University of Agronomic Sciences
and Veterinary Medicine of Bucharest
Faculty of Land Reclamation
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LAND RECLAMATION, EARTH OBSERVATION & SURVEYING, ENVIRONMENTAL ENGINEERING

Volume X

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RESEARCHES REGARDING THE IMPACT OF WASTE LANDFILL IN SIBIU COUNTY, ROMANIA ON THE ENVIRONMENT AND MEASURES TO REDUCE IT

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Abstract

Environmental impact assessment has emerged as a basic tool in identification and reduction of negative environmental consequences due to anthropogenic activities, reflecting a preventive approach to environmental management, with a view to sustainable development. Our research is made in Sibiu County, from Romania, and concerns the impact of the local waste landfill on the main environmental factors (water, air, soil). The proposed methods of prevention and reduction of pollution are characteristic of the technological process, and are given by the following conformations: waterproofing of the warehouse, realization of leachate drainage / discharge / treatment system, procedures for: acceptance of waste at storage, technological self-monitoring, self-monitoring of emissions and quality factors environment, procedures for cell closure with the implementation of the biogas combustion system resulting from anaerobic decomposition of waste, fencing (with fence and forest curtain).

Key words: *biogas, collection, landfill, recycling, waste.*

INTRODUCTION

Waste management represents the most important component of sanitation services and refers to activities of collection, transport, treatment, recovery and their disposal. Waste recycling and the circular economy are among the most important issues in the European Union strategies.

Because Romania has yet to meet many requirements of the European Commission's policies, there have been opened several infringement proceedings against our country for pollution, wood management, and waste management.

This paper presents our researches regarding the implementation of an integrated waste management system in one of the most important touristic sites of Romania - Sibiu County.

As a result of rapid increase in production and consumption, urban society generates solid material, which regularly leads to considerable increase in the volume of waste generated from several sources.

A proper management system of solid waste is a central pillar of the policies for a sustainable environment.

The management system of the solid waste is associated with the control of the processes regarding generation, storage, collection, transfer and transport, processing and disposal of solid wastes in a manner in accord with known principles of public health, economics, conservation, environmental engineering, and other considerations.

MATERIALS AND METHODS

The landfill analysed in this study is located in Sibiu County (Figure 1).

Figure 1. Map of Sibiu County, Romania

The water supply is made from the underground source, through drilling located near the administrative pavilion. Water captured from underground is used for hygienic-sanitary, technological, and partial for purposes to ensure the reserve intangible fire.

The categories of wastewater discharged are the following: domestic wastewater from the administrative pavilion, rainwater, and leachate generated by waste storage.

Rainwater is discharged through the perimeter gutters of the deposit, located at the base the outer slopes of the cell contour dam, in the authorized receiver, the Salcii Valley brook (right tributary of the Ruscior brook), located 100 m away from the warehouse location.

The leachate taken over by the drainage and collection system is directed to the leachate basin (three-compartmented with V = 500 m^3), from where it is pumped to the leachate treatment plant.

Within the ecological landfill located on a land from Cristian commune, Sibiu County, it is stored and neutralized household and industrial waste assimilated to household waste and at the same time insured monitoring the cell whose operation has been completed.

The main activities carried out in the warehouse are as follows:
- a visual control of waste;
- weighing of waste;
- waste unloading on the concrete platform and visual inspection;
- levelling and compaction with the help of the bulldozer and the compactor;
- periodic coating with inert material;
- permanent anaerobic decomposition of waste;
- permanent collection of storage gas;
- permanent collection of domestic, technological wastewater and leachate;
- leachate treatment and evacuation into the natural emissary from the area, an operation that is performs periodically;
- permanent disinfection of the wheels of motor vehicles leaving the warehouse.

The control system on pollutant generating processes corresponds to the concept design as well as the operation which in turn, comply with the regulations of national legislation transposing European Union waste disposal one.

The wastes are brought to the landfill with the means of transport of the sanitation operators and are unloaded from the car access platform to the unloading ramp.

The waste is placed in successive layers, using blade bulldozers, then is compacted with heavy earthmoving equipment. Thanks to the front blade of the bulldozer also performs waste levelling. In addition, the high weight of the equipment can ensure a mixture and an efficient compaction as well as a crushing of the waste that increases their specific surface area and, in this way, an acceleration of biodegradation process.

The leachate resulting from the fermentation of waste and rainwater falling on the landfill is drained through collector wells and the drainage pipe system over the layer waterproofing in the lowest level fireplace, from where it is pumped into the leachate storage basins, and from here by pumping it reaches the treatment plant; the treated effluent is discharged into the natural emissary.

The leachate is pumped from the leachate collection tank into the storage leachate tank station; then, concentrated sulphuric acid is added to adjust the pH to 6.5, thus reducing the number of hydrocarbons in the leachate, where it is pre-filtered through a filter multilayer sand; microfiltration follows through cartridge filters and then it is sent to the treatment phase of leachate (reverse osmosis - stage I - nano-filtration).

Water will have values below the usual standards for drinking water, in terms of salt content and can thus be well used as industrial water or for other purposes; ex. irrigation of parks public buildings, gardens, orchards, etc.

The maximum storage capacity is 1125000 m^3 for the third cell of landfill (Figure 2).

Figure 2. Waste treatment plant from Sibiu County

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The storage of household waste is ensured and industrial assimilated to them and the non-hazardous ones, in ecological conditions for Sibiu municipality, Sibiu County and the surrounding areas. Total surface is of 18 ha.

The average height of the deposited waste will be 20 m measured from the average level of soil. The minimum degree of compaction will be 0.9 tons/m^3.

Waste disposal will be carried out in such a way that the impact on the environment and the population to be minimal.

The deposition and distribution of waste in the cells is done in layers as much as possible thin up to 1 m, which then compacts.

The compaction density must be cat longer, increasing the life of the cell. Non-hazardous waste that does not come from households are deposited only mixed with household waste.

Discharged and compacted waste is periodically covered with a layer of inert material of 10-15 cm, to avoid odours, light scattering of light waste and the appearance insects and birds.

The inert material may be of solid mineral waste or of constructions and demolitions.

A household waste cover is not required if the next day is storage continues. After complete filling and levelling of a storage cell, the layer surface waterproofing is applied immediately.

The temporary coating is made on the surface on which the storage was stopped with soil with a thickness of 30-50 cm; lawn is planted on it.

Temporary coverage with earth is made during the period when the highest settlements take place (3-5 years).

From a topographical point of view, the location of the ecological deposit is a valley, dug in the formations of the upper terrace of the Cibin River, at the contact with the hilly area neighbouring to the west, so that by successive cell filling, covering and grassing enclosed areas will be framed in the pasture area with which the warehouse is borders in the Southeast and West.

Laying the last layer of waterproofing on the surface is done only when the settlements of the body of the deposit can no longer cause its deterioration.

The leachate collection system ensures that it is kept to a minimum the body of the warehouse and the capacity of the storage tank takes into account the average value of the volume of leachate generated and the dimensions of the deposit.

Periodically, in addition to the qualitative monitoring of the leachate emission purified (permeate) and its quantity and volume are measured (Hester et al., 2002). The passive degassing solution was used to evacuate the storage gas; through creation of areas of depression in the mass of waste (gases formed passing through the gaps in walls of prefabricated homes) leading to free discharge into the atmosphere.

Following the mathematical modelling performed, we noticed that the amounts of methane and carbon dioxide did not exceed the threshold value.

In the case of facilities for combating and controlling pollution, such as landfills, are not provided emission limit values for emissions from the main activity, ex.: for biogas emissions.

The biogas installation is related in Figure 3.

Figure 3. The biogas installation from Sibiu County

There is also a quarterly monitoring, with analysis bulletins performed by an accredited laboratory - of CH_4 and CO_2 emissions.

Following the anaerobic decomposition of the waste, the landfill gas is formed (fermentation gas) with a calorific value of 5000-6000 kcal/m^3 and a composition in which predominates, when gas generation reaches steady state, CH_4 (54%) and CO_2 (45%) at which add small amounts of hydrogen sulphide, carbon monoxide, mercaptans, aldehydes, esters, traces of non-methane organic compounds.

Installations for the collection and evacuation of storage gas have the role of ensuring controlled collection of fermentation gas that is formed for a long time of time, in all landfills containing biodegradable waste and periodically (monthly), it is eliminated by combustion, through the wells provided with installations intended for this process.

If the formed gas is not discharged controlled from the deposit, migration and its accumulation can present a series of risks, among which: fire danger through self-ignition, release of unpleasant odor and toxic compounds (hydrogen sulphide, organic-phosphorus compounds, other unsaturated organic substances), damage to the component biological properties of the soil, by reducing the concentration of oxygen, danger of explosion by possible occurrence of gas accumulations in the vicinity of residential areas, increasing accumulations of gases that contribute to the greenhouse effect.

RESULTS AND DISCUSSIONS

The general concept of the ecological landfill of household and industrial waste that serve the population of the entire county corresponds to the most modern system of organization of non-hazardous waste disposal.

The leachate collection and storage gas collection systems correspond to the best worldwide practices.

The way of covering the warehouse corresponds to the most demanding norms at the level being provided with a waterproofing and drainage system above it, as well as with a layer of soil and soil fertile enough for a efficient ecological restoration of the surface released by technological loads.

The leachate treatment plant corresponds to a modern technology - reverse osmosis.

The main types of waste that will be generated as a result of the activities:

- technological waste: fertile soil and excavated soil, construction waste (waste from polyethylene), used oils, batteries and used tires, materials impregnated with products oil tankers (ex.: cloths, car oil filters);
- waste assimilated to household waste resulting from the activities of staff on location.

The main types of waste that will be generated as a result of the operating activities are:

- technological waste;
- waste resulting from maintenance activities of vehicles and equipment: oils, used batteries and tires, materials impregnated with petroleum products (ex.: cloths, car oil filters);
- scrap metal (resulting scrap metal and unusable spare parts);
- assimilable waste, following the activities of the employed staff.

The packaging of chemical reagents used both to regulate the pH of wastewater entering the treatment plant, as well as when cleaning the membranes of the treatment plant are collected separately and periodically returned to suppliers of hazardous chemicals.

The resulting concentrate is returned to the depot and subsequently taken over as leachate.

Green waste is collected and transported to a compost station.

The sludge is collected and transported for disposal to the nearest landfill of non-hazardous waste (Figure 4).

Figure 4. The ecological landfill from Sibiu County

Regarding the environmental factor - water, the categories of wastewater discharged are the following:

- domestic wastewater from the administrative pavilion;
- rainwater;
- the leachate generated by the storage of waste in the landfill.

Wastewater is discharged through sewerage networks.

The quality indicators of the wastewater discharged into the natural emissary are observed (Salcii Valley brook), established in accordance with the norms in force.

The decomposition process of landfill waste is complex and variable; the main products of waste decomposition - leachate and biogas - can become a problem for neighbouring areas in non-compliant management conditions.

The network of drainage pipes is built above the sealing system of the base of the deposit, having the role of collecting the leachate resulting from the fermentation of the organic materials stored in cells.

The leachate collection system ensures that it is kept to a minimum the body of the warehouse and the capacity of the storage tank takes into account the average value of the volume of leachate generated and the dimensions of the deposit.

Periodically, in addition to the qualitative monitoring of the leachate emission purified (permeate) and its quantity and volume are measured (Pelt, 1993).

CONCLUSIONS

The values of the quality indicators for wastewater falls within the permitted limits. Given that the limits are respected, the current impact is insignificant.

Regarding the operation of the machines, the way of working, the age of the machine and the condition of its technique are elements that can constitute sources of surface water pollution and even depth. This can cause diesel leaks and engine oils that can damage it the quality of water resources.

Leaching is the major source of environmental pollution in case of management non-compliance or the occurrence of incidents/ accidents. Because of its content (high organic load, heavy metals, pathogens, other polluting chemical compounds - e.g. vinyl chloride), a possible untreated discharge caused by system failures sealing or collection and treatment leads to a significant impact on water resources. Due to the configuration of the land, the leachate will flow to the valley lines with a high speed.

The potential contamination of groundwater resources can have the effect of alteration the health of the inhabitants of the adjacent areas. Contamination of surface waters with untreated leachate leads to changes in water quality and changes in the existing aquatic ecosystems.

Excess water (incorrectly catalogued by some sources as leachate) which can result in leakage from the waste mass placed in the pile subjected to the intensive treatment process (the first phase of the biological process) has leachate-like properties. The pollutants contained are usually on an order of magnitude smaller, instead the effects induced of a potential direct discharge (without purification) into the surface water bodies or underground are similar in intensity to those generated by leachate.

Pollutant content of wastewater resulting from car washing and the machinery on site is similar to leaching (however the concentrations are lower). The impact of their uncontrolled discharge is similar to that of the discharge unpurified leachate (Agafitei et al., 2018).

Other activities that can have a negative impact on water are management non-compliance of the waste produced on site and the operation of the equipment and equipment. The impact produced is similar to that produced in the construction phase of the warehouse.

In order to reduce the impact, it is necessary to permanently monitor the wastewater discharged from the treatment plant, as well as the permanent monitoring of the groundwater from the three monitoring wells.

To monitor the influence of waste storage activity on underground water quality, all the analyses will be compared with the control samples initially performed at the drilling execution.

Regarding the air pollution sources, we mention that there are agricultural lands in the vicinity of the landfill, and they are:

- those specific to zoo-technical activities: ammonia NH_3, methane CH_4, nitrogen oxides, specific odor, also those specific to agriculture: ammonia (NH_3 - 20000-40000 g/ton fertilizer) in the case of the use of fertilizers, nitrous oxide (N_2O - 2500 g/ha) for surfaces without fertilizers.

As mobile air pollution sources, we mention road traffic on DN 1 and in the area. In addition to particulate emissions, there will be emissions of pollutants specific to greenhouse gases exhaust from the equipment with which the operations will be carried out and from the vehicles for transport of materials.

Pollutant's characteristic of Diesel internal combustion engines with which are equipped the equipment's and vehicles for transport are: nitrogen oxides, carbon oxides, sulphur oxides, heavy metal particles (Cd, Cu, Cr, Ni, Se, Zn), organic compounds (including polycyclic aromatic hydrocarbons - PAHs, substances with carcinogenic potential).

In conclusion, the air pollutants are: mineral particles in suspension, but which settle rapidly even in an atmosphere real estate; exhaust gases: SO_x, NO_x, CO, particulates, organic compounds (including hydrocarbons polycyclic aromatics - PAHs, substances with carcinogenic potential).

Landfill gas generated by the decomposition of municipal waste must collected and treated in a way that reduces the negative effects that it can have them on the environment and to reduce the potential danger of the main components are methane (danger of explosion) and carbon dioxide (danger of suffocation) (Robu et al., 2010).

The gas treatment is done depending on the capture technique used - active or passive. The treatment and recovery techniques of the gas are chosen depending on the concentration of methane.

The passive degassing solution was used to evacuate the storage gas; by creating some areas of depression in the mass of waste (gases formed passing through the gaps in the walls prefabricated homes) leading to free discharge into the atmosphere.

Pollutant dispersion study was performed to determine the distribution method in the atmosphere relative to local climatic and location conditions.

The dispersion study of air pollutants was done with the SIMGP program v.4.1. This program simulates the transport of gases and dusts and calculates concentrations for them averages for different periods of time.

Emissions on the ventilation tubes were considered as point sources, taking an equivalent diameter, the calculation being coverage (Figure 5).

The graph shows that the concentration areas are much smaller than these values, therefore the impact is insignificant for the outside of the site, more importantly on the site where the limits of pollutants in the workplace apply.

Figure 5. Dispersion graphic for Sibiu ecological ramp

As measures to reduce particulate emissions from material handling (especially earth), we propose:

- watering of work platforms and access roads during periods without precipitation;
- washing the wheels of motor vehicles when leaving the site;
- avoidance of loading/unloading activities of vehicles with materials dust generators in windy periods with speeds over 3 m/s;
- limiting the disturbed areas around the platforms;
- rehabilitation of disturbed lands around the sites, after the completion of the works construction/closure.

The degassing system must be constructed in such a way as to guarantee the safety of the construction and the health of the operating personnel, to be perfectly watertight to the external environment and to be located in isolation from the leachate drainage and drainage systems, respectively precipitation.

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IMPROVING A BIOGAS PLANT PARAMETERS IN THE CONVERSION CONTEXT OF REPLACING THE CORN SILO WITH AGRI-FOOD WASTE

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Abstract

The large amount of organic waste resulted from the large urban agglomerations is an important source of landfill gas and consequently represents an important factor in the climate changing pollution effect. Although there are consistent efforts to reduce the volume of organic waste or to process it in a way which generate less landfill gas, there it is more work to be done in order to solve this problem. This article presents the work conducted to convert a biogas plant originally designed to use corn silage into a biogas plant which uses agri-food waste. Another important aspect presented in this article is the research on improving the qualitative parameters of biogas and the technical modifications conducted on the initial design to achieve a double quantity of biogas.

Key words*: agri-food waste, biogas, biogas plants.*

INTRODUCTION

Using land for cultivating crops that are meant to be used in biogas plants instead of food is not the best solution. The United Nations (UN) deemed food waste reduction as a global priority and included it in the list of sustainability goals (United Nations. Transforming our world: The 2030 agenda for sustainable development). Following this reality many countries changed their approach regarding the substrates that are going to be used in biogas plants (Galit et al., 2019; Brémond et al., 2021). In the USA the EESI (Environmental and Energy Study Institute) presented a plan (Fact Sheet | Biogas: Converting Waste to Energy) for 13500 biogas plants based on waste to be opened. In Europe EBA, (European Biogas Association) issued strong recommendations (Circular Economy and Waste Management) to the EU Council regarding the need to ensure quick and efficient implementation of the Waste Framework Directive to force separate collection of organic waste streams and its treatment according to the waste hierarchy. Anaerobic Digestion makes the best use of organic materials by producing renewable energy and organic fertilizer while closing the nutrients cycle and reducing greenhouse gas emissions (Dobre et al., 2014; Baredar et al., 2020). However, both in USA and in Europe there are very few examples of biogas plants using only food waste, due to the lack of experience in this field.

To this moment there are implemented thousands of biogas plants around the world however, many of them relays on corn silage, maize silage or manure as feedstock (Sravan et al., 2021).

There is a real challenge in adapting the technology initially implemented for using corn silage in these plants and making them suitable to use agri-food waste as feedstock (Diguta et al., 2007; Ohnmacht et al., 2021). Different substrates with different dimensions present different digestion rates also, the availability of different categories of waste varying from season to season as well as the quantises of agri-food waste randomly depending on social events and/or accidents that appear on food production lines (Liu et al., 2021). All these aspects make almost impossible to establish a certain mix of waste material, with well-established dimensions and controlled

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properties capable to be introduced in the fermenter and to deliver a constant output (Prabhu et al., 2021).

MATERIALS AND METHODS

The configuration of the facility used for test is a classic biogas plant consisting in fermenter tank, post-fermenter tank and digestate storage tank as well as the feeding system. The plant layout is presented in Figure 1.

Figure 1. Initial biogas plant design

The research was conducted over a period of 5 years and encompasses three main methods:
1. Replacing in a controlled manner the corn silage substrate with agri-food waste materials;
2. Analyse both the output of biogas and biological environment in the reaction tanks;
3. Tuning the composition of feedstock and its properties (size and concentration of dry materials) to continuously improve the quantity and quality of the produced biogas;

In order to achieve the established objective, a complex and flexible research methodology was elaborated, starting from the few research data existing (Popescu & Jurcoane, 2015) but keeping an open mind to absorb all the novelty elements that appeared along the way. Thus, the latest study methods, simulations of underlayermixingwereused.Hardware elements such as agitators introducing new products equipped with carbon fiber propellers, crushing installations as well as nutrient inputs to compensate for the nutrients which were missing during the replacement of the underlayers, were installed.

Before the experiments started a thorough study on the market was conducted and the type and quantities of agri-food waste were established as presented in Table 1.

Table 1. Available agri-food waste

Materials	Monthly average [t]	Annual average [t]
Fruits and vegetables	488796.00	5865555.00
Meat and meat products	21760.00	261115.00
Bakery and pastry	15722.00	188659.00
Dairy and eggs	25432.00	305180.00

Experiments conducted

The experiments performed for reaching this goal were extensive, involving detailed analysis of the main parameters influencing the fermentation process pH, FOS (volatile organic acids), TAC (alkaline buffer capacity), FOS/TAC ratio (FOS/TAC measure the risk of acidification of a biogas plant) and CH_4 content in the biogas obtained and the quality of the digestate obtained. Furthermore, in order to avoid the impact on the biogas production, the underlayers used were also analysed, constantly controlling the content of carbohydrates, starches, proteins, fatty acids, pectin, cellulose, hemicellulose, etc., the percentage of organic matter contained in the dry matter, the micronutrients contained, for the fed underlayers.

Table 2. The planning/implementation of substrate changing

Year	Agricultural biomass (%)		Agri-food waste (%)	
	Planned	Realised	Planned	Realised
2015	80.00	81.67	20.00	18.33
2016	50.00	48.72	50.00	51.28
2017	30.00	28.48	70.00	71.52
2018	10.00	11.94	90.00	88.06
2019	<5	2.46	95.00	97.54
2020	Maintain stability of the process with less than 5% biomass from agriculture			

The planning of experiments (replacing the agricultural biomass with agri-food waste was established based on consultation with some other specialists in this area as presented in the Table 2.

There it was well establish to implement a continuously monitoring regime of the main parameters in such a way to be ready to apply the required correction if the fermentation

process is presenting dysfunctions. Also, it was established to consider as main indicator of the entire process the daily readings of quality and quantity of the produced biogas. If any perturbations occurred this was a trigger for additional sampling and analysing of material from fermenter and post fermenter.
In parallel with the gradual change in the ratio between underlayers, a study was performed on other process elements such as shredding the underlayer, mixing it to homogenize heat and nutrients throughout the volume of the fermenter to optimize biogas production.

RESULTS AND DISCUSSIONS

Although during the entire period were collected monthly samples of materials from fermenter, post fermenter and biogas which were analysed, in this study are presented only the results which are indicating significant changes in the fermentation process.
In 2015 the monthly analysed samples from fermenter reports for pH, FOS, TAC, and FOS/TAC are presented in Table 3.

Table 3. The results of analysis conducted in 2015

2015	pH	FOS	TAC	FOS/TAC
	[-log.c H+]	[mgHAcäq/l]	[mgCaCO₃/l]	[-]
Jan	7.64	2.79	10.31	0.27
Feb	7.57	3.00	11.67	0.26
Mar	7.55	2.89	11.47	0.25
Apr	7.55	2.91	11.55	0.25
May	7.54	3.30	11.41	0.29
Jun	7.43	3.06	12.02	0.25
Jul	7.57	3.10	12.08	0.26
Aug	7.61	3.93	13.07	0.30
Sept	7.72	3.70	15.39	0.24
Oct	7.85	4.37	17.30	0.25
Nov	8.04	4.21	17.98	0.23
Dec	8.11	6.63	20.02	0.33

It is significant to observe that although both FOS and TAC are slowly increasing, the report FOS/TAC is maintained constant which prove that the fermentation process is stable and the biology into the fermenter is slowly adapting to the substrate changing.

Thus in 2015, when the experiments started, the components of biogas were quite stable as presented in the Figure 2, although there it is a slow increase of the amount of CH_4 from 51.1% to 54.1%.

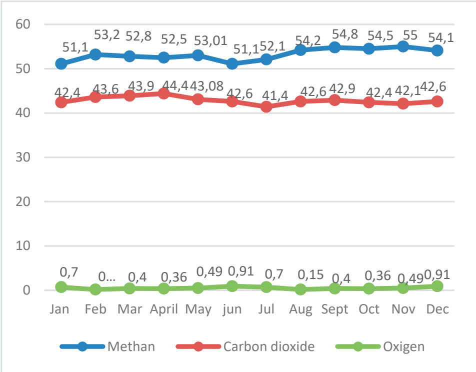

Figure 2. Biogas components analysis in 2015

Although apparently the process was varying smooth and there was an improvement in the biogas quality it has to be mentioned that in this first year 20% of agri-waste materials consisted of fruits and vegetables and this could be an explanation of process stability over the substrate changing.
In 2016, the changing was much significant since the target was to replace up to 40% of corn silage and in addition to the fruits and vegetables, were added meat, fats, bakery and pastry as well as dairy products and mixed together.
As it could be observed in the Table 4 the FOS and TAC values were growing higher which provided the information that the fermenter was over-feed.
Gradually the quantity of organic material feed to fermenter was downsized in order to lower the values of FOS and TAC. The process of correlating the amount of material fed to the fermenter with the FOS TAC variation was difficult and improvements were obtained only at the end of 2016.

Table 4. The results of analysis conducted in 2016

2016	pH	FOS	TAC	FOS/TAC
	[-log.c H+]	[mgHAcäq/l]	[mgCaCO₃/l]	[-]
Jan	8.11	7.308	20.18	0.36
Feb	8	9.67	24.597	0.39
Mar	8	8.129	25.235	0.32
Apr	8.2	11.272	28.601	0.39
May	8.1	11.494	25.309	0.45
Jun	8.2	13.551	22.101	0.61
Jul	8.1	16.227	23.732	0.68
Aug	7.9	14.936	26.572	0.56
Sept	8	11.049	23.239	0.48
Oct	8.1	11.494	25.309	0.45
Nov	8.04	4.213	17.984	0.23
Dec	8.11	6.629	20.024	0.33

Although the process control was difficult the output of biogas was good, the increase of CH_4 into the biogas produced growing with over 1% as presented in Figure 3.

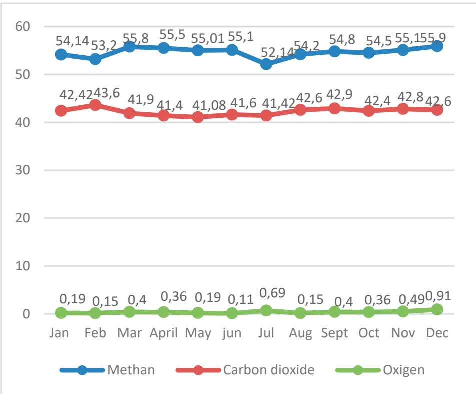

Figure 3. Biogas components analysis in 2016

Although the diversity of materials introduced as substrate was increasing, based on the acquired experience in 2016 the amount of agri-food waste feed to the fermenter was much better controlled. The quality of the substrate introduced into the fermenter was better correlated with the quantity delivered and thus the previous variations of substrate fermentation were reduced significantly.

In 2017 the changes were controlled better and the amount of agri-food waste material feed was raised up to 71.2% and further diversified adding gelatine, Omega 3 pills, chocolate, and potatoes chips. The increased value of NaCl in potatoes chips produced some small variations into the FOS value, however, due to the continuous monitoring process it was possible to add some other materials which compensate this inconvenient (Table 5).

Table 5. The results of analysis conducted in 2017

2017	pH	FOS	TAC	FOS/TAC
	[-log.c H+]	[mgHAcäq/l]	[mgCaCO₃/l]	[-]
Jan	8.00	11.05	23.24	0.48
Feb	8.20	6.47	27.70	0.23
Mar	8.20	6.48	27.10	0.24
Apr	8.30	10.17	29.53	0.34
May	8.20	10.60	27.75	0.38
Jun	8.00	9.55	28.81	0.33
Jul	8.20	10.60	27.75	0.38
Aug	8.00	9.55	28.81	0.33
Sept	8.20	10.80	29.14	0.37
Oct	8.00	12.36	28.79	0.43
Nov	8.20	10.60	27.75	0.38
Dec	8.20	6.48	27.10	0.24

The quantity of CH_4 in the produced biogas was increasing from 55.9% in 2016 up to 59.1% in 2017 as presented in Figure 4.

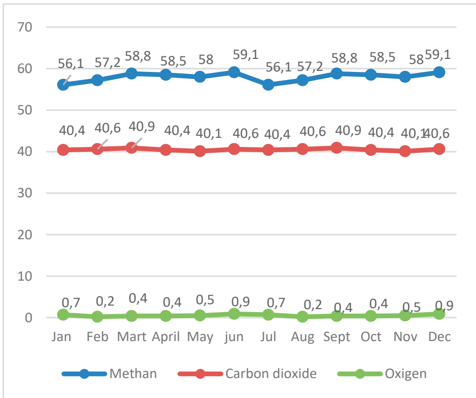

Figure 4. Biogas components analysis in 2017

This improvement of biogas quality had a good impact on the CHP functioning, the gain obtained being significant. Another advantage observed was related to the CO_2 content in the produced biogas. The CO_2 content was decreasing from 42% in 2015 to 40% in 2017.

In 2018 the goal was very ambitious, to decrease the content of corn silage down to 10%. In the previous years the corn silage was used as a fermenting reaction "regulator" being used when it was necessary to compensate variations of fermenting process and the 30% material used was enough to control the system. With only 10 % corn silage available it was much more difficult to regulate the process taking also in consideration that some quantities of sludge were added to the fermenter. The variation of quantities of agri-food waste was now significant as presented in Figure 5.

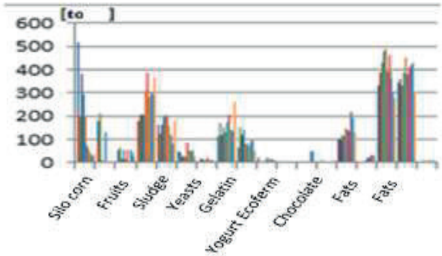

Figure 5. Variation of quantities of agri-food waste

Although the challenge was higher the team was able to control the system and as presented in Table 6, the obtained results were within the margins of required operational values. Due to the need to reduce operational costs there it was taken the decision to conduct sampling and testing at two months.

Table 6. The results of analysis conducted in 2018

2018	pH	FOS	TAC	FOS/TAC
	[-log.c H+]	[mgHAcäq/l]	[mgCaCO₃/l]	[-]
Feb	8.2	6.482	27.096	0.24
Apr	8.3	10.168	29.528	0.34
Jun	8.2	10.602	27.746	0.38
Aug	8	9.55	28.813	0.33
Oct	8.2	10.804	29.143	0.37
Dec	8	12.362	28.787	0.43

The biogas quality and quantity were good as presented in the Figure 6.
During 2019, only adjustments were made to the system. Small amounts of corn silage have been intentionally withdrawn/introduced to see if it is possible for biology to function without corn silage. It is noteworthy that during this year a complete replacement of corn silage was achieved.

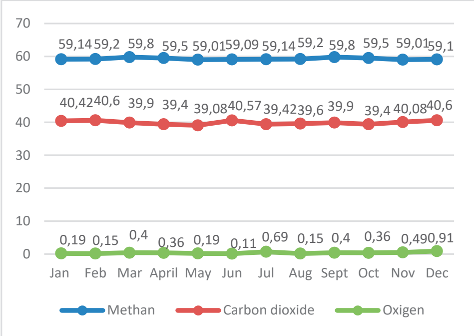

Figure 6. Biogas components analysis in 2018

The analysis proved that the system is functioning well as presented in the Table 7.

Table 7. The results of analysis conducted in 2019

2019	pH	FOS	TAC	FOS/TAC
	[-log.c H+]	[mgHAcäq/l]	[mgCaCO₃/l]	[-]
Mar	8.3	6.579	28.561	0.19
June	8.4	6.245	26.894	0.19
Sept	8.4	6.625	28.857	0.19
Dec	8.4	6.650	28.055	0.19
Feb 2020	8.4	6.822	28.123	0.19

The biogas produced contained around 59% CH_4 continuously and the amount produced was constant at 500 m^3/hour.

Modifications conducted on biogas plant

Based on the experience gained during the 5 years of experiments, there were conducted several modifications to the plant in order to improve and adapt its capabilities to process agri-food waste:
One of the first modifications was to introduce a liquid waste tank where lower quality substrates are mixed with higher quality substrates as presented in Figure 7. Another advantage of this tank is that the process of hydrolyzation would start in advance and when introduced in the fermenters the substrate will be digested by the existing biological media faster reducing thus the time of mineralization and increasing the output of biogas.

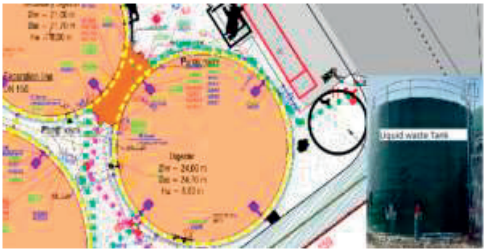

Figure 7. Liquid waste tank

The second step of modification was much bigger involving the transformation of the post fermenter into a fermenter and of the digestate storage tank in post fermenter. The transformation of the post fermenter into a fermenter was quite simple requiring to establish a separate feeding line for the substrate. The modification of the digestate storage tank was quite complex requiring installation of two additional mixers, separate feeding lines from fermenters, insulation of the tank on the outside with styrodur and steel plates as well as the installation of a tank heating system (Figure 8) capable to maintain the temperature of the digestate at 40^{0}C.

Figure 8. Heating system installed into the post fermenter

Due to the need of better processing the agri-food material a significant improvement was conducted at the solid feeding system. There a grinder provided with a stone removal system was installed to avoid the destruction of the pumps by the stones mixed with potatoes.
The last major improvement was the results of periodic analysis of material inside fermenter in 2018 presented in Figure 9. While the corn or any other technical crop silage does not require hygienization, the use of agri-waste materials requires by law to install a hygienization station (Figure 10) capable to process the estimate of 40-60 tons of digestate per day.

Figure 9. Grinding system installed at the exit of solids feeding system

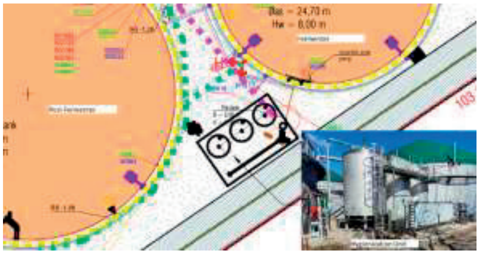

Figure 10. Digestate hygienization station

CONCLUSIONS

The conversion of BIO 2 Filipestii de Padure biogas plant was a process that required quite a long period of time and significant technological modifications; however, the result was successful and lead to a major improvement in its capacity.
Through the introduction of additional grinders, the size of input materials was reduced from 7 cm to less than 3 cm and consequently the digestion time was reduced in a significant manner. Thus, the digestate retention time for complete mineralization was reduced to less than 3 months. This fact provided the opportunity of changing the post fermenter into a second fermenter and consequently of the digestate storage tank into a post fermenter.
These changes increased the capacity of biomass processing and consequently increased biogas production from 500 m^3 to 1000m^3. The additional biogas was used in a second CHP providing the necessary amount of thermal power for the digestate hygienization station and the electrical power for internal use.

Although the conversion required a significant investment, the expected economic return is quite high considering that instead of buying the plants silage the factory will receive the gate fee for the processed waste.

The most significant result is however, the environmental impact of this conversion. Through the bio digestion of agri-food waste there it will be avoided the release of a large quantity of landfill gas with a great impact on greenhouse effect.

There it could be concluded that the work conducted in BIO1 Filipestii de Padure was a pioneering work for Romania and the experience acquired during this research could be used further into the development of new such facilities both in Romania and around the world.

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KINETIC STUDY FOR THE REMOVAL OF COPPER IONS BY FLY ASH/NaOH ADSORBENT

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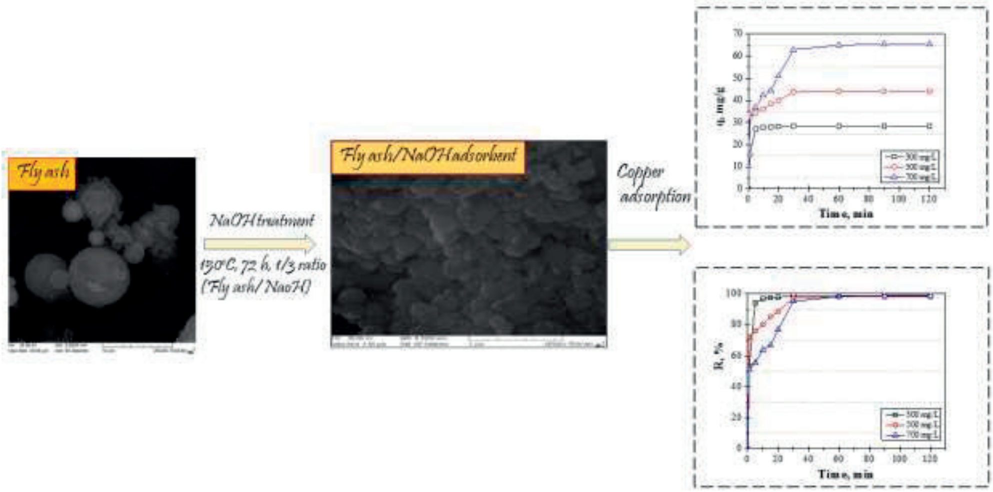
Abstract

The adsorption study of copper ions from aqueous solution using fly ash as a feed material was investigated. The proposed adsorbent was synthesized through the treatment of fly ash with NaOH at 150^{0}C, 72 hrs. The different parameters, such as: pH, dose of adsorbent, initial copper concentration, and contact time were examined. The adsorbent was characterized by SEM, EDX, XRD, FTIR, BET surface area, and thermal analysis. The copper adsorption process is very fast, a removal efficiency of 99% being reached in approx. 25 min. Three adsorption kinetic models presented in this paper: Pseudo first order, Pseudo second order, and Intraparticle diffusion model for describing the data were compared. The best model that described the kinetic data was the Pseudo second order kinetic model, Type 1. This research confirmed that the adsorbent prepared from fly ash, can be used successfully to remove copper ions from aqueous solution. The material prepared presents a high adsorption capacity for copper ions: 28.16 mg/g, 43.91 mg/g, and 65.15 mg/g for an initial copper concentration of 300 mg/L, 500 mg/L, and 700 mg/L.



Key words: *fly ash, synthesis, characterization, copper, adsorption, kinetic.*

INTRODUCTION

The removal of heavy metals from wastewater has been considered in many studies and represents a current trend (Noli et al., 2016; Buema et al., 2020; Forghani et al., 2020; He et al., 2020; Zhao et al., 2020; Mohammadi et al., 2021; Shahrashoub and Bakhtiari, 2021). Copper ions are classified as highly toxic metals. The toxic effects due to copper reported are diseases and disorders (Wu et al., 2018). The ability of different materials to eliminate copper ions from aqueous solution is often studied through adsorption technique, the other conventional methods being expensive.

The continuous produce of fly ash generated by power plants poses an environmental problem (Duan et al., 2016; Kankrej et al., 2018; Angaru et al., 2021). The capitalization of fly ash can be made in some applications, such as: cement industry, production of glass, zeolites, mesoporous materials, vitreous materials, and ceramics manufacture (Ahmaruzzaman, 2009). The current scientific research is focused is involvement of fly ash in synthesis of adsorbents for heavy metals removal due to its major chemical components: alumina, silica, ferric oxide, calcium oxide, magnesium oxide, and carbon (Sočo and Kalembkiewicz, 2013). Unfortunately, the fly ash shows lower adsorption capacity. For this reason, its activation has been proposed in order to improve its adsorption capacity. It is well known the fact that the synthesis conditions have a highly impact for the structure of the material obtained.

The pure-form zeolites A and X were synthesized from fly ash for copper and zinc removal. For the FA-ZA adsorbent, the adsorption capacity for Copper ions calculated from Langmuir isotherm was 82.74 mg/g (working conditions: adsorbent dosage 0.5 g, 25°C, pH 3.0). Zeolite A was more effective in removing Cu^{2+} and Zn^{2+} compared to zeolite X (Wang et al., 2009). Harja et al. studied copper ions removal from aqueous solutions by four new materials synthesized from Romanian fly ash by direct activation of ash with NaOH at 70^0C and 90^0C. The adsorption capacity was about 2 times higher compared to that of unmodified ash (Harja et al., 2012).

Zeolites synthesized from low and high calcium fly ash were tested for different heavy metals: Zn^{2+}, Cu^{2+}, Cd^{2+}, and Pb^{2+} (Ji et al., 2017).

Zeolite Y synthesized from fly ash using the fusion-hydrothermal method has an adsorption capacity of 231.03, 248.29, and 250.71 mg/g at temperature of 301.15K, 318.15K, respectively 338.15K (Liu et al., 2019).

Qiu et al., in 2018, show that a maximum adsorption capacity of 27.55 mg/g is obtained by treating the fly ash with 1 mol/L Na_2HPO4, at a liquid-solid (solution/fly ash) ratio of 3 ml/g, 200ºC, 30 min.

A study by Darmayanti et al. (2019) for copper ions found the maximum adsorption capacity on two materials from fly ash was 40 mg/g.

Qiu reported the adsorption of copper ions using fly ash modified by microwave-assited hydrothermal process. The material obtained gave an adsorption capacity between 8.664 mg/g to 32.05 mg/g at an initial concentration range of 100-500 ppm (Qiu et al. 2019).

Vavouraki et al. have synthesized zeolite from Greek Fly Ash in order to be used as adsorbent for copper removal. Zeolites were synthesized through fusion of fly ash with NaOH or KOH (Vavouraki et al., 2020).

Using a material synthesized from fly ash with NaOH at room temperature, Buema et al. found that the maximum adsorption capacity of copper ions was between 27.32 to 58.48 mg/g (Buema et al., 2021a).

In this research, the fly ash was applied as feed material for the synthesis of a new adsorbent for the adsorption of copper ions. The basic characterization SEM, EDX, XRD, FTIR, BET surface area, and thermal analysis point of view was performed. The effect of different parameters, such as: pH, dose of adsorbent, initial copper concentration, and contact time was researched. Additionally, Pseudo first order model, Pseudo second order model (four types of its linearization), and Intraparticle diffusion model for describing the data were compared. The best model that described the kinetic data was the Pseudo second order kinetic model, Type 1.

