev. C sensor at 17.95 dollars (https://moderndevice.com/products/wind-sensor).
The conclusion is that "low-cost" sensors have become very efficient thanks to the new advanced technologies that have become accessible up to the gadget-hobby level.

ACKNOWLEDGMENT

Thank you to SC ELABORATOR FEERIA SRL and its team for assuring all the important elements of the experimental setup.

REFERENCES

Ardeleanu, M.N., Popescu, I.N., Udroiu, I.N., Diaconu, E.M., Mihai, S., Lungu, E., Alhalaili, B., Vidu, R., 2019. Novel PDMS-Based Sensor System for MPWM Measurements of Picoliter Volumes in Microfluidic Devices. *Sensors* 2019, *19*, 4886. https://doi.org/10.3390/s19224886

https://www.thermokon.de/direct/en-gb/categories/avt

https://www.thermokon.de/download-archive/Druck%20&%20Str%C3%B6mung/Gasf%C3%B6rmige%20Medien/AVT/Produktbl%C3%A4tter/AVT_Datasheet_en.pdf

https://moderndevice.com/products/wind-sensor-rev-p
https://moderndevice.com/
https://moderndevice.com/products/wind-sensor
https://moderndevice.com/products/wind-sensor
Rusca, M., Dimen, L., Marcuta, L., 2022. Enviromental pollution due to road vehicles, alternative solutions (electric vehicles, hybrids, bicycles) sustainability of crowded centers of cities, *Land Reclamation, Earth Observation & Surveying, Environmental Engineering*. Vol. XI, 2022, Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ISSN 2285 – 6064
ISSN-L 2285 – 6064