MATERIALS AND METHODS

Materials

The fly ash used in this research with the aim to obtain a new material with the applicability in adsorption of copper ions from contaminated water was sourced from CET II Holboca (Iasi, Romania).

The chemical reagents were used as received.

The properties of the adsorbent including SEM, EDX, XRD, FTIR, BET surface area, and thermal analysis were performed using the following equipment:

- The morphology and the chemical composition were observed using Vega Tescan 3 SBH (Brno, Czech Republic), QUANTA 3D - AL99/ D8229 (FEI Company, Hillsboro, Oregon, USA);
- The material was characterized using X'PERT PRO MRD Diffractometer (PANalytical, Almelo, The Netherlands) in the 2θ range for phase determination.
- Fourier transform infrared spectroscopy (FT-IR) analysis was recorded on a Thermo

Scientific Nicolet 6700 FT-IR spectrometer. The investigation was performed over a wavenumber range of 4000-400 cm^{-1}

- Nitrogen adsorption/desorption isotherm was measured out at – 196°C on an Autosorb 1-MP gas sorption system (Quantachrome Instruments, Boynton Beach, FL, USA);
- The thermal analysis was performed with METTLER TOLEDO TGA/SDTA 851;
- The pH was measured with a pH-meter (Hanna Instruments, Cluj-Napoca, Romania), and the Spectrophotometer Buck Scientific was used for copper ions detection (Buck Scientific, East Norwalk, CT, USA).

Adsorbent synthesis

In short, 15 g of fly ash were mixed with 45 g of NaOH pellets and then the mixture was ground into powder that was kept at 150^0C for 72 h. After the NaOH treatment, the material obtained was washed several times with deionized water until neutral pH. Finally, the material was dried 24 hrs. at 60^0C.

Batch adsorption experiments

The stock solutions were prepared by dissolving appropriate amounts of $CuSO_4\ 5H_2O$ in distilled water. Copper concentration in the supernatant was analyzed spectrophotometrically. 0.1 M HCl or 0.1 M NaOH solution was used to adjust pH.

The adsorption experiments were carried out in order to investigate the effect of some experimental conditions: pH, contact time, dose of adsorbent, initial copper concentration. All the experiments were performed at room temperature under stirring at 300 RPM.

- Effect of pH: 2, 4, and 5; initial copper concentration = 500 mg/L, dose of adsorbent = 10 g/L;
- Effect of dose of adsorbent: *10 g/L (1 g ads/100 mL solution), 20 g/L (2 g ads/100 mL solution), and 40 g/L (4 g ads/100 mL solution),* initial copper concentration = 300 mg/L, the pH of the solution was kept constant at 5.
- Effect of initial copper concentration: *300 mg/L, 500 mg/L 700 mg/L,* dose of adsorbent = 10 g/L, pH = 5;
- Effect of contact time: *1-120 min,* initial copper concentration = 300, 500, 700 mg/L, dose of adsorbent = 10 g/L, pH = 5.

The quantity of copper ions adsorbed per gram of adsorbent and removal efficiency, R (%) were calculated based on the equations below:

$$q, mg/g = \frac{(C_0 - C_e)V}{m} \quad (1)$$

$$R, \% = \frac{(C_0 - C_e)}{C_0} x100 \quad (2)$$

Where C_0 and C_e are the initial and equilibrium copper concentrations (mg/L), q is the amount of copper adsorbed onto adsorbent (mg/g), V is the volume of copper solution (L), and m is the quantity of adsorbent (g).

RESULTS AND DISCUSSIONS

Characterization of adsorbent

SEM, EDX, XRD, FTIR, BET surface area, and thermal analysis measurements were used to characterize the prepared adsorbent. A comprehensive characterization is already presented in the literature (Buema et al., 2021b).

Effect of parameters

The adsorption process is controlled by several factors, such as: pH, dose of adsorbent, initial metal concentration, and contact time. All these parameters were taken into account in this research.

Effect of pH

In the first stage of the research, the pH influence was investigated. The interaction between copper ions and adsorbent is highly dependent on pH value. The adsorption capacity is generally improved with increasing of pH.

The effect of pH was investigated at 2, 4, and 5 (Figure 1). No higher pH values were used to avoid precipitation.

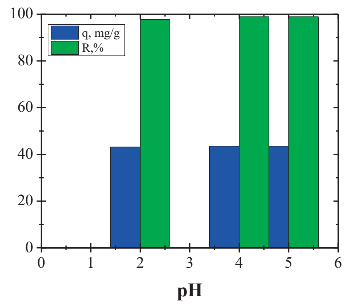


Figure 1. Effect of pH on the adsorption capacity and the removal efficiency

Copper ions adsorption was found to be 43.15 mg/g, 97.77% at pH 2, respectively 43.53 mg/g, 98.88% at pH values of 4 and 5. Similar observation has been reported in the literature for adsorbents based on ash synthesized by direct activation, but at lower temperatures (Buema et al., 2021a). So, it can be concluded that the adsorption capacity, respectively the removal efficiency values remain constant at pH 4 and 5.

Therefore, the effect of the other parameters was determined at pH of 5.

Effect of dose of adsorbent

This parameter was investigated by increasing the dose of adsorbent from 1 to 4 g adsorbent/100 mL solution. The data can be consulted in the Figure 2.

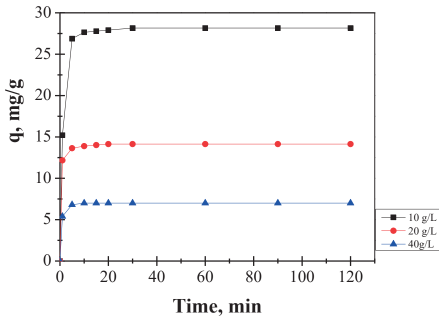


Figure 2a. Effect of dose of adsorbent on the adsorption capacity

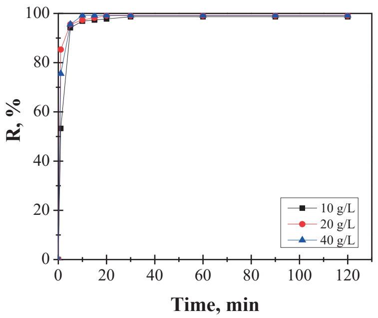


Figure 2b. Effect of dose of adsorbent on the removal efficiency

In the previous study it was reported that the copper adsorption capacity depends on dose of adsorbent. The results show that an increase in the adsorbent dose determines a lower value of the adsorption capacity. On the other hand, removal efficiency values of approx. 99% can be obtained by using adsorbent doses ratio of 1 g/100 mL, 2 g/100 ml, and 4 g/100 ml.

By using 10 g/L of adsorbent (1 g/100 mL) the adsorption capacity is higher compared with those observed at 20 g/L (2 g/100 ml) and 40 g/L (4 g/100 ml). However, the tests highlight that copper ions were rapidly removed, after 25 min the equilibrium being reached in all three cases.

Effect of copper initial concentration and contact time

The initial metal concentration presents a significant impact through adsorption capacity and removal efficiency (Hamid et al., 2020; Claros et al., 2021).

Conform to Figure 3a, a high maximum adsorption capacity of 65.15 mg/g was observed at 700 mg/L initial copper concentration compared to that of 300 mg/L initial copper concentration, 28.16 mg/g. As shown above, copper ions were rapidly adsorbed. No significant adsorption was observed after 60 min. of contact time.

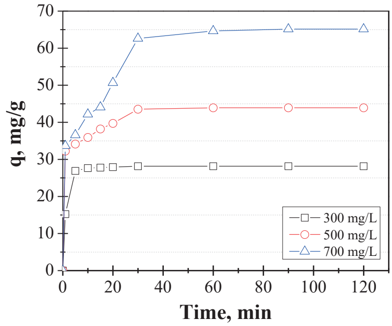


Figure 3a. Effect of initial copper concentration on the adsorption capacity

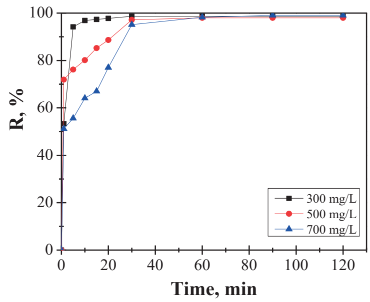


Figure 3b. Effect of initial copper concentration on the removal efficiency

Kinetics study

To obtain information regarding the adsorption mechanism of the modified fly ash, the experiments of kinetics were investigated. Pseudo first order model, Pseudo second order model, and Intraparticle diffusion model are typical for analyzing the adsorption kinetics in the solid/liquid system (Yang et al., 2019; Bashir et al., 2020).
The results are presented in Figures 4, 5 and 6, respectively in Table 1.

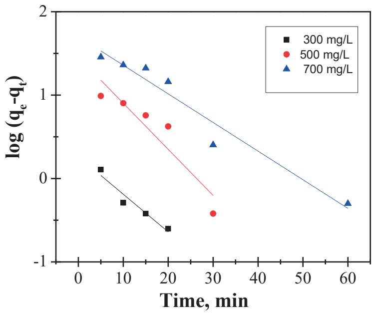


Figure 4. Pseudo first order model

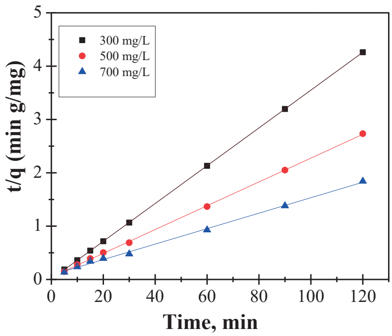


Figure 5. Pseudo second order model

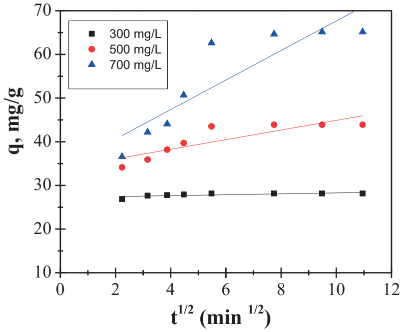


Figure 6. Intraparticle diffusion model

The kinetic equations are presented in eq. 3, 4 and 5.

$$\log(q_e - q_t) = \log q_e - \frac{(k_1 t)}{2.303} \quad \text{..............(3)}$$

$$\frac{t}{q_t} = \frac{1}{k_2 {q_e}^2} + \frac{t}{q_e} \quad (4)$$

$$q_t = k_i t^{0.5} + c \quad \text{..............................(5)}$$

From the data presented in Table 1, the correlation coefficients (R^2) of the Pseudo second order model are generally higher than the other two investigated models.
The experimental q_e values of 28.16, 43.91, and 65.15 mg/g for 300, 500, and 700 mg/L are in agreement with the q_e value of 28.25, 44.84, 68.96 and mg/g calculated from the Pseudo second order model.
Based on this, Pseudo second order model was linearized to four different forms. The results are given in Figures 7-9. Parameters including qe, k_2, and R^2 are listed in Table 2.
Analyzing the data presented in Table 2, it can be noted that the values of R^2 for Types 2, 3 and 4 were lower than 0.89. Therefore, the good correlation with the experimental data is for the Pseudo second order model, Type 1.

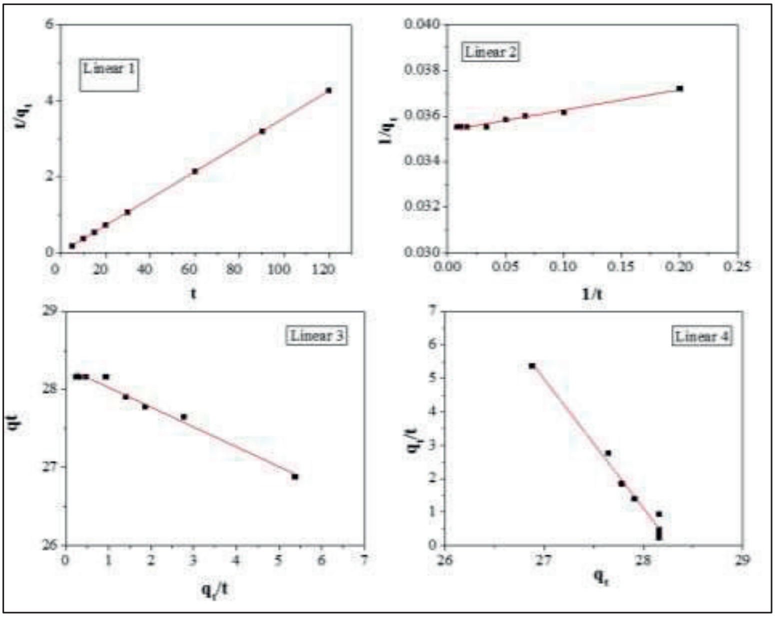


Figure 7. Pseudo second order (Type 1-Type 4) plot of copper ions, 300 mg/L

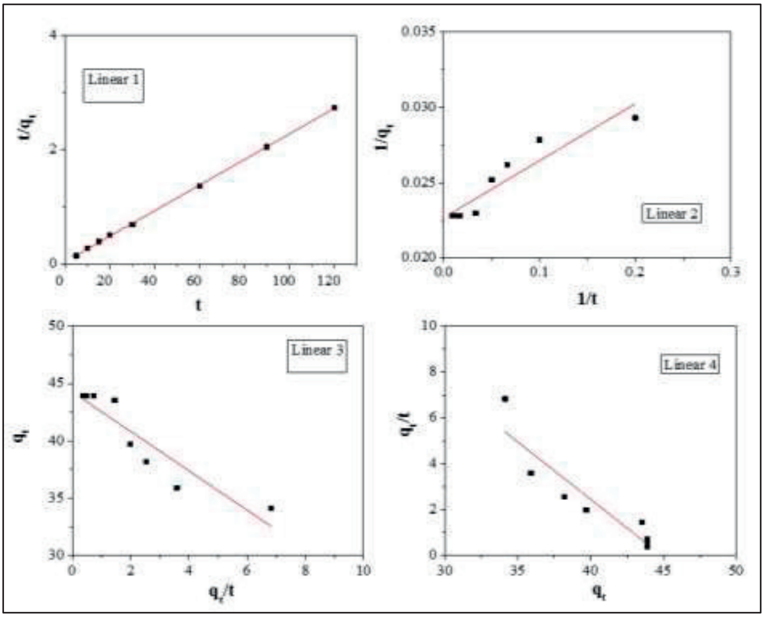


Figure 8. Pseudo second order (Type 1-Type 4) plot of copper ions, 500 mg/L

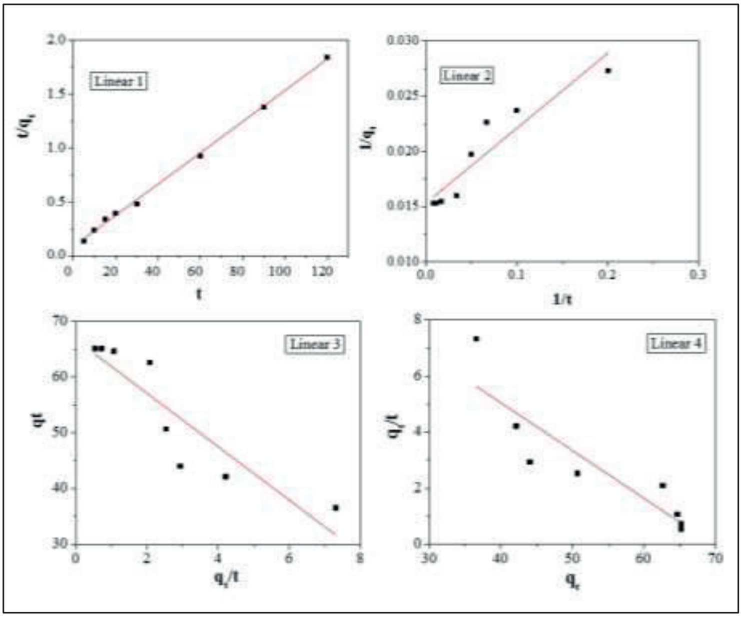


Figure 9. Pseudo second order (Type 1-Type 4) plot of copper ions, 700 mg/L

Table 1. The relevant parameters of the kinetic models

	Pseudo fist order		Pseudo second order			Intraparticle diffusion model		
	k_1, 1/min	R^2	k_2, g/mg min	qe, mg/g	R^2	ki, mg/g·min$^{0.5}$	c	R^2
300 mg/L	0.1038	0.9381	0.1843	28.25	1	0.1054	27.232	0.5587
500 mg/L	0.1273	0.8659	0.0114	44.84	0.9997	1.1035	33.86	0.7539
700 mg/L	0.0789	0.9508	0.0025	68.96	0.9981	3.3807	33.85	0.7978

Table 2. Kinetic constants for Pseudo second order model, Type 1-Type 4

Kinetic type	Parameters	Values		
		300 mg/L	500 mg/L	700 mg/L
Type 1 $q_e = 1/m$ $k = m^2/c$	k_2, g mg/min	0.1843	0.0114	0.0025
	qe, mg/g	28.25	44.84	68.96
	R^2	**1**	**0.9997**	0.9981
Type 2 $q_e = 1/c$ $k = c^2/m$	k_2, g mg/min	0.1394	0.0136	0.0034
	qe, mg/g	28.25	44.05	65.4
	R^2	0.9822	0.8824	0.8786
Type 3 $q_e = c$ $k = -1/c \times m$	k_2, g mg/min	0.0089	0.0388	0.0717
	qe, mg/g	28.281	44.26	66.716
	R^2	0.9807	0.8592	0.8173
Type 4 $q_e = -c/m$ $k = m^2/c$	k_2, g mg/min	0.1365	0.0111	0.0024
	qe, mg/g	28.287	44.89	69.56
	R^2	0.9807	0.8592	0.8173

CONCLUSIONS

The following conclusions can be drawn based on the above study:

- The fly ash was used in order to obtain a new material with applicability in copper ions adsorption.
- The full characterization of the material is described as well as the adsorption study of copper ions from aqueous solution.
- The new adsorbent tested in copper adsorption was synthesized through the treatment of fly ash with NaOH at 150^{0}C, 72 hrs and it was characterized by SEM,

EDX, XRD, FTIR, BET surface area, and thermal analysis.
- The different parameters: pH, dose of adsorbent, initial concentration, and contact time were examined.
- The removal efficiency of 99% is reached in approx. 25 min.
- Three adsorption kinetic models were applied in this paper. The highest correlation coefficients, R^2, were obtained for the Pseudo second order kinetic model.
- Finally, this research confirmed that the adsorbent prepared from fly ash, can be used successfully to remove copper ions from aqueous solution, with a maximum adsorption capacity of 28.16, 43.91, and 65.15 mg/g for 300, 500, and 700 mg/L.

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ANALYSIS FOR SOILS CHARACTERIZATION IN THE PURPOSE OF RAINFALL-RUNOFF PROCESS MODELING

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Abstract

The paper presents the results of a pedological study conducted on the soils of Baltati commune, Iasi County. 25 profiles were executed from which soil samples were taken, both in a natural and modified settlement, on horizons, for the following physical and chemical analyses: granulometric composition, bulk density, current acidity (pH), alkaline earth carbonates, hummus, total azote, mobile phosphorus, mobile potassium, soluble salts, anions CO^{-2}, HCO^{-}, anion Cl^{-}, anion SO_4^{-2}, cation Ca^{+2}, cations Na^{+} and K^{+}, T (total cation exchange capacity) and Na^{+} changeable.
The research conducted revealed the existence of a varied soil coating. According to their characteristics and limitations, the soils in the study area were classified into 5 classes, from II to VI. They are soils with varied fertility, and some of them are affected by processes of erosion, landslides, gleization, pseudogenization, alkalization, and salinization.

Key words*: classes, fertility, processes, soils.*

INTRODUCTION

Soil is an open, dynamic system, influenced by many natural and anthropogenic factors. Therefore, in many situations, it is necessary to update knowledge of the physical, chemical, and biological properties of soils in an area.
The process of transforming precipitation into runoff over a basin is complex and shows both temporal and spatial variability. However, in a river basin, the variability is controlled mainly by the physical and chemical properties of the soil surface.
The runoff surface is an important factor in soil loss as well as in the movement of nutrients from the soil surface with consequences in decreasing soil productivity and crop yield, especially in agricultural land.
The purpose of this study conducted on the soils of Baltati village, Iasi County is to provide a series of the necessary information to analyse the process of precipitation runoff. Using mathematical models, we will verify with measurements, the rain-flow runoff relationships, depending on the hydraulic characteristics of the soils from the studied area.
Considering these aspects, soil samples were taken from the field, which was then analysed in the laboratory.
A characterization with enough degree of detail of the soils from the studied area was made, so we can be able to define as accurately as possible the conditions under which the infiltration of water from precipitation occurs (Statescu et al., 2011).
One of the most important factors favouring the formation of runoff is the soil, which by diversity and its characteristics, also play a fundamental role in water exchanges between shallow and underground runoff, intermediate between meteorological factors (precipitation) and underground drain.
The runoff processes are influenced by soil character and their physical condition: water saturation, degree of compaction, degree of freezing.
A good understanding of the topographic, hydrological, and climatic state of the study area and the appropriate set of data that define them is very important to analyze and simulate as realistic as possible the hydrological and hydraulic situation in the basin. Moreover, the quality of the data used for modeling directly

affects the result, so the data collected should be screened and processed before use.

MATERIALS AND METHODS

The study was carried out on the common territory of Baltati, about 35 km from the municipality of Iasi, located in the southwestern part of the Moldavia Plain (Figure 1).

From a hydrological point of view, the territory of Baltati belongs, for the most part to the Bahluet middle basin. The hydrological regime of Bahluet is characteristic of this area of lower terrain (Moldavia Plain) with moderate rainwater supply and snow water supply. The period of high water is in February-March. The density of the hydrographic network is 0.5-1.25 km/km^2. The climatic regime is characterized by an average annual rainfall of 487.9 mm at Podu Iloaiei and 502.3 mm at Targu Frumos; an average annual temperature of 9.1°C.

As a topographical basis, land-keeping plans with level curves were used at a 1:10000 scale.

Were executed 25 main profiles from which soil samples were taken, both in a natural and modified settlement, on horizons, for physical-chemical analysis.

Figure 1. Area location

The granulometric composition of soils is dependent on land use. Figure 2 illustrates the map of land use in the river basin Bahluet.

The land uses of the studied area are arable-corn, arable-wheat, scorch, degraded pasture, pasture, arable-stubble, wheat, orchard: pear tree, quince.

The main properties analysed and the laboratory methods used are shown in Table 1 (Cucu et al., 1995).

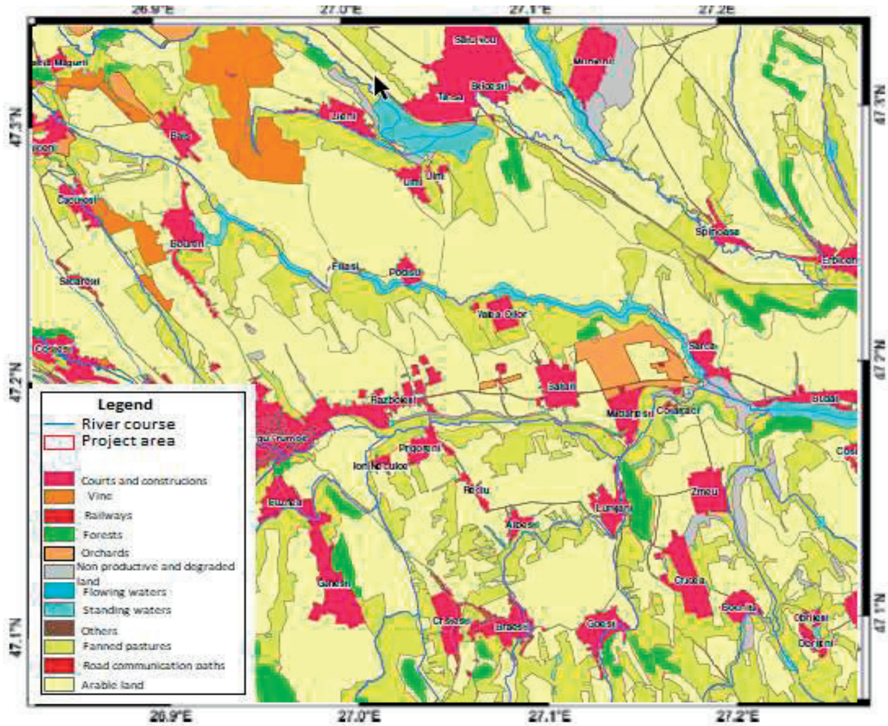

Figure 2. Map of land use in river basin Bahluet

Table 1. Laboratory-determined soil properties

Soil analysis	Method used
Granulometric composition	Kacinski (treatment of soil with hydrochloric acid and separation of fractions by pipetation)
Bulk density	Cylinders with known volume and weighing
Current acidity (pH)	Potentiometric
Alkaline earth carbonates	Scheibler
Humus	Titrimetric after Schellenberger.
Total azote	Kjeldahl
Mobile phosphorus	Egner-Riehm-Domingo
Mobile Potassium	Ammonium acetate-lactate solution and dosing to the photometer with flame
Soluble salts	The watery solution, evaporation, and weighing
Anions CO_3^{2-} and HCO_3	Titrimetric
Anion Cl^-	Mohr
Anion SO_4^{2-}	Gravimetric as $BaSO_4$
Cation Ca^{2+}	Complexometric
Cations Na^+ and K^+	Flame photometer
T (cation exchange capacity)	Percolation with a solution of ammonium acetate at pH 7 and distillation, Schollenberger-Cernescu method
Na^+ changeable	Ammonium acetate extract and photometer flame

RESULTS AND DISCUSSIONS

By analysing the properties of the soil can notice their impact on the process of runoff formation.

The solution to most of the problems of transport and flow requires knowledge of the physical properties of the soil in unsaturated conditions.

The establishment of the hydrological soil group is done considering primarily the physical properties of soil: texture, structure, and porosity.

Soil texture, porosity, infiltration speed, and hydraulic conductivity influence hydro physical behaviour through water drainage capacity (Statescu et al., 2010).

The modification of the pedological conditions in a river basin directly influences the processes of infiltration, the formation of runoff surface area, their concentration, and the formation of floods (Statescu et al., 2011).

The values of characterization of the analytical properties in the laboratory were centralized, for each soil profile.

For each soil sample were determined in the same way, the physicochemical properties (L.P. van Reeuwijk, 2002).

Table 2. Soil Profile No.1

Relief	Parental material	Horizons	Am	Am	Ab	CA	Cca
		Depths (cm)	0-25	25-40	40-50	50-75	75-120
Trays- terrace	Loessoid deposits	Fine sand (0.2-0.02 mm) %	43.8	50.6	44.8	42.8	45.5
		Dust (0,02-0,002 mm) %	23.1	21.1	25.7	27.4	25.7
		Clay 2 (less than 0.002 mm) %	33.1	28.3	29.5	29.8	28.8
		Physical clay (less than 0.01 mm) %	43.5	35.9	43.6	43.0	42.5
		Texture	LL	LL	LL	LL	LL
		Ph	6.9	7.0	7.8	7.9	8.0
		Carbonates (%)			2.6	6.1	8.2
		Humus (%)	3.9	3.6	3.0		
		Total N (%)	0.191	0.182	0.148		
		Mobile P (ppm)	10	19	30		
		K immovable (ppm)	216	162	156		

Based on the criteria for framing the properties of the soils studied, the following classes and soil units have been identified (SRTS 2012).

From the class II of soils belong typical chernozem, typical cambic chernozem, typical cambic chernozem, cumulic; coluvosoil molic, weakly alkalized; coluvosoil molic, strongly gleized; typical chernozem with weak surface erosion, typical cambic chernozem with poor erosion in the surface.

Table 3. Analytical data for each soil unit of class II

Soil units / Characteristics	Clay (%)	Humus (t/ha)	Humus reserve	pH	N (%)	P (ppm)	K (ppm)
Typical chernozem, typical cambic chernozem, typical cambic chernozem,cumulic	33.1-36,9	3.6-4.2	204-241	6.5-6.9	0.179-0.209	4-10	204-216
Coluvosoil molic, weakly alkalized	27.4-32.4	3.24-3.84	195-225	7.0-7.8	0.165-0.189	35-200	335-400
Coluvosoil molic, strongly gleized	24.3-31.1	3.07	185	6.7-7.2	0.143	13	175
Typical chernozem with weak surface erosion	24.9-28.9	2.16-3.18	185	6.8-8.1	0.175	24	282
Typical cambic chernozem with poor erosion in the surface	33.6-38.2	3.6	231	6.0-7.9	0.182	6	313-363

Class II of soil includes lands with good suitability, with reduced limitations on fine texture, slope, surface erosion, temporary excess groundwater, or stagnant humidity.

From the class III of soils belong cambic pseudorendzin; typical chernozem with moderate surface erosion, typical cambic chernozem with moderate surface erosion; aluviosoil molic strongly gleized; aluviosoil strong gleized, weakly salinized, moderately alkalized; gleiosoil weakly salinized and alkalized, aluviosoil strongly gleized, weakly salinized and alkalized; coluvosoil molic, poorly salinized, moderately alkalized, typical chernozem complex (30%), typical cambic chernozem (30%), gleized chernozem, salinized and weakly alkalized (40%).

Table 4. Analytical data for each soil unit of class III

Soil units / Characteristics	Clay(%)	Humus (t/ha)	Humus reserve	pH	N (%)	P (ppm)	K (ppm)
Cambic pseudorendzin	50.4-53.5	6.32	400	6.6	0.317	6	363
Typical chernozem with moderate surface erosion, typical cambic chernozem with moderate surface erosion	34-35	3.14	180	6.8-8.4	0.160	25	210
Aluviosoil molic strongly gleized	57-59	4,9	305	7.9-8.0	0.245	42	313
Aluviosoil strong gleized, weakly salinized, moderately alkalized	21-33	1.53-3.7	128-167	7.8-8.2	0.251-0.265	22-126	190-317
Gleiosoil weakly salinized and alkalized, aluviosoil strongly gleized, weakly salinized, and alkalized	69	6.2-7.5	210-366	7.7-8.4	0.224-0.336	37-40	331-386
Coluvosoil molic, poorly salinized, moderately alkalized	25.1-30.2	3.8-5.2	175-209	7.7-8.1	0.175-0.265	26-48	240-400
Typical chernozem complex (30%), typical cambic chernozem (30%), gleized chernozem, salinized and weakly alkalized (40%)	35-41	4-5	290	7-7.8	0.199-0.242	10	244

Class III of soils includes lands with medium suitability for arable land, with moderate limitations on erosion, fine texture, salinization, and alkalization.

From the class IV of soils belong: typical chernozem with strong surface erosion, typical erodic anthrosoil; aluviosoil weakly gleized, salinized, and weakly alkalized, aluviosoil strongly gleized, weakly salinized, moderately alkalized, aluviosoil strong gleized, moderately salinized, low moderated alkalized, gleiosoil moderately salinized, low alkalized, typical chernozem complex with moderate surface erosion (50%), typical erodic anthrosoil (25%), erodic anthrosoil salinized (25%) around stabilized landslides.

Table 5. Analytical data for each soil unit of class IV

Soil units / Characteristic	Clay (%)	Humus (t/ha)	Humus reserve	pH	N (%)	P (ppm)	K (ppm)
Typical chernozem with strong surface erosion, typical erodic anthrosoil	28.7-30.2	0.9-2.34	24-61	7.9-8.0	0.071- 0.123	13-35	129-282
Aluviosoil weakly gleized, salinized, and weakly alkalized, aluviosoil strongly gleized, weakly salinized, moderately alkalized	13.1-28.9	1.51-3.72	75-92	7.9	0.078-0.190	42-44	208-400
Aluviosoil strong gleized, moderately salinized, low moderated alkalized	43.3-45.6	46.2–55.3	260	7.8–8.4	0.259-0.290	51-122	282–400
Gleiosoil moderately salinized, low alkalized	45.9	3.43	230	7.8–8.1	0.174	39	296
Typical chernozem complex with moderate surface erosion (50%), typical erodic anthrosoil (25%), erodic anthrosoil salinized (25%) around stabilized landslides	34-36.5	3.50	242	7.7-7.9	0.160	10	190

Class IV of soils comprises land with low pretentiousness with severe limitations on slope, erosion, excess moisture, texture, inundability, landslides. Limitations cause appreciable systematic decreases in plant growth and development.

From the class V of soils belong: gleiosoil marshy salinized, complex of salinized and alcalized chernozem from weak to strong, with weak and moderate surface erosion (60%), solonet moderately salinized (20%), anthrosol erodical salinized (20%), on saliferous deposits with texture from clayey to clay, complex of aluviosoil molic, gleized, salinized (50 %), gleiosoil marshy salinized (25%), coluvosoil molic gleized, sometimes salinized and alkalized (25%), Typical chernozem complex with strong surface erosion (25%), salinized and alkalized erodical anthrosol (25%), pseudorendzinic erodical anthrosol (50%), around semi-stabilized slips.

Table 6. Analytical data for each soil unit of class V

Soil units / Characteristics	Clay (%)	Humus (t/ha)	Humus reserve	pH	N (%)	P (ppm)	K (ppm)
The complex of salinized and alkalized chernozem from weak to strong, with weak and moderate surface erosion (60 %), solonet moderately salinized (20 %), anthrosol erodical salinized (20 %), on saliferous deposits with texture from clayey to clay	22-51	2.26-6.64	60-450	8.3-9	0.115-0.289	10-51	160-400
The complex of aluviosoil molic, gleized, salinized (50 %), gleiosoil marshy salinized (25 %)	>31	2.1-3,5	50-340	8-9	0.250-0.270	20-25	200-300
Typical chernozem complex with strong surface erosion (25%), salinized and alkalized erodical anthrosol (25%), pseudorendzinic erodical anthrosol (50%), around semi-stabilized slips	>30	2-4.5	40-250	6.6-9	0.100-0.300	9-52	150-400

This class of soils is recovering gleiosoil marshy salinized soils. It is in narrow valleys, depression areas in meadows, contact of the plain with the slopes, where springs appear at the base of the slopes. The soil is submerged most of the year. The reaction for this type of soil is weakly alkaline, the content of calcium carbonates and soluble salts is generally low.

The land for this class V of the soils has very severe limitations and to be taken in cultivation requires special, complex, and intensive planning and improvement measures.

Limiting factors are the permanent excess of groundwater and stagnant water, salinization and alkalization of soils, surface erosion, slopes, fine texture due to the high clay content, floodability, rare in some areas, frequent in lower areas, a landslide by sliding.

In general, the chemical properties have large variations in the horizontal plane due to the relief kneaded by sliding.

The landslides were triggered under the influence of the geological structure and the presence of coastal springs.

In class VI of soil is identified complex erodical anthrosol salinized (50%) and pseudorendzinic erodical anthrosol (50%) in the active slip area. They represent the most mobile areas of the slopes where the movement of earth masses continues to this day.

Class VI of soils is represented by land with extremely severe limitations on active landslides and deep erosion (ravines).

These forms of degradation occur and develop due to the:

- easily erodible geological substrate;
- accentuated slopes;
- rainfall regime with heavy precipitations;
- degradation of meadows on the slopes.

CONCLUSIONS

The researches made revealed the existence of a variety of soil coating. According to their characteristics and limitations, the soils in the studied area were classified into 5 classes, from II to VI. They are soils with different fertility due to their physical-chemical properties. Some of these are affected by processes of erosion, landslides, gleization, pseudo gleization, alkalization, and salinization (Statescu et al., 2004).

Soils through their hydrophysical properties and especially through the texture and use of land play a particularly important role in the formation of maximum liquid runoff, in the flow of alluvium in suspension, and the process of groundwater supply through infiltrations.

A relevant analysis of the formation of soil surface leakage in the study area cannot be done without considering the many factors influencing this process. In addition to these analyses, they must be carried out in addition to others, such as determination of pore shape and size, determination of hydraulic conductivity, determination of the suction curve (Statescu et al., 2011).

Given a large number of soil types and subtypes identified in the studied area, the conditions for producing the rain-drain process will be very different and difficult to quantify. Particularly good integration of soil conditions in the modelling process leads to certain value results, close to those obtained by direct measurements.

The process of transforming precipitation into runoff over a basin is complex, nonlinear, and shows both temporal and spatial variability. The runoff modelling is the first step in designing and planning many engineering projects for water resources.

Theoretical and field studies have also shown that the generation of runoff is strongly uneven due to the spatial variability of soil infiltration capacity. However, while in wetlands this variability is mainly attributed to spatial differences in soil moisture, in dry areas runoff is mainly controlled by the physical and chemical properties of the surface and precipitation characteristics.

The rate of water infiltration into the soil depends on several properties of the soils, especially the physical characteristics of the soil.

Plant production in agricultural land in this area of the Bahluet basin depends largely on rainfall conditions, which are marginalized by water stress.

Preventing runoff is a key issue for conserving soil productivity and water supply for crop production. Therefore, determining the soil properties that influence runoff in agricultural land is the first step in choosing a runoff control strategy.

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THE CHARACTERISTICS OF FORESTS SITUATED IN KARST AREAS FROM BANATULUI MOUNTAINS

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Abstract

The present paper intends to synthesize stand characteristics from karst areas located in Banatului Mountains, based on data from forest management plans realized during 1995-2007. As such, 1220 stand elements were analysed from this area where forests occupy a total surface of 2.904 ha. Common beech is the most widespread species from this area. The stand's age distribution is relatively uniform, with a slight increased number recorded for the age class of over 120 years. The stands vegetate al altitudes between 185-1005 m, with an average altitude of 665 m for all studied stand elements. Asperula-Dentaria is the most common flora type, while calcic eutric cambisol is the most widespread soils type. Bm common beech mountain-premontane, average edaphic rendzinic is the most well represented station type.

Key words: *Banat, forests, carst, stand composition, station types.*

INTRODUCTION

Banatului Mountains are located in southwest Romania, between Reșița-Caransebeș basin in the north and Danube's Pass in the South and includes the following units: Dognecei Mountains (northwest), Aninei Mountains (central part), Semenic Mountains (east), Locvei and Almaj (south). Aninei and Locvei Mountains contain an important calciferous area and one of the largest and compact carbonate areas from Romania - Reșița - Moldova Nouă sinclinorium which covers 800 km^2. The low mountains landscape is characteristic for the entire area (Iurkiewicz et al., 2005).

Some of the karst's distinctive features are represented by rivers going underground, great springs emerging from the ground, independent hollows and basins instead of connecting valleys, deep potholes and vast caves, and isolated tower like hills (Jennings et al., 1971).

A multitude of dry and blond karst valleys complete Banatului Mountains' landscape and show an advanced karstification of chalk and the hydrographical network's disarray. From the total of 908 caves recorded in Banatului Mountains, 655 are mapped (70 caves being active) (Nae, 2008). Many geomorphologic sites, such as karst springs, caves, gorges and karst plateaus with a high density of karst features are situated in this area (Artugyan, 2017).

Taking into consideration the vast surface of 800 km^2 occupied by Reşiţa - Moldova Nouă sinclinorium, a large part of Banatului Mountains' forests are located in karst areas and have field and soil protection purposes.

Silvicultors have tried many times to classify forests based on their purpose.

A first forest classification in forests destined to wood production (*production forests)* and forests destined to fulfil certain protection functions (*protection forests*) dates back to the XVIth century. Professor Viktor Dieterich (1953) has classified forests based on their functions: production functions, protection functions and social functions (Blum, 2004).

In present times, the following functions are attributed to forests (Hasanagas and Shoesmith, 2002; Blum, 2004):

1. Ecologic functions: a) to regulate climate, air quality, water systems and soil potential; b) to protect against natural risks and noises; c) to conserve biodiversity;

2. Economic functions: a) production (wood and other wood and non-wood products), b) activities and services;
3. Social functions: landscape, recreation, educational, cultural and social functions.

In our country, forests are classified based on their attributed functions and the technical norms for managing forests and for choosing and applying treatments in 2 functional groups, Group 1: Forests with special protection functions and Group 2: Forests with production and protection functions.

In its turn, the first functional group is divided in five subgroups that contain Subgroup 2: Forests with field and soil protection functions. This subgroup also contains 12 categories, including 1,2K category = Forests situated in karst areas.

MATERIALS AND METHODS

The object of this article is represented by forests from Banatului Mountains situated in the 1,2K functional category = Forests situated in karst areas. The used data were taken from forest management plans realized during 1995-2007 for four forest districts that manage national forests from Banatului Mountains (*** Forest management plans, 1995-2007). A total number of 1220 value groups were used that correspond to stand elements from this area, complemented by eight studied characteristics, namely: surface, species, composition, stand structure, altitude, flora, soils and station type. The data was analysed with the help of the Excel program.

RESULTS AND DISCUSSIONS

Forests from Subgroup 2. Forests with field and soil protection functions occupy a total surface of 147.378 ha in Banatului Mountains. Amongst them, the 1,2K functional category = Forests situated in karst areas are widespread on 2.904 ha. The forests situated in karst area occupy the fourth place (2%) amongst all forest situated in Subgroup 2. The first places are occupied by Forests situated on cliffs, on deep erosion fields and on fields with a slope higher than 35 degrees (75%), Forests situated on fields with very vulnerable erosion and landslide lithologic substratum (19%) and Forests strips from around alpine gaps (3%), (Figure 1).

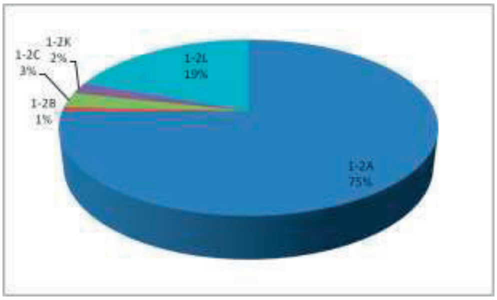

Figure 1. The surface occupied in Banatului Mountains by functional category forests from the subgroup of forest with field and soil protection functions

These forests are widespread in Anina (1970 ha), Berzeasca (516 ha), Reșița (411 ha) and Sasca Montană Forest Districts (2 ha).

The most widespread species from this forest category located in Banatului Mountains are: fir (*Abies alba* Mill.) = 202 ha, hornbeam (*Carpinus betulus* L.) = 297 ha, beech (*Fagus sylvatica* L.) = 1686 ha, ash (*Fraxinus excelsior* L.) = 106 ha, Norway spruce (*Picea abies* (L.) H. Karst.) = 111 ha, maple (*Acer platanoides* L.) = 50 ha, black pine (*Pinus nigra* J.F. Arnold) = 38 ha, and lime (*Tilia cordata* Mill.) = 113 ha (Figure 2).

Other species present in these forests are: wild cherry (*Prunus avium* L.), sessile oak (*Quercus petraea* (Matt.) Liebl.), larch (*Larix deciduas* Mill.), birch (*Betula pendula* Roth.), manna ash (*Fraxinus ornus* L.), aspen (*Populus tremula* L.), goat willow (*Salix caprea* L.), and black locust (*Robinia pseudoacacia* L.).

Oak stands have an extremely important purpose against landslides and erosion (Dincă and Achim, 2019). Furthermore, they are not affected by grazing as it happens in other European areas (Hinkov et al., 2019). Norway spruce is also spread on these fields even though this is not his optimal ecologic environment (Dincă et al., 2019). The pine from this area is naturally widespread, unlike many other areas from the country where it was introduced artificially in order to improve degraded lands (Constandache et al., 2019; Popov et al., 2017; Vlad et al., 2019). On the other hand, locust was planted (Murariu et al., 2019).

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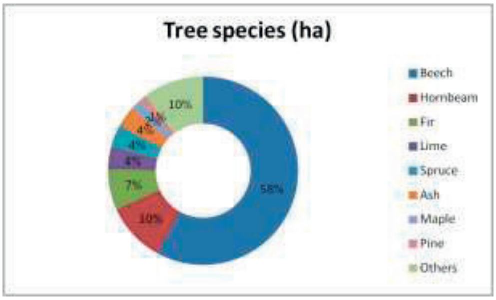

Figure 2. The surface occupied by species in forests from Banatului Mountains situated on karst

The stand composition is mainly mixed (96% of the surface occupied by these stands), with one or more species being present in a stand (Figure 3).

As an individual percentage, the most widespread stands are those in which the dominant species occupies 100% of the composition (398 ha), followed by 70% (331 ha) and 60% (227 ha). The stands in which the stand's element participation is very small (between 10 and 50%) are the most common. This is a general characteristic of stands from Banatului Mountains, but also a characteristic of stands that vegetate here on karst areas.

Pure stands are generally composed on common beech or Norway spruce, while linden, ash, manna or fir do not form pure stands.

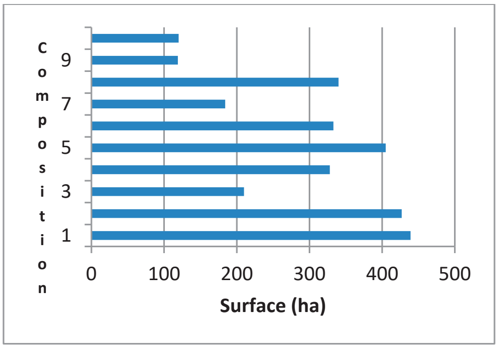

Figure 3. Stand composition of forests situated in karst areas from Banatului Mountains

The stands' distribution on age classes is relatively uniform, with the exception of the first age class. As such, a lack of very young stands can be observed and can be explained by the maintenance of old stands in order to protect these fields (Figure 4). This fact contributes to the high percentage of stands with ages over 120 years.

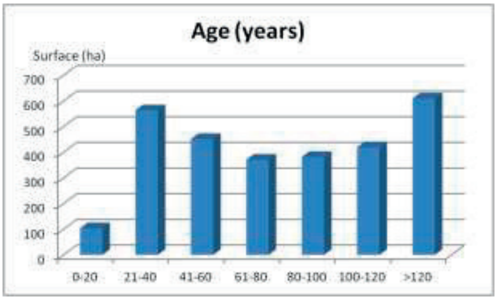

Figure 4. The age of stands situated in karst areas from Banatului Mountains

The stands' structure is relatively uniformed distributed between three structure types (the uneven-aged structure stands are lacking entirely): even-aged (1108 ha), relatively even-aged (889 ha), relatively uneven-aged (907 ha).

The altitude at which these stands are widespread ranges between 185 m at Sasca Montană and 1005 m at Berzeasca. An average altitude of 665 m was obtained by calculating the average altitudes of all 1220 analysed stand elements. The most common altitudes are of 600-800 m (Figure 5).

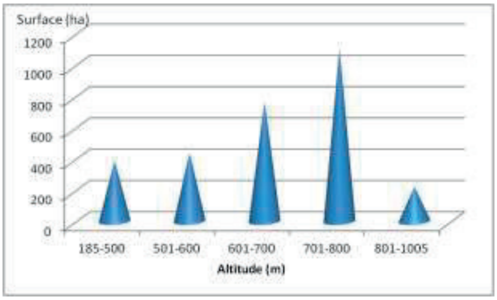

Figure 5. The altitudes of stands situated on karst areas from Banatului Mountains

The flora characteristic for these stands is *Asperula-Dentaria* (which appears on 1897 ha), *Asperula-Asarum* (955 ha) and *Festuca altissima* (30 ha).

The most common soils for these stands are the following: calcic eutric cambisol = 2071 ha, rendzina = 306 ha, eutric cambisol = 210 ha, lithic eutric cambisol = 203 ha, and lithic rendzina = 111 ha. These soils are influenced by the karstic substratum through a high $CaCO_3$ quantity (calcic eutric cambisol and rendzina) and through a reduced depth (lithic subtypes from eutric cambisol and rendzina). In addition, they are rich in humus and nutritive elements (Crișan et al., 2017; Dincă et al., 2018), being favourable in general to forest vegetation (Chisăliță et al., 2015).

The most representative forest stations are the following: Bm common beech mountain-premontane, average edaphic rendzinic = 768 ha, Bs common beech mountain-premontane, high edaphic eutricambosol with *Asperula-Dentaria* = 599 ha, Bm common beech mountain-premontane, average edaphic eutricambosol with *Asperula-Dentaria* = 486 ha, Bm common beech hill, average edaphic eutricambosol with *Asperula-Asarum* = 234 ha, and Bi common beech hill, low edaphic eutricambosol= 177 ha.

CONCLUSIONS

Forest areas from Banatului Mountains shelter important forests that vegetate on some of the largest karst areas from our country. According to the group forest framing, these forests are situated in Group 1 - Forests with special protection functions, Subgroup 2 - Forests with field and soil protection functions and category 1-2K - Forests situated in karst areas. As such, these forests are under a conservation regime.

The forests from Subgroup 2 - Forests with field and social protection functions occupy 147.378 ha in Banatului Mountains. Amongst them, the 1-2K functional category (Forests situated on karst areas) occupy 2.904 ha. The forests from karst areas can be found in the following forest districts: O.S. Anina (1970 ha), O.S. Berzeasca (516 ha), O.S. Reșița (411 ha) and O.S. Sasca Montană (2 ha).

Common beech is by far the most widespread species present in forests located in karst areas from Banatului Mountains (1686 ha), followed by hornbeam (297 ha) and fir (202 ha). Significant surfaces are also covered by linden, Norway spruce, ash, maple and black pine. The stands' composition is mixed for the 96% of the surface covered by them.

In regard with the stands' age that vegetates on karst areas from Banatului Mountains, the age class distribution is relatively uniform, with the exception of the first age class (0-20 years). As such, the conservation and maintenance of old stands in order to protect these areas has led to their higher percentage, especially for those that exceed 120 years.

The stands from these karst areas vegetate at altitudes between 185 m (O.S. Sasca Montană) and 1005 m (O.S. Berzasca). The average altitude for all 1220 studied stand elements is of 665 m.

Asperula-Dentaria is the most widespread flora type from this area and can be found on 1897 ha. Calcic eutric cambisol is the most widespread soil (2071 ha), while the most common station is Bm common beech mountain-premontane, average edaphic rendzinic (768 ha).

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MODEL OF DESCRIBING THE DIVING PHENOMENON AND THE DIVING DISTANCE OF THE LAND UNDER THE INFLUENCE OF MINING ACTIVITY. CASE STUDY JIU VALLEY, ROMANIA

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Abstract

The study analysed the phenomenon of diving (Div) and the diving distance (DivD) of the land under the influence of coal mining in the specific conditions of the Jiu Valley, Romania. 16 control points (CP1 to CP16) placed randomly on the study area were used. Measurements of control point coordinates (X, Y, Z coordinates) were made at a reference time (t_0) and at an interval of 3 months (t_1). ANOVA test confirmed the statistical safety of the data and the presence of variance in the data set ($p \leq 0.001$, F>>Fcrit, for Alpha = 0.001). The variation of the Div parameter according to Z_1 and Z_0 was described, in general conditions of statistical safety at the level of $R^2 = 0.999$; $p \leq 0.001$. The variation of the Div phenomenon according to X_0 and Z_0 was described under reduced statistical safety conditions ($p = 0.895$). The variation of DivD according to Z_1 and Z_0 was described in statistical safety conditions at the level of $R^2 = 0.697$, $p = 0.0142$, and according to X_0 and Z_0 it was described in statistical safety conditions at the level of $R^2 = 0.722$, $p = 0.0095$. The cluster analysis led to the grouping of control points based on affinity, in relation to the values Div and DivD, in statistical safety conditions (Coph.corr = 0.850).

Key words: *3D model, diving, diving distance, isoquant,t mining area.*

INTRODUCTION

The underground mining, the coal mining or the mining for various ores, generate a number of side effects on the environment, topography and quality of natural and agricultural land, human habitats and human health (Banash et al., 2016; Garci-Gomez & Perez-Cebada, 2020; Lechner et al., 2014; Schueler et al., 2011). Among the effects of underground mining operations can be mentioned the displacement and deformation of the lands following the exploitation of the useful mineral substance.

The different models have been developed for the study of objectives of interest, measurements and evaluation of spatio-temporal variation of surfaces (Bhattacharjee et al., 2020; Leibovici et al., 2020; Merciu & Paunescu, 2013; NourEldeen et al., 2020; Paunescu et al., 2015; Scaunas et al., 2019).

The need for underground resources obtained through mining and the negative impact of these operations already recorded, has led some studies to address issues for the sustainability of mining for the future (Sahu et al., 2015). In this context, there were introduced some concepts such as "ecological mining" respective "intelligent coal mining" (Wang et al., 2019; Wang et al., 2016).

The surfaces of the lands affected by the underground exploitations need to be monitored in time in order to know their dynamics and to take measures to protect the surfaces, the natural and anthropized ecosystems, as well as the existing constructions on them (Abaidoo et al., 2019; Dlamini & Xului, 2019; Ren et al., 2019). It is also necessary and very useful to forecast the phenomena that affect over time the areas in the mining perimeters, in order to sustainably develop these areas, these being generally mono-industrial and disadvantaged areas (Carvalho, 2017; Dubiński, 2013; Que et al., 2018; Segerstedt & Abrahamsson, 2019; Segura-Salazar & Tavares, 2018).

The ecosystems affected by coal mining have the ability to recover naturally, and the phenomenon of natural restoration has been recorded in various regions around the world (Cui et al., 2019).

Some studies have evaluated methods of bioremediation of areas affected by mining activities, especially in relation to heavy metals, by establishing and optimizing mixtures of tree species (Gorman et al., 2001; Samara et al., 2020).

From the analysis of a number of articles, that addressed the subject of mining, it was found increasing interest in addressing issues related to this sector, a low interdisciplinary, intersectorial and international interdisciplinary approach, but also the formation of trans-continental clusters in more collaborative countries, which indicated the need for research collaboration for solutions in sustainable mining (Bemke-Świtilnik et al., 2020).

To assess the impact of mining on land surface morphology, certain models were used that took into account parameters such as land slope, slope gradient, slope type, but also other parameters capable of capturing small variations in land (Ning et al., 2019).

Based on satellite technologies, some studies have evaluated the impact of mining on the environment using remote sensing and GIS (Bian et al., 2011; Padmanaban et al., 2017; Paull et al., 2008; Rudke et al., 2020).

In the context of these aspects, the present study analysed an area affected by underground coal mining operations and proposed models for assessing the diving and diving distance of the land in relation to the X, Y, Z reference coordinates of some control points.

MATERIALS AND METHODS

Based on the X, Y, Z reference coordinates and the regression analysis, the study proposed models to describe the phenomenon of landslide as a side effect associated with coal mining activities. The study area was located in the Jiu Valley, Romania (Figure 1), on a representative surface of 95,403.89 ha.

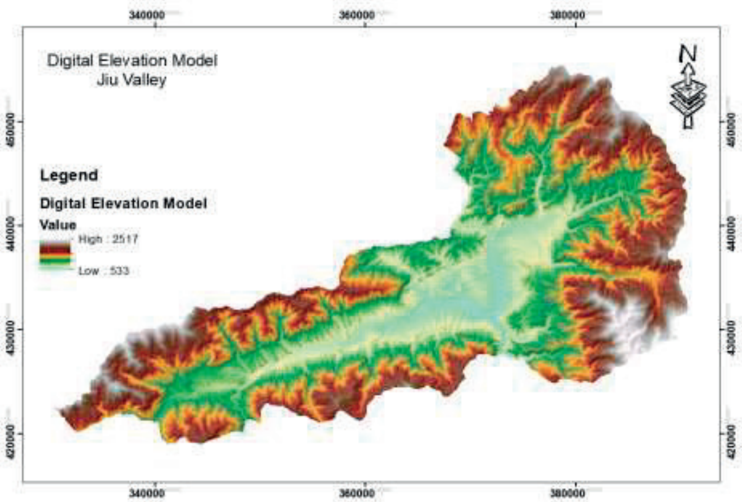

Figure 1. Map of digital elevation model, Jiu Valley, Romania

Land diving (Div) and diving distance (DivD) were assessed. To monitor the study area, 16 control points were established (PC1 to PC16), placed randomly on the surface of the affected land and taken into study.

For each control point, the reference coordinates (X, Y, X) were measured in the national projection system, Stereographic 1970, using GNSS satellite technologies, at two different times, t_0 as the initial moment and a moment t_1 at an interval of 3 months.

Diving is a vertical component of the displacement vectors, of the points located at the ground surface, in the diving bed. As a theoretical model, the point P (Figure 2) was considered to have moved during the period of influence in the P' position, along a curvilinear trajectory.

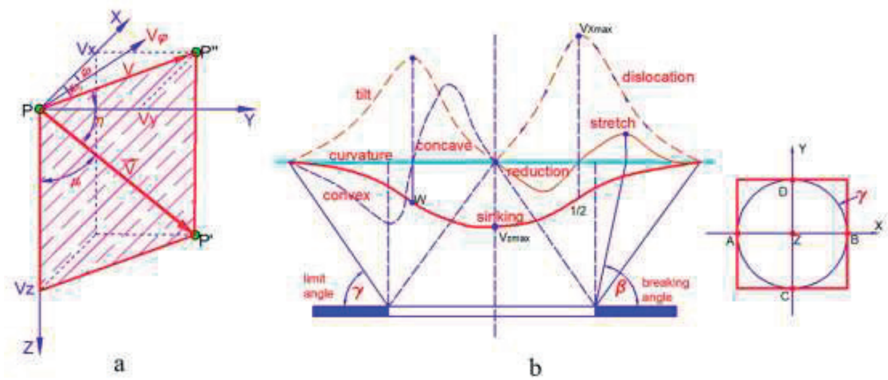

Figure 2. Scheme of principle for moving a point - a; The components of the ground surface movement above a critical extracted area: vertical components, horizontal components, plan view of the critical area - b

The line segment joining the starting point P with the end position P' defines the displacement vector V in a system of three-dimensional axes X, Y, Z, with the angle of inclination η and the orientation φ_0. This spatial vector can be projected on the horizontal plane XY obtaining the size of the horizontal displacement v and can be decomposed and analysed on the components VZ (immersion), VX and VY.

In other words, diving is the lowering of the surface area of the area in relation to the initial level of the same area, according to relation (1).

$$Div_i = H_i^* - H_i \tag{1}$$

where: Div - Diving the ground; H_i^* - height of the landmark at zero measurement; H_i - height of the current landmark.

It is necessary that the surface immersion be determined by topographic measurements of geometric-geodetic levelling. An observation mark is considered to be stable from a level point of view if its final immersion is less than 20 mm.

The horizontal movement (D_i^*) represents the horizontal component of point displacement vectors. It is the horizontal displacement of a point relative to its precedent, located in the area of influence of the operation. It is determined by the difference between the current distance and the same distance initially measured (before the sinking phenomenon), respectively:

$$D_i^* = D_{i,i+1} - D_{0i,i+1} \tag{2}$$

where: $D_{i,i+1}$ - the horizontal distance between the two marks on the current measurement;

$D_{0i,i+1}$ - the horizontal distance between the same two marks at the "zero" measurement.

The experimental data processing was done by ANOVA test, regression analysis, PCA and Cluster analysis. Parameters p, R^2, Coph. corr were used to express the statistical safety of the experimental data. ArcGis software was used to take over the data acquired from the field and to develop the DEM. PAST software (Hammer et al., 2001), mathematical module from EXCEL, and the Wolfram Alpha soft (Wolfram Research, 2020), were used for statistical analysis of the data.

RESULTS AND DISCUSSIONS

For the analysis and evaluation of the diving phenomenon in the study area, measurements were made in 16 control points for which the X, Y, Z coordinates were measured using GNSS satellite technology.

The data on the elevations at two different measurement moments (t_0 - initial reference moment and t_1 - evaluation moment), as well as the values for land diving (Div) and diving distance (DivD) are presented in Table 1.

The ANOVA test confirmed the safety of the data and the presence of variance in the data set collected in the study ($p \leq 0.001$, F>>Fcrit, for Alpha = 0.001).

Table 1. The experimental data regarding the slope of the land, Jiu Valley

PC	Current measurement (t_1)			Reference measurement (t_0)			Diving parameters	
	Northing X_1	Easting Y_1	Z_1	Northing X_0	Easting Y_0	Z_0	Diving the ground (mm/m)	Diving distance (m)
PC1	375545.4	436724.4	753.2381	375545.44	436724.37	753.2509	12.80	0.00
PC2	375561	436735.4	751.926	375560.99	436735.44	751.9441	18.10	19.090
PC3	375156.5	436244.8	824.3654	375156.46	436244.86	824.442	76.60	635.860
PC4	375145.3	436247.6	823.6287	375145.25	436247.61	823.7567	128.00	11.534
PC5	375083.1	436036.5	773.9746	375083.13	436036.56	773.0532	-921.40	220.002
PC6	374894.3	435984	752.8033	374894.34	435984.04	752.8398	36.50	195.967
PC7	375829.6	435197.4	824.734	375829.65	435197.41	824.7341	0.10	1222.123
PC8	375838.1	435229	824.2524	375838.1	435229	824.3261	73.70	32.702
PC9	374007.4	436017.2	647.994	374007.43	436017.22	648.0599	65.90	1993.150
PC10	373716.7	436636.2	687.221	373716.73	436636.18	687.2205	-0.50	683.830
PC11	373708.6	436587	679.6566	373708.63	436586.99	679.6912	34.60	49.855
PC12	375014.9	436186.5	806.1427	375014.94	436186.49	806.2434	100.70	1366.326
PC13	375442.8	436121.3	830.6045	375442.8	436121.26	830.6333	28.80	432.802
PC14	375828.1	436275.2	775.8731	375828.09	436275.2	775.8539	-19.20	414.906
PC15	374418.6	435822.4	676.3189	374418.57	435822.45	676.3487	29.80	1480.448
PC16	375185.1	436083.8	786.0972	375185.15	436083.77	786.1562	59.00	809.898

A digital model of the study area is presented in Figure 3. The graphical distribution of the terrain diving in relation to the diving distance, based on the measured values, is presented in Figure 4, and real images from the terrain are shown in Figure 5.

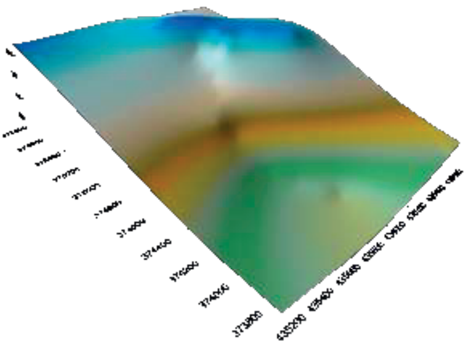

Figure 3. Digital model of the studied area

Considering the overall appearance of the area under study, and the variation of the values recorded for diving and the diving distance of the land under specific conditions in the Jiu Valley, Romania, an analysis was made of the variance of these elements (Div, DivD) in the report with the values of the elevations of the 16 control points (PC1 to PC16).

Multiple regression analysis was used which analysed the variation of the studied elements Div and DivD depending on the elevations of the control points at the reading times t_0 and t_1.

Based on this analysis, models of variation of Div and DivD were found, in statistical safety conditions only in relation to X_0, Z_0 and Z_1. The models found were of the form f (X_0, Z_0) and f (Z_1, Z_0). The variation of the Div parameter according to Z_1 and Z_0 was described by equation (3), in general conditions of statistical safety ($R^2 = 0.999$; $p \leq 0.001$).

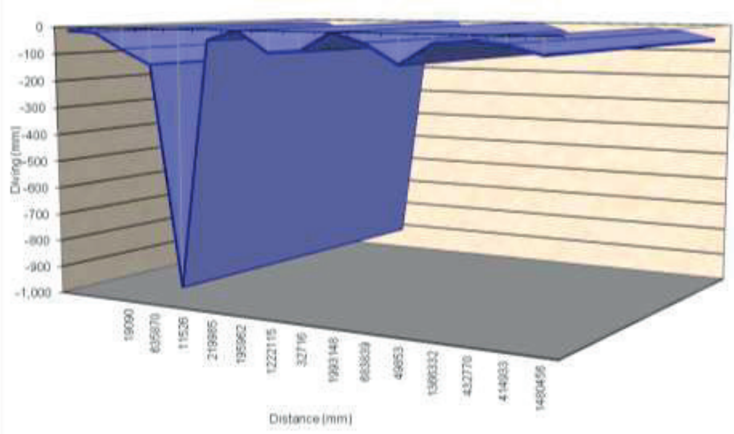

Figure 4. The diving and the diving distance of the land in the study area, Jiu Valley

Figure 5. Images of the diving process in the studied area, Jiu Valley, Romania

The 3D graphic representation is shown in Figure 6, and the isoquant graphic representation is presented in Figure 7.

$$Div = ax^2 + by^2 + cx + dy + exy + f \qquad (3)$$

where: x - Z_1;
y - Z_0;
a, b, c, d, e, f - coefficients* of the equation (3);
a = -6.56289;
b = -6.50970;
c = -999.99998;
d = 999.99998;
e = 1.30726;
f = 0.

*For high accuracy, the values of the coefficients of equations were 16 decimal digits.

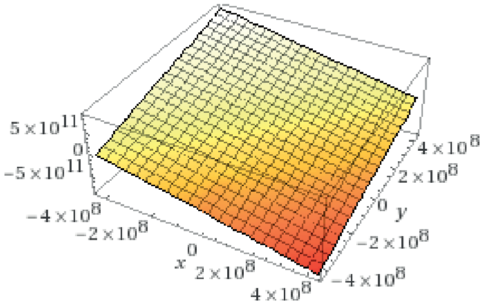

Figure 6. The 3D graphic representation of the Div variation in relation to the Z_1 (x-axis) and Z_0 (y-axis) elevations of the land in the study area

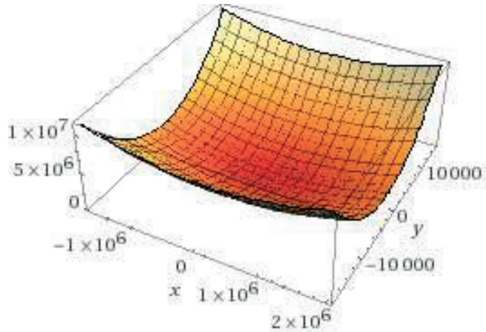

Figure 8. 3D graphic representation of the Div variation in relation to X_0 (x-axis) and Z_0 (y-axis) of the field in the study area

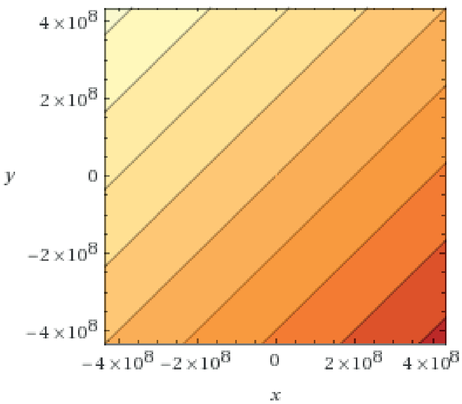

Figure 7. Isoquant distribution of Div values as a function of Z_1 (x-axis) and Z_0 (y-axis) in the study area

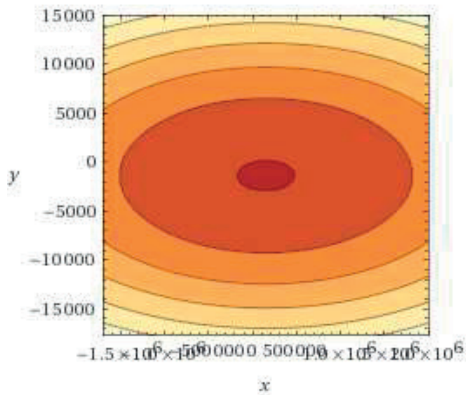

Figure 9. The isoquant distribution of Div values as a function of X_0 (x-axis) and Z_0 (y-axis)

The variation of the Div parameter according to X_0 and Z_0 was described by equation (4), under reduced statistical safety conditions ($p = 0.895$). The 3D graphical representation is shown in Figure 8, and the graphical representation in the form of isoquants is shown in Figure 9. Similar results for the Div variation were obtained in relation to the values X_0 and Z_1.

$$Div = ax^2 + by^2 + cx + dy + exy + f \quad (4)$$

where: x - X_0;
y - Z_0;
a, b, c, d, e, f - coefficients of the equation (4);
a = 7.47012;
b = 0.03307;
c = -0.23027;
d = 90.39512;
e = -0.00037;
f = 0.

Similarly, multiple regressions were used to find the variation of the diving distance (DivD) depending on the values of the X and Z elevations. Equation (5) resulted which described in statistical safety conditions ($R^2 = 0.697$, $p = 0.0142$) the DivD variation depending on Z_1 and Z_0. The 3D graphical distribution is shown in Figure 10. Based on equation (5), the optimal values for x (Z_1) and y (Z_0) were found in the amount of and for $x_{opt} = 805.0131243$, and $y_{opt} = 805.0387029$. The graphical distribution in the form of isoquants is shown in Figure 11. In relation to these values x (Z_1) and y (Z_0) found for the DivD variation, between the control points 10 were positioned with lower values (PC16, PC14, PC5, PC1, PC6, PC2, PC10, PC11, PC15, PC9, in descending order), and 6 with higher values (PC13, PC7, PC3, PC8, PC4, PC12, in descending order).

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$$DivD = ax^2 + by^2 + cx + dy + exy + f \quad (5)$$

where: x - Z_1;
y - Z_0;
a, b, c, d, e, f - coefficients of the equation (5);
a = 5681.51674;
b = 5501.25820;
c = -144828.33875;
d = 144825.18381;
e = -11182.77013;
f = 0.

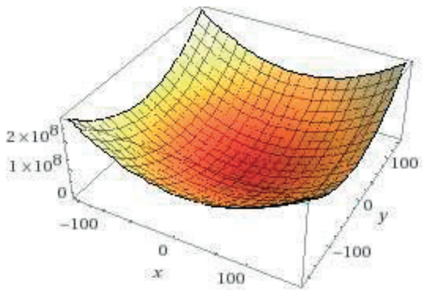

Figure 10. The 3D graphic representation of the DivD variation in relation to the Z_1 (x-axes) and Z_0 (y-axes) elevations of the land in the study area

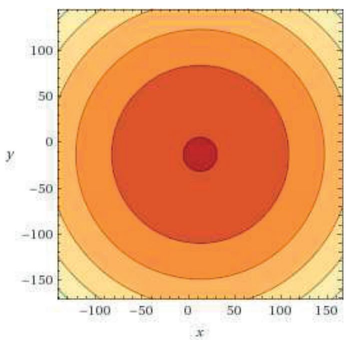

Figure 11. The isoquant distribution of DivD values according to Z_1 (x-axes) and Z_0 (y-axes)

Regarding the variation of DivD as a function of X_0 and Z_0, the multiple regression analysis led to equation (6) in statistical safety conditions (R^2 = 0.722, p = 0.00952). The 3D graphical distribution is shown in Figure 12. From the analysis of the values but also of the 3D graphical distribution, it was found that under the study conditions, the DivD variation in relation to X_0 and Z_0 was very strongly influenced by the Z_0 quota (y-axis) for which the optimal value y_{opt} = 777.24169 was found. Under the same conditions, the contribution of the X_0 quota (x-axis) to the DivD variation was reduced. The distribution of the graph in the form of isoquants is shown in Figure 13.

$$DivD = ax^2 + by^2 + cx + dy + exy + f \quad (6)$$

where: x - X_0;
y - Z_0;
a, b, c, d, e, f - coefficients of the equation (6);
a = 0.000017;
b = 0.18259;
c = -5.99179;
d = 2894.59422;
e = -0.00846;
f = 0.

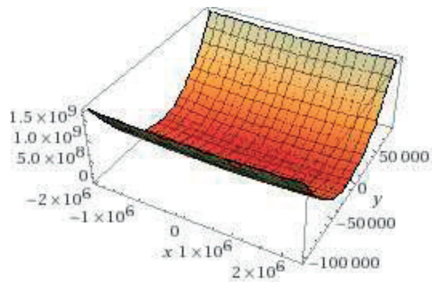

Figure 12. The 3D graphic representation of the DivD variation in relation to the X_0 (x-axes) and Z_0 (y-axes) elevations of the land in the study area

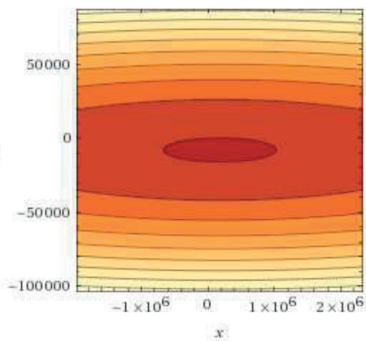

Figure 13. The isoquant distribution of DivD values as a function of X_0 (x-axes) and Z_0 (y-axes)

The cluster analysis led to the grouping of control points based on affinity, in relation to the Div and DivD values, in statistical safety conditions (Coph.corr = 0.850), Figure 14.

The control points were found to be grouped into two distinct clusters C1 (12 control points) and C2 (4 control points), with several subclusters each. A high degree of similarity in terms of Div and DivD was found in CP1 and CP2, CP8 and CP11 (these five control points having the common root in the cluster structure, C1 cluster), respectively CP13 and CP14.

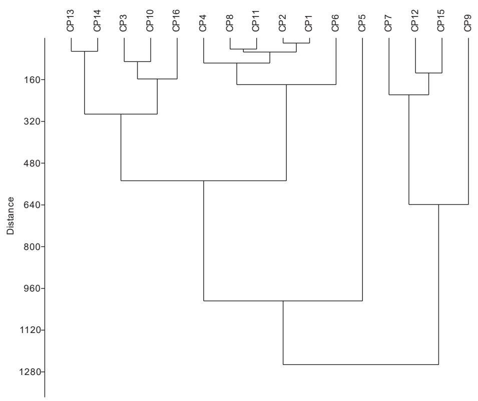

Figure 14. The dendrogram for grouping control points in relation to Div and DivD based on Euclidean distances

The natural, agricultural or urban areas are studied by remote sensing and imaging analysis from the perspective of natural resources assessment, environmental monitoring and quality of life conditions, farm management, so that numerous studies have addressed such topics and provided information, models and methods. (Govedarica et al., 2016; Popescu et al., 2020; Sala et al., 2020). The lands affected by the mining activities acquire in time an ecological stability in natural conditions (Zipper et al., 2011). Some studies have confirmed a direct relationship between the content of some mineral elements in the rock and substrate (e.g. K) and the volume of the trees (Wang et al., 2016). At the same time, such areas can be ecologically rehabilitated through tree plantations to consolidate the land (Weijer, 2019; Corrêa et al., 2018; Macdonald et al., 2015). Plantations of fruit trees, vines (local germplasm is recommended for adaptability and high resistance), or agricultural crops can be set up according to specific conditions, being promoted alternative technologies and different optimization models (Dobrei et al., 2015; Sala and Boldea, 2011). Also, some studies have addressed aspects of urban development and quality of life in areas where mining predominates, especially coal, these areas being generally mono-industrial areas and disadvantaged areas (Oncia et al., 2013a; Obiri et al., 2016; Oncia et al., 2013b;).

The secondary influence of mining activities on the distribution of post-mining permeability and water regime in the respective basins was studied based on numerical models and permeability functions (Fan et al., 2020).

“Post-mining” areas were evaluated through different scenarios in relation to the depth of subsidence and integrated models of simulation and optimization of their use structure in relation to the landscape structure, ecological benefits, agricultural land area, urban or industrial development (Li et al., 2020).

Some studies that have considered the promotion of ecological mining have proposed models that have integrated as actors both mining companies and the local administration and that have taken into account various factors on the choice of exploitation (Zhao et al., 2020).

The present study described the phenomenon of diving and the distance of land diving as a side effect of coal mining in the Jiu Valley, Romania.

The diving phenomenon represents the vertical component (Z) and in relation to the values Z_1 (time t_1) and Z_0 (time t_0) of the control points the diving process was described most accurately, $R^2 = 0.999$, $p << 0.001$, equation (3). When X values were taken alongside the Z values, the estimation accuracy of Div decreased ($p = 0.895$), equation (4). However, the 3D model, Figure 7, showed that the variation of the Z values (y-axis, in the graph) has great significance in the description of the diving phenomenon (Div).

The description of the diving distance (DivD) based on the values Z_1 and Z_0, equation (5), was made in low safety conditions ($R^2 = 0.697$, $p = 0.014$), which confirms that the Z values are closely associated with the vertical component, so with the diving process, not with the diving distance, for which the values X and Y are necessary.

In the context of the presented aspects, the present study evaluated the diving

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phenomenon and the diving distance and proposed models to describe this phenomenon in the concrete conditions of the Jiu Valley, Romania.

CONCLUSIONS

The diving phenomenon and the diving distance of the land under the influence of mining operations in the Jiu Valley, Romania, was analysed based on coordinate values in the Stereographic 1970 projection system of 16 control points, as current determinations (t_1) compared to a reference moment (t_0).

Diving (Div) and diving distance (DivD) were described by mathematical models according to the values of X, Y, Z coordinates. 3D and isoquant distributions of the diving variation were obtained according to the values X_0, Z_0 and Z_1, as graphical models of behaviour of the analysed phenomena.

Z-values are recommended for models that describe the diving phenomenon (vertical component of the process as a whole), and X and Y values are recommended in models for describing the direction of immersion of the ground.

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QUALITY OF DENSIFIED SOLID BIOFUELS PRODUCED FROM SOME ENERGY CROPS SPECIFIC TO THE CONDITIONS OF THE REPUBLIC OF MOLDOVA

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Abstract

This paper refers to the qualitative study of densified solid biofuels, obtained from the plant biomass of the Asteraceae family. Nestro cylindrical briquettes produced at a hydraulic press manufactured by Briklis company within the Laboratory of Solid Biofuels, SAUM, served as the object of the research. The plant biomass of Silphium perfoliatum cultivated under the conditions of the Republic of Moldova was used as raw material. The research results demonstrate the prospects of using the studied crops as raw material for the production of densified solid biofuels in the form of briquettes.

***Key words**: solid biofuels, Silphium perfoliatum, properties, briquettes, ENPlus 3.*

INTRODUCTION

New trends regarding renewable energy are required by increasing global energy demand and Moldova's enhanced interest in decreasing dependence on the sources of imported energy, the urgent need to mitigate climate change, inevitable depletion of fossil fuels and their negative effects on the environment.

The energy obtained from biomass is one of the most accessible directions for the promotion of renewable energy under the conditions of the Republic of Moldova (Arion et al., 2008). This is explained by the existence of an inherent variety of plant biomass that can be used as raw material for the production of densified solid biofuels. It should be mentioned that the lignocellulosic biomass from agricultural residues is the most comprehensively studied in our country.

The research conducted at ITA "Mecagro" (Habasescu et al., 2012; Habasescu, 2008) and the State Agrarian University of Moldova (Marian, 2016; Gudima, 2018; Pavlenco, 2018) contributed to the identification of energy potential and qualitative estimation of residual biomass from different crops. Meanwhile, researchers from the Laboratory of Solid Biofuels, SAUM showed that only 9% of the whole number of residues generated from agricultural activities can be used directly without being modified as raw material for the production of densified solid biofuels with the features that comply with European requirements and ENPlus 3 standards (Gudima, 2017; Pavlenco et al., 2018).

Thus, the search for raw material sources needed to produce densified solid biofuels with the characteristics that are in line with the requirements of ENPlus 3 standards is interesting for both producers of densified solid biofuels and researchers in the field.

A number of energy plants can serve as an important source of raw materials for the production of solid biofuels that comply with ENPlus 3 requirements. *Silphium perfoliatum,* a plant from the Asteraceae family, is of special interest.

The increased interest in this plant is explained by its high biomass productivity, resistance to both drought and frost and the possibility to cultivate it on marginal lands that are not efficient enough to grow other crops (Titei, 2014).

It should be noted that existing studies on the use of *Silphium perfoliatum* biomass as raw material for solid biofuels are quite modest, which limits its efficient use for the production of solid biofuels with the characteristics that meet international standards.

The paper presents research results on qualitative estimation of the biomass derived

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from growing *Silphium perfoliatum* and the finished product obtained from the biomass in the form of briquettes.

MATERIALS AND METHODS

The research was conducted at the Laboratory of Solid Biofuels (LSBF), SAUM. The samples were taken from the experimental plantations of the Botanical Garden (Institute) of the Academy of Sciences of Moldova. The samples were taken and prepared in accordance with the requirements of the following standards SM EN ISO 18135: 2017 and SM EN ISO 14780: 2017.

The taken biomass was crushed in the SV 7 hammer crusher, and its densification took place at the hydraulic press produced by Briklis company within the LBCS, SAUM (Figure 1).

Figure 1. The pictures taken while preparing and testing the samples of *Silphium perfoliatum:* a) Grinding of the raw material; b) Biomass densification process; c) Determination of the calorific value of the studied samples; d) Determination of moisture content; e) Determination of ash content; f) Chemical analysis of the sample at the Vario MACRO cube CHNS and Cl elemental analyzer

The quantity of heat produced by the combustion of *Silphium perfoliatum* samples was determined by measuring the calorific value at the constant volume by means of LAGET 10 calorimeter. Measurements and calculations were performed in accordance with the requirements of the standard SM EN ISO 18125: 2017.

The lower calorific value was determined for the biomass with humidity 0% and 10% using the following relations:

$q_{p,net,d}=q_{v,gr,d}-212,2 \cdot w(H)_d-0,8 \cdot [w(O)_d+w(N)_d],$. (1)

$q_{p,net,M}=q_{v,gr,d}-(1-0,01M)-24,43M,$ (2)

where:

$q_{(p,net,d)}$ is net calorific value at constant pressure of the dry (moisture-free) fuel, J/g;

$q_{p,net,m}$ is net calorific value at constant pressure of the biofuel with moisture content M, J/g;

$q_{v,gr,d}$ is gross calorific value at constant volume of the biofuel of the dry (moisture-free) fuel (dry basis, in the dry matter), J/g;

$w(H)_d$; $w(O)_d$; $w(N)_d$. are, respectively, the hydrogen, oxygen and nitrogen content, in percentage by mass, of the moisture-free biofuel, %;

M - moisture content, in percentage by mass.

The moisture content was determined on a dry basis and on a wet basis according to the SM EN ISO 18134 1-3: 2017 series of standards by heating them in the Memmert UNBU furnace.

The moisture content was calculated using the following calculation formulas:

$$U_d = \frac{m-m_0}{m_0}100\%, \quad (3)$$

$$M_{ar} = \frac{m-m_0}{m}100\%, \quad (4)$$

where:

U_d and M_{ar} are the moisture content of the dry basis and, respectively, of the wet basis;

m - the mass of the biomass sample in the wet state, g;

m_0 - the mass of the same biomass sample estimated after drying in the furnaces to a constant value, g.

The ash content was determined for the samples previously crushed in the SM 100 hammer crusher with sieve mesh sizes up to 1 mm according to the SM EN ISO 18122: 2017 standard.

The method involves heating the examined samples to a temperature of (250 ± 10)ºC at a rate of +5ºC/min for 50 minutes, maintaining this temperature for 60 minutes, with subsequent heating of the furnace to a temperature of (550 ± 10)ºC for 60 minutes, maintaining the temperature at this level for at least 120 minutes and cooling the samples to the room temperature.

The ash content was calculated by means of the formula 5:

$$A_d = \frac{(m_3-m_1)}{(m_2-m_1)} \cdot 100 \cdot \frac{100}{100-W}, \quad (5)$$

where:

m_1 is the mass of the empty crucible, g;

m_2 is the mass of the crucible plus the mass of the test sample, g;

m_3 is the mass of the crucible plus the mass of ash, g;

W - humidity of the analyzed sample, %.

The chemical analysis of the biomass was carried out at the elementary analyzer Vario MACRO cube CHNS & Cl at the Laboratory of Solid Biofuels of SAUM. The detection and quantitative analysis were done using a TCD (Thermal Conductivity Detector). The results were processed with the EAS software.

The particle density was determined by means of the stereometric method in accordance with the SM EN ISO 18847: 2017 standard.

The density of the chopped bulk biomass and briquettes was determined according to the MS EN ISO 17828: 2017 standard in the dry basis and the one with the humidity of 10%, using a standard cylindrical container of 50 l. The sample was poured slowly into the container, after that the excess material on the top was leveled with a wooden bar.

The ability of briquettes to withstand shock and wear resistance was estimated by determining the mechanical durability according to the requirements of the SM EN ISO 17831-2: 2017 standard. The tested samples in the amount of (2 ± 0.1) kg were subjected to controlled blows by their collision with each other and with the walls of a rotating chamber for 5 min with a frequency of (21 ± 0.1) min^{-1}. The tested samples were then passed through a 45 mm eye sieve in a circular motion about 5-10 times along the diameter of the sieve.

RESULTS AND DISCUSSIONS

Silphium perfoliatum is a representative of the *Silphimgen Steraceae* family. The name of the *Silphium* genus originates from the Greek "silphion" and means "the one that secretes resin".

The plant was imported in Europe around the 18th century as a decorative plant. However, they expanded the range of *Silphium perfoliatum*'s use quite quickly and it has become a multifunctional plant due to the advantages that characterize it (Peni et al., 2020). It has low maintenance requirements and increased energy potential due to its high productivity; it can be used for up to 15 years (Gansberger, et al., 2015). The flowers of the plant, which appear in the first summer months and last until late autumn, make the plant an attractive and important source of food for pollinating insects (Frączek, et al., 2011).

The increasing number of scientists support the idea of using *Silphium perfoliatum* for energy purposes, because its energy potential is high, cultivation costs are reduced, production profitability is also high (RHS A-Z, 2008), calorific value is satisfying (Mariani et al., 2014; Fraczek et al., 2011; Titei, 2014). It is known as a raw material for biogas production from the energy point of view (Haaga et al., 2015; Wever et al., 2019).

The analysis of data from various sources has shown that the information on the use of *Silphium perfoliatum* biomass as raw material for the production of densified solid biofuels is modest enough, and it also has a contradictory character in some cases. For example, researchers from Lithuania (Jasinskas et al., 2014) showed that the calorific value of the *Silphium perfoliatum* ranges from 16.98 to 17.58 MJ/kg depending on the amount of nitrogen in the soil and the pH of the soil itself. Researchers of Lithuanian Research Center for Agriculture and Forestry along with their colleagues from the Institute of Agricultural Engineering and Safety, do not recommend the use of the *Silphium perfoliatum* biomass for the production of densified solid biofuels based on the analysis of quality parameters of densified solid biofuels in the form of pellets (Siaudinis et al., 2015) (Table 1).

At the same time, researchers from the University of Agriculture in Krakow say that *Silphium perfoliatum* briquettes are of very good quality. The statements are based on the study of the biomass and the finished product in the form of briquettes. Thus, according to the data presented by the authors, the calorific value of the biomass is equal to 17.3 MJ/kg (it is not specified which calorific value - the upper or the lower one) and the ash content equals to 3.4%, mechanical durability of briquettes is equal to 93.1% and particle density of briquettes is 920 kg/m^3 (Fraczek et al., 2011).

Table 1. Data for the qualitative analysis of densified solid biofuels from *Silphium perfoliatum*

Parameters	**[Siaudinis, G et al., 2015]**	**Values obtained in SBFL, SAUM**	**Requirements according to ENPlus 3 standards (SM EN 17225: 2017)**					
			ENplusA1	**ENplusA2**	**En-B**	**ENplusA1**	**ENplusA2**	**En-B**
	Briquettes	Briquettes	Pellets			Briquettes		
W_r, %	11.6 ± 0.09	9.97 ± 0.37	≤ 10			≤ 12	≤ 15	
A_d, %	9.96 ± 0.38	6.5 ± 1.11	≤ 0.7	≤ 1.2	≤ 2	≤ 0.7	≤ 1.5	≤ 3
A_r, %		6.69 ± 0.79						
$q_{v,\,gr,\,d}$, J/g		18.673 ± 0.85						
$q_{p,\,net,\,d}$, J/g		17.405 ± 0.94						
$q_{p,\,net,\,m=10\%}$, MJ/kg		15.42 ± 0.085	≥ 16.5			≥ 15.5	15.3	14.9
C, %	45.44 ± 1.16	45.58 ± 0.47						
N, %	0.68 ± 0.32	0.22 ± 0.13	≤ 0.3	≤ 0.5	≤ 1	≤ 0.3	≤ 0.5	≤ 1
H, %	5.28 ± 0.46	5.8 ± 0.11						
S, %	0.07 ± 0.28	0.17 ± 0.05	≤ 0.04	≤ 0.05		≤ 0.04		≤ 0.05

Parameters	[Siaudinis, G et al., 2015]	Values obtained in SBFL, SAUM	Requirements according to ENPlus 3 standards (SM EN 17225: 2017)					
			ENplusA1	ENplusA2	En-B	ENplusA1	ENplusA2	En-B
	Briquettes	Briquettes	Pellets			Briquettes		
O,%	38.57	45.18						
DU, %		94.78±0.38	≥ 98.0	≥ 97.5				
F (< 3.15 mm)			(≤ 1.0)[1)]; (≤ 0.5)[2)]					
BD, kg/m^3			600 ≤ BD ≤ 750					
DE, g/cm^3		0.83±0.02				≥1	≥0.9	≥0.9

[1)]at the factory gate or when loaded on trucks to be delivered to end users (a part of the delivered cargo and the completely delivered cargo); [2)]at the factory gate, when filling bags with pellets or when sealing big bags.

Note: W_r - moisture content as received; A_d - ash content (w-% dry basis); A_r - ash content (w-% as received); BD - dulk density; DU - mechanical durability; $q_{v,gr,d}$ - gross calorific value at constant volume of the biofuel of the dry basis; $q_{(p,net,d)}$ - net calorific value at constant pressure of the dry (moisture-free) fuel; $q_{p,net,m}$ - net calorific value at constant pressure of the biofuel with moisture content m; *C, N, H, S, O* are, respectively, the Carbon, Nitrogen, Hydrogen, Sulphur and Oxygen content, in percentage by mass, of the moisture-free biofuel; *DU* - mechanical durability; *BD* - bulk density; *DE* - particle density.

Similar conclusions are made by the researchers from the National Botanical Garden (Institute), Chisinau. Therefore, Titei states that the biomass of *Silphium perfoliatum* can be used to produce pellets and briquettes, showing that the biomass collected in winter has a calorific value of approximately 18.3 MJ/kg and the ash content equal to 2.5% (Titei, 2014).
According to Titei et al., a more recent research on the *Siphium perfoliatum* biomass, collected in March, showed that its ash content is 3.0%, its net calorific value is 16.7 MJ/kg, bulk density of pellets is 656 kg/m^3, specific density of briquettes is 949 kg/m^3 and that of pellets equals to 1038 kg/m^3.
The following table presents the results of the *Silphium perfoliatum* briquettes analysis obtained by us at LSBF. The values provided by researchers from Lithuania and regulations imposed by ENplus 3 standards for pellets and briquettes are given for comparison.
Comparing the results obtained by us in this study with the values recommended by the ENPlus 3 standards, we can state that the briquettes produced from *Silphium perfoliatum* comply with strict ENPlus 3 standards only in case of the calorific value at the lower limit (15.42 ± 0.085 MJ/kg) and the content of nitrogen (0.22 ± 0.13)%. The other parameters exceed the limits stipulated in the standard, particularly, the high ash content (6.5 ± 1.11)%. It should be noted that the research carried out by the colleagues from Lithuania shows an even higher ash percentage (9.96 ± 0.38) %.
Furthermore, *Silphium perfoliatum* can be used as raw material for energy purposes to produce biogas or as a filler for biomass mixtures to produce densified solid biofuels in the form of briquettes. This biomass cannot be used as a raw material for the production of pellets.

CONCLUSIONS

The demand for raw materials to produce densified solid biofuels with qualitative characteristics according to the requirements of the ENPlus 3 international standards is constantly increasing.
Studies published in specialized literature along with our data show that *Silphium perfoliatum* is both of increased interest for the chemical and the pharmaceutical industries to protect the ecosystem and feed pollinating insects and a promising source in terms of quantity to be used as a raw material for energy purposes.
The testing results of densified solid biofuels in the form of briquettes demonstrate that the biomass obtained from the cultivation of *Silphium perfoliatum* in the raw state does not ensure a finished product that would meet all the quality requirements densified solid

biofuels have and it is not recommended to be used in the raw state for the production of briquettes and pellets for non-industrial uses. Although, it can be used as a filler to form mixtures with other types of biomass, which will later be used for the production of briquettes.

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PROSPECTS FOR THE USE OF SEABUCKTHORN RESIDUES IN THE PRODUCTION OF DENSIFIED SOLID BIOFUELS

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Abstract

The paper presents research results of the prospects of using residues from the cultivation of sea buckthorn in the production of densified solid biofuels. The paper aims to evaluate energy and physical-mechanical characteristics of both the wood biomass that results from the cultivation of sea buckthorn and the finished product in the form of pellets. The research was carried out on biomass samples taken from the technological cultivation chain of the Cora sea buckthorn within the Laboratory of Solid Biofuels of the State Agrarian University of Moldova. The research results proved the possibility of using sea buckthorn residues in the production of densified solid biofuels in the form of pellets with the characteristic features that comply with ENPlus 3 standards.

Key words: *solid biofuels, sea buckthorn, properties, use.*

INTRODUCTION

Our preliminary research on the biomass, obtained from the sea buckthorn production chain has shown that the calories and ash content of the biomass from the sea buckthorn, Cora variety allows using it as raw material for the production of densified solid biofuels (Marian et al., 2020).

Similarly, our research (Marian et al., 2017), as well as other researchers' work indicate that the particle size before densification affects the correct choice of raw material, the quality of solid biofuels as well as specific particle density and mechanical durability (Styks et al., 2020).

The aim of this study is to argue the perspectives of using sea buckthorn residues for the production of densified solid biofuels by thoroughly studying the pellets produced from sea buckthorn.

Based on the analysis of the particle size distribution of sea buckthorn wood biomass carried out after their final crushing and the study of both physical and chemical properties of pellets produced from this raw material, the paper reflects some thoughts on the prospects of using the sea buckthorn biomass as raw material for the production of densified solid biofuels in the form of pellets for both residential and industrial use.

MATERIALS AND METHODS

The following materials were used as subjects of research: the biomass resulting from sea buckthorn pruning (BPSB); the biomass obtained from sea buckthorn harvesting by freezing (BHSB) and solid biofuels in the form of pellets, produced from sea buckthorn residues resulting from tree pruning and culture harvesting by freezing.

The sea buckthorn biomass was collected at the enterprise MONSTERAX-GSG Ltd. from the village of Pohrebea, Dubasari district, Republic of Moldova. The biomass was transported to the Laboratory of Solid Biofuels, State Agrarian University of Moldova where it was dried to the humidity of (8 ± 2) w-%.

The research implied two stages. Initially, at the first stage, we studied the main components of the sea buckthorn biomass, suitable to be used as raw material for the production of densified solid biofuels in the form of pellets. The research was focused on the study of the granulometric distribution of biomass particles after their crushing at the SV 7 hammer mills using 4 and 6 mm sieves.

The particle size distribution was determined by sieving biomass sample, taken after the final crushing for 10 minutes. The sieving was performed at the Retsch 100 laboratory installations according to the SM EN ISO

18135: 2017 standard. The samples were prepared by means of the quarter's method in accordance with the requirements of the SM EN ISO 14780: 2017 standard.

At the second stage, we studied the properties of densified solid biofuels in the form of pellets, produced from the studied sea buckthorn biomass. The pellets with the diameter of 6 mm were produced at the mini semi-automatic pellet production line MGL 200 within the Laboratory of Solid Biofuels, State Agrarian University of Moldova, equipped with a fixed mould, placed horizontally, and two rotating cylindrical rollers.

Both physical and mechanical properties of the raw material and pellets were determined in accordance with current requirements presented in Table 1.

RESULTS AND DISCUSSIONS

In order to study the influence of the biomass particle size from various sea buckthorn residues on the quality level of the finished product in the form of pellets, we analysed the particle size distribution for the biomass resulting from spring pruning of sea buckthorn trees and fruit harvesting by detaching and beating branches in the frozen state (Cimpoies et al., 2018).

The biomass was shredded at the SV 7 hammer mill with both 6 and 4 mm mesh screen. Before crushing, all two types of biomasses were brought to the same humidity, equal to 10 ± 2ºC by keeping all samples in the EV MGGA 1 vacuum conditioning furnace, where they were kept for 60 min at the temperature of 20ºC and the relative humidity of 60 ± 5%.

The particle size distribution was determined by sieving them with vibrating sieves with the following mesh screen dimensions: 0.25, 0.5, 1, 1.4, 2.0, 2.8, and 3.15 mm. The percentage of ground biomass distribution with the indication of the confidence interval is presented in Table 1 and Figure 1.

The experimental results show that the biomass from sea buckthorn pruning, grinded with the use of sieves with mesh sizes of 4 and 6 mm, has a slightly more uniform particle size distribution than the biomass grinded with the use of the same sieve that results from frozen cultures. Thus, the share of BPSB with particle sizes greater than 0.5 mm and less than 2.8 mm is 73.93 w-% in the case of 6 mm sieve crushing and 76.08 w-% in the case of crushing with a 4 mm sieve. In the case of BHSB, this ratio is 70.17 and 72.59 w-%, respectively. This can be explained by the presence of a certain number of leaves, which are difficult to separate from the biomass mixture obtained from harvesting by the cold method.

Moreover, the share of particles larger than 3.15 mm is quite small for all investigated cases, being of the highest values (2.38 ± 0.19) w-% in the case of BPSB grinded with the use of the mesh size of the sieve that equals to 4 mm, and the lowest values in the case of BHSB grinded with the use of sieves with the mesh size of 6 mm.

This shows that grinding can be used with both 4 mm and 6 mm mesh sieves, as over 95% of the biomass has particles smaller than the radius of the pellets that meet the requirements for the raw material used for pelleting.

This recommendation is also argued by the fact that the particle content finer than 0.25 mm, when using sieves with the mesh size of 6 mm, is on average lower than when using sieves of 4 mm. This feature is a positive aspect, because very fine particles worsen the conditions for the formation of adhesion bonds between particles and cohesion inside them (Gudima, 2018).

From the point of view of labor productivity, it is more effective to use a sieve with a mesh size of 6 mm for crushing.

Approximately the same particle size distribution is observed in the case of wood residues resulting from the pruning of fruit trees (Gudima, 2018). This paper also mentions that, in the case of natural drying of biomass, the distribution of particles is more uniform which favors better densification of pellets.

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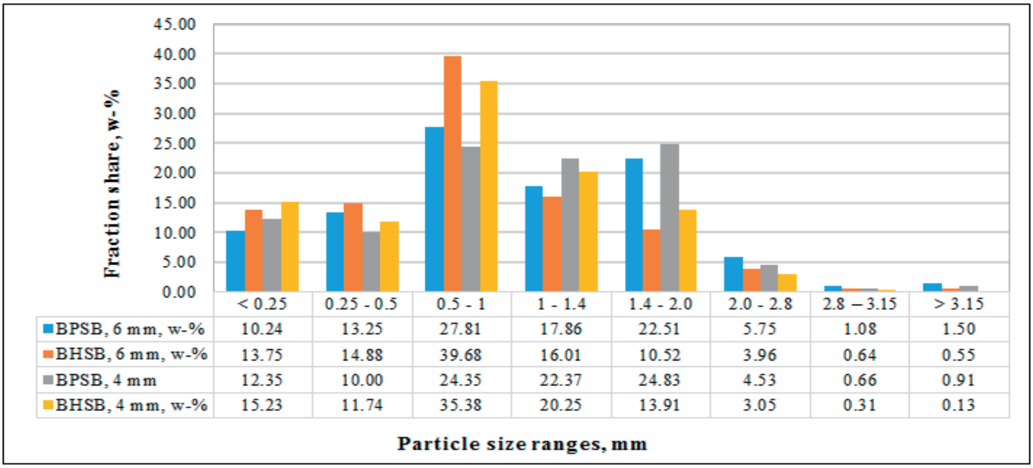
Table 1. Particle size distribution of sea buckthorn biomass particles after grinding at the SV 7 hammer mill

Mesh size of the sieve insert	Biomass type	Particle sizes, mm							
		< 0.25	0.25-0.5	0.5-1	1-1.4	1.4-2.0	2.0-2.8	2.8-3.15	> 3.15
		Fraction share, w-%							
4 mm	BPSB	18.67±0.72	18.93±0.98	25.68±0.74	14±0.69	15.1±1.05	5.06±0.27	0.17±0.08	2.38±0.19
	BHSB	8.29±0.55	14.58±0.22	40.54±1.09	24.2±0.87	9.83±0.47	1.63±0.16	0.1±0.06	0.83±0.23
6 mm	BPSB	10.24±0.74	13.25±0.86	27.81±0.66	17.86±0.56	22.51±0.96	5.75±0.22	1.08±0.06	1.5±0.12
	BHSB	13.75±0.62	14.88±0.42	39.68±0.87	16.01±0.66	10.52±0.41	3.96±0.12	0.64±0.04	0.55±0.11



Note: w-% - weight-percentage; BPSB - biomass from sea buckthorn pruning; BHSB - biomass from sea buckthorn harvesting

Figure 1. Biomass particle sizes distribution of Cora Sea buckthorn sawdust

The study of pellets made from sea buckthorn residues shows that the qualitative parameters of pellets made from BPSB are within the specifications of ENPlus 3, and those made from BHSB are partially within the requirements of ENPlus 3. Thus, according to the ash content, BPSB pellets are classified in A1 class with a dry base ash content of 1.16 w-% and can be used for residential use, and those of BHSB that result from combustion, show 2.89 w-% of ash estimated in the dry base and can be used only for industrial use (St., 2016).
In terms of calorific value, the pellets produced from BPSB comply with the A1 class ENpPlus 3 standards, and those from BHSB have a lower calorific value than the one recommended by ENPlus 3 requirements. Thus, BHSB in its raw state (without the addition of other types of biomass), does not guarantee that the obtained pellets will be certified according to ENPlus 3 standards neither for residential nor for industrial use (St., 2016, pp. 9-11, Tables 1 and 2).

As to other qualitative parameters, the pellets produced from BPSB and BHSB meet the ENPlus standards except for the Sulfur content, because the pellets produced from BHSB exceed the quota provided by the ENPlus standards by 0.05 w-%.

CONCLUSIONS

This study has carried out a qualitative analysis of the biomass from the technological chain of sea buckthorn (the Cora variety) cultivation and processing. We studied the biomass obtained from tree pruning and fruit harvesting by means of freezing as well as the finished product in the form of pellets. Based on the analysis of the particle size distribution of the grinded biomass, it has been established that the particle size distribution is quite uniform in the case of crushing with the use of sieves with both 4 mm and 6 mm mesh sizes.
The analysis of pellets produced from BPSB and BHSB showed that the pellets produced

from BPSB meet the requirements of the ENPlus standards, and those produced from BHSB partially comply with them.

Based on the obtained data, one can state that the biomass received from sea buckthorn pruning is an important source of raw material with a prospect of being used for the production of ENPlus 3 certified pellets. BHSB can only be used as a mixture component with other types of biomasses that have better quality characteristics or can be recommended as a raw material for other purposes, for example, in biogas production.

Table 2. Properties of pellets produced from sea buckthorn residues, Cora variety

Property class/method of analysis	**Efficient values**		**ENPlus 3 Class**	
	BPSB	**BHSB**	**BPSB**	**BHSB**
Moisture, M_r, w-%, ISO 18134-3	10.90±0.08	10.38±0.08	A1	A1
Ash, A_d, w-%, ISO 18122	1.16±0.02	2.89±0.024	A2	I3
Ash, A_r, w-%, *by calculation*	1.29±0.02	3.21±0.024		
Gross calorific value, $q_{v,\ gr,\ d}$, MJ/kg,ISO 18125	20.39±0.12	19.58±0.11	A1	-
Net calorific value, $q_{p,\ net,\ d}$, MJ/kg,ISO 18125	19.09±0.12	18.82±0.11		
Net calorific value, $q_{p,\ net,\ m=10\%}$, MJ/kg, ISO 18125:2017	16.75±0.11	16.21±0.11		
Carbon, C, w-%, ISO29541	48.86±0.4	49.98±0.4		
Nitrogen, N, w-%, ISO29541	0.83±0.04	0.98±0.04	B	B
Hydrogen, H, w-%, ISO29541	5.93±0.2	5.94±0.2		
Sulphur, S, w-%, ISO29541	0.05±0.01	0.06±0.01	A2	-
Oxygen, O, w-%, *by calculation*	41.34	40.15		
Mechanical durability, DU, w-%, ISO 17831-1	97.71±0.28	98.62±0.3	A1	A1
Particle density, DE, kg/m^3, ISO 18847	1.09±0.02	1.09±0.02		
Bulk density,kg/m^3, ISO178828	689±2	689±2	A1	A1
Fines, $_d$, w-%, ISO 17830	0.39±0.02	0.35±0.02	A1	A1

Note: $_r$ - as received; $_d$- dry basis; $_{v,\ gr,\ d}$ - constant volume of the dry basis; $_{p,\ net,\ d}$ - constant pressure of the dry basis; $_{p,\ net,\ m=10\%}$ - constant pressure of the 10% moisture.

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FOUNDATION SOLUTIONS FOR AN INDUSTRIAL PLATFORM BUILT ON CONTAMINATED SOFT SOIL

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Abstract

The paper presents the optimal solutions for the foundation of an industrial platform built on an old tailings pond consisting of drilling wells residues. The study of the foundation solutions was carried out based on the properties of the foundation soil from the site and based on pressures applied to the foundation soil by the industrial platform. Geotechnical properties were determined based on soil samples taken from 10 geotechnical boreholes with depths between 6 and 15 m. The paper analyzed the direct and indirect foundation solutions. In the hypothesis of direct foundation solution, the construction of the industrial platform was analyzed in the case of natural and improved foundation soil. Based on technical-economical point of view, two foundation solutions were detailed in the conclusions chapter.

Key words: *contaminated soft soil, industrial platform, drilling waste, foundation solution.*

INTRODUCTION

On contaminated sites, physical and mechanical properties of foundation soils suffer some changes that can lead to the loss of stability of embankments or significant settlements of the constructions. In this case, it is necessary to determine the geotechnical properties of the contaminated soils in order to estimate properly the effect of pollutant contamination on the constructions to be built (Dumitru et al., 2016; Olinic, 2016).
The paper presents the optimal solution for the foundation of an industrial platform built on an old tailings pond consisting of drilling wells residues. The study of the foundation solutions was carried out based on the properties of the soils from the site and based on the pressures applied to the foundation soil by the industrial platform.

MATERIALS AND METHODS

A preliminary geotechnical study was carried out on site and, according to this, the foundation soil consists in a filling layer (drilling wells residues) of 3.00-4.00 m thickness and a silty clay with stiff consistency.

In order to establish the foundation soil properties, a new geotechnical study was carried out, and were taken samples from 10 geotechnical boreholes with depths of 6.00-15.00 m. Due to the massive dimensions of the fillings of construction materials waste, several boreholes were blocked at depths between 2.50 and 4.00 m (Figure 1).

Figure 1. The position of the geotechnical boreholes (red points - existing boreholes, blue points - blocked boreholes) (Google Earth)

The groundwater level was identified as infiltrations in some of the boreholes conducted at depths between 2.60 and 6.30 m.

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GEOTECHNICAL PROPERTIES

From the granulometric point of view, the filling layer is composed of predominantly cohesive or low cohesive materials in a clayey - silty clay matter, materials that have low - medium - high plasticity (I_P = 12.0 ÷ 33.2%) and are in a state of plastic to stiff consistency (I_C = 0.61 ÷ 1).

The natural foundation soil, beneath the soil fill, is composed of cohesive materials such as sandy clay, clay, fat clay, silty clay, clayey sand, with high and very high plasticity (I_P = 21.2 ÷ 58.6%) in a state of consistent plastic to stiff consistency (I_C = 0.48 ÷ 0.9). The stratification is complex, not a parallel and horizontal one.

In order to establish the optimal foundation solution, an essential geotechnical property is the compressibility of the foundation soil (Sridharan & Gurtug, 2005).

Figure 2 shows all the compressibility tests performed on samples from the filling or from the natural foundation soil. The oedometric deformation modules between the steps of 200 and 300 kPa ($E_{oed200-300}$) are grouped and divided on calculation layers, as follows:

- 0.00 ÷2.00 / Layer 1 - clayey sand - sandy clay, with high plasticity, in a state of consistent plastic to stiff consistency, with a high to very high compressibility ($E_{oed200-300}$ = 4695 ÷ 6211 kPa).
- 2.00 ÷ 4.00 / Layer 2 - clay, with high and very high plasticity, in a state of consistent - stiff consistency, with a medium to high compressibility ($E_{oed200-300}$ = 8850 ÷ 11236 kPa).
- 4.00 ÷ 6.00 / Layer 3 - clay, with a very high plasticity, in a state of consistent - stiff consistency, with a medium to high compressibility ($E_{oed200-300}$ = 8929 ÷ 13158 kPa).
- 6.00 ÷ 10.00 / Layer 4 - silty clay – clayey sand, with high and very high plasticity, in a state of consistent plastic to stiff consistency, with a high to very high compressibility ($E_{oed200-300}$ = 5848 ÷ 7042 kPa).

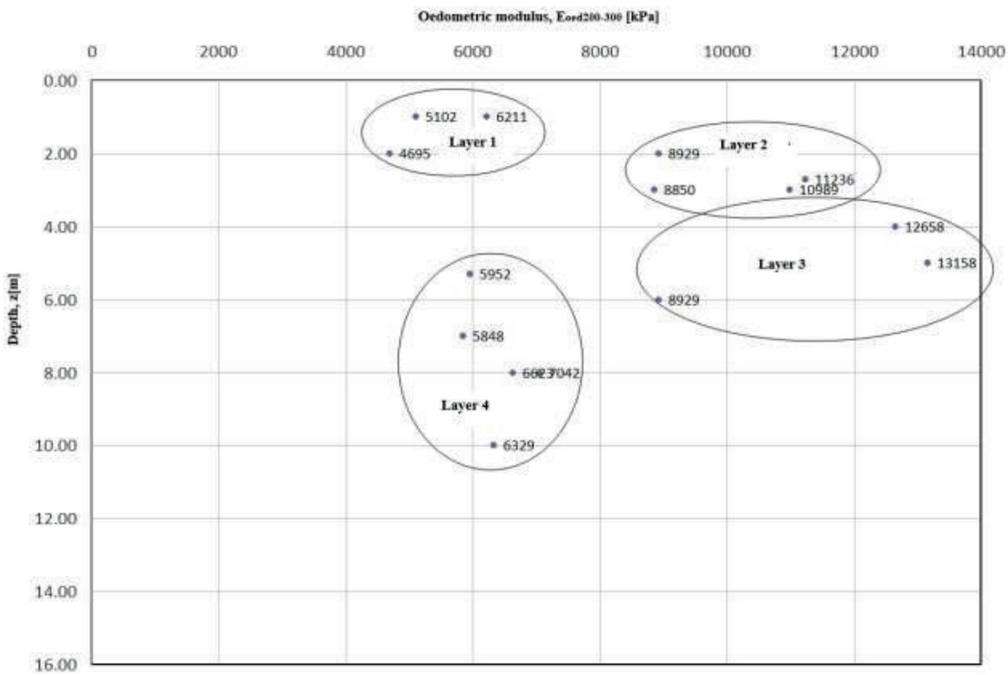

Figure 2. The variation of the oedometric deformation modules on depth

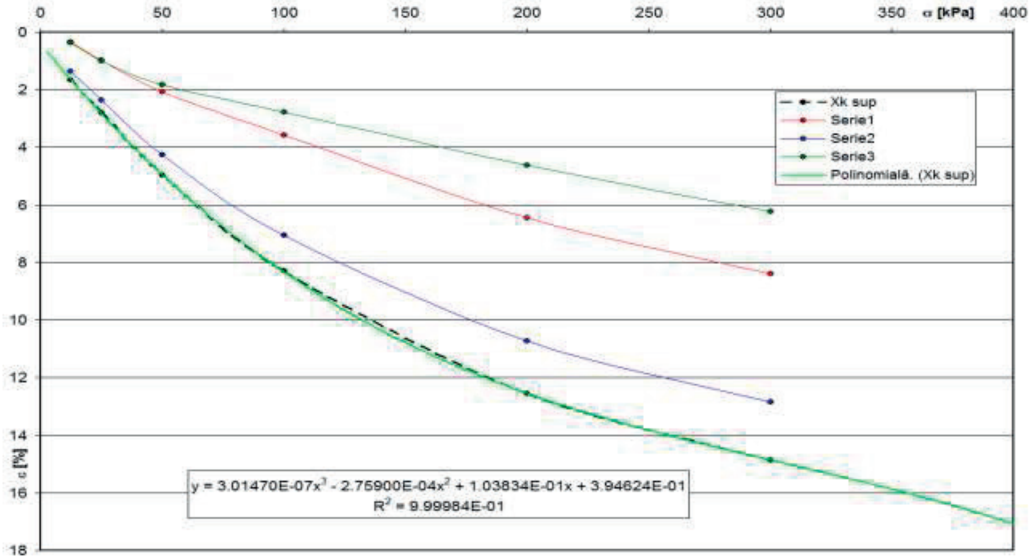

Figure 3. Layer 1 - Oedometric curves and stress - strain relationship of characteristic values

For each previously defined calculation layer, the specific characteristic settlements under each loading stage were calculated and, in a comprehensive way, the superior characteristic values were selected and the functions that best approximate the strain-strain relationship were identified (Figure 3) (NP 122:2010, NP 112:2014).

These stress-strain relationships, which were previously affected by the M_0 coefficient (which makes the transition from the oedometric strain modulus to the elastic modulus), were introduced in specific settlement calculations (M_0 = 1 for layer 1 and M_0 = 1.5 for layer. 2, 3 and 4) (SR EN 1997-1:2004).

Following the analysis of the loads and pressures at ground level transmitted by the equipment which will be positioned on the industrial platforms, the settlement calculations were performed for the hypothesis considered the most unfavourable, namely: metal jacks, contact surface 1.135 x 5.142 m and a field pressure of 243 kPa.

FOUNDATION SOLUTIONS

On the site, will be built a platform with an area of 6659 m^2, from which the northern area would be founded on natural soil and the southern area on the former tailings pond. Thus, the platform will be constructed on improved soils (STAS 2914-84) which cover an area of approx. 4360 m^2.

Considering the nature of the foundation soil and the type of request loads to the foundation soil, with significantly higher loads in the execution stage of the wells than in their exploitation stage, the following foundation solutions were distinguished:

- Direct foundation on natural soil - for comparison with engineering solutions that follows:
- Direct foundation on improved ground:
  - Improved on the entire soil fill thickness
  - Partially, improved on the surface (cushion of compacted granular material)
- Indirect foundation on piles.

Table 1. Analysis of foundation solutions

Foundation solution	Analysis/feasibility
Direct foundation on natural ground	Settlement, s = 16.7 cm Due to the very high value of settlement, this solution is not viable and, practically, argues the reason for the need to find an alternative foundation solution.
Direct foundation of controlled compacted cushion made from granular material	The solution was analyzed in two cases: **filling** over the current level of the natural land (after removing the topsoil) and **excavation** with return to the level of the natural land by controlled compacted fill. In each case were considered cushion thicknesses of compacted granular material of 1 and 2 m. **Filling** / **Excavation** H = 1 m, s = 11.7 cm / H = 1 m, s = 8.5 cm H = 2 m, s = 8.9 cm / **H = 2 m, s = 3.6 cm** The results of the settlement calculations shows that the most efficient solution is to remove a filling layer with a thickness of approx. 1.5 m to limit the settlement to about 5 cm.
Ground improved by dynamic compaction	This method is especially effective on non-cohesive soils in dry or wet state (degree of compaction, Sr <0.6). The existing foundation conditions are practically saturated cohesive soil, in which this technique has a low efficiency.
Improved ground with ballast/concrete columns (rigid elements)	The method is efficient in the given conditions of the location. Two variants were analyzed: columns of coarse granular material (ballast, broken stone) on the depth of the active area (approx. 7 m below the base of the foundation) considering: columns with a diameter of 65 cm, in a square network with a distance of 1.5 m. Thick cushion, H = 1 m **Filling** / **Excavation** s = 6.9 cm / **s = 5.1 cm** The optimal method would be to remove 1 m of the filling, return to the level with a compacted cushion realized by granular material and execution of columns with a length of 7 m, below the lower level of the compacted cushion.
Ground improved by deep mixing (deep chemical mixing)	The method is effective in cohesive soils with high water content (the case of this site). However, the presence of petroleum substances in the soil makes the chemical hydration reactions of the hydraulic binder not as strong as in the case of uncontaminated soil. The costs of this solution may be similar to columns of granular materials.
Ground improved by injections	The method is effective in non-cohesive or poorly cohesive, loose soils. In practically saturated cohesive soils (the case of the present location) the dispersion of the injected material in the soil mass is not achieved and practically some cement columns with insufficient diameter are obtained in order to improve the average compressibility characteristics of the soil mass.
Indirect foundation on piles	It is the simplest, but also the most expensive method; this method significantly limits settling. The piles must be embedded/supported in a good foundation layer, which was not intercepted to a depth of 15 m.

CONCLUSIONS

Considering the nature of the foundation ground (complex stratification, not a parallel and horizontal one), the rigid elements intercepted at different depths, the shape of the old tailing pond (identified after performing geotechnical investigations, Figure 4.a), the foundation on a compacted cushion made by granular materials could generate differentiated settlements. From the technical point of view, the optimal foundation solution becomes: foundation on columns of compacted granular material.

From the technical-economical point of view, the costs for two foundation solutions were analyzed:

- compacted cushion made by granular materials after an excavation of 2.00 m depth (Figure 5) - estimated total cost of 321,323.28 EUR;
- ballast columns with a diameter of 65 cm, in a square network with a distance of 1.5 m and a compacted cushion made after an excavation of 1.00 m depth (Figure 6) - estimated total cost of 734,999.98 EUR.

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a. 30.08.2011 b. 01.06.2018

Figure 4. Satellite images from the site (Google Earth)

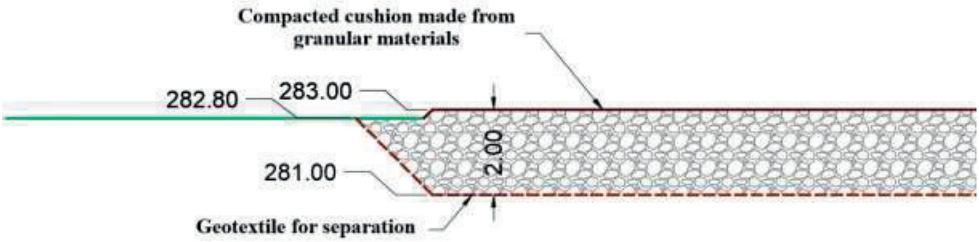

Figure 5. Cross section. Foundation solution 1: compacted cushion made by granular materials after an excavation of 2.00 m depth

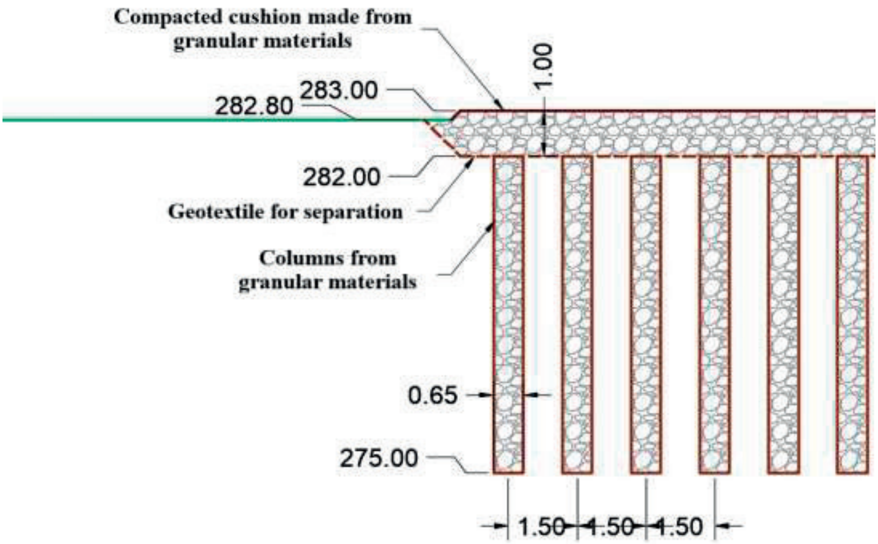

Figure 6. Cross section. Foundation solution 2: ballast columns with a diameter of 65 cm, in a square network with a distance of 1.5 m and a compacted cushion made after an excavation of 1.00 m depth

From the financial point of view, there are significant differences between these two foundation solutions; the solution with columns of granular material has at least a double price than the solution with a compacted cushion.

From the technical point of view, the optimal solution is to improve the soil with columns of granular material. The foundation solution to be chosen will be put into practice on the basis of a technical project.

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CHARACTERISTICS OF EXTREME TEMPERATURES RELEVANT FOR AGRICULTURE IN THE NEAR FUTURE (2021-2040) IN ROMANIA

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Abstract

Extreme temperature episodes may have a significant impact on agriculture, as temperature is a primary factor affecting the rate of plant development. In Romania, agriculture is an important contributor to PIB and up to 19% of active population is employed in this sector. Therefore, assessing the changes in the thermal regime and its extremes in the near future may contribute to a sounder approach for developing and implementing adaptation measures in agriculture. In this view, we investigate the changes in the extreme temperature's characteristics in Romania for the near future (2021-2040) by making use of climate projections of maximum and minimum temperature in the context of two climate change scenarios. We employ a series of climate indices focusing on high/low temperatures, selected from the INDECIS project indices database (www.indecis.eu), which are used to highlight the change in extreme temperatures occurrence compared to the base (reference) period 1991-2010. The results are presented for the entire territory, also discussing the uncertainties associated with the methodological aspects.

***Key words**: agriculture, climate change, extreme temperature, Romania.*

INTRODUCTION

Agriculture is an important economic sector in Romania, with a contribution to GDP of 4-6%, compared with an average of 1.7% at UE level in 2015 (MADR, 2015) and about 19% of population formally employed (EC, 2020). Considering its significant dependence on weather and climate, the long-term planning in this sector may benefit from insights on possible evolutions of specific climate conditions, based on available climate scenarios.

Studies on the temporal evolution of some parameters in the current climate over Romania showed an increasing tendency of air temperature and related parameters.

Dumitrescu et al. (2014) shows that over 1961-2013 period the annual thermal extremes present decreasing trends for the cold-related indices and increasing trends for the warm-related ones, with the warming signal being consistent over the region. The same is valid for the Carpathian region, as shown by (Birsan et al., 2014).

Busuioc et al. (2014) highlighted that during period 1961-2010 significant increasing trends for the temperature extremes are detected in all seasons, except for autumn, with the highest increasing rate in summer and the lowest in spring. Furthermore, other studies more oriented toward agriculture (ORIENTGATE, 2014; Sima et al., 2015; Colan et al., 2019; Şmuleac et al., 2020) showed increasing trends for some thermal indices relevant for agriculture. In this context, assessing the changes in the thermal regime and its extremes in the near future may contribute to a sounder approach for developing and implementing adaptation measures in agriculture.

To this end, our study focuses on the changes in the extreme temperatures over Romania in the near future (2021-2040) in the context of two climate change scenarios by using thermal indices related to low/high temperatures relevant for agriculture sector.

MATERIALS AND METHODS

The analysis presented in this study focuses on the near-future period (2021-2040), highlighting the changes in 6 thermal indices by comparison with the base (reference) period 1991-2010.
For the climate projection data, we employ bias-adjusted daily time series of minimum and maximum temperature from an ensemble of Regional Climate Models (RCMs) from EURO-CORDEX, available from https://data.jrc.ec.europa.eu/dataset/jrc-liscoast-10011. The data are run over a numerical domain covering the European continent at a resolution of 0.11°. Historical runs, forced by observed natural and anthropogenic atmospheric composition, cover the period from 1950 to 2005; the projections (2006-2100) are forced by two Representative Concentration Pathways (RCP), namely, RCP4.5 and RCP8.5. RCMs' outputs have been bias-adjusted using the methodology described in e.g. (Dosio and Paruolo, 2011) using the observational data set EOBSv10, and applied to the EURO-CORDEX data by (Dosio, 2016) and (Dosio and Fischer, 2018).
From the 11 simulations available within this dataset (Table 1), we employed 2 simulations (marked in bold in Table 1).

Table 1. Climate projection simulations available from http://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/LISCOAST/10011/LATEST/EURO-CORDEX/EUR-11/

Regional model	Driving model
CCLM-4-8-17	**CNRM-CEFACS-CNRM-CM5**
	MPI-M-MPI-ESM-LR
	ICHEC-EC-EARTH
DMI_HIRHAM	ICHEC-EC-EARTH
IPSL-INERIS-WRF331F	IPSL-IPSL-CM5A-MR
KNMI-RACMO22E	ICHEC-EC-EARTH
SMHI-RCA4	CNRM-CEFACS-CNRM-CM5
	ICHEC-EC-EARTH
	IPSL-IPSL-CM5A-MR
	MOHC-HadGEM2-ES
	MPI-M-MPI_ESM-LR

To select these, we firstly identify the models simulations leading to the lowest changes in the mean temperature at country level, for RCP45 scenario and respectively to the highest change in the mean temperature averaged over the entire country in the context of RCP85 climate change scenario compared to the BASE period (1991-2010) (Figure 1). The selection method allows highlighting the range of change in the indices considered, taking into account the uncertainties associated with the numerical climate models, both at large scale and on limited areas, as well as the uncertainties associated with climate changes, by employing two scenarios.

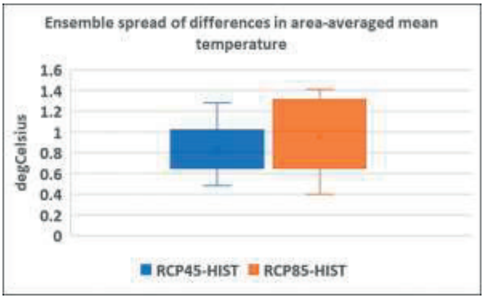

Figure 1. Ensemble spread of differences in the mean temperature area-averaged over the Romanian territory, for 11 climate projection simulations for the periods 1991-2010 (BASE) and 2021-2040 (RCP45, RCP85)

For the next step, we used projections of minimum and maximum temperatures (T_{min} and T_{max}) from each of the selected simulations, to compute six thermal indices, for BASE and near-future periods, for each climate change scenario. The indices are selected from INDECIS project database of indices (http://www.indecis.eu/indices.php) and they are defined as follows:
- **NTN** - Minimum value of monthly maximum air temperature (Klein et al, 2009);
- **FD** - number of frost days (when T_{min} < 0°C) (Klein et al, 2009);
- **STN10** - sums of minimum air temperatures below -10°C recorded in December-February interval (Sandu et al, 2010);
- **XTX** - Maximum value of monthly maximum air temperature (Klein et al, 2009);
- **ID** - Number of days with T_{max} < 0°C (ice days);
- **STX32** - Temperature sums above 32°C (June-Aug) (Sandu et al., 2010).

The results are presented in terms of spatial distribution of absolute differences between climate projections and the associated BASE simulations (denoted as RCP45-BASE and

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RCP85-BASE, respectively). Also, we present the results for BASE period corresponding to each selected simulation, for each index.

RESULTS AND DISCUSSIONS

The indices derived from minimum temperature for the BASE period from the two selected simulations are presented in Figure 2. The mountainous regions show the lower values of monthly minimum temperature (-10°C up to -8°C) as well as the largest values of frost days (150 ÷ 170 days/year) and sums of temperatures
below the threshold of -10ºC (between 600 and 1000°C), followed by the extra-Carpathian regions. The western, southern and eastern areas have, as expected, higher temperatures as seen through higher values of minimum monthly temperatures (-3°C ÷ -0°C), a smaller number of frost days (90 ÷ 120 days) and lower values of STN10 index.

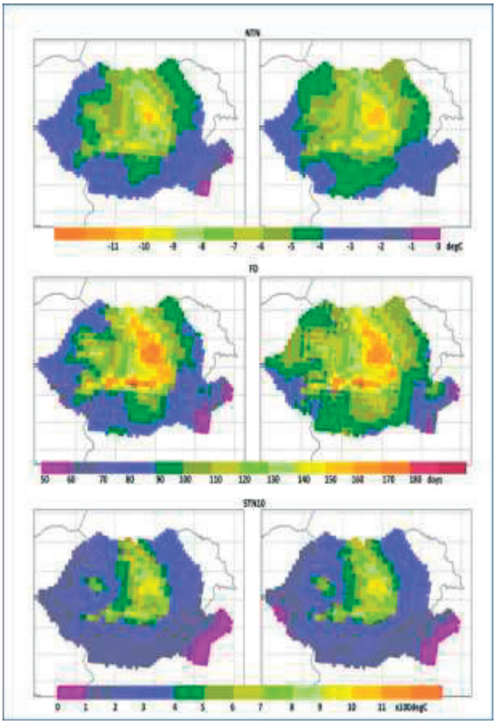

Figure 2. Spatial distribution of the indices based on minimum temperature (NTN, FD, STN10), for BASE period (1991-2010) for simulations corresponding to RCP45 scenario (left column) and RCP85 scenario (right column)

It is worth noting that the two simulations, although in general agreement with regard to spatial pattern, present some differences too, related to smaller values of minimum temperatures in some regions like Eastern Carpathians, southern and eastern areas. These differences are more likely due to the ability of the regional climate model in simulating the observed temperature regime. These differences do not affect the overall analysis, as the expected changes of the indices are assessed by comparison of the climate projections with the BASE period provided by the same combination of large scale and regional climate models. Nevertheless, they are important for understanding the characteristics of the tools used (i.e. numerical models) and for properly addressing the uncertainties associated with them.
The change of indices related to the minimum temperature in the context of climate changes is shown in Figure 3. In general, the minimum monthly temperature (NTN) is expected to rise in both scenarios compared to BASE period. However, for the RCP45 scenario and in particular for the south-western region, the two scenarios indicate divergent evolutions of the minimum temperature- a light decrease in the RCP45 scenario (-0.5°C) and increase in the RCP85 scenario (1.5°C ÷ 2.5°C). For the rest of the territory, the increasing tendency is visible in both scenarios, but more pronounced in RCP85 scenario. The most affected regions in this latter case are in the Eastern Carpathians and Apuseni Mountains (up to 3.5°C), followed by western, southern and eastern sectors, with an increase of 2÷2.5°C.
The mixed signal between the RCP45 and RCP85 scenarios is visible in the other two indices too. In the RCP45 scenario, an increase in the number of frost days is visible for southern, western and Eastern Carpathians (5-10 additional days), while the RCP85 scenario suggests a sizeable decrease of about 10-15 days less in southern, eastern and western regions and more than 5 days less in the hilly and mountainous regions. Similarly, the sum of degrees below -10ºC is expected to increase in the RCP45 scenario in almost the entire country with about 25% compared to the BASE period, while in the RCP85 scenario the STN10 index presents lower values in the entire country

except for some small areas in the western and eastern parts. The differences between the results of the climate projections for the near-future are more pronounced for the indices looking at extreme cases (frost days, STN10) than at the mean values (i.e. NTN) and they are most likely related to the uncertainties associated with the climate change scenarios.

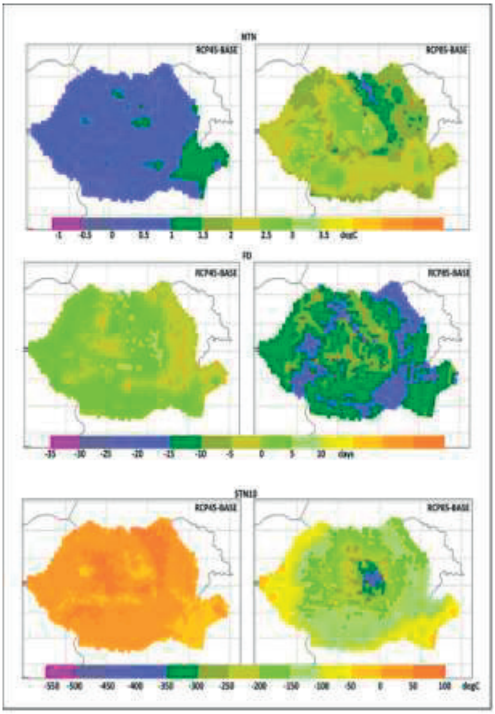

Figure 3. Spatial distribution of the change in the indices based on minimum temperature (NTN, FD, STN10), for simulations corresponding to RCP45 scenario (left column) and RCP85 scenario (right column) compared to the BASE period (1991-2010)

For the indices derived from the maximum temperature the spatial distribution for the BASE period in the two climate change scenarios are shown in Figure 4.

Just as the in the case of indices based on minimum temperatures, there are some differences between the two sets of results, the regional climate model associated with the RCP85 scenario indicating slightly larger maximum temperatures (up to 1°C) on limited areas in the western, southern and eastern regions. Yet, this translates only in a smaller degree in the values of the other two indices. More specifically, the number of days with maximum temperature below 0°C is in general lower based on the regional climate model associated with the RCP45 scenario and, also in this case, the sum of temperatures above 32°C is larger, on limited areas, than in the model associated with RCP85 scenario. This suggests that the two models present a lower agreement with regard to the simulation of current climate in terms of extreme (low/high) temperature, the model associated with RCP45 scenario leading to higher positive temperatures.

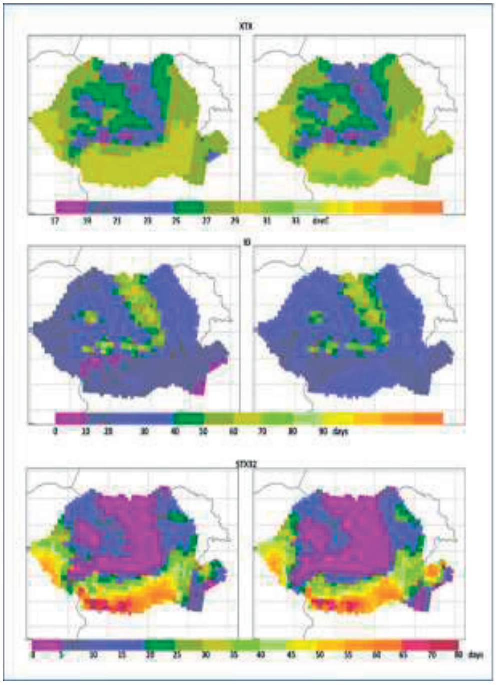

Figure 4. Spatial distribution of the indices based on maximum temperature (XTX, ID, STX32), for BASE period (1991-2010) for simulations corresponding to RCP45 scenario (left column) and RCP85 scenario (right column)

The changes for the near-future period in the indices derived from maximum temperatures in the context of climate changes are presented in Figure 5.

The maximum monthly temperature is expected to increase in both scenarios over the entire country, the amplitude of the increase being slightly larger in the RCP85 scenario (up to 0.5°C). This is further translated, in the RCP85 scenario, into a smaller number of ice days (around 10-15 days less in the high mountainous regions and up to 5 days less in the western, southern and eastern areas) and in a larger value of STX32 index especially in the south and eastern regions, compared to the RCP45 scenario. It is worth noting that the number of ice days may also increase, in the RCP45 scenario, with up to 5 days in the western, southern and eastern areas.

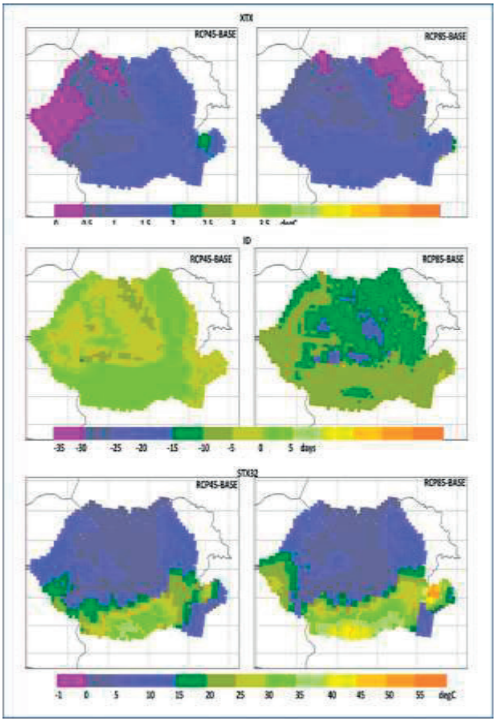

Figure 5. Spatial distribution of the indices based on maximum temperature (XTX, ID, STX32), for simulations corresponding to RCP45 scenario (left column) and RCP85 scenario (right column) compared to the BASE period (1991-2010)

CONCLUSIONS

We presented an analysis of the changes in six indices related to extreme low and high temperatures, relevant for agriculture, for the near-future period (2021-2040) in the context of two climate change scenarios.

The results suggest that both minimum and maximum monthly temperature may increase in the near future, more pronounced in the context of RCP85 scenario, the most affected regions being the Eastern Carpathians and Danube Delta. For the indices related to low values of temperatures, based on either minimum or maximum temperature (i.e. FD, STN10, ID) the selected climate projections present mixed signals: in the context of RCP45 scenario these indices present an increasing tendency on some limited areas in western, southern and eastern regions, while the RCP85 scenario suggest a decrease of their value over the entire country. The change in the regime of high temperature, expressed through the STX32 index, presents a clear positive tendency in both scenarios, more pronounced in the RCP85 scenario, especially in the southern and eastern areas.

The results contain the limits related to the data and method used. The climate projection data is affected by several sources of uncertainty, the most important being associated with the limitations of numerical models in simulating the climate system, with the climate change scenarios, but also with the natural variability of the climate system. This is already visible in the results presented, for example in the differences between the spatial distribution pattern of indices for the BASE period as derived from the two selected combinations of large scale and regional climate models or in the mixed signal for the projected changes of indices related to low temperatures. The method used addresses these sources of uncertainty (e.g. by employing more than once climate change scenario). By employing two model simulations which describe 'extreme' instances of possible evolution of climate in the near future, in terms of change of mean temperature at country level, based on a set of 11 simulations, our approach fits the aim of the study and it is tailored for the specific region of Romania. Nevertheless, it is possible that a higher level of confidence may be obtain by using more model simulations. Furthermore, selecting the indices such that to be more specific (e.g. with thresholds for specific cultivated plants) would bring significant added value for developing efficient adaptation measures in agriculture.

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THE PRODUCTIVITY OF PINE STANDS ON DEGRADED LANDS

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Abstract

The surface of degraded agricultural lands continues to increase under the influence of climatic changes. Pines have been the most frequent forest species used for afforestation in the past (period 1950-1990).
The present paper presents data regarding the current state, biometric and auxologic characteristics of pine stands which emphasize the bioproductive and ecologic potential. The productivity and production were analyzed in the pine stands formed by main species such as European black pine and Scots pine, pure or mixed. The wood production (m^3ha^{-1}) recorded in pine stands is different, being based on the degradation form, phytoclimatic layer and age. As such, the volume of stands with European black pine varies between 258.89 and 512.66 m^3ha^{-1}, while for the stands with Scots pine, the values varies between 206.75 and 418.04 m^3ha^{-1}. For both species, it was obtained an semnificative correlation coefficient (R^2>0.8) between diameter class (D) and unit volume (v). In the forest steppe of hill (S_s), on strongly fragmented landslides, the European black pine has proved better growth than Scots pine. In the hill zone (FD_3), similar growth conditions for both species were obtained.

Key words: *afforestation, degraded lands, bioproductive potential, average radial growth, volume.*

INTRODUCTION

The degraded agricultural lands surface is in continuous growth in the context of climate changes. Thus, in our country, the surface of these lands summing aproximatively 6.3 million hectares from which 2.5 million hectares are strongly degraded (Nistor and Nistor, 2002).
The degraded agricultural lands afforestation represents the principal way of ecological reconstruction and the valorification of these types of lands (Untaru et al., 2013). In this regard, the Strategy and the National Programme of Actions for Desertification Control (2008), and also the new Forest Code (Law 46/2008), they provided for afforestation almost 2 million hectares of degraded agricultural lands at the national level.
Forestry species frequently used in the past (1950-1990 period) at the degraded lands afforestation were the pines, in present being less and less used, in the detriment of some fast-growing species (locust and so on) but also for biodiversity. The pine species utilised at the degraded lands afforestation were, especially, the European black pine, Scots pine, Weymouth pine and also the Western yellow pine and so on.
The effects of the pine forestry cultures realised onn degraded lands consist in improvement/amelioration, stabilization and the valorification of ineffective lands making the object of other uses (Constandache et al., 2010) but also in the mitigation of global warming effects through the highly capacity of atmospheric carbon dioxide storage (CO_2) (Dincă et al., 2015), the stop of lands degradation due to the capacity of fixing and improvement of the soils (Nicolescu et al., 2018), the anthropogenic pressure reduction on the natural forestry ecosystems and the utilisation of those as an alternative for obtaining the fossil fuels (Spîrchez and Lunguleasa, 2016).
Deforestation and exploitation activities have generated a multitude of degraded lands, being subsequently subjected to the phenomena of collapse, landslide and intensification of floods frequency, especially on lands with high slopes (Silvestru-Grigore, 2016).
The pine stands occupy almost 5% from the forests surface from our country being realised both on degraded lands and another types of lands from the outside range (Constandache et al., 2017; Untaru et al., 2008; Enescu and Dănescu, 2015). These kinds of stands have been realised on different types of degraded

lands (eroded, ravenous, rocky, tailings) and in another countries (Bulgaria, Anglia, Austria, Finlanda, Germania, Spania).

In eastern England, in Scots pine stands were elaborated studies regarding on influence of physiological factors which can affect the evapotranspiration and it was analyzed on vertically and horizontally have been developed in wild pine trees and the root system has been analyzed vertical and horizontally the root system in function of the distance between trees and soil properties (Roberts et al., 1976). In Scots pine plantations in the middle boreal region established in Finland, it was estimated that the volume of carbon dioxide and the water vapor flow stored by the Scots pine using the covariance method (Lohila et al., 2007).

Between the years 1993-1994, in Germany, were efectuated measurements in pine stands regarding the gas exchanges at the leafs level, the transpiration as well as the sap flow analysis (Sturm et al., 1997).

In northwestern Spain, in the Scots pine stands, the quantitative characteristic represented by the commercial volume was analyzed, using 14 volume equations (Diequez, 2006).

The abroad specialty literature mentions that the scots pine forests had shown significant differences in regard with the biometric parameters, in comparison with broad-leaved species.

Even though the number of trees was 5.4 times lower, this species reached a base surface larger than 189.6%, a higher volume with 30.8% and a growth of 30.9% of the current volume in comparison with broad-leaved species (Vlad et al., 2019). Furthermore, the dimensions of average trees were also larger in scots pine stands, with an average diameter larger with 128.2% and an average height higher with 40.7% than the locust stands (Lukić et al., 2015). Although that the pine species have made the object of many previous research, at the national level exists a real need of updated informations regarding at the productivity of those species in different vegetation conditions, in the context of climate change. The obtained results emphasized the fact that scots pine is a species that can adapt to extreme site conditions and can be successfully used in afforestation projects for degraded lands (Vlad et al., 2019).

Nevertheless, managing stands towards a future stable desired ecosystem should be validated by long-term studies that should examine the ecosystem’s changes through more successive stages (Ganatsas et al., 2011).

Regarding the analysis of the internal structure of the wood, in the pine stands installed in the Buzău Subcarpathians, Silvestru-Grigore found that the species of Scots pine and european black pine have different behaviors on degraded lands. Thus, the european black pine shows a better stability than the Scots pine, rendered by a lower coefficient of variation for heights (Silvestru-Grigore et al., 2016). These two species of pine, are different is terms of radial growth dynamics, Scots pine proving an faster juvenile growth spurt and also high growth range that European black pine (Silvestru-Grigore et al., 2018).

The effectuated researches in the current stage have had as scope the continuity of previous researches in the view of actual state knowledge, the biometrics and auxological characteristics of the stands from different pine species, with different ages (38-70 years), realised in the past on different categories of degraded lands, showing the bioproductive potential of those.

The results have been obtained after the made researches in the period 2015-2020 in the research plots located in the improvement perimeters in degraded lands from the south-east contry zone.

The obtained results are very important having in the view the afforestation necessity of some large surfaces of existing degraded lands at the national level, as well as the necessity of sustainable management of the realised forestry cultures.

MATERIALS AND METHODS

The researches have been made in the 12 experimental plots (SE) on long term, in representative situations of pine stands and of degradation forms. It has been analysed the forestry cultures pure or mixed of Scots pine, European black pine, Weymouth pine. It was analysed and highlighted the current state, biometrics and auxological characteristics, the productive potential of pine stands in different environmental conditions.

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It was made the measurements and observations in forestry cultures from different species of pine, from the improvement perimeters of degraded lands in which exists or were located in the research plots (on long term).

Territorial, the researched were held in the forest steppe zone (Livada Perimeter- Râmnicu Sărat forest district; the hilly oak stands storey (Murgești perimeter- Râmnicu-Sărat forest district; the oak stands storey (Caciu-Bârsești, Experimental Base Vidra); the beech stands storey (Roșoiu-Andreiașu perimeter- Focșani forest district. The research consisted in collecting field data, processing and interpreting of them. The processing of field data was performed in a computer system by using specific statistical programs in silviculture. In order to highlight the structural characteristics of the pine stands, the analysis of the experimental distributions of the main biometric parameters of the trees was performed by means of the theoretical distribution functions (normal, beta) corresponding to the horizontal structure. Another way of analyzing the stand structure was represented by the analysis of the correlations between different qualitative and quantitative characteristics, through general statistical methods. The unit volume expressed in m^3*ha^{-1} was determined using the bifactorial regression equation method provided in "*Dendrometric methods and tables, 2004*" (Giurgiu *et al.,* 2004), using the corresponding regression coefficients for Scots pine, European black pine species and Weymonth pine.

Plotting the curves of the unit volumes were highlighted by using the exponential regression equations of the form $y = ax^b$ (Figures 1 and 2), in which y-represents the unit volume, and x-the diameter.

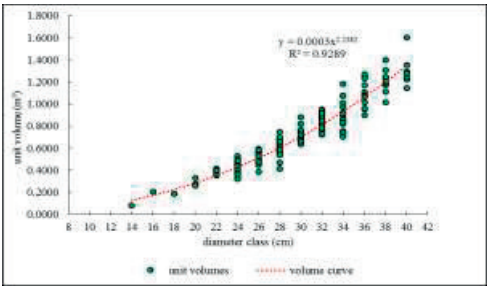

Figure 1. The regression equation of unit volume (European black pine– SE12 Livada)

Unit volumes are evenly distributed by diameter classes, due to the number of trees that are found in approximately equal proportions. The correlation coefficient (R) has a value close to 1 which denotes a very close interdependence relationship between volume and diameter (Figures 1 and 2).

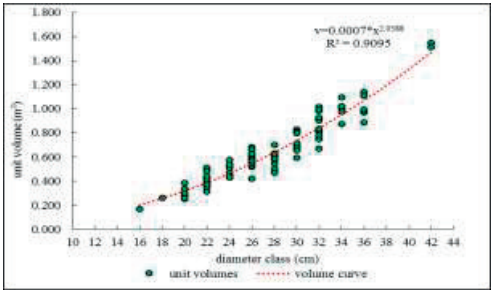

Figure 2. The regression equation of unit volume (Scots pine- SE6 Livada)

RESULTS AND DISCUSSIONS

It was analyzed the Scots pine, European black pine, Weymonth pine stands and were installed on lands affected by different forms and intensities of degradation (Tables 1), in different sites (phytoclimatic layers).

The forestry cultures analyzed are in general pure or mixed cultures between different species of pine as well as pine mixed with deciduous species. On lands with advanced degradation, forestry cultures were made from a smaller number of main species (pines) and secondary species and/or shrubs. On lands with better conditions, a larger number of main and mixed species (pines, oaks, maples, ashes and so on) were used. The number of seedlings planted per hectare generally varied between 6700 and 10000. In the case of mixtures, deciduous species were introduced in intimate mixture, on lands with advanced degradation and in small bouquets (bouquets of 10-50 pine seedlings alternating with bouquets of 10-30 deciduous seedlings), on lands with more favorable conditions or with various microstational conditions.

Mixed deciduous species and shrubs introduced in mixture with pines from the planting or previous naturally installed, have an important ameliorative role but also in regulating the structure of the stand, contributing at the

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assurance of the necessary biological diversity. An important role in the improvement/ stabilization of the land and in the evolution of the pine plantations have had the sea buckthorn used in mixture with the pine or in the planning/consolidation of very strongly to excessively eroded lands, in the Roşoiu-Andreiaşu and Caciu-Bârseşti perimeters.

Thus, the pine plantations made in mixture with sea buckthorn or through consolidation technologies of the lands, with the help of sea buckthorn (where sea buckthorn entered in the vegetation), on very heavily eroded lands, have recorded growth increases of pines by 20-30% higher compared to pure pine cultures or made on consolidated lands through other methods (terraces supported by fences), as a result of soil enrichment in nitrogen (Constandache et al., 2016; Dincă et al., 2018).

Depending on the shape and intensity of degradation, at the installation of plantations is where necessary various landscaping/ console-dation works, in order to ensure the minimum vegetation conditions of the seedlings (Constandache et al., 2006; Constandache et al., 2010). The dynamics of biometric parameters (diameter and height) in the stands made on degraded lands, is realised under the influence of the complex of harmful abiotic and biotic factors, in close interdependence with the land conditions on which the forest cultures were made, with the phytoclimatic storey, with forestry works (tending and management) applied, with the effect of harmful abiotic factors, with the species in the stand composition.

Pines have given good results in terms of growth in diameter and height (Table 1) even on land with advanced degradation conditions, having an important role in improving and capitalizing on degraded lands.

Analyzes carried out in pine stands on lands affected by landslides and strong erosion (Murgesti perimeter), located in the hilly oak stands storey (FD_1) showed that pine species have larger diameter growths, achieving at the age of 30 years, basal diameters which varies between 16-17 cm ahead of the other species (ash, manna ash 9 cm), and at older ages at 40 this gap widens: pines 21.1-25.6 cm and ashes 11-13.2 cm (Table 1, Figure 3).

Table 1. The evolution of average diameter in relation with age

Experimental block	Experimental plot (SE)	Species	Mean diameter (cm)							
			Age (years)							
			10	15	20	25	30	35	40	45
M	12	Pi.n	5.30	7.75	10.20	13.70	19.50	-	-	19.86
		Pi	-	10.40	13.00	16.20	18.40	19.10	20.20	21.27
		Fr/Mj	-	6.10	7.10	9.50	9.60	9.50	10.70	13.18
		Fr/Mj	-	-	-	-	-	-	-	11.04

Symbols semnifications: M - Murgeşti; Pi - Scots pine; Pi.n - European black pine; Fr - ash; Mj - manna ash

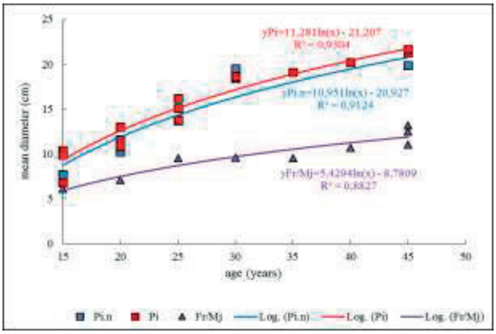

Figure 3. The evolution of average diameter for different species on strongly eroded ± landsliding - FD_1

The decenal average growths in diameter (cm) and height (m) of the species analyzed in the Murgeşti perimeter are as follows:

Species	*Diameter growth (cm)*	*Height growth (m)*
Pi.n	3.80	2.76
Pi	3.91	3.15
Fr/Mj	1.88	1.75

Regarding the recorded biometric characteristics, the largest diameters (between 26 and 30 cm) and heights (between 21 and 23 m) were registered by the Scots pine and the European black pine, at the age of over 60 years, on moderately to heavily eroded lands (Table 2).

The analysis of the differences between the two species (Scots pine and European black pine) showed that, in moderately eroded land conditions, Scots pine achieves, on average, smaller diameters with 0.99 cm (3-5%) and higher heights by 1.26 m (5-6%) compared to European black pine.

The number of trees is lower in the case of Scots pine stands (647-756 exemplars/hectares) with 13.6-21.2% compared to European black pine stands, the cause being the higher vulnerability of Scots pine to the damage

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provoked by factors abiotics (wind, snow) (Constandache et al., 2017).

Table 2. Biometric characteristics of stands on different bioclimatic storeys - it should be larger and clearer

SE Number	*Degradation form*	*Current composition*	*Age (years)*	*Consistency*	*Dmed (cm)*	*Hmed (m)*	*Number trees on species per hectares*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Livada - Râmnicu Sărat Perimeter (internal forest steppe)							
6	E2	80 Pi	64	0.7-0.8 / 0.69	26.00	19.70	691
		4 Pin			30.00	19.00	28
		5 Mj			7.70	7.60	461
		5 Ul			8.90	7.80	362
		5 St			15.10	10.50	105
		1 Pa			16.00	10.19	54
		Total			**16.50**	**13.00**	**1700**
8	E1	83 Pis	59	0.8/ 0.79	26.90	18.00	630
		11 Pi			32.00	19.90	78
		6 Pa			10.30	10.70	292
		Total			**22.10**	**17.00**	**1000**
9	E1	92 Pin	59	0.7/ 0.93	25.80	17.10	930
		3 Mj			7.30	7.10	338
		2 Sc			8.00	6.60	169
		3 Pa			22.67	17.80	42
		Total			**19.00**	**13.40**	**1479**
10	E1	86 Pi	61	0.8/ 0.98	24.70	18.50	796
		12 Pa			9.10	12.80	747
		1 Cs			8.40	6.50	67
		1Pin			30.00	16.65	9
		Total			**16.87**	**17.78**	**1619**
12	E1	98 Pin	63	0.8/ 0.76	27.90	19.20	767
		1 Fr			6.40	6.30	180
		1 St			16.86	14.24	29
		Total			**23.50**	**16.60**	**976**
Murgeşti - Ramnicu Sărat perimeter (hilly storey of oak stands with common oak)							
12	A1	52 Pi	43	0.8	21.27	16.74	850
		34 Mj			11.04	11.98	560
		14 Fr			13.18	14.65	220
		Total			16.66	14.82	1630
17	E2 / A1	100 Pin	44	0.9	18.31	14.85	1545
18	E1 / A1	100 Pi	44	0.5-0.6	22.72	16.90	693
Caciu- Bârseşti Perimeter (Sessile Oak storey)							
5	E3	49 Pin	38	0.6-0.7	13.69	12.62	1027
		47 Pi			14.56	13.57	982
		4 An			12.00	10.65	91
		Total			**14.02**	**12.98**	**2100**
8	E3	82 Pi	37	0.7-0.8	11.16	12.14	2165
		18 Pin			9.17	9.36	392
		Total			**10.80**	**11.70**	**2557**
Roşoiu-Andreiaşu Perimeter (European beech stands storey)							
9	E3	96 Pi.n	50	0.7	26.11	18.78	744
		4 Ar.t, Ci			13.33	9.19	133
		Total					**877**
10	E3	95 Pi	50	0,6-0,7	27.33	19.53	400
		5 Ar.t			13.96	9.62	71
		100					**471**

Symbols semnification: SE - experimental plot; Dmed - average diameter (centimeters); Hmed - average height (meters); Pi - Scots pine; Pi.n - European black pine; Pi.s - Weymonth pine; St - common oak; Pa.c - Norway maple; Fr - ash; Mj - manna ash; An - alder; Cs - chestnut; Ul - elm; Ci - European sweet cherry; Ar.t - Tartarian maple

On very strongly eroded soils (e3), in cultures with an age of approx. 40 years old, the average diameter is 12-14.6 cm, and the average height is between 11-13.6 m). The two species have been introduced into the intimate mixture, and the Scots pine recorded higher growths than the European black pine, both in diameter and height. The average number of trees/hectares is approx. of 2000 exemplars/hectares.

Pine stands recorded different auxological characteristics (growths, volumes) in relation with species, age, environmenal conditions and production class. Thus, in Romania, according to the relative production tables (Giurgiu and Drăghiciu, 2004), the total production (m^3ha^{-1}) is between 57-1175 m^3ha^{-1} in the case of the Scots pine and between 59-951 m^3ha^{-1}, in the case of European black pine, values that are estimated according to age and production class (I-V). In the case of the both species, the production cycles are different (cycle of 100 years - Pi; cycle of 90 years-Pi.n) and the total productivity is calculated for the pine species that are part of their natural range, at full consistency (c = 1.0).

According to Cotos and Duduman, 2017, in the case of European black pine, the technical cutting age (years) adopted for the target assortment "5-34", "> 5" cm is 55 years, for production class III, depending on the evolution of average growths. In production class V, the technical cutting age was increased by 20 years for reaching the assortments with target diameters "5-24", "5-34" and "> 5", due to lower increases in seasonal conditions characterized by inferior productivity and on soils with small edaphic volume, sometimes superficial, skeletal. The age of maximum technical cutting adopted for European black pine is 90 years, for all production classes, but for assortments with different target diameters in size.

In order to estimate the total volume per hectare (m^3ha^{-1}) (Figures 4, 5 and 6), the volume of healthy trees was taken into account, and the values obtained depend on the characteristics of the stand (stand density, age, species in the composition) and of environmental conditions.

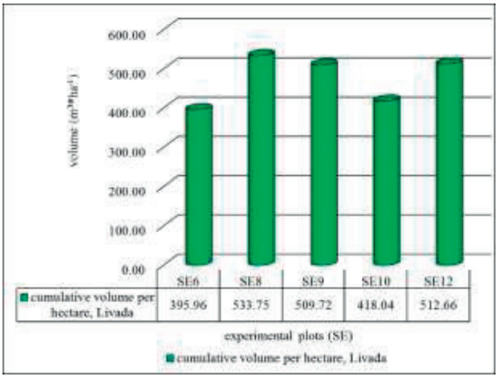

Figure 4. Graphic distribution of cumulative unit volumes (m^3ha^{-1}) recorded in the case of pine stands in the Livada perimeter

On moderately to heavily eroded lands, at the ages of 65-69, a maximum volume of 533.75 m^3ha^{-1} was obtained for the Weymonth pine. In the case of Scots pine, a volume was recorded in the range of 395.96-418.04 m^3ha^{-1}, and for European black pine, it was obtained values of the volume between 509.72-512.66 m^3ha^{-1}, higher compared to Scots pine.

The distribution of volumes on diameter classes shows that the Scots pine reaches a maximum volume (Figure 5) at the diameter class 26 (65.93 m^3ha^{-1}), and the European black pine registers a maximum volume at the diameter class 28 (95.74 m^3ha^{-1}).

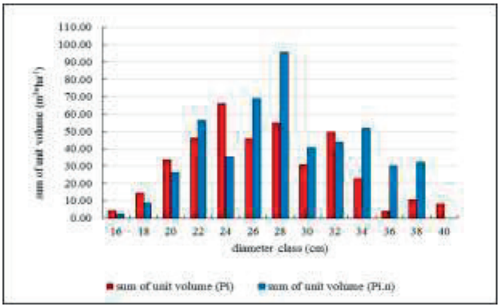

Figure 5. Comparative productivity situation (m^3ha^{-1}) for the both pine species in experimental plots SE9 and SE10, Livada - it should be larger and clearer

On slippery/landsliding and heavily eroded lands, the pine stands (Figure 7) with the age of 48-49 years, recorded volumes generally between 206.75-369.96 m^3ha^{-1} (Figure 6).

On very heavily eroded lands, the pine stands with the age of 55 years old, in SE9 (74% European black pine and 8% Scots pine) it was obtained a higher volume (258.89 m^3ha^{-1}) compared with SE10 (83% Scots pine - 224.47 m^3ha^{-1}), although the proportion of pines in the composition is almost equal in the two plots (Table 3, Figure 5).

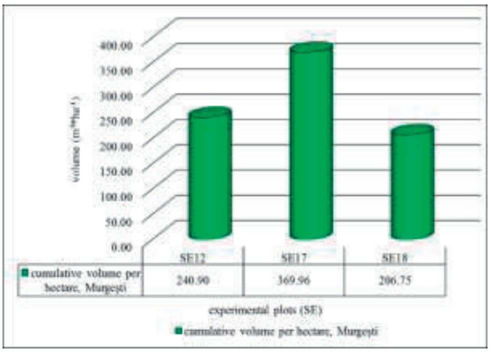

Figure 6. Graphic distribution of cumulative unit volumes (m^3ha^{-1}) recorded in the case of pine stands from Murgeşti perimeter

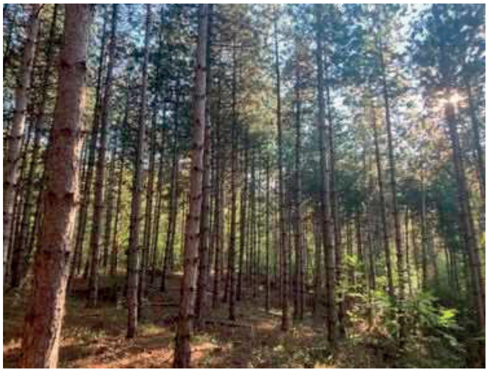

Figure 7. Pure stand of European black pine in SE17 Murgeşti (landslide)

In stands with the age smaller (38-42 years) a higher volume was achieved in the case of plot SE 5 (223.43 m^3ha^{-1}), where the two pine species are in almost equal proportions (Pi - 47%, Pi.n - 49%), compared to the volume obtained in the case of SE 8 (157.54 m^3ha^{-1}), where the Scots pine has a higher proportion (74% - Pi, and 26% - Pi.n - Table 3).

Table 3. Volumes and average growths ($m^3year^{-1}ha^{-1}$) in pine stands located on degraded lands

SE Number	*Degradation form*	*Pine species and their proportion in composition*	*Age (years)*	*Volume (m^3*ha^{-1})*	*Average growth ($m^3*an^{-1}*ha^{-1}$)*
1	*2*	*3*	*4*	*5*	*6*
Livada - Râmnicu Sărat Perimeter (internal forest steppe)					
6	E2	80 Pi	69	395.957	5.657
8	E1	83 Pis	64	533.750	8.340
9	E1	92 Pin	64	509.718	7.964
10	E1	86 Pi	66	418.060	6.334
12	E1	98 Pin	68	512.662	7.539
Murgeşti - Ramnicu Sărat perimeter (hilly storey of oak stands with common oak)					
12	A1	52 Pi	48	240.900	4.818
17	E2 / A1	100 Pin	49	369.964	7.399
18	E1 / A1	100 Pi	49	206.749	4.135
Caciu- Bârseşti Perimeter (Sessile Oak storey)					
5	E3	47 Pi	38	118.220	3.110
		49 Pin		105.210	2.770
8	E3	74 Pi	42	98.106	2.336
		26 Pin		59.434	1.415
Roşoiu-Andreiaşu Perimeter (European beech stands storey)					
9	E3	74 Pi.n	55	234.560	4.260
		8 Pi		24.330	0.440
10	E3	83 Pi	55	224.471	4.081

Legend: Al - landslide; E1-E3 - moderately eroded lands (1), strongly (2), very strongly (3)

The analyzes show that the wood production (m^3ha^{-1}) recorded in the pine stands on degraded land is different in relation with the shape and intensity of degradation, phytoclimatic storey, age of stands, proportion of pines in the composition of the stand (Figure 8).

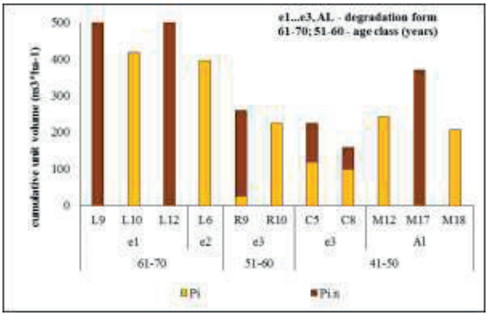

Figure 8. The volume (m^3ha^{-1}) of wood in pine stands situated on degradated lands (L - Livada perimeter; R - Roşoiu perimeter; C - Caciu perimeter; M - Murgeşti perimeter; 5, 6, 8, 9, 10, 12, 17, 18 - number of SE)

Thus, on the moderately eroded lands (E1), the productivity it's bigger at the old age. Between two pine species, on the ladns with similar environmental conditions, the recorded productivity by the European black pine is bigger than for Scots pine, having an behaviour better on lands from internal forest steppe. The difference it's determined by the biometric characteristics (diameter, height), and also by the number of exemplars per hectare. In the similar mode, the annual average growth ($m^3year^{-1}ha^{-1}$) varies in ration with same factors (degradation intensity, age and so on) being between 4.08 and 6.33 $m^3year^{-1}ha^{-1}$ at Scots pine and between 4.26 şi 7.96 $m^3year^{-1}ha^{-1}$, at European black pine (Table 3).

The pine stands from degraded lands suffered damages (ruptures, drying) caused by harmful abiotic factors (wind, snow, drought, and so on) in all areas/vegetation storeys. The Scots pine, in pure stands on lands with lower degradation intensity, was more severely affected in contrast to European black pine and pine stands mixed with deciduous species.

As a result of damages caused by harmful factors (wind, snow) especially on moderately eroded lands, the proportion of pines in the composition has decreased from 50-100% to 36-49%. The analyzes performed show an increase in the proportion of European black pine in relation to Scots pine, the latter being more strongly affected. With age, the number of species in the composition of trees has increased from 1-4 species at planting to 3-6 species today, some of which are subsequently installed by natural regeneration (Figure 2).

As they get older, the number of species in the stand's composition has grown from 1-4 species at planting at 3-6 species in present, some of them previous installed through natural regeneration (Figure 9).

Figure 9. The apparition on the natural regeneration of manna ash and maple, at the shelter of mature stands of pine (SE6 Livada)

Under the massif of pine stands have been installed the local hardwood species such as maple, ash and especially manna ash, since the age of 25-30 years, with the thinning of the stands caused by damages. Pine stands (mixed with deciduous trees) have a structure formed by two storeys, consisting of a dominant pine storey and a second storey composed from deciduous storey.

The intimate mixture with the pines (at planting) but also the younger age of these species (further installed by natural regeneration), makes them achieve lower growths, being dominated by pines.

From the analysis of afforestation compositions in permanent research plots results that in most situations of degraded lands, at the afforestation were used comparative pine species with other species (Traci, 1975; Untaru, 1976).

Pine stands installed on degraded lands are not natural types of forest specific and they were viewed as transition stands whose purpose was to improve the vegetation conditions and to prepare the ground for the gradual installation of the forestry species specific to the natural type of forest. One's they get older, the assortment of species naturally installed in pine stands on degraded lands, marks the succession trend towards deciduous compositions favorable to the zonal vegetation, with structural diversity and higher ecological stability.

CONCLUSIONS

Among the existing pine species, European black pine, Scots pine and sometimes Weymonth pine have been used in afforestation of degraded lands, in pure cultures or mixtures (between pine or deciduous species).

Pines have given good results even on lands with advanced degradation conditions, having an important role in the improvement and capitalization of degraded lands.

The dynamics of biometric parameters (diameter and height) in pine stands realised on degraded lands, is made under the influence of the complex of harmful abiotic and biotic factors, in close interdependence with the land conditions on which forestry cultures were made, with phytoclimatic storey, with forestry works (tending and management) applied, with the effect of harmful abiotic factors, with the species from the composition of the stand.

The volume of wood accumulated of the pine stand on degraded lands, between 157.54 and 533.75 m^3ha^{-1}, is different in relation with the shape and intensity of degradation, phyto-climatic storey, age of the stands, proportion of pines in the composition of the stand, being larger on moderately eroded lands with older ages.

Between the analyzed pine species, the Weymonth pine achieved the largest volume, followed by the European black pine and then the Scots pine, on lands with similar environmental conditions. The differentiation is determined by the biometric characteristics (diameter, height) as well as by the number of exemplars per hectare.

The average annual growths vary in relation with the the same factors, being between 4.08 and 6.33 $m^3year^{-1}ha^{-1}$, at the Scots pine, between 4.26 and 7.96 $m^3year^{-1}ha^{-1}$, for the European black pine, and the Weymonth pine achieves 8.34 $m^3year^{-1}ha^{-1}$, achieving the maximum growth on moderately eroded lands, in the internal forest-steppe.

The stands from pine species on degraded lands have suffered damages (ruptures, drying) caused by harmful abiotic factors (wind, snow, drought, etc.), of which the Scots pine is the most vulnerable.

Under the massif of pine stands, since the age of 25-30 years, with the thinning of stands caused by damages, native deciduous species such as maple, ash, manna ash, and so on, have naturally installed. The intimate mixture with the pines (at planting) but also the younger age of these species (later installed by natural regeneration), makes them achieve lower growths, being dominated by pines.

Favoring the natural installation of deciduous species under the shelter of thinned pine stands, highlights the importance of pines in the ecological reconstruction works of degraded lands.

Considering the significant plots of degraded lands existing at national level, as well as the need for those improvement and sustainable use, the use of pines for ecological reconstruction through afforestation of these lands contributes, in addition to generating essential ecosystem services in zones exposed to degradation (soil protection and water) and to achieve additional incomes from the capitalization of the wood or non-wood products resulted.

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OPTIMIZATION MODEL FOR FERTILIZATION OPERATIONS

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Abstract

The aim of the present study is to present an option for reducing the technological operation costs of fertilization. The research paper examines the available equipment of a specific agricultural producer (PA) in the Republic of Bulgaria. The characteristics of the fertilizing machines and the energy sources in the agricultural holding are made, the hourly productivity of the assembled units is calculated and the transport costs are optimized by solving a transport task under certain conditions. The proposed algorithm for describing a transport task and its subsequent solution, using MS Excel Solver significantly speeds up the calculation procedures and helps to reduce costs when performing the technological operation fertilization.

***Key words**: fertilizing machines, transport task, Solver.*

INTRODUCTION

On the one hand, the proper fertilization is an important factor for plants. Many of our plant problems come from a lack of fertilization - even diseases and pests, as a weak plant is more susceptible and easier to get sick. On the other hand, when we talk about fertilization, the maxim "the more, the more" does not apply.
In today's competitive market, obtaining the maximum yield, in compliance with the health requirements of a crop, with minimum fertilizer costs is the most critical part of creating a successful agriculture. The economic reality of the overall agricultural industry is forcing producers to look for ways to increase the yield of existing agricultural land.
Fertilization is a very important technological process, because if not carried out properly it allows the saturation of the soil with chemicals.
The basis for the development of each project in agriculture is the technological maps, which give the technology and resources for the production of a specific agricultural product.
The technological maps for mechanization of fertilization provide relatively constant information about the agro-technical term, the number and duration of working days, the composition of the unit, the required number of tractors and CCM. With this treatment we aim to apply a method for optimizing the transport costs of fertilization in a sample farm of a farmer.

MATERIALS AND METHODS

The characteristics of fertilizer machines and energy sources are taken from the prospectuses of the machines. The main parameter required for the study is the performance of the MTA. It is a function of the working width of the machines (Palevski, 1990).
For fertilizer spreaders, the working width depends on the type of fertilizer (Trankov, 1993).
The hourly productivity of the assembled aggregates is calculated as follows:

$$Wh = \frac{Bp\,.\,S}{10000}\,[\text{ha}], \qquad (1)$$

where:
Bp - the working width of the aggregate [m];
S - the way of the aggregate for one hour [m].
For a maximum correctness of the calculations, we should take out 30%, which is the time spent for curves, pauses, fertilizer loading, etc.
Algorithm for solving a transport problem with the possibilities of MS Excel Solver
(used MS EXCEL 2010)
MS Excel has a module for solving optimization tasks. The module is called Solver and can be found in the Data menu (Figure 1). It must be activated before using it for the first time. This is done in the following sequence:

- MS Excel starts;
- from the File menu select Options;
- the Option dialog box of Excel appears;
- submenu Add-Ins → Manage select Excel Add-ins;
- The dialog box closes with OK.

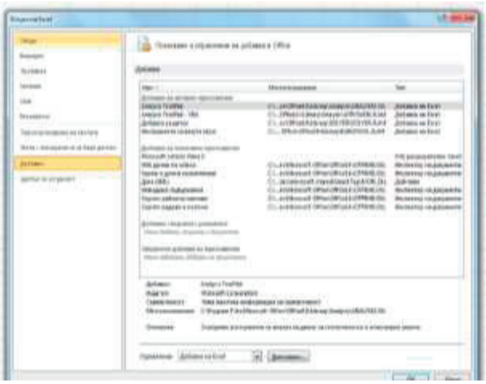

Figure 1. Solver Activation Dialog Box

In this way we already have the program for solving optimization problems. Such an approach has also been used in the development of (Ivanova et al., 2011; Ivanova et al., 2018; Marinov, 2016).

RESULTS AND DISCUSSIONS

The farm is located in the region of Dobrich, Bulgaria. It grows mainly cereals on an area of about 1200 ha.
MTA for fertilization
The following MTAs are used for on-farm fertilization:
1. tractor "Kubota GX135M" + "AMAZONE ZM"
2. John Deere 8270R tractor + AMAZONE ZM
The working width of both units is 24 m.
The speed is on two levels 10 and 15 km/h.
For MTA "1" and "2" of the made characteristics we can calculate the energy required for the processing of 1 ha.

$Wh_1 = \frac{24.10000}{10000}$ = 24-30% =16.8 ha/h

$Wh_2 = \frac{24.15000}{10000}$ = 36-30%=25.2 ha/h

The calculations show that the MTA is quite productive - for 8 hours a day the two units fertilize 400 ha or for 3 days the whole farm could be fertilized. In order for the machines to be loaded, the services of colleagues - manufacturers are performed.
Terms of reference for optimizing transport costs during fertilization:
Perform the fertilization operation with the two MTA units on the following fields:

1. field1 - 4.6 ха х 200 кг/ха =920 кг within a base distance of 0.7 km
2. field2 - 4.2 ха х 200 кг/ха = 840 кг within a base distance of 0.6 km
3. field3 - 6.3 ха х 200 кг/ха = 1260 кг within a base distance of 1km
4. field4 - 8.1 ха х 200 кг/ха = 1620 кг within a base distance of 1.8 km

The data for the average fuel consumption during transport have been established experimentally - 0.244 L/km and the calculations are made at an average fuel price of BGN 2 (Figure 2).

Figure 2. Experimenal data

Task. Solve the following transport task

Bj / Ai	B1	B2	B3	B4	ai
A_1	0,34	0	0	1,85	2540
A_2	0	0,29	0,68	0	2100
b_j	920	840	1260	1620	4640 / 4640

Solution: The given transport task is closed because we have a balance between production and consumption, ie.

$\sum_{i=1}^{2} a_i = \sum_{j=1}^{4} b_j = 4640.$

We solve the obtained closed transport task according to the solving algorithm in MS Excel (Solver). In Figure 3 is given a spreadsheet

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with the mathematical model of the specified problem.

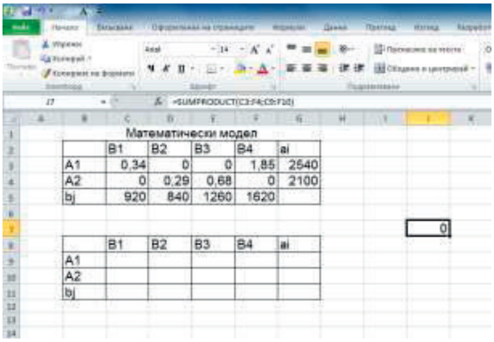

Figure 3. Spreadsheet with the task model

Filling in the worksheet:
1. Enter the values of transport costs in cells $ C $ 43: $ F $ 4, in cells $ G $ 3: $ G $ 4 - the constants of matrix A (ai), and in cells $ C $ 11: $ F $ 11 - the constants of matrix B (b) of the task.
2. In cell $ J $ 7 we enter the formula by which the value of the objective function is calculated, ie. = SUMPRODUCT (C3: F4; C9: F10).
3. In the second table in cell C11 we enter the formula = SUM (C9: C10) and after clicking the mouse appears zero.

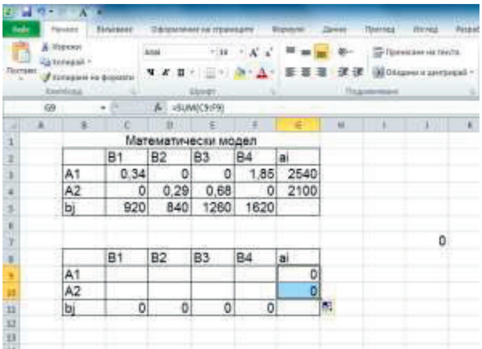

Figure 4. A Dialogue Box expressing the function for summing the quantities of the consumers

And then it is copied to the other cells D11: F11, where a zero value also appears. Similarly, enter a formula for cell G 9 and copy to cell G 10.
When compiling the formula, it is necessary to use absolute addressing of the cells that contain the variables of the task (the $ sign is placed in front of the column name and/or the row number).
For large tasks, it is convenient to use the built-in function, SUMPRODUCT, which calculates a scalar product of two vectors of equal dimension (Figure 4).

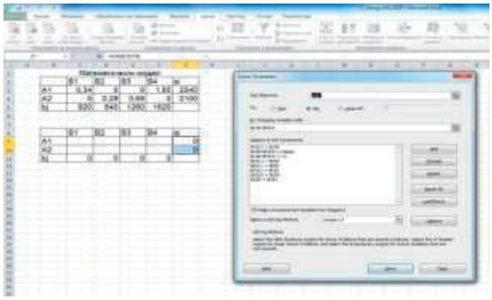

Figure 5. "Solver Parameters" dialog box

After entering the input data and activating the formula from the menu Data → Solver, an empty Solver Parameters dialog box opens, in which the formula for calculating the value of the target function is shown in Figure 5.
It is recommended that the cell with the target function be current before calling Solver - in this case cell $ J $ 7.
In Equal to the radio button corresponding to the criterion of the model is selected, in the specific task Min is selected.
In by Changing Cells, the cells in which the values of the task variables are located are entered. In the specific task, these are the cells $ C $ 11: $ F $ 13 which minimize the target function.
In the field Subject to the Constraints the restrictive conditions are entered through the buttons located next to it - in this case Add, or change by the Change button and deletion of already existing restrictions by the Delete button.
When you click the Add button, a dialog box with restrictive conditions appears.
The Add Constraint dialog box consists of the following fields:
Cell Reference - enter the cells on the left side of the restriction conditions. Several restrictions of the same type can be introduced at the same time.
Constraint type: <=, =,> =.
Constraint - enter the cells on the right side of the restrictive conditions.

After the current restriction has been entered, the Add button is selected if a new restriction is to be entered, or OK if the entry is completed.
We check the Make Unconstrained Variables Non-Negative option because all variables in the task must meet a non-negative condition. It is not recommended to change the other items in the dialog box. Finally, with the OK button we return to the Solver Parameters dialog box.
In Figure 5. the Solver Parameters dialog box for the considered task is shown.
From the Solver Parameters dialog box, select the Solver button to perform the task. The solution of the problem is shown in Figure 6.

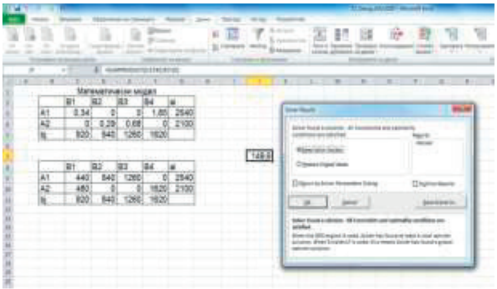

Figure 6. The spreadsheet and the dialog box Solver Results

The Solver Results dialog box provides information about the result of the performed optimization. In the present case, it turns out that for the obtained solution all restrictive conditions and optimality conditions are satisfied. The optimal solutions are from the \$ C \$ 9: \$ F \$ 10 cells and an optimal plan is obtained $L_{min} = 149.6$.
The Solver Results dialog box allows you to save the optimal solution found (with the Keep Solver Solution button) or to restore the original appearance of the worksheet (with the Restore Original Values radio button).
From this dialog box it is possible to create a report on the solution of the task (Answer Report).
Based on the proposed description and the presented solution of a transport problem in the environment of MS Excel, by using the capabilities of MS Excel Solver, the following conclusions can be made:
The proposed algorithm for describing a transport task and its subsequent solution, using MS Excel Solver, is easily applicable;
The use of software applications significantly speeds up computational procedures;
The considered functionality of the "Solver" add-on can be used both for solving transport-type tasks and for solving tasks in other areas as well.

CONCLUSIONS

The following conclusions can be drawn from the present study:
• The proposed algorithm for describing a transport task and its subsequent solution, using software applications significantly speeds up computational procedures and is an easily applicable method for optimization.
• Through the optimization the transport costs for fertilization are minimized to BGN 149.6.
• In view of the load on the equipment owned by the farm, it could increase its arable land or offer services with fertilization equipment to other farmers.

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FORMATION AND IMPLEMENTATION OF THE AGRICULTURE SUSTAINABLE DEVELOPMENT STRATEGY UNDER ECONOMY DIGITALIZATION CONDITIONS

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Abstract

A sustainable development strategy is a compromise between multidirectional targets: social, economic and environmental. It is formed at the state level and is reflected not only in agricultural and regional policy, but also in other areas of the country's socio-economic development. Moreover, sustainability is becoming a guiding principle for development at all levels of management and planning. The main trend in the sustainable development strategy of the Russian Federation is digitalization. This direction is aimed at introducing and improving the use of new technologies in all spheres of the state's life. Agriculture in the Russian Federation has always been one of the most important areas in the economy, so technological development is very important. The main directions of digitalization of agriculture should be: the use of unmanned aerial vehicles, smart tractors and combines, GIS technologies, rural e-commerce, distance learning in education and professional retraining of agricultural specialists in the agricultural business, the development of all kinds of IT services in social life.

Key words: *agriculture, directions, digitalization of the economy, strategy.*

INTRODUCTION

Attainment sustainable development goals requires the introduction of a wide range of new technologies, especially in the field of agriculture. One of the most promising technological trends in the agricultural sector is digitalization, which can significantly affect the growth of crop yields, increase labor productivity, reduce production costs, stimulate the implementation of sustainable land use practices and, in general, harmonize the operation of food systems.

Digitalization in agriculture includes robotics technologies, big data analysis, artificial intelligence, e-commerce.

Assuming systemic changes, the digitalization of agriculture can facilitate the simplification of relations between agricultural producers and the state (facilitating document circulation, obtaining preferential loans, gaining access to digital platforms), improving the situation in the supervision and certification of products, environmental control, and the development of the educational sphere.

In Russia, in recent years, much attention has been paid to the development of the digital economy in general and digital agriculture in particular. So, in 2019, a national project was approved "Digital Economy of the Russian Federation" and a departmental project has been developed "Digital agriculture", one of the goals of which is the introduction of digital technologies and platform solutions to ensure a technological breakthrough in the agro-industrial complex and achieve a 2-fold increase in productivity at digital agricultural enterprises by 2024.

The rapid and widespread introduction of digital technologies in modern conditions requires a conceptual and methodological substantiation of the modernization process, taking into account the peculiarities of the transition to the digital economy, including by identifying the degree of readiness of agribusiness entities and the system of sectoral digital transformation management. The digitalization of the economy is primarily focused on improving efficiency and competitiveness. Thanks to digitalization, the costs of servicing the production of products are reduced (by 10.0-40.0%), equipment downtime (by 30.0-50.0%), time to market (by 20-50%) and maintenance costs. product quality (by 10.0-20.0%), storage costs (by 20.0-50.0%), etc. (Shumilina, 2020).

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Over the past five years, under the influence of geopolitical factors, agriculture has become a driver of the domestic economy, while not being a high-tech type of economic activity and not showing a significant increase in productivity and labor efficiency. The digital inequality of territories, manifested in unequal access to digital infrastructure, does not allow the use of a uniform standard set of measures for different regions and territorial entities.

Along with the basic conditions, there are a number of important factors contributing to the digitalization of agriculture:

- the use by farmers and extension workers of the Internet, mobile and social networks;
- the rural population has the skills to use digital technologies;
- a cultural environment that encourages rural entrepreneurs to adopt digital technologies and innovations.

Building a digital agriculture ecosystem requires an enabling environment for farmers and entrepreneurs to embrace innovative approaches. In particular, funding is increasing and cooperation is expanding within the framework of agricultural digitalization projects, startups are beginning to attract the interest of international investors and the media. (Digital technologies).

MATERIALS AND METHODS

Rural territories of the Russian Federation are the country's most important resource, the value of which is rapidly growing in the context of deepening globalization, while the importance of natural and territorial resources is increasing.

The development of rural areas is extremely uneven. Despite the dynamic growth of the agro-industrial complex, the level and quality of life of the rural population as a whole lag significantly behind the standard of living in cities, the population's access to the services of social organizations is narrowing, the information and innovation gap between urban and rural areas is deepening, which leads to an increase in the migration outflow of rural population, to the loss of development of rural areas.

The strategy for sustainable development of rural areas of the Russian Federation (Order of the Government, 2015) for the period up to 2030 is aimed at creating conditions for ensuring a stable improvement in the quality and standard of living of the rural population based on the advantages of the rural lifestyle, which will preserve the social and economic potential of rural areas and ensure their fulfillment national functions - production, demographic, labor resource, spatial and communication, preservation of the historical and cultural foundations of the identity of the peoples of the country, maintenance of social control and development of rural areas.

RESULTS AND DISCUSSIONS

The agricultural sector, which occupies a dominant position in the rural economy, is multifunctional and not only produces marketable products, but also ensures the reproduction of socially significant values that are not always quantifiable or valued. (Kukharev, 2015). The agricultural sector makes a decisive contribution to maintaining the vitality of rural areas, preserving the agricultural landscape and cultural heritage, preserving agrobiologically diversity and maintaining ecological balance in the biosphere. Agriculture plays an important role in preserving soil fertility and protecting land from erosion and other negative natural and man-made phenomena. These non-food aspects have the characteristics of public goods, but are not traded and cannot be fully measured by market performance criteria.

In 2019, agricultural production increased by 4.0%, amounting to about 5.9 trillion. rubles, including growth in crop production amounted to 6.1%, in animal husbandry - 1.6%. The country's GDP increased by 1.4% in 2019 compared to 2018.

The gross grain harvest in 2018 amounted to 120.7 million tons, the yield of the main oilseeds - sunflower, soybeans and rapeseed - reached a record 22.4 million tons, the production of sugar beet increased by almost 21.0% to 50.8 million also, new records were recorded in the collection of vegetables (14 million tons), fruits and berries (3.4 million tons).

The production of livestock and poultry in live weight at all farms increased by 1.9% to 15.2 million tons. The main driver of the sector is still pig breeding (an increase of 5.1%, which

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amounted to more than 5 million tons). Production of cattle for slaughter increased by 0.8% to 2.8 million tons, poultry - by 0.6% to 6.7 million tons. Production of sheep and goats for slaughter last year decreased by 4.3% up to 462.2 thousand tons. The gross milk yield in 2019 was 2.4% more than in 2018, amounting to 31.3 million tons, including in agricultural organizations - increased by 4.4% and amounted to almost 17 million tons. Egg production last year decreased by 0.1% to 44.86 billion pieces.

Society is interested not only in increasing the level of food self-sufficiency in the country, but also in maintaining the multifunctionality of agriculture, the historical way of life of the rural population, and improving the environment (Fudina, 2020).

Sustainable rural development will ensure the improvement of the rural way of life, the more complete fulfillment by the village of its national functions - production, socio-demographic, cultural, recreational, environmental, social control over the territory, the convergence of living conditions in the city and in the countryside (Figure 1).

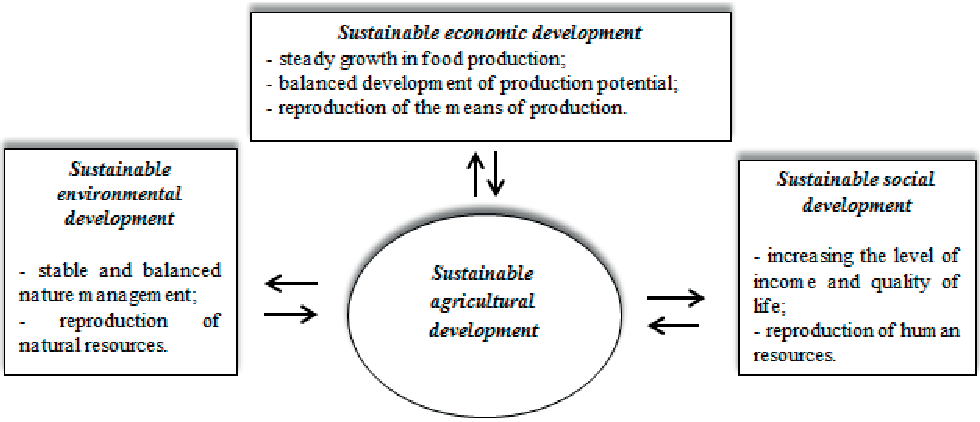

Figure 1. Interrelation of the components of sustainable agricultural development

Agriculture has always been and remains the most important resource of any state, influencing the natural, economic, human and ethnocultural potential. Most regions of Russia have a pronounced agrarian character (Kukharev, 2015). At the same time, the development of agriculture and rural areas is extremely uneven. Multifunctionality of agriculture is one of the components of ensuring national well-being and determines the need for state support in ensuring conditions for sustainable development of rural areas. Agricultural production indices are presented in Table 1.

Table 1. Indices of agricultural production of the leading constituent entities of the Russian Federation in 2019 (in comparable prices; in % to 2018)

Region	Farms of all categories	including		
		agricultural organizations	households	peasant (farming) households, individual entrepreneurs
RUSSIAN FEDERATION	104.0	105.8	98.1	110.2
Krasnodar region	108.3	108.9	99.0	116.1
Rostov region	105.4	103.2	99.7	117.2
Voronezh region	106.1	111.0	95.1	109.3
Chelyabinsk region	97.1	98.9	92.4	101.0
Astrakhan region	101.8	122.3	92.3	105.0
Republic of Tatarstan	103.0	105.2	97.1	120.8
Republic of Bashkortostan	102.0	103.8	98.9	108,7

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The analysis of the development of agriculture in the regional context allows us to note that:
- Krasnodar Territory occupies a leading position in grain collection, as well as 4th place in all other indicators of agricultural development;
- The Rostov region is a leader in fish production (or in the fish industry), is in second place in the ranking for the production of grain and eggs, and is in fifth place in the vegetable and dairy industry;
- Voronezh region - one of the five leaders in grain harvest and potato yield;
- The Chelyabinsk region has high rates of livestock and poultry raising, as well as egg production;
- The Astrakhan region maintains a leading position in the fish and vegetable industries;
- The Republic of Tatarstan and the Republic of Bashkortostan are the leading regions in the production of dairy products and the cultivation of potatoes.

The profitability of crop production in Russia as a whole from 2005 to 2019 increased 2.9 times and reached 32.4% in 2019.

The level of profitability in animal husbandry is lower than in crop production, which is explained by significant costs and disparity in prices for raw materials of livestock products. For the same period 2005-2019, in Russia, profitability increased from 4.7% to 12.8%.

In the period from 2005 to 2019, the ratio of the shares of products in the total volume of production in farms of all categories changed by 6.5 percentage points, namely, the share of crop production increased from 47.8 to 54.3% and the share of animal husbandry decreased from 52.2 to 45.7%. Moreover, in agricultural organizations, crop production is 43.2%, and livestock - 57.4% of the total; in households - 22.3% and 38.7%, respectively. It follows from this that agricultural organizations are of decisive importance in the development of the agro-industrial complex and the life support of the rural population.

The efficiency of production of grain and leguminous crops per organization increased by 33.5% and amounted to 55.0 thousand centners; per 1 hectare of harvested area - by 20.1% to 16.7 centners/ha. Also, the yield of potatoes increased by 3.2%, perennial grasses for hay by 26.5%.

The efficiency of milk production per organization increased by 40.5%, or 333.8 centners, on average, but per 100 hectares of agricultural land, this figure decreased by 7.4%, or 4.3 centners.

In animal husbandry, the second important area is the raising of animals and poultry for meat. In the dynamics over the past 13 years, the cultivation of livestock and poultry for slaughter in live weight as a whole decreased by 4.4% and in 2019 amounted to 222.5 thousand tons. This was mainly due to a decrease in the number of animals in households and peasant (farm) farms, as a result, the production of livestock and poultry for slaughter in live weight decreased by 41.4% (or 45.7 thousand tons) and 18.7% (or 1.4 thousand tons), respectively. At the same time, it should be noted a significant increase in this indicator in agricultural organizations, which amounted to 32.1%, or 36.9 thousand tons, which indicates the development of not only dairy, but also beef cattle breeding. In the period from 2005 to 2019, the total volume of meat production in Russia increased by 33.0%. This was mainly due to an increase in the production of poultry meat by 4.0 times, as well as an increase in the production of semi-finished meat products by 2.4 times. At the same time, during the analyzed period, there is a significant reduction in the production of chilled and frozen cattle meat by 84.2%.

In recent years, activities aimed at import substitution have been actively carried out as a response to the current anti-Russian sanctions (Fudina, 2018). A wide range of whole milk products is produced in Russia, including not only drinking milk, but also fermented milk products (kefir, fermented baked milk, bifidok and others), butter, cheese and raw products, cottage cheese and ice cream. In the total volume of manufactured products, it should be noted that the producers of cheese and dairy products benefited from the imposed sanctions, their production volumes in 2019, compared to 2005, increased by 4.5 and 2.4 times, respectively. The production of butter for the same period increased slightly - by 5.6%.

In the rating of the regions of the Volga Federal District in terms of the index of the physical volume of agricultural production, the Penza region occupies a leading place (Table 2).

Table 2. Indices of agricultural production of the constituent entities of the Volga Federal District (for January-September 2019 (in farms of all categories; in comparable prices; as a percentage of 2018)

Region	December 2019			
	January-August		January-September	
	IFO	rating	IFO	rating
Penza region	113.3	one	117.9	one
Mari El Republic	107.4	2	110.7	2
Saratov region	95.5	8	106.6	3
Republic of Mordovia	100.3	four	105.8	four
Samara Region	*	-	105.6	five
Perm Territory	*	-	102.9	6
Republic of Tatarstan	100.2	five	102.5	7
Ulyanovsk region	*		102.5	8
Udmurt republic	99.2	7	102.4	9
Nizhny Novgorod Region	101.4	3	102.3	ten
Chuvash Republic	*	-	102.0	eleven
Kirov region	*	-	101.5	12
Republic of Bashkortostan	99.3	6	100.0	thirteen
Orenburg region	92.7	9	93.5	14

CONCLUSIONS

Thus, digitalization, being the basis of socio-political and economic sustainability, leads to optimization of management processes, improvement and increased transparency of political processes, increased efficiency and competitiveness in all types of economic activity, provides the creation of high-performance jobs, contributes to the development of social infrastructure and the preservation of the environment. Wednesday.

A new technological standard of work is being formed in the agricultural regions. "Smart" technologies are fundamentally changing the possibilities and conditions of management, which ensures the preservation of rural areas, improves the demographic situation.

The future of agricultural regions is sustainable development, high quality of life of the population based on constant technological progress and comprehensive digitalization.

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METHODS FOR DETERMINING EXPENSES OF HORIZONTAL DRAINAGE UNDER PRODUCTION CONDITIONS

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Abstract

Currently horizontal drainage is a key ecological reclamation measure aimed at regulating water and salt regimes of soils, especially under conditions of irrigated agro-landscapes. Taking this measure becomes especially important under conditions of global and regional climate change. The operating conditions for horizontal drainage have changed resulting in changes in its efficiency. It is especially important for durable drainage, when its efficiency decreases it could even stop functioning. It requires a considerable number of research activities, but very few Ukrainian farmers can carry out monitoring research on the performance of horizontal drainage, constructed on their plots. It prevents from finding out negative aspects in horizontal drainage in time and taking appropriate measures. These difficulties can be avoided in case of using the developed and approbated methodology of recovering a number of horizontal drainage expenses through expenses of the research plots, determining the performance of horizontal drainage by these results and developing appropriate ecological reclamation measures to increase productivity of irrigated drained agro-landscapes.

Key words: *horizontal drainage, drainage outflow, methods for recovering expenses.*

INTRODUCTION

Land reclamation in the modern context is a system of economic organizational and technical measures, aimed at comprehensive improvement of lands to create the most favorable conditions for agricultural development or general improvement of a territory. There are hydro-technical, agro-technical, forest-engineering, chemical measures and land clearing operations depending on the operating conditions and their effect on plants and soil (Lavrenko et al., 2014).

Changing water and air regime of soil, agricultural hydro-technical reclamation (irrigation, watering and drainage) has the most considerable impact on improving environmental conditions. With this aim, large and small irrigation and drainage canals, pipelines and chutes, storage reservoirs and dams are constructed. Implementing hydro-technical reclamations is associated with considerable investments therefore it requires technical and economic argumentation. The highest efficiency of reclamation is achieved while using a complex of measures when irrigation is combined with drainage and drainage is accompanied by periodical land irrigation (Beauchamp, 1987; Bueno et al., 2020; Doke et al., 2020; Helmers, 2016; Panuska, 2015; Schwab & Fouss, 1999; Shakya & Singh, 2010; Zinkernagel et al., 2020).

A similar situation is examined in the studies of many other scientists (Bueno et al., 2020; Doke et al., 2020; Mahapatra et al., 2020; Wahba & Amer, 2017; Wojewodzic et al., 2020; Zucker & Brown, 1998). Such a balanced approach allows applying drainage water to irrigate agricultural crops (corn, rice etc.) systematically and efficiently, using natural resources more effectively. This approach requires additional financial resources to support the performance, maintenance and updating of the system of drainage operation (Dementieva & Lavrenko, 2017; Dementieva & Lavrenko, 2018; Dementieva & Lavrenko, 2018; Lavrenko et al., 2019; Lavrenko et al., 2019; Lykhovyd et al., 2019; Ushkarenko et al., 2018).

While using drainage systems it is important to maintain them. The research conducted in a tile-drained field in Harrow, Ontario from June 2008 to December 2011 shows that the application of Simultaneous Heat and Water (SHAW) model to improve its hydrological responses to cold climates makes it possible to evaluate drainage performance and its impact on productivity of

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agricultural crops accurately with error within 15%, Nash-Sutcliffe model efficiency coefficient (NSE) > 0.5 and the index of agreement (IoA) > 0.75 (Qianjing et al., 2020).

Considering infiltration processes and the impact of polluted groundwater, inefficient land use, vegetation cover and agro-physical soil properties is also an important element for efficient use of drainage systems (Mahapatra et al., 2020).

Currently the efficiency of reclamation systems has decreased considerably. The reason for this phenomenon is a great number of factors, the first of them being out-of-date systems. A large number of mistakes have been found out in the process of exploitation and the need of correcting them may cause considerable financial expenses (Balyuk & Romashchenko, 2006; Golovanov et al., 2011).

Nowadays designing and using the systems of agricultural modeling is a main factor for analyzing the problem and assessment of quantitative impact of management methods in agricultural production. The application of such methods allows obtaining quick information to determine the most efficient management method (Singh et al., 2020).

Restoration and professional application of drainage will allow using land resources efficiently, taking reclamation measures (irrigation, drainage) effectively, perform soil desalinization, minimizing the risk of polluting groundwater (Luthin, 1957; Savchuk et al., 1992; Zinkernagel et al., 2020).

Currently, taking into account the economic condition of farms, agro-ecological conditions and institutional factors, scientists think that it is necessary to stimulate commodity producers in making decisions, ensuring appropriate management of land resources to increase agro-ecological sustainable agricultural production (Abera et al., 2020).

In Ukraine, whose considerable part is located in the zones of unsteady and insufficient moisture, the largest area (2.6 million ha) was occupied by irrigated lands at the beginning of the 90s in the past century, making 8% of the tilled soil area. At that time the real productivity corresponded to its planned level for almost 80% of the irrigated lands, and crop production was up to 30% of its gross production in Ukraine, and irrigated lands played the role of a peculiar insurance fund in food supply of the country, especially in dry years because of a high level of their exploitation.

Irrigation against the background of horizontal drainage is an obligatory factor of maintaining soil fertility on territories without outflows and poorly drained territories, including the South of Ukraine. A reliable method for preventing secondary soil salinization is closed horizontal drainage. Engineering drainage must provide optimal water and salt regimes and the balance of both irrigated land and surrounding landscape. The character and intensity of changes in hydrogeological ecological reclamation condition of irrigated lands of Ukraine prove the necessity of permanent control over ecological reclamation condition of irrigated lands, including reclamation efficiency of horizontal drainage. However, the regime of horizontal drainage operation has changed. Its performance is considerably affected by regional climate change. It requires permanent monitoring research that is ignored under present production conditions, there are time intervals when the efficiency of horizontal drainage operation has not been evaluated. The emergence of this problem explains the topicality of the research given below.

Under conditions of arid climate in the South of Ukraine, closed horizontal drainage is a necessary measure to prevent salinization of both irrigated lands and the adjacent dry lands on irrigated territories with poor natural drainage. When there is a lack of drainage under the water table of 1.5-2.0 m and its mineralization of 5-20 g/dm^3 within the aeration area in the course of 10 and more years of irrigation under conditions of the South of Ukraine, salts accumulate up to 20-100 t/ha (Tupitsin et al., 1987), causing an increase in the amount of secondarily salinized soils.

The regime of closed horizontal drainage operation depends on the degree of soil salinization, the type of an agricultural crop and the availability of irrigation. Mineralization of drainage water depends on the value of drainage outflow, caused by infiltration feeding from irrigation and precipitation, soil salinization in the aeration zone that changes in the course of time, mineralization of groundwater that is the most stable factor.

The main indicator of reclamation efficiency of horizontal drainage is drainage outflow. However, when the lands are shared and there are changes in land owners, not every land owner (or a farmer) is able to continue monitoring research with respect to the performance of horizontal drainage, constructed on their production plots (PP). It, in its turn, allows identifying negative aspects in drainage operation in time and taking appropriate measures.

It can be avoided at certain stages of agro-landscape development, when using the developed and approbated methodology of recovering a number of horizontal drainage expenses through expenses of research plots (RP) and determining the performance of horizontal drainage by these results and taking appropriate ecological reclamation measures to increase productivity of irrigated drained agro-landscapes.

The research purposes. To determine monthly and annual expenses of horizontal drainage empirically on the basis of modeling hydrographs of drainage outflow by selected data.

MATERIALS AND METHODS

In order to conduct our research, we chose and equipped research plots with well-known history. The main research method was a complex field agricultural experiment of many years. The undrained and drained territories are characterized by general direction of groundwater rises and falls in different periods of a year, but the height of rises and the duration of water table position at certain depth are different. It requires a comprehensive approach to choosing research plots. Research objects are located within Kherson (Henichesk district) and Crimean (Dzhankoi district) Prysyvashshia, the Right Bank (Chaplynka district) and the Left Bank (Bilozerka district) of the Dnipro within Kherson region and are typical by the generally accepted methods (Figure 1).

The regime of groundwater on all the research plots with horizontal drainage by a genetic type, according to the world-famous and generally accepted classification by Katz D.M. (Katz, 1976), is referred to the irrigation-climatic group and characterized by mainly one peak and one fall per year. The lack of outflows on the most research territories shows that this territory is hardly suitable for irrigation without additional measures (drainage), because it is potentially dangerous in terms of flooding. The research plots are located in the zone of moderately hot, arid climate. Dark chestnut and chestnut soils comprise the main fund of farmlands, prevailing on the research territory.

Figure 1. The scheme of the location of the research plots with horizontal drainage: 1 - Henichesk district, Pavlivka; 2 - Dzhankoi district of Crimea, Aprelivka village; 3 - Chaplynka district, Strohanivka;
4 - Bilozerka district, Stanislav

The research on irrigated and drained plots covers a wide range of issues: water and salt processes in soils, improvement of drain construction elements, soil desalinization, determination of optimal parameters of drainage, reclamation efficiency of drainage, productivity of agricultural crops.

Drainage outflow, being one of the main components of water balance on a drained territory and an indicator of reclamation efficiency of horizontal drainage, has been examined on the research plots with the drain spacing of 240 m, 300 m and 400 m under the equal drain depth of 3 m.

Drainage outflow and its dynamics were determined by the data on measuring drain expenses with a volume method in wellhead that were performed with three replications every decade (on the 10th, 20th, and 30th days of every month) and additionally in a day and in three days after each irrigation over a drain or after substantial (more than 20 mm) rain. Using the measurement data, we determined water expenses and modules of drainage outflow for typical periods of drainage operation by months and periods of the year.

The research was conducted on the territory of Kherson Prysyvashshia (Henichesk district) with the following approbation on other RP. The error of the complex research did not exceed 3.0-4.3%.

Irrigation on all the research plots was performed using the closed internal network DMF-K «Frehat», «Western Irrigation», Zimmatic 434M.

The main method used in the research was an approximation method with the following interpolation of the desired values on the basis of the analysis of the hydrographs of drainage outflow.

RESULTS AND DISCUSSIONS

The main preconditions for developing the methodology were the basic characteristics of drainage outflow and the factors affecting its changes.

It is well-known that drainage outflow depends on groundwater head between drains (Duplyak et al., 1992; Oleynik, 1981; Savchuk et al., 1992) and, at the same time, it affects changes in water tables as a result of water-diversion purpose of drainage.

The analysis of drainage outflow on each research plot with different drain spacing shows that there was a decrease in its value on all the plots in 2009-2019.

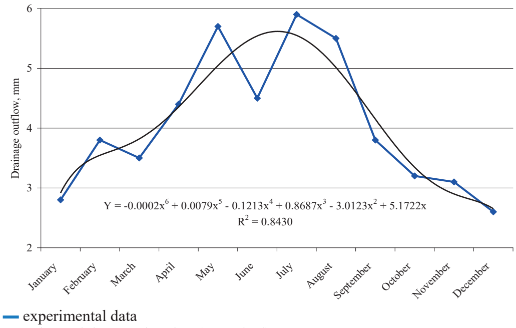
As the research shows, the change in drainage outflow (and the module of drainage outflow) does not depend on the amount of precipitation in the years of the research, but it mainly depends on irrigation norm and the location of water tables. The provision (P, %) of the annul amount of precipitation in Kherson Prysyvashshia in the research period varies considerably from P = 96.0% in 2011 to P = 12% in 2019.

The calculated value of drainage outflow for a closed internal irrigation network is 0.040-0.045 l/s from 1 ha. On the whole, the module of drainage outflow for the research zone is a value varying considerably from 0.05 to 0.25 l/s from 1 ha.

The annual outflow of drainage water is 10–15% of the total water intake of irrigation water from a source of irrigation. The maximum of outflow coincides with the total rise of water tables in the regions and makes 30-40% of the annual drainage outflow. Annually from 700 to 2000 m^3 is taken from 1 hectare.

The analysis of the modules of drainage outflows for each research plot with different drain spacing shows that the direction of changes in the modules of drainage outflow on the research plots with B = 240 m and B = 400 m coincides, however, the value of the module of drainage outflow on the plot with B = 400 m is 2.0 times higher than on the plot with B = 240 m.

These research plots are characterized by a decrease in the value of the module of drainage outflow in the second period of the research by 2.4 times with its following stabilization. The value of the module of drainage outflow is almost unchangeable - 0.038 l/s from 1 ha on the research plot with B = 300 m in the research period (Figures 2 to 9).



Note: the plot of the horizontal drainage with the drain spacing a - B = 240 m.

Figure 2. Hydrograph of drainage outflow for a calendar year on the research plots with horizontal drainage (the average for 2016-2019)

The analysis of drainage outflow on each research plot with different drain spacing shows that there was a decrease in its value on all the plots in the course of 10 years.

Maximum values of the module of drainage outflow (l/s from 1 ha) and drainage outflow (mm) for all the drains under study were characteristic of the year with much precipitation (the beginning of the research – by the efficiency of the horizontal drainage performance), and minimum values were recorded in the last period of the research - 2016-2019.

For the period of 2016-2019, in order to examine the distribution of drainage outflow, correspon-ding hydrographs were created (Figures 2 to 9)

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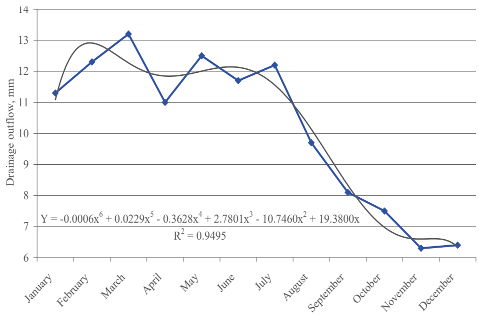
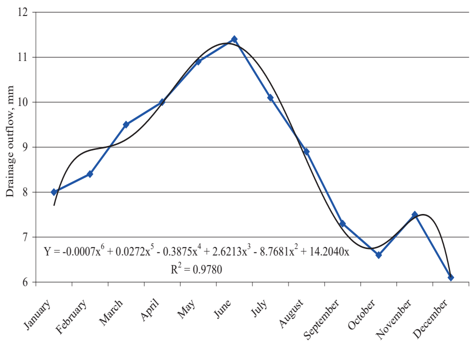
(the research was conducted under the following conditions: 2016 - large amount of precipitation, 2017 - medium amount of precipitation; 2018 - small amount of precipitation; 2019 - large amount of precipitation).

The hydrographs were created by taking into consideration a calendar year (the 1st-12th months) and a hydrological year (the 9th-3rd months) of the distribution of drainage outflow.



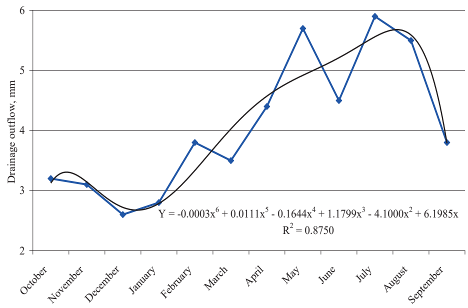
experimental data
polynomial approximation (smoothed) curve
Note: the plot of the horizontal drainage with the drain spacing a - B = 300 m.

Figure 3. Hydrograph of drainage outflow for a calendar year on the research plots with horizontal drainage (the average for 2016-2019)



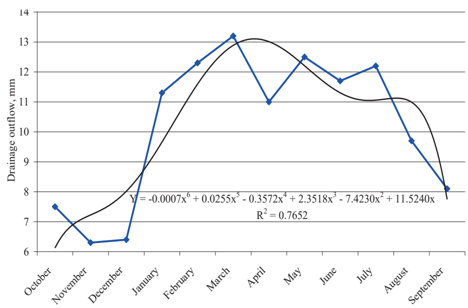
experimental data;
polynomial approximation (smoothed) curve
Note: the plot of the horizontal drainage with the drain spacing a - B = 400 m

Figure 4. Hydrograph of drainage outflow for a calendar year on the research plots with horizontal drainage (the average for 2016-2019)



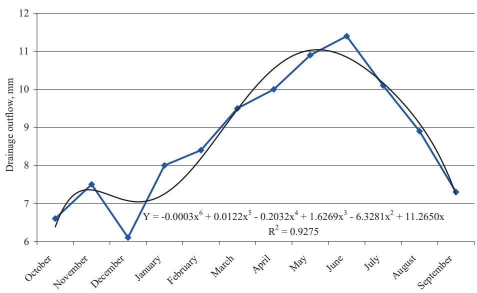
experimental data
polynomial approximation (smoothed) curve
Note: the plot of the horizontal drainage with the drain spacing a - B = 240 m.

Figure 5. Hydrograph of drainage outflow for a hydrological year on the research plots with horizontal drainage (the average for 2016-2019)



experimental data;
polynomial approximation (smoothed) curve
Note: the plot of the horizontal drainage with the drain spacing a - B = 300 m

Figure 6. Hydrograph of drainage outflow for a hydrological year on the research plots with horizontal drainage (the average for 2016-2019)



experimental data;
polynomial approximation (smoothed) curve
Note: the plot of the horizontal drainage with the drain spacing a - B = 400 m

Figure 7. Hydrograph of drainage outflow for a hydrological year on the research plots with horizontal drainage (the average for 2016-2019)

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When analyzing the drainage outflow, we used an approximation method with the following drawing a trend line and determining the value of approximation reliability (R^2). The polynomial trend line proved to be of the highest quality. The obtained results for determining the approximation reliability value for the hydrographs of drainage outflow with different drain spacing for the hydrological and calendar years are presented in Table 1.

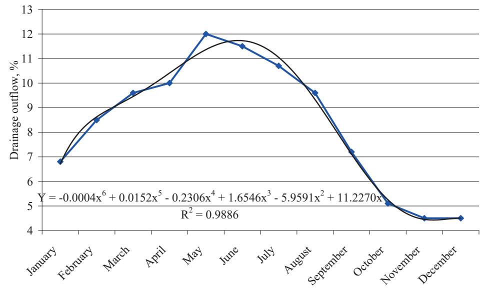
Table 1. Values of approximation reliability (R^2) for hydrographs of drainage outflow with different drain spacing for hydrological and calendar years

Years	Drain spacing, m					
	240		300		400	
	Hydrological year	Calendar year	Hydrological year	Calendar year	Hydrological year	Calendar year
2016	0.779	0.730	0.782	0.964	0.947	0.943
2017	0.883	0.923	0.907	0.881	0.651	0.932
2018	0.441	0.324	0.426	0.796	0.963	0.960
2019	0.755	0.841	0.862	0.982	0.972	0.978
The average	0.875	0.843	0.765	0.950	0.928	0.978

On the plots with the drain spacing of 240 m there is uneven distribution of drainage outflow during both hydrological and calendar years (R^2=0.324-0.923), indicating to inhomogenous drainage outflow, especially in the first years after construction. On the plots with the drain spacing of 300 m there is uneven drainage outflow for the hydrological year (R^2 = 0.426-0.907) and an increase in its uniformity for the calendar year (R^2 = 0.796-0.982). On the plots with the drain spacing of 400 m there is an increase in its uniformity for the hydrological year (R^2 = 0.651-0.972) and the distribution is almost uniform for the calendar year (R^2 = 0.932-0.978).

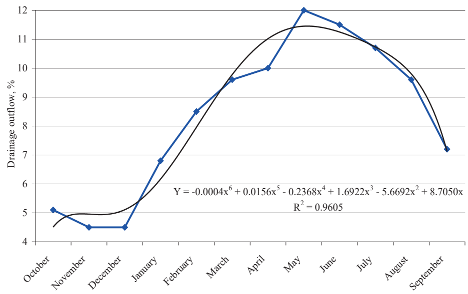
It is confirmed by the comparison of hydrographs of drainage outflow for calendar and hydrological years on the research territory (Figures 8 and 9).

Thus, with an increase in drain spacing, drainage outflow, despite different amount of precipitation in the years of the research, becomes more uniform and determining the distribution of drainage outflow under conditions of a calendar year becomes the most topical task in order to solve the research problem.



experimental data;
polynomial approximation (smoothed) curve

Figure 8. Hydrograph of drainage outflow for a calendar year for the research territory with horizontal drainage



experimental data;
polynomial approximation (smoothed) curve

Figure 9. Hydrograph of drainage outflow for a hydrological year for the research territory with horizontal drainage (the average for 2016-2019)

Therefore, the hydrograph of drainage outflow characterizing the average percent distribution of drainage outflow in the course of a year can be used for ascertaining the value of drainage outflow in the field production crop rotations for a certain period of time by its selective measurements.

Further the research problem is solved with interpolating the desired values using the following correlations.

1. Recovering annual expense

1.1. A direct problem. Annual expense is determined by the correlation 2:

$$Q_{PP} = \sum_{i=1}^{n=11} q_X^{PP} + \sum_{i=1}^{n=11} q_i^{PP} \quad (1)$$

$$\frac{\sum_{i=1}^{n=12} q_i^{RP}}{\sum_{i=1}^{n=11} q_i^{PP}} = \frac{\sum_{i=1}^{n=12} q_X^{RP}}{\sum_{i=1}^{n=11} q_X^{PP}} \quad (2)$$

where:

- Q_{PP} - the annual expense on the production plot;

- $\sum_{i=1}^{n=11} q_i^{PP}$ - the sum of known monthly expenses on the production plots (PP);
- $\sum_{i=1}^{n=11} q_X^{PP}$ - the sum of unknown monthly expenses on the PP;
- $\sum_{i=1}^{n=12} q_X^{RP}$ - the sum of monthly expenses of the RP with the indexes corresponding to the indexes of unknown monthly expenses on the PP;
- $\sum_{i=1}^{n=12} q_i^{RP}$ - the sum of monthly expenses of the RP with the indexes corresponding to the indexes of known monthly expenses on the PP.

The correlation (1) results in:

$$\sum_{i=1}^{n=11} q_X^{PP} = \frac{\sum_{i=1}^{n=11} q_i^{PP} * \sum_{i=1}^{n=12} q_X^{RP}}{\sum_{i=1}^{n=12} q_i^{RP}}$$

Therefore:

$$Q_{ВД} = \sum_{i=1}^{n=11} q_X^{PP} + \sum_{i=1}^{n=11} q_i^{PP}.$$

1.2. An indirect problem. Annual expense is determined by the correlation 3:

$$\frac{\langle Q^{RP} - \sum_{i=1}^{n=12} q_i^{RP} \rangle}{\langle Q^{PP} - \sum_{i=1}^{n=11} q_i^{PP} \rangle} = \frac{\sum_{i=1}^{n=12} q_i^{RP}}{\sum_{i=1}^{n=11} q_i^{PP}}$$

Consequently,

$$Q^{PP} = \frac{\langle Q^{RP} - \sum_{i=1}^{n=12} q_i^{RP} \rangle * \sum_{i=1}^{n=11} q_i^{PP}}{\sum_{i=1}^{n=12} q_i^{RP}} + \sum_{i=1}^{n=11} q_i^{PP} \quad (3)$$

2. Recovering a number of monthly expenses

Having a number of these expenses of the RP and some monthly expenses of the PP, we can determine monthly expenses of the PP by the correlation 4:

$$x_n = \frac{\langle Q^{PP} - \sum_{i=1}^{n=11} q_i^{PP} \rangle * \langle \sum_{i=1}^{n=12} q_i^{RP} + y_n \rangle}{\langle Q^{RP} - \langle \sum_{i=1}^{n=12} q_i^{RP} + y_n \rangle} \quad (4)$$

where:

- Q^{RP}- the annual expense on the research plot;
- $x_n = q_n^{PP}$- the expense on the production plot for n-month;
- $y_n = q_n^{RP}$- the expense on the research plot for n-month.

It is necessary to start determining the desired monthly values of drainage outflow from the peak values on the hydrograph: for the year with small amount of precipitation – from maximum peak values, for the year with large amount of precipitation – from minimum peak values.

CONCLUSIONS

The research results make it possible to establish that it is necessary to use the distribution of drainage outflow as a basis for the compared values under conditions of a calendar year to solve the research problems. It allows increasing accuracy of the desired values on typical production drainage plots by 15-18% (depending on drain spacing) in comparison to the distribution of drainage outflow under conditions of a hydrological year.

The calculations show that the relative error for two known values of drainage outflow expenses on the production drainage plots makes 10-11%. At the same time, the relative error makes 4-5% for eleven known values of drainage outflow expenses. Application of this methodology will allow evaluating the current state of agro-landscapes to develop and implement timely ecological reclamation measures aimed at its improvement, with minimum research expenses (reduction by 80%) and less time (up to 20 minutes when using the computer program developed on the basis of this methodology).

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ASSESSMENT OF ECONOMIC LOSSES CAUSED BY DEGRADATION PROCESSES OF AGRICULTURAL LAND USE

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Abstract

The instability and excessive intensity of modern agriculture's systems are the result of a number of unresolved environmental and economic problems. The main purpose of our study is to assess the economic losses caused by degradation processes within the research facility. Comparing the current cost of future losses from unreceived agricultural products by years while maintaining the existing rate of land degradation, which is 1070.45 thousand UAH, with the total cost of CAOT on erosion-hazardous areas within Kamyanobrid village council Lysyansky district of Cherkasy region - 798.85 thousand UAH, it is possible to determine the economic efficiency of land protection measures in the long run, which is equal to 271.60 thousand UAH, because the arrangement of CAOT elements allows to preserve the existing state of land resources, stop degradation processes and prevent reduction of agricultural production.

Key words: *economic losses, degradation processes, land use, agricultural land, land degradation.*

INTRODUCTION

The instability and excessive intensity of modern agriculture's systems are the result of a number of unresolved environmental and economic problems. As a result of reorganization of land use of agricultural organizations, the current state of agricultural production is in crisis, primarily due to the fact that land distribution was carried out without ecological and landscape justification, therefore, erosion resistance of territories was broken, land management projects regarding the formation crop rotation are not developed, the balance of individual elements of agro landscapes is disturbed, including the ratio of area arable land, natural lands, forest and water resources, etc. (Openko, 2019; Openko, 2019).
As a result of the use of inefficient approaches to the organization of the territory, there is soil compaction, loss of humus and imbalance of soil nutrients, which leads to reduced soil fertility and land degradation. Thus, in Ukraine, the annual losses of crop production from land degradation exceed 9-12 million tons of grain, and the total loss reaches more than $ 10 billion per year, which hinders the economic development of the state (Ievsiukov, Openko, 2014; Kryvoviaz et al., 2020; Tarariko, 1998).

MATERIALS AND METHODS

According to Krasnianska O.V. (2011), ecological and landscape organization of the territory is a set of land management measures or actions that lead to the formation or ordering of a concrete part of the earth's surface (land tenure, land use) with the establishment on it the order of land use, as well provide as creating a stable, sustainable, capable to self-reproduction of the landscape with their own unique properties (optimal ratio of lands, structure of crops, etc.) with appropriate specific production, social and environmental goals.
Recently, significant development received the adaptive-landscape approach has been significantly developed, which is carried out taking into account the category of agro-landscape and its main morphological units (Kiryushin, 2000).

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Implementation of the landscape approach is realized with the help of soil protection system of agriculture with contour-ameliorative organization of the territory (here in after CAOT), which provides the most rational use of land resources, as well as protection of soils from degradation (Martyn et al., 2019; Openko et al., 2020; Openko et al., 2020; Openko et al., 2019).

The essence of the CAOT is to bring the existing agro landscape to the appropriate environmental requirements through the differentiated use of land resources; more complete consideration of the strip structure of natural complexes; contour organization of land use territory; creation of a field hydrographic network by introducing permanent anti-degradation measures into the agroecosystem (different types of water regulating shafts, creation of meadows on watercourses, creation field protective forest belts); application of soil protection methods of tillage; of optimization of ratio in agro landscapes of intensive agriculture, natural phytocenoses and water spaces (Tarariko, 1990).

According to Shvebs H. I. (1985), the basis of the CAOT is the differentiated use of arable land, taking into account the terrain by dividing them into three ecological and technological groups (hereinafter ETG).

The first ETG includes arable land with full-profile and weakly eroded soils located on the plateau and slopes up to 3°, the nature of the terrain and the quality condition of which allows to place grain-row crop rotations, if necessary, with optimal allowable saturation with sugar beets, corn and sunflower.

The second ETG includes arable land located on slopes from 3° to 5° in a complex with weakly and average eroded soils, where soil protective grain-grass and grass-grain crop rotations with complete exclusion of row crops are design. Restoration of soil fertility is carried out due to saturation of crop rotations with perennial grasses (up to 50% and more), application of maintenance doses of fertilizers and introduction of soil-protective technologies of soil cultivation.

The lands of third ETG include slopes with a steepness of more than 5°, with medium- and strongly-eroded soils, where it is difficult to perform basic technological operations of cultivation of even grain crops. It is expedient to remove them from composition of arable land permanently, followed by creation of meadows or afforestation (Shelyakin et al., 1990; Shvebs, 1985).

The essence of the division of arable land into ecological and technological groups is the differentiated use of land resources and crops by optimizing the structure of sown areas and crop rotations, taking into account the ratio of technological groups of land.

The main purpose of our study is to assess the economic losses caused by degradation processes within the research facility on the example of Kamyanobrid village council of Lysyansky district of Cherkasy region (Figure 1).

RESULTS AND DISCUSSIONS

Using scientific developments N.M. Sheliakin, V.A. Belolipskyi ta I.N. Holovchenko (1990) taking into account the change in the value of soil erosion coefficient depending on the terrain (slope steepness and slope length) (Figure 2), the forecast of land use dynamics in the study area for the next 50 and 100 years was determined (Figures 3 and 4).

The analysis of the obtained results showed that further use of lands without a system of land protection measures will increase the area of eroded lands in relation to non-eroded ones. There will be observed a decline in soil quality, which will lead to a loss of ecological balance of the agro landscape.

Ukraine State Service of Geodesy, Cartography and Cadastre annually by the consumer price index for the previous year calculates the coefficient of the indexation of regulatory monetary value of land, which is indexed normative monetary valuation of land and land. The calculation is carried out according to the formula:

$$Ki = i : 100, \qquad (1)$$

where: i - consumer price index for the previous year.

The use of coefficients of indexation of monetary valuation of land (3.2) for the valuation of arable land (1.756) allowed establishing the normative monetary valuation of 1 ha of arable land of Zhashkiv natural-agricultural district of

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Cherkasy region (Letter from the State Agency of Land Resources of Ukraine, 2014; Resolution of the Cabinet of Ministers of Ukraine, 2011). Predicting the indicators of land valuation, using the scores of soil quality, for 50 and 100 years, the level of depreciation of arable land was determined (Table 1).

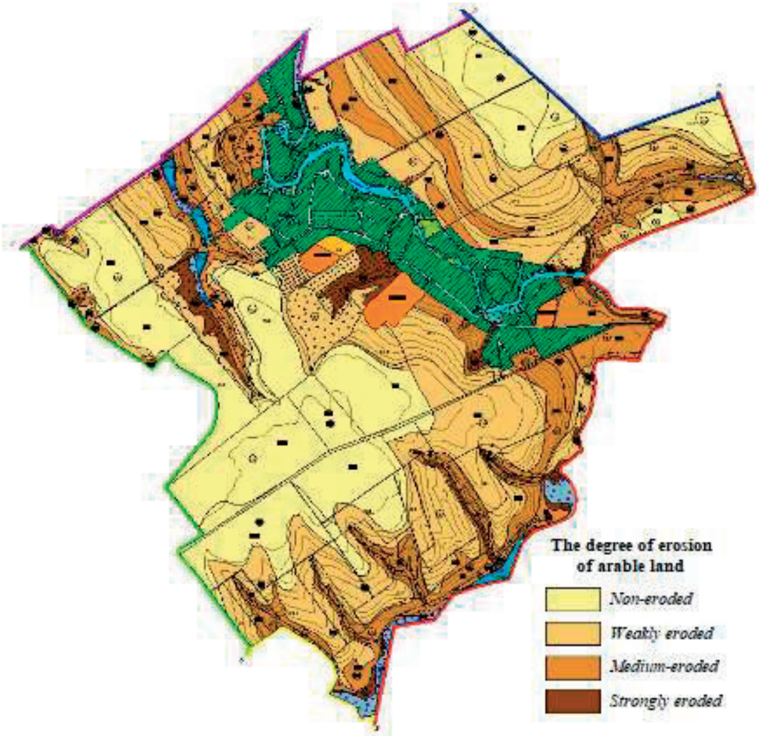

Figure 1. The current state of land resources of Kamyanobrid village council of Lysyansky district of Cherkasy region
Source: own developments

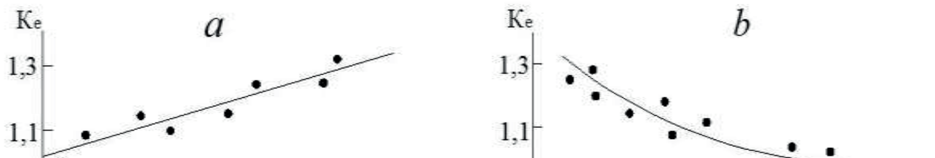

Figure 2. Change in the value of the coefficient of erosion of the soil cover (Ke) depending on:
a) the slope; b) slope lengths (Openko, 2019)

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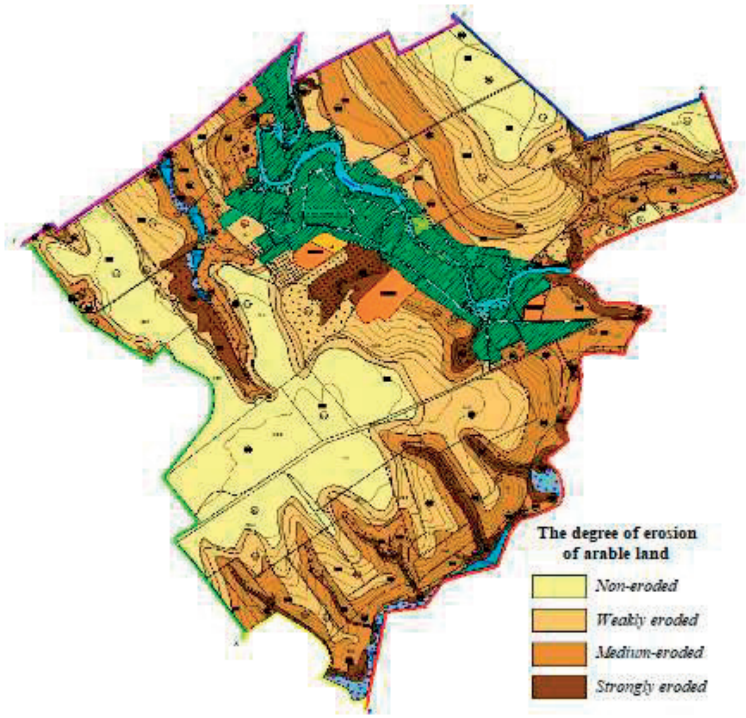

Figure 3. Geoinformation model of the state of land resources of Kamyanobrid village council of Lysyansky district of Cherkasy region in 50 years. Source: own developments

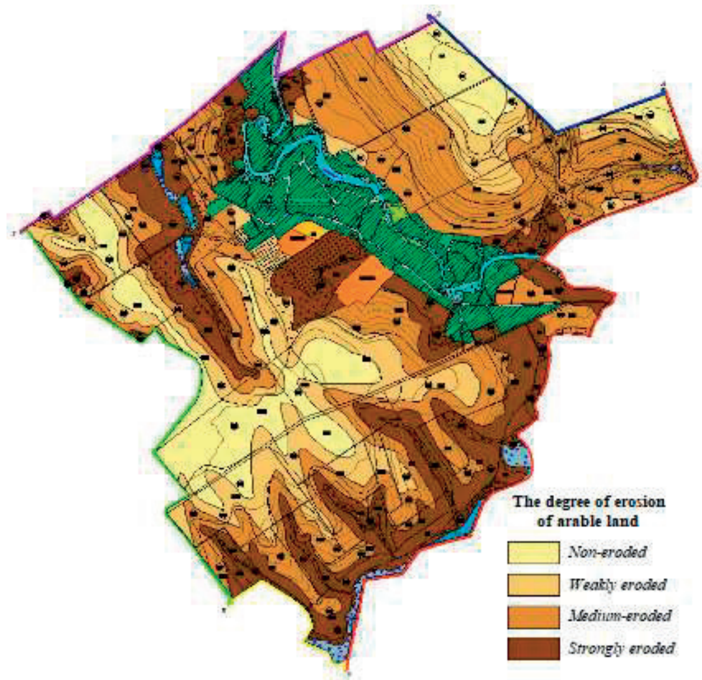

Figure 4. Geoinformation model of the state of land resources of Kamyanobrid village council of Lysyansky district of Cherkasy region in 100 years. Source: own developments

Table 1. Monetary valuation of arable lands of Kamyanobrid village council of Lysyansky district of Cherkasy region

Codes of agricultural groups of soils	Area agricultural groups of soils, ha	Scores of quality of agricultural groups of soils	The general score of quality in the natural-agricultural area (NAA) 06 of Cherkasy region	Normative monetary value of 1 ha of arable land of Zhashkiv NAA, UAH	Normative monetary value of 1 ha of agricultural soil group, UAH	Normative monetary valuation of the entire area of the agricultural group of soils, UAH
The existing cost of arable land						
209d	93.1	82	71	34288.36	39600.64	3686819.69
41d	613.3	67			32356.62	19844315.91
40d	10.9	64			30907.82	336895.21
55g	824.2	61			29459.01	24280118.94
52g	363.0	53			25595.54	9291179.69
49d	104.6	53			25595.54	2677293.10
50d	23.8	41			19800.32	471247.63
57g	58.7	37			17868.58	1048885.76
56g	237.6	32			15453.91	3671848.71
139d	6.6	24			11590.43	76496.85
141	21.9	14			6761.09	148067.76
215d	8.7	9			4346.41	37813.78
Total	2366.4					65570983.05
The cost of arable land in 50 years						
209d	67.10	82	71	34288.36	39600.64	2657203.02
41d	514.10	67			32356.62	16634539.07
40d	8.40	64			30907.82	259625.67
55g	690.00	61			29459.01	20326719.33
52g	281.70	53			25595.54	7210262.59
49d	167.60	53			25595.54	4289811.89
50d	35.30	41			19800.32	698951.32
57g	119.20	37			17868.58	2129934.97
56g	395.90	32			15453.91	6118202.47
139d	14.40	24			11590.43	166902.21
141	48.00	14			6761.09	324532.08
215d	24.70	9			4346.41	107356.37
Total	2366.4					60924040.98
The cost of arable land in 100 years						
209d	38.00	82	71	34288.36	39600.64	1504824.36
41d	372.90	67			32356.62	12065784.12
40d	2.50	64			30907.82	77269.54
55g	584.50	61			29459.01	17218793.40
52g	193.9	53			25595.54	4962974.50
49d	182.8	53			25595.54	4678864.04
50d	52.40	41			19800.32	1037536.80
57g	198.20	37			17868.58	3541552.95
56g	494.70	32			15453.91	7645048.65
139d	31.50	24			11590.43	365098.59
141	152.40	14			6761.09	1030389.36
215d	62.60	9			4346.41	272085.38
Total	2366.4					54400221.7

Source: own calculations according to (Shvebs, 1985)

The calculation showed that as a result of the negative impact of degradation processes on the agro-landscape, the monetary value of arable land will decrease by UAH 6.52 million in 50 years, and in 100 years it will decrease by UAH 11.17 million. The production direction of the farm of Kamyanobrid village council is grain and beet with developed animal husbandry, and the specialization is aimed at growing such crops as: winter wheat, sugar beets, winter rye, corn for grain, barley and oats (Table 4). After calculating the amount of unreceived agricultural products, through the score of the quality of major crops, it was found that the damage caused to land by degradation significantly affects the yield of gross agricultural output in the farm. The projected gross agricultural products in 50 years will decrease by 8664.6 quintals, in 100 years the losses will be 36444.2 quintals. Using the statistical data of the State Statistics Service of Ukraine - the average sales prices of agricultural products, installed the size of sales of crop products, both actual and projected for 50 and 100 years.

Using the data from Table 2, namely, the size of sales of crop products, determined the loss from unreceived crop products by year. From these calculations it follows that in 100 years will receive than 4.1 million UAH less agricultural products, and in the amount for 100 years - 168.8 million UAH (Figure 5). Losses from unreceived agricultural products on crops of Kamyanobrid village council are reflected in Table 3.

Table 3. Discounting the value of unreceived agricultural products of Kamyanobrid village council of Lysyansky district of Cherkasy region for a period of 100 years*

Years	Gross output, thousand UAH	The cost of unreceived products, UAH / year	Coefficient discount rate (at a discount rate of 1.167)	The current value of unreceived , UAH	Years	Gross output, thousand UAH	The cost of unreceived products, UAH / year	Coefficient discount rate (at a discount rate of 1,167)	The current value of unreceived, UAH
1	26709.44	-25568.0	1.167	-21909.2	51	25399.89	-1335121.2	2633,987	-506.9
2	26683.87	-51136.0	1.362	-37547.8	52	25343.17	-1391842.6	3073,863	-452.8
3	26658.30	-76704.0	1.589	-48262.0	53	25286.44	-1448563.9	3587,198	-403.8
4	26632.74	-102272.0	1.855	-55140.8	54	25229.72	-1505285.3	4186,260	-359.6
5	26607.17	-127840.0	2.164	-59062.6	55	25173.00	-1562006.6	4885,366	-319.7
6	26581.60	-153408.0	2.526	-60732.7	56	25116.28	-1618728.0	5701,222	-283.9
7	26556.03	-178976.0	2.948	-60715.4	57	25059.56	-1675449.3	6653,326	-251.8
8	26530.46	-204544.0	3.440	-59459.3	58	25002.84	-1732170.7	7764,431	-223.1
9	26504.90	-230112.0	4.015	-57319.4	59	24946.12	-1788892.0	9061.091	-197.4
10	26479.33	-255680.0	4.685	-54574.3	60	24889.39	-1845613.4	10574.294	-174.5
11	26453.76	-281248.0	5.467	-51441.1	61	24832.67	-1902334.7	12340.201	-154.2
12	26428.19	-306816.0	6.380	-48087.0	62	24775.95	-1959056.1	14401.014	-136.0
13	26402.62	-332384.0	7.446	-44639.5	63	24719.23	-2015777.4	16805.983	-119.9
14	26377.06	-357952.0	8.689	-41193.9	64	24662.51	-2072498.7	19612.583	-105.7
15	26351.49	-383520.0	10.141	-37820.3	65	24605.79	-2129220.1	22887.884	-93.0
16	26325.92	-409088.0	11.834	-34568.7	66	24549.07	-2185941.4	26710.161	-81.8
17	26300.35	-434656.0	13.810	-31473.2	67	24492.34	-2242662.8	31170.757	-71.9
18	26274.78	-460224.0	16.117	-28555.8	68	24435.62	-2299384.1	36376.274	-63.2
19	26249.22	-485792.0	18.808	-25828.8	69	24378.90	-2356105.5	42451.112	-55.5
20	26223.65	-511360.0	21.949	-23297.5	70	24322.18	-2412826.8	49540.447	-48.7
21	26198.08	-536928.0	25.615	-20961.8	71	24265.46	-2469548.2	57813.702	-42.7
22	26172.51	-562496.0	29.892	-18817.4	72	24208.74	-2526269.5	67468.590	-37.4
23	26146.94	-588064.0	34.884	-16857.6	73	24152.02	-2582990.9	78735.845	-32.8
24	26121.38	-613632.0	40.710	-15073.3	74	24095.30	-2639712.2	91884.731	-28.7
25	26095.81	-639199.9	47.509	-13454.4	75	24038.57	-2696433.6	107229.481	-25.1
26	26070.24	-664767.9	55.442	-11990.2	76	23981.85	-2753154.9	125136.804	-22.0
27	26044.67	-690335.9	64.701	-10669.6	77	23925.13	-2809876.2	146034.650	-19.2
28	26019.10	-715903.9	75.506	-9481.4	78	23868.41	-2866597.6	170422.437	-16.8
29	25993.54	-741471.9	88.116	-8414.7	79	23811.69	-2923318.9	198882.984	-14.7
30	25967.97	-767039.9	102.831	-7459.2	80	23754.97	-2980040.3	232096.442	-12.8
31	25942.40	-792607.9	120.004	-6604.8	81	23698.25	-3036761.6	270856.548	-11.2
32	25916.83	-818175.9	140.045	-5842.2	82	23641.52	-3093483.0	316089.592	-9.8
33	25891.26	-843743.9	163.432	-5162.6	83	23584.80	-3150204.3	368876.554	-8.5
34	25865.70	-869311.9	190.726	-4557.9	84	23528.08	-3206925.7	430478.938	-7.4
35	25840.13	-894879.9	222.577	-4020.5	85	23471.36	-3263647.0	502368.921	-6.5
36	25814.56	-920447.9	259.747	-3543.6	86	23414.64	-3320368.4	586264.531	-5.7
37	25788.99	-946015.9	303.125	-3120.9	87	23357.92	-3377089.7	684170.707	-4.9
38	25763.42	-971583.9	353.747	-2746.6	88	23301.20	-3433811.0	798427.215	-4.3
39	25737.86	-997151.9	412.823	-2415.4	89	23244.48	-3490532.4	931764.560	-3.7
40	25712.29	-1022719.9	481.764	-2122.9	90	23187.75	-3547253.7	1087369.242	-3.3
41	25686.72	-1048287.9	562.218	-1864.6	91	23131.03	-3603975.1	1268959.905	-2.8
42	25661.15	-1073855.9	656.109	-1636.7	92	23074.31	-3660696.4	1480876.210	-2.5
43	25635.58	-1099423.9	765.679	-1435.9	93	23017.59	-3717417.8	1728182.536	-2.2
44	25610.02	-1124991.9	893.548	-1259.0	94	22960.87	-3774139.1	2016789.020	-1.9
45	25584.45	-1150559.9	1042.770	-1103.4	95	22904.15	-3830860.5	2353592.786	-1.6
46	25558.88	-1176127.9	1216.913	-966.5	96	22847.43	-3887581.8	2746642.782	-1.4
47	25533.31	-1201695.9	1420.137	-846.2	97	22790.70	-3944303.2	3205332.126	-1.2
48	25507.74	-1227263.9	1657.300	-740.5	98	22733.98	-4001024.5	3740622.591	-1.1
49	25482.18	-1252831.9	1934.069	-647.8	99	22677.26	-4057745.9	4365306.564	-0.9
50	25456.61	-1278399.9	2257.058	-566.4	100	22620.54	-4114467.2	5094312.760	-0.8
Всього		32599197.5		1066013.3			136239711.1		4437.9
Losses from unreceived products for 100 years, UAH								168838908.6	
The real value of future losses from unreceived products in prices 2014, UAH								1070451.2	

Source: own calculations

The above data - UAH 168.8 million (see Table 2) are projected funds in 100 years, to actually reflect the damage caused by unreceived agricultural products, we need to determine how much they will cost now. In order to recalculation future income as of today, the mechanism of discounting cash flows is used all over the world, i.e. bringing future cash flows to the present time. The application of the cash flow discounting approach is based on the discount rate (capitalization), which allows you to set the real value of future losses. The discount rate (capitalization) can be determined by such approaches as element-by-element method, extraction method; the method of related investments, the method of cumulative construction (the method of "summation of risks"), the method of Elwood (Dekhtyarenko et al., 2002). In this case, we use the method of cumulative construction, which is calculated through the product of the risk-free rate and the risk of agriculture. The risk-free rate is formed as the average for the year for business entities in foreign currency on foreign currency deposits and commercial banks and is 7.5%. The risk of agriculture is based on the rate of agricultural insurance, for Cherkasy region. The minimum insurance rates for insurance of crops with state support is 9.2%. According to the above data, the coefficient discount rate (capitalization) for agricultural land is 1.167. Taking into account the discount rate, the real value of future losses of the studied territory was determined, which in total of 100 years amounted to UAH 1.07 million.

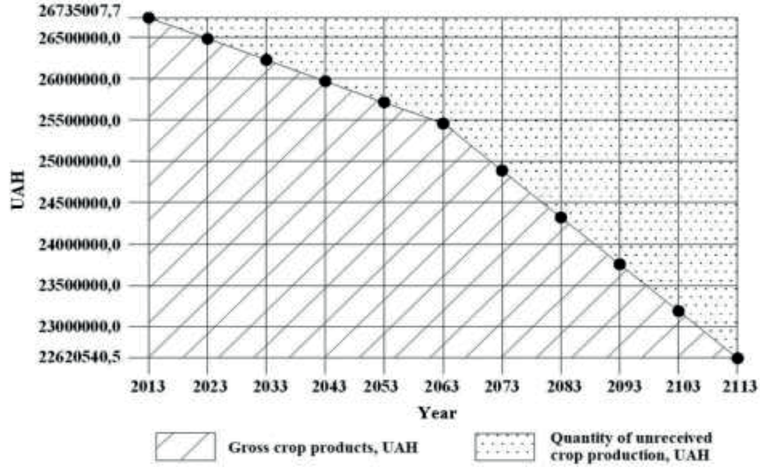

Figure 5. Reduction of agricultural production within the Kamyanobrid village council of Lysyansky district of Cherkasy region while maintaining degradation processes. Source: own calculations.

Table 4. Unreceived agricultural products by cultures of Kamyanobrid village council*

№ п/п	Cultures	Area, ha	The actual size of sales of crop products, UAH	Project size of sales of crop products, UAH (in 50 years)	Project size of sales of crop products, UAH (in 100 years)	Losses from unreceived products for 100 years, UAH
1.	Winter wheat	887.1	8745195.7	8185951.6	7384787.9	62652603.9
2.	Sugar beets	392.8	9472913.0	9348327.9	8374251.1	34245133.5
3.	Winter rye	265.4	1322732.7	1220748.0	1136679.9	9843581.4
4.	Corn for grain	389.2	4803654.2	4529020.3	3745257.1	40720821.1
5.	Barley	280.9	1720865.4	1557510.7	1391581.7	16564469.3
6.	Oat	151.0	669646.7	615049.3	587982.8	4812299.4
Total		2366.4	26735007.7	25456607.8	22620540.5	168838908.6

Source: own calculations.

Based on the above indicates, the need to implement measures to stop degradation processes, as well as to preserve and increase soil fertility is not in doubt. The introduction of the CAOT will contribute to the optimization of lands and the preservation of agro landscape.

CONCLUSIONS

Comparing the current cost of future losses from unreceived agricultural products by years while maintaining the existing rate of land degradation, which is 1070.45 thousand UAH, with the total cost of CAOT on erosion-hazardous areas within Kamyanobrid village council Lysyansky district of Cherkasy region - 798.85 thousand UAH, it is possible to determine the economic efficiency of land protection measures in the long run, which is equal to 271.60 thousand UAH, because the arrangement of CAOT elements allows to preserve the existing state of land resources, stop degradation processes and prevent reduction of agricultural production. The productivity of the agro-landscape depends on the one hand on the soil, relief and other natural and climatic conditions, and on the other hand on the human factor, i.e. on the technology of land use, the introduction of various anti-degradation measures and so on. Therefore, in modern conditions, rational and efficient use of agricultural land involves the implementation of the principle of natural-agricultural adaptability, which is to systematically take into account the natural properties and socio-economic characteristics of land use. Agricultural production should be organized in accordance with the landscape structure of the area, ie should take into account the natural morphological structure of agro landscapes, while maintaining their ability to self-reproduction and natural stabilization.

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THE RELATION BETWEEN THE POWER REQUIRED TO DRIVE A ROTATING VOLUMETRIC PUMP AND THE IRRIGATED AGRICULTURAL AREA

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Abstract

The constructive solution of a rotating volumetric pump with two profiled rotors is presented; each rotor is provided with two triangular-shaped rotating pistons. The calculation relation of the driving power of the volumetric pump is established and the graph $P = f(n_r)$ is drawn. Subsequently, the pump is placed in an "in situ" hydraulic network and the pump load and the water transport distance are specified; linear and local pressure losses are calculated, resulting in total pressure loss. The driving power of the pump is determined and $V = f(n_r)$ and $P = f(n_r)$ is plotted.

Key words: *rotating volumetric pump, profiled rotors.*

INTRODUCTION

This paper belongs to the category of scientific papers that address the field of land reclamation for rotating machines that transports fluids.
There is a type of rotating working machine with profiled rotors that can operate (Dobrovicescu et al., 2009; Băran et al., 2010):
- As a fan, for the circulation of different gas mixtures with or without suspensions;
- As a low-pressure compressor;
- As a rotating volumetric pump for transporting any type of fluid, liquid or gas, namely:
- general fluids: water, air, steam, etc.;
- polyphase fluids: water + air, water + sand, water + ash, etc.;
- viscous fluids: oil, diesel, oil, etc.

The advantage of the rotating working machine is that the entire motor torque received from the driving motor is used to transport the fluid.
Table 1 presents a classification of rotating machines (Dobrovicescu et al., 2009; Băran et al., 2010).
The construction of rotating working machines (pumps, fans, blowers) with high performance is topical.
The researches aim to build machines that ensure the transformation of the motor torque received from the shaft into useful effects, but with energy losses as small as possible.

Table 1. A general classification of rotating machines

According to the pursued purpose	Depending on the constructive solution	According to the working parameters
Working machines	With profiled rotors	a) Fans, blowers, pumps
	With pallets	b) Fans, blowers
Force machines	With profiled rotors	c) Internal combustion engines, steam or gas engines, pneumatic engines
	With pallets	d) Steam turbines, gas turbines

The construction of rotating working machines (pumps, fans, blowers) with high performance is topical.
The researches aim to build machines that ensure the transformation of the motor torque received from the shaft into useful effects, but with energy losses as small as possible.
Table 2 presents the classification of rotating machines with profiled rotors according to the intended purpose and the adopted constructive solution (Dobrovicescu et al., 2009).
A more difficult problem is to make a rotating machine that can be used as a working machine or as force machine, i.e., theoretically to be a "reversible" machine (Motorga, 2011; Băran et al., 2012).
Such a type of machine must ensure:

- transforming the useful moment with minimal losses, when it operates as a working machine;
- full use of the working agent's energy to drive the shaft when it is working as a power machine.

Table 2. Classification of rotating machines with profiled rotors

According to the pursued purpose	Depending on the constructive solution
Working machines	Fans for the circulation of gases or vapors
	Blowers for gas and vapor compression
Force machines	Hydraulic motors
	Pneumatic motors
	Steam or flue gas engines

Volumetric pump architecture and the operating principle

Figure 1 shows the sketch of the demonstration model of the rotating machine with two profiled rotors, a constructive solution that allows the height of the rotating piston (z) to aim at the rotor radius (R_r). It is noted that, in order to prevent "reverse flow", a central portion of 4 mm thick of the rotor was left.

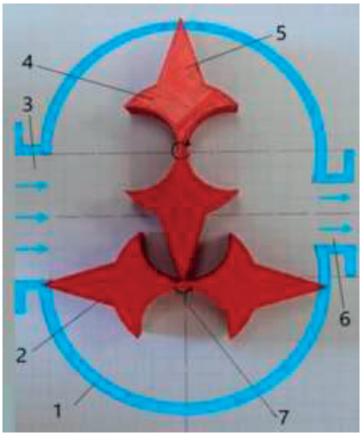

Figure 1. Cross section through the demonstration model of the rotating machine with two profiled rotors:
1- machine case; 2- lower rotor; 3- fluid suction connection; 4- upper rotor; 5- rotating piston; 6 - fluid discharge connection; 7- cavity into which the piston of the upper rotor enters

In (Stoican Prisecaru et al., 2021), the relation between the rotor radius of the and the height of the rotating piston was established, where the maximum value of the height of the rotating piston should be equal to the rotor radius ($z = R_r$).

Basically, this condition can be partially fulfilled because:
- if $z = R_r$, then the fluid can flow in the "reverse direction" from discharge to suction between the gaps between the two rotors; $z < R_r$ is chosen;
- the shafts on which the rotors are fixed must disappear.

This is possible by attaching the rotors to the gearwheels (Figure 2).

The gears fixed to the rotors by screws, ensure the synchronous rotation of the rotors.

A single gearwheel attached to the lower rotor has a driving shaft that takes power from the outside from an electric motor.

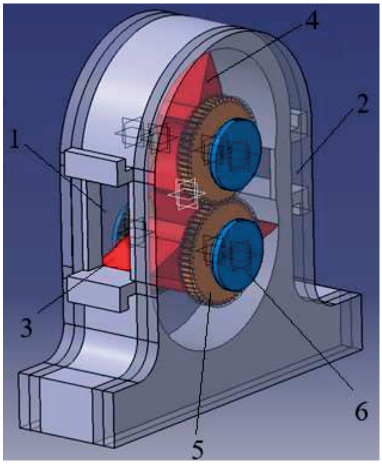

Figure 2. Axonometric view of the volumetric rotating machine model with profiled rotors:
1 - suction chamber; 2 - discharge chamber; 3 - lower rotor; 4 - upper rotor; 5 - gearwheels; 6 - sealing caps

Figure 3 shows the operation of the rotating volumetric pump with profiled rotors. One can observe that after a 180° rotation, the useful volume of the transported fluid (V_u) is discharged into the discharge chamber.

The useful volume is the volume between two pistons and the case (Figure 3.a).

When operating as a rotating volumetric pump with profiled rotors, two volumes (V_u) will be transported from the suction to the discharge at a complete rotation of the shaft.

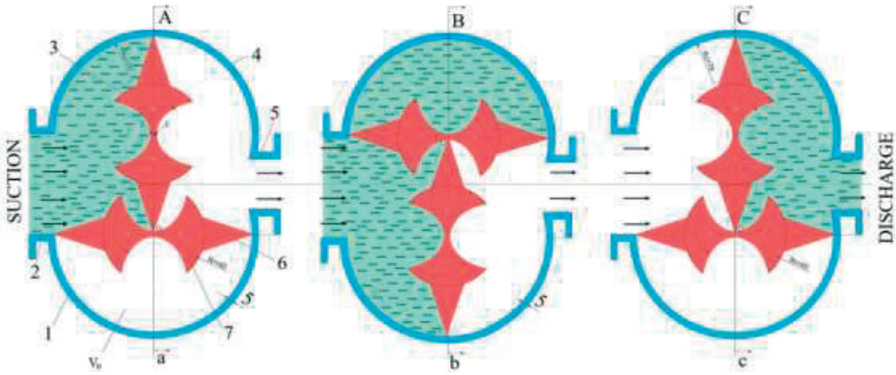

Figure 3. Operating principle of the rotating volumetric machine
1 - lower case; 2 - fluid suction connection; 3 - upper rotor;
4 - upper case; 5 - fluid discharge connection; 6 - rotating piston; 7 - lower rotor.

Determination of the driving power of the rotating volumetric pump with two profiled rotors

The theoretical driving power of the rotating pump for the three constructive solutions can be calculated as follows (Bansal, 2005; Băran et al., 2008):

$$P = \dot{V} \cdot \Delta p \ [W] \tag{1}$$

The increase in total pressure achieved by the rotating pump (*Δ*p) changes as the pump speed increases; the hydrostatic load and pressure losses that occur on the hydraulic circuit of the pump are evaluated at about 4 mH_2O (Isbăşoiu, 2011):

$$\Delta p = \rho_{H_2O} \cdot g \cdot H = 10^3 \cdot 9.81 \cdot 4 = 0.3924 \cdot 10^5 \ [Pa] \tag{2}$$

where:

* $\dot{V}$ - volumetric flow rate [m^3 / s];
* Δp - pressure increase [N /m^2];
* ΔH - pumping height [m];
* ρ_l - density of the circulated fluid [kg /m^3].

In [9], the calculation relation of the volumetric flow rate of the fluid transported by the pump was established:

$$\dot{V}_u = \left[\pi l z\left(z+2R_r\right) - V_p\right] \cdot \frac{n_r}{30} \ [m^3/s] \tag{3}$$

where n_r is the rotating machine speed [rpm].

Substituting relation (3) and (2) in relation (1) one can obtain:

$$P = \dot{V} \cdot \Delta p = \left[\pi \cdot l \cdot z \cdot (z+2R_r) \cdot \frac{n_r}{30} - \dot{V}_p\right] \cdot \Delta p \ [W] \tag{4}$$

Substituting l = 0.05 [m], R_r = 0.04 [m], z = 0.038 [m], n_r = 100… 500 [rpm] and $\Delta p = 0.3924 \cdot 10^5 \ [Pa]$, the values of the flow rate and the theoretical driving power of the rotating pump are presented in Table 3.

Table 3. The values of the flow rate and the theoretical driving power of the rotating pump depending on the speed

n_r [rpm]	100	200	300	400	500
$\dot{V}$ [m^3/h]	8.1058	16.211	24.317	32.423	40.529
P [W]	88.353	176.70	265.06	353.41	441.76

One can observe that $P_m = f(l, z, R_r, n_r, \rho l, \Delta H)$.

Based on the data in Table 3, the graphs in Figures 4 and 5 were constructed.

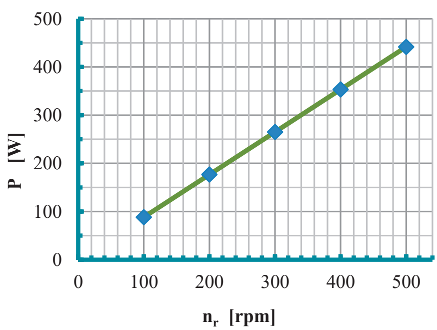

Figure 4. Variation of the theoretical driving power of the pump depending on the speed

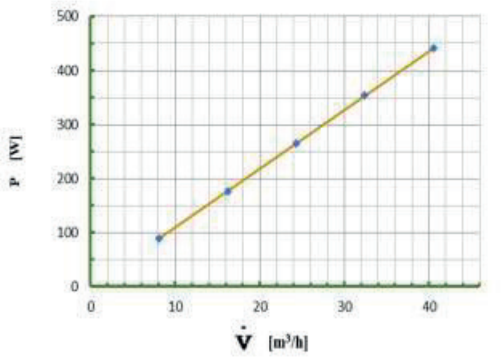

Figure 5. Variation of the theoretical driving power of the pump depending on the flow rate

Figures 4 and 5 show a linear dependence of the theoretical driving power of the pump depending on the speed and the flow rate.

Establishing the connection between the theoretical driving power of the rotating volumetric pump and the irrigated agricultural area

For a certain geometry of the irrigation system, it is necessary to know:
1. The flow rate required for a single watering;
2. Irrigation network architecture:
- The length of the straight pipe sections for which, the following are calculated:
*linear pressure losses are calculated with the relation (1):

$$\Delta p_{lin} = \lambda \frac{\sum l_i}{d} \rho \frac{w^2}{2} \left[N/m^2 \right] \quad (5)$$

*local pressure losses (elbows, tee-joints, changes in water flow section) are calculated by the relation:

$$\Delta p_{loc} = \sum_{i=1}^{n} \xi_i \rho \frac{w^2}{2} \; \left[N/m^2 \right] \quad (6)$$

*the total pressure loss will be:

$$\Delta p_{tot} = \Delta p_{lin} + \Delta p_{loc} \; \left[N/m^2 \right] \quad (7)$$

The pump load will be: $\rho g H_{AB} + \Delta p_{tot}$.

Figure 6 shows the technological scheme of an irrigation system.

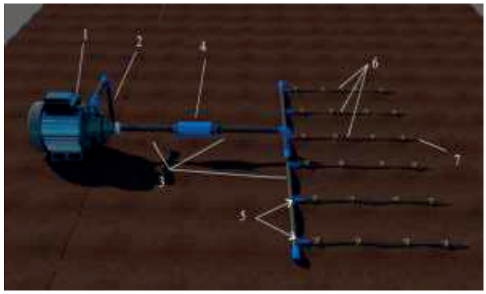

Figure 6. Technological scheme of an irrigation system:
1 - water pump; 2 - water source; 3 - distribution pipe;
4 - filtration-fertilization unit; 5 - connectors;
6 - drip tube; 7 - plugs

Calculation of the water flow rate required for watering and the driving power of the pump

It is considered an agricultural land area of 1 hectare. Watering is once a day with 10 l/m^2.
So, $10^4 \cdot 0.010 = 100 \; \left[m^3/day \right]$ are needed.

Watering time per square meter - 5 minutes.
The volumetric flow rate will be:

$$\dot{V} = \frac{100 \; m^3}{300 \; s} = 0.33 \; [m^3/s] \quad (8)$$

The main water distribution pipe (3) will have a diameter (d). The speed of the water in the pipe is $w = 1.5 \left[m/s \right]$.

$$\dot{V} = A \cdot w = \frac{\pi d^2}{4} w \quad (9)$$

$$d = \sqrt{\frac{4\dot{V}}{\pi w}} = \sqrt{\frac{4 \cdot 0.33}{\pi \cdot 1.5}} = 0.28 \left[m \right] \quad (10)$$

The pipe is made of steel for which the roughness is [1]: $\varepsilon = 0.2 \left[mm \right]$; $\frac{d}{\varepsilon} = \frac{0.28}{0.2 \cdot 10^{-3}} = 1400$

$$\mathrm{Re} = \frac{wd}{\nu} = \frac{1.5 \cdot 0.28}{1 \cdot 10^{-6}} = 420000 \quad (11)$$

From the diagram (9): $\lambda = f\left(\mathrm{Re} \frac{d}{\varepsilon} \right) = 0.01$.

Linear pressure losses with l = 2 km = 2000 m, transport length.

$$\Delta p_{lin} = \lambda \frac{l}{d} \rho \frac{w^2}{2} \left[N/m^2 \right] \quad (12)$$

$$\Delta p_{lin} = 0.01 \cdot \frac{2000}{0.28} \cdot 10^3 \cdot \frac{1.5^2}{2} = 80.357 \cdot 10^3 \left[N/m^2 \right] \quad (13)$$

$$\Delta p = 80357 \left[N/m^2 \right] = 0.8 \left[bar \right]$$

Local pressure losses plus the suction = 0.8 + 0.2 = 1 bar are also added.
Local losses are due to elbows, changes in flow section, valves, etc. It is estimated that these losses plus the pressure drop for suction (H = 10 m) are of the order of 0.2 bar = 20 mH_2O.
The theoretical power of the pump will be:

$$P = \dot{V} \cdot \Delta p = 0.33 \cdot 1 \cdot 10^5 = 33000\ [W] = 33\ [kW] \quad (14)$$

To transport 0.33 m^3 /s: l = 0.2 m, R_r = 0.15 m, z = 0.1 m are chosen:

$$\dot{V} = \pi l z \left(z + 2R_r\right) \cdot \frac{n_r}{30} = 0.000837 \cdot n_r \left[m^3 / s\right] \quad (15)$$

$$0.333 = 0.000837 \cdot n_r \Rightarrow n_r = 397.8 \approx 400 [rpm]$$

So, for l = 0.2 m, R_r = 0.15 m, z = 0.1 [m] and n_r = 400 [rpm]:

$$\dot{V} = 0.000837 \cdot n_r = 0.334 \left[m^3 / s\right] \quad (16)$$

In relation (14) and (16) the number n_r = 100-500 rpm is replaced and the values of the flow rate and the driving power of the rotating pump are presented in Table 4.

Table 4. The values of the flow rate and the driving power of the rotating pump depending on the speed

n_r [rpm]	100	200	300	400	500
$\dot{V}$ [m^3/s]	*0.0837*	*0.1674*	*0.2511*	*0.3348*	*0.4185*
P [W]	8370	16740	25110	33480	41850

Based on the data in Table 4, the functions $\dot{V} = f(n_r)$ and $P = f(n_r)$ from Figures 7 and 8 were plotted.

Figures 7 and 8 show a linear dependence of the theoretical driving power of the pump depending on the speed and on the transported flow rate.

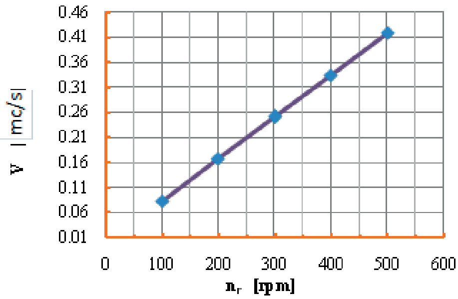

Figure 7. Graphical representation of the function $\dot{V} = f(n_r)$ for different pump speeds

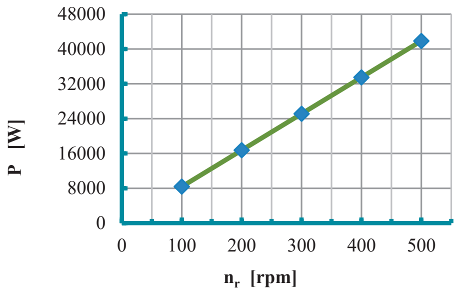

Figure 8. Graphical representation of the function $P = f(n_r)$ for different pump speeds

CONCLUSIONS

Compared to working machines with reciprocating pistons used for transporting the same fluid flow rate, the energy consumption is lower in the case of rotating machines with profiled rotors, because the motor torque at the shaft level is almost entirely transmitted to the transported fluid.

Because $P = \dot{V} \cdot \Delta p$, the power required to drive the rotating machine will also increase.
When the rotational speed of the machine increases, the fluid flow rate increases linearly accordingly.
The volumetric pump with profiled rotors has an increased reliability and can be used in the field of land reclamation, in wastewater treatment plants, in: mining, energy, petrochemical industry.

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ENERGY AND RESOURCE SAVING, LABOR AND ENVIRONMENTAL PROTECTION DURING RUNNING-IN AUTOMOTIVE-TRACTOR DIESEL ENGINES BY USING NEW TECHNOLOGIES AND MEANS FOR THEIR IMPLEMENTATION

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Abstract

The article is devoted to the problem energy and resource-saving, labor and environmental protection during running-in automotive-tractor diesel engines. To solve this problem, new testing technologies have been developed and implemented: separate running-in, additional running-in, hot running-in diesel engines by dynamic loading in and cold running-in by static-dynamic loading. The essence of the proposed technologies is disclosed, methods for calculating fuel consumption and the number of harmful substances in exhaust gases are presented. Technical means for the implementation of the proposed technologies are presented: automated control systems for running-in diesel engines with dynamic loading, systems for increasing gas loads and air recirculation when implementing the technology of separate running-in and device for cold running-in diesel engines by static-dynamic loading. As a result of comparative experimental studies of the proposed running-in technologies, a high quality of running-in diesel was established with a significant reduction in capital and operating costs, reduce the total energy consumption by 4 ... 5 times and reduce diesel fuel consumption by 2…3 times and emissions of harmful components in exhaust gases compared with standard running-in technologies.

***Key words**: labor and environmental protection, diesel engine, running-in, energy saving technologies, automated control systems, loading.*

INTRODUCTION

At present, enterprises engaged in the production, maintenance and repair of agricultural machinery are faced with rather high requirements for the quality of their products and compliance with legislation in the field of environmental protection.
When operating the machine and tractor fleet of the agro-industrial complex (AIC) of the country, the urgent tasks are to reduce the cost of maintaining, restoring and repairing equipment, ensuring normal working conditions for personnel and meeting the environmental safety requirements of the technologies, equipment and machines used.
Most of the mobile energy machines of the agro-industrial complex are equipped with diesel internal combustion engines (ICE), the improvement of the quality of repair of which is ensured by correctly performed running-in, which is the final operation of the technological process of production, overhaul or current repair of the internal combustion engine.
The technologies used for running in internal combustion engines are complex and laborious processes that have a number of technical, economic and environmental drawbacks, and therefore the development of new effective technologies for running in and means for their implementation is an urgent task of great national economic importance.

MATERIALS AND METHODS

Running-in diesel engines is an important component of the technological process of repair and production, which largely determines the efficiency of their operation during subsequent operation. In the process of running-in, there is a mutual running-in of movable couplings of mechanisms, correction of micro- and macro geometric deviations of their shape, an increase in the contact area of surfaces and a decrease in friction forces; faulty assemblies and parts, deficiencies in assembly and adjustment operations are identified.

Typical ICE run-in technologies are implemented using stationary electric break-in and brake stands. They provide cold running, hot running at idle speed, hot running under load at recommended conditions, as well as after running-in tests of diesel engines. A full-fledged technological run-in ensures the compliance of the main technical, economic and environmental indicators of diesel engines with the standard values during subsequent operation and a greater, up to 30%, service life of their work in comparison with non-rolled ones.

Carrying out the running-in according to standard technologies requires the presence of special sections at the enterprises for it carrying out, equipped with expensive running-in test and auxiliary equipment, is associated with a significant consumption of fuel and electricity, is accompanied by a high level of noise and vibrations, a significant emission of harmful substances with the exhaust gases of the internal combustion engine in atmosphere.

As a result of the research and development work carried out, the authors have developed and investigated a number of new technologies for running in internal combustion engines and means for their implementation, including separate running-in, additional running-in and alternative to standard ones.

The essence of separate running-in lies in the fact that after assembling the engines on conveyors or running-in sections, at the factories-manufacturers of automotive equipment and repair enterprises that carry out its overhaul, only their cold running-in is carried out with gas loads increased up to two or more times and with crankshaft cranking frequencies, shaft, up to nominal values for additional, the last stages, and hot running-in and testing is carried out after their installation on machines using the dynamic loading method (DN) and autonomous attachments, for example, at storage areas for equipment (RF patent, 2000).

To implement this method, a system for increasing the pressure of the end of air compression in the internal combustion engine cylinders has been developed, the diagram of which is shown in Figure 1. It contains a receiver 1, connected to the outlet 2 and inlet 3 of the internal combustion engine manifolds, compressor 4, pressure gauge 5, bypass flap 6, inlet flap 7, air cleaner 8, valve 9 for pressure regulation in receiver 1, line 10 for the release of excess air with oil separator 11.

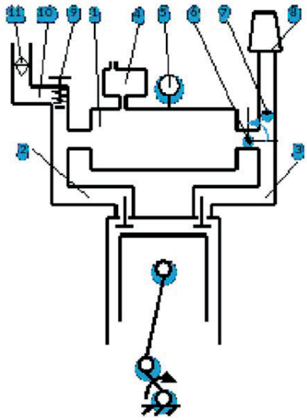

Figure 1. System for increasing the pressure of the compression end: 1 - receiver; 2, 3 - exhaust and intake manifolds, respectively; 4 - compressor; 5 - manometer; 6 and 7 - bypass and intake flaps;
8 - air cleaner; 9 - control valve; 10 - line of release of excess air, 11 - oil separator

At the first stages of cold running, typical modes are implemented, with compressor 4 off, bypass flap closed, and flap 7 and valve 9 open. At the additional, last stages, compressor 4 is turned on, the bypass damper is open, damper 7 is closed, and valve 9 maintains the pressure required for this stage in the receiver and at the inlet of the internal combustion engine, providing the design pressure of the end of air compression and the load on the parts and interface of the internal combustion engine.

Increased load-speed modes of cold running-in make it possible to ensure the necessary loading of ICE interfaces, to identify shortcomings in their production or repair, to remove the hot running-in of ICEs from the production area of enterprises, to obtain a higher degree of running-in of interfaces and, as a result to reduce the duration and number of stages of the subsequent hot run-in with LP, which leads to fuel savings and a reduction in emissions of harmful substances into the atmosphere.

Reducing the running-in wear, increasing the running-in efficiency and the absence of harmful emissions is ensured by the developed method of cold running-in with static-dynamic hydraulic impulse loading (SDP) of ICE interfaces (RF patent, 2007).

The essence of the method consists in scrolling the crankshaft of an internal combustion engine (Figure 2) through a torsion bar 1 with an ultra-low portable angular speed by a drive station 2 with a worm gear motor within one or several revolutions of the crankshaft, with closed valves 3, 4 of the gas distribution mechanism with simultaneous impulse supply to above the piston space of the break-in or engine oil by the pumping station 5.

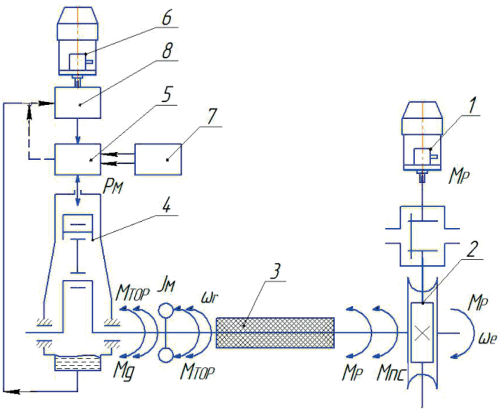

Figure 2. Functional-kinematic diagram of the device for cold running-in with SDV using the example of a single-cylinder internal combustion engine: 1 - gear motor; 2 - worm gear; 3 - torsion bar; 4 - ICE; 5 - electrohydraulic distributor; 6 - electric motor; 7 - control unit; 8 - oil pump

In the initial state, the crank mechanism of the internal combustion engine is, for example, at the top dead center, the torsion bar 3 is untwisted (MTOP = 0).

When the drive station is turned on, the crankshaft starts scrolling through the torsion bar 3 with a frequency of 0.1 ... 0.3 min^{-1}, while the torsion bar is spinning due to the moment of mechanical losses of the MMP ICE by a certain angle.

When the pumping station is turned on, part of the oil from the crankcase of the internal combustion engine through the pressure regulator is supplied to the main oil line of the internal combustion engine to lubricate the interfaces (P = 0.3 MPa). Another part of the oil is supplied at a pressure of more than 4 MPa to the electrohydro-distributor 5.

When the control unit 7 is turned on the electrohydraulic distributor 5 will begin to receive control pulses for the solenoid valves. When an impulse arrives at the supply solenoid valve, it will open into the over-piston space of the internal combustion engine cylinder, through which the fitting installed instead of the internal combustion engine nozzle will begin to flow oil, exerting pressure rm. on the piston.

It will begin to move downward, overcoming the resistance of the friction forces in the mates and the inertial forces of the parts associated with it, as well as the torsion moment of the torsion 3. As a result of the rapid increase in pressure, a forceful shock effect on the running-in mates occurs, which ensures the hardening of their surfaces, a rotation by a certain angle crankshaft and additional torsion. At this stroke of the pressure surge, the state of the system is described dynamics equation of the form:

$$M_i - M_{\text{TOP}} - M_{\text{МП}} = J \cdot \varepsilon \qquad (1)$$

where: M_i, M_{TOP}, $M_{\text{МП}}$ - moments from the force of oil pressure, torsion bar and friction in the mates, respectively; - angular acceleration of the crankshaft; Im - the moment of inertia of the moving parts of the system reduced to the crankshaft of the internal combustion engine.

On the pressure relief stroke, the drain solenoid valve opens and, due to the moment of the torsion bar spinning, the crankshaft turns in the opposite direction, while the piston pushes part of the oil into the drain line. Consecutive strokes of pressure rise and release in the above-piston space of the internal combustion engine form an SDP cycle.

Carrying out VOS cycles with the required value of the load, determined by the oil pressure, with a high (more than 10 Hz) frequency, within the estimated time, ensures the efficiency of the running-in process and the possibility of a significant reduction in the duration of the subsequent hot running-in under load. The total energy consumption with this technology is significantly less than with a typical cold run-in.

The essence of hot running-in of an internal combustion engine with dynamic loading lies in their operation in cyclic non-braking modes of increase (acceleration) and decrease (run-out) of the angular velocity of the crankshaft (USKV) ω (Figure 3) in a certain interval from ω1 to ω2 with a gradual, as running-in, an increase in the

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angular acceleration of acceleration εp, which is achieved by controlling the fuel supply according to a certain law, which ensures that the fuel supply is switched on at the acceleration stroke t1, with the possibility of setting its value for each stage of the run-in and turning off the fuel supply at the coasting stroke t2.

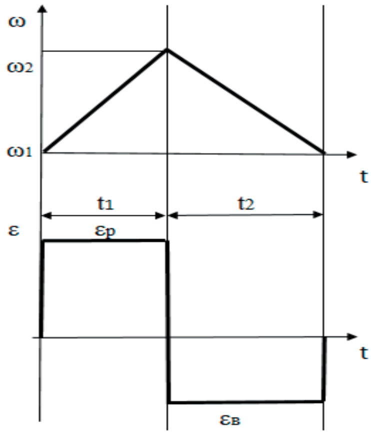

Figure 3. Dynamic loading cycle:
t1 and t2 are the acceleration and coasting cycle times; ω1 and ω2 - initial and final angular velocity of the crankshaft; εp and εв - acceleration of acceleration and run-out

The amount of fuel supply during acceleration determines the amount of torque MK developed by the internal combustion engine, and equal to it in magnitude, counteracting the load dynamic moment of the MND:

MK = MND = εp ID, (2)

where ID is the moment of inertia of moving parts reduced to the crankshaft of the internal combustion engine (the average value of ID = const for the kinematic cycle of the operation of the crank mechanism of the internal combustion engine).

According to equation 2, the dynamic load on the engine during running-in can be controlled by the amount of acceleration εr, determined, for example, by electronic differentiation of the USSKV signal in time, that is:

εp = dω/dt (3)

The amount of acceleration during run-in is determined by the current value of the moment of mechanical losses of the internal combustion engine Mmp, and reflects break-in rate of mates

εw = Mmp/Id (4)

The complex of sequential acceleration and run-out cycles form a dynamic loading cycle (DCS) of the internal combustion engine interfaces.

Multiple repetition of the CPM in a given interval of change in the USCV from ω1 to ω2 with the required values of the load dynamic moment at the stages of running in under load and during the required time of the stages, ensures the running-in of the internal combustion engine interfaces and is the essence of the considered method of running in with the DN.

The control of the central pressure pump is reduced to a cyclic effect on the fuel supply controls with the control of the magnitude of the dynamic load by the magnitude of the angular acceleration of acceleration. The limited range of changes in the USCV and the rapidity of the dynamic loading processes necessitate the automation of control and monitoring processes.

In the process of research, a number of automated control systems for running-in (ACS) and testing of diesel engines with DP have been developed, which implement various ways of controlling the central pressure pump with the impact on the lever of the speed regulator (RFV) or the rail of the high-pressure fuel pump (USSR patent, 1987). Figure 4 shows one of the variants of the automated control system for running-in diesel engines with dynamic loading. It includes an electric machine actuator mechanism 1, acting on the diesel speed control lever, control and monitoring unit 2, power supply unit 3, as well as a crankshaft speed sensor (Figure 4).

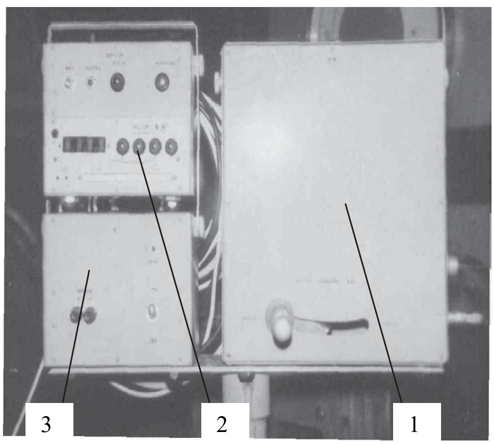

Figure 4. General view of the automated control system for running-in diesel engines with dynamic loading:
1 - actuator; 2 - control unit; 3 - power supply

The small dimensions and weight of the ACS elements make it possible to effectively run in and test the internal combustion engines installed on the machines with minimal cost and labor intensity. In addition, ACS can be a good addition to stationary run-in stands, in terms of expanding the range of speeds and power of run-in internal combustion engines and implement an alternative standard run-in technology with hot run-in under load and dynamic loading tests.
A significant difference between the running-in method with DN from the brake one is that the mechanical energy generated by the internal combustion engine during the non-brake acceleration stroke is spent on the implementation of running-in and necessary accompanying processes, and is also stored in the form of the kinetic energy of the system. At the run-out stroke, the kinetic energy is also spent on running-in processes, which in total determines the high value of the energy efficiency factor Ke of the DN mode and the running-in method with its use.
This coefficient is equal to the ratio of the energy spent on the implementation of the running-in APR and the necessary accompanying APW processes to the total mechanical energy (indicator work) Ai generated in the ICE cylinders, that is:

$$æ_{ý}=\frac{À_{ð}+À}{À_{i}}=\frac{A_i}{A_i}@1. \quad (5)$$

Analysis of expression 5 shows that the value of the energy efficiency coefficient of this method is close to 1. When implementing typical technologies of brake running-in, the value of Ke does not exceed 0.3 ... 0.4, since 60 ... 70% of the mechanical energy generated by the internal combustion engine is absorbed by the brake.
During running-in with DN, almost all energy is spent on running-in and accompanying processes, while providing the potential for saving up to 60 ... 70% of fuel compared to brake running.
Operational running-in of an internal combustion engine as part of machines with limited load-speed modes of their operation is important for the final running-in of interfaces and is recommended for both new and repaired internal combustion engines. Its implementation in the initial period of machine operation is subject to the negative influence of both production and subjective factors. The additional running-in of the internal combustion engine, carried out in stationary conditions before the start of operation, makes it possible to carry out the program of operational running-in in accordance with the optimal conditions and to ensure the possibility of subsequent operation of the machines with full load.
Reducing fuel consumption during running-in and testing of internal combustion engines with dynamic loading provides a corresponding reduction in harmful emissions into the atmosphere (Höniga, 2014).
In accordance with GOST R 56163-2014, emissions of harmful substances into the atmosphere were determined during the running-in of 100 D-240 diesel engines, presented in Table 1, which decreases when implementing an alternative typical and separate running-in 2.2 and 2.5 times, respectively, in comparison with typical running-in.

Table 1. Emission of harmful substances into the atmosphere

Gross emission of substances, kg	Typical running in	Alternative run-in with DN	Separate Running in
CO	48.60	21.50	19.44
NO2	55.35	24.49	22.14
CH	25.38	11.23	10.15
C	5.06	2.24	2.03
SO2	6.21	2.75	2.48
CH2O	0.95	0.42	0.38

RESULTS AND DISCUSSIONS

As a result of the research of the automated control system for the implementation of the developed technologies of tractor diesel engines D-240, D-65N, D-245, D-160, D-144, it was found that they allow realizing the established regularities of control actions and the required load-speed modes of running in with the DN, while the range of smooth adjustment of the load dynamic moment is from 10 to 100% of its nominal value in the operating range of the crankshaft rotation frequency. comparative studies of the technical and economic indicators of the internal combustion engine and the quality indicators of the running-in interfaces show their identity, while the total area of the running-in surfaces of the first compression piston rings during running-in with DN is 5 ... 15% more than with brake, and the total fuel consumption for the period run-in is reduced by 2.2 ... 2.3 times, depending on the model of the run-in engine.

Comparative studies of typical and separate running-in of the D-240 diesel engine showed approximately the same results, both in terms of running-in quality indicators and in terms of its output diesel indicators. It was found that the total area of the running-in cylindrical surfaces of the first compression rings after typical running-in reached 31.. 38%, with separate running-in 35...50%, and the second and third 12...20% and 15...29% respectively. Reducing the number and time of hot running-in stages with separate running-in reduced fuel consumption by 2.5-2.6 times compared to the standard one.
Comparative studies of a typical cold run-in and cold run-in from a D-144 tractor diesel engine with SDV showed that the area of the running-in surfaces of the crankshaft liners during running-in with SDV is 2 ... 5 times larger, and the power consumption is 4 ... 5 times less than with a typical one, in this case, the scrolling moment and the total length of the gaps between the piston rings and the cylinder liner also have smaller values.

CONCLUSIONS

As a result of the theoretical and experimental studies of the developed technologies and means of running-in, a high quality of running-in of ICE interfaces was established, with a significant reduction in capital costs for the acquisition and placement of equipment, the labor intensity of the process, fuel consumption, electricity and emissions of harmful components in exhaust gases compared to standard run-in technologies.

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SAFFLOWER OIL AS A BIOLOGICAL COMPONENT OFBLENDED FUEL FOR DIESEL ENGINES

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Abstract

One of the types of motor biofuels for diesel engines is blended fuel obtained by mixing petroleum diesel and vegetable oils. One of these oils can be safflower oil produced from the seeds of Carthamnus tinctorius. The main physical, chemical, and calorific properties were studied for the safflower oil and for its blends with petroleum diesel oil. The results of bench dynamometer tests of D-243 diesel engine (four-stroke, four-cylinder, direct injection, compression ignition engine), running on safflower biodiesel blends, are presented. The proportions of safflower oil and diesel oil in the fuel blends were 20/80, 25/75, 33/67, and 50/50. Moreover, the blended fuel 50/50 was processed with 25 kHz ultrasonic emitting. When the diesel engine was running on blended fuel, brake power decreased by 1-4 percent, brake specific fuel consumption increased by 4-10 percent, while the exhaust smoke opacity was less by 10-40 percent compared to the engine operation on the petroleum diesel oil. The processing of the fuel blend 50/50 with ultrasonic allows improving engine power capacity, efficiency, and smoke opacity compared to the engine operation on unprocessed blended fuel.

***Key words**: biodiesel, blended fuel, diesel engine, safflower oil, ultrasonic.*

INTRODUCTION

A perspective source of heat energy for automotive diesel engines is biodiesel.

One of the types of motor biofuel is blended fuel obtained by mixing of petroleum diesel oil and vegetable oil when the second one performs functions of biological component (Kampmann, 1993; Fajman and Ondracek, 1999; Dorado et al., 2002; Megahed, 2004; Campbell et al., 2008; Ukhanov et al., 2009a; 2011).

The most studied biological components of blended fuel are rapeseed oil, camelina oil sunflower oil and mustard oil (McDonnell et al., 1995; 2000; Niemi et al., 1998; Moreno et al., 1999; Erdiwansyaha et al., 2019). However, other types of vegetable oils have technological, calorific, physical and chemical properties not worse than the aforementioned oils.

One of these types is safflower oil produced from the seeds of *Carthamnus tinctorius* (Ukhanov et al., 2016).

MATERIALS AND METHODS

Safflower (*Carthamnus*) is a genus of annual, biennial and perennial herbs from the Asteraceae family. The average yield of safflower seeds is 1.5-2.2 tons per hectare, the oiliness is 45-50%.

For evaluation of physical, chemical, and calorific properties of safflower oil and blended safflower-diesel fuel, a series of laboratory tests and theoretical studies was performed. The studies included a definition of the following parameters: fatty acids content, hydrocarbons content, lower calorific value, density, kinematic viscosity and dynamic viscosity.

Definition of fatty acids content in the safflower oil was based on the results of the analysis with chromatographic tester «Kristall-2000».

On the grounds of fatty acids content, an average chemical formula and average molar mass of safflower oil were calculated. According to obtained data, hydrocarbons content and lower calorific value of safflower oil were identified.

The lower calorific value of blended safflower-diesel fuel (MJ/kg) with a percentage of biofuel and diesel 20/80, 25/75, 33/67, 50/50 was calculated by modified Mendeleev's formula (1):

$$H_u = K_D \cdot [34{,}013C_D + 125{,}6H_D - 10{,}9(O_D - S_D) - 2{,}512(9H_D + W_D)] + K_{SaffOil} \cdot [34{,}013C_{SaffOil} + +102{,}452H_{SaffOil} - 10{,}9O_{SaffOil}] \quad (1)$$

where: K_D, $K_{SaffOil}$ are contents (mass portions) of petroleum diesel oil and safflower oil in blended fuel (at any ratio of components $K_D + K_{SaffOil} = 1$); C_D, H_D, O_D, S_D, W_D are contents of carbon, hydrogen, oxygen, sulphur and water in petroleum diesel oil; $C_{SaffOil}$, $H_{SaffOil}$, $O_{SaffOil}$ are contents of carbon, hydrogen and oxygen in safflower oil.

The density of the safflower oil and safflower-diesel fuel at the different ratios of biological and petrochemical components was measured with vibration meter VIP-2M. Kinematic viscosity was determined with capillary viscometer VPZh-2 by Pinkevich. Dynamic viscosity was measured with micro-viscometer «HAAKE».

For evaluation of the influence of blended fuel (unprocessed and processed with ultrasonic) on diesel engine power capacity, fuel economy and ecological parameters, the bench dynamometer tests were completed.

The tests were performed on an experimental motor setup (Figure 1) including D-243 tractor diesel engine (four-cylinder, four-stroke, direct injection, compression ignition engine). Its fuel supply system was equipped with an ultrasonic mixer.

Figure 1. Experimental motor setup: 1 - D-243 diesel engine with the set of instruments; 2 - PC

The engine was coupled with KS-56/4 dynamometer brake including the remote controller, air and fuel flow meter and PC equipped with the integral analogue-to-digital converter of signals. The gas analyser «AVTOTEST CO-CH-D» was used for measuring of engine's exhaust smoke opacity.

The treatment of blended fuel with ultrasonic vibrations at the emitting frequency 25 kHz was performed during the engine operation with the help of an ultrasonic mixer (Ukhanov et al., 2014a; 2017; Ukhanova et al., 2017a) built in the fuel supply system (Ukhanov et al., 2009b; 2013; 2014b; 2017b). The input channel (3) of mixer housing (2) (Figure 2) is connected with the fuel filter, the outlet channel (4) - with a high-pressure fuel pump. A piezo emitter (1) is placed in the inner chamber of the housing (2) and connected with the electronic control unit (5) which is coupled with the 12V voltage power source.

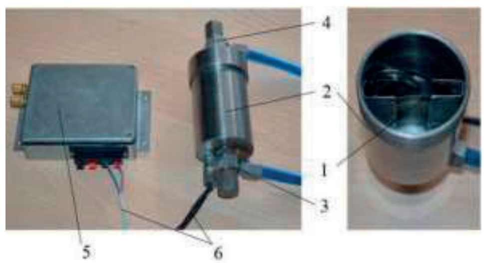

Figure 2. Ultrasonic mixer: 1 - piezo emitter; 2 - housing; 3, 4 - input and outlet channels; 5 - electronic control unit; 6 - electric wires

The performance of the diesel engine was evaluated with the following parameters: brake power (BP), hourly fuel consumption (HFC), brake specific fuel consumption (BSFC) and exhaust smoke opacity.

RESULTS AND DISCUSSIONS

The petrochemical component of blended fuel was conventional diesel oil DT-L-62 containing carbon 0.870, hydrogen 0.126, oxygen 0.004. The lower calorific value (LCV) of diesel oil was 42.4 MJ/kg, density 830 kg/m^3, kinematic viscosity 4.2 mm^2/s, dynamic viscosity3 MPa·s (at 20° C).

The biological component of blended fuel was safflower oil containing carbon 0.775, hydrogen 0.115, oxygen 0.110. The LCV of safflower oil was 36.99 MJ/kg, density 920 kg/m^3, kinematic viscosity 67.3 mm^2/s, dynamic viscosity 58.3 MPa·s (at 20°C).

The results of evaluation physical, chemical and calorific parameters of blended fuel with a ratio of biofuel and diesel 20/80, 25/75, 33/67, 50/50 are presented in Table 1.

Table 1. Physical, chemical and calorific parameters of blended safflower-diesel fuel

Blended fuel	Element's content (carbon, hydrogen and oxygen)	Lower calorific value, MJ/kg	Density, kg/m^3	Kinematic viscosity, mm^2/s	Dynamic viscosity, MPa·s
20% SaffOil + 80% Diesel	C = 0.851; H = 0.124; O = 0.025	41.44	843	8.2	16.8
25% SaffOil + 75% Diesel	C = 0.846; H = 0.123; O = 0.031	41.14	850	8.4	17.5
33% SaffOil + 67% Diesel	C = 0.839; H = 0.122; O = 0.039	40.68	858	9.3	19.5
50% SaffOil + 50% Diesel	C = 0.822 H = 0.121 O = 0.057	39.81	867	12.2	23.6

From the analysis of Table 1, it follows, that the blended safflower-diesel fuel has slightly worse parameters of the physical, chemical and calorific properties compared to the conventional (petroleum) diesel oil.

As a result of research, experimental data of power capacity, fuel economy and ecological parameters were obtained when the diesel engine was running at the external speed characteristic on blended fuel with percentage (ratio) of biological and petrochemical components 20/80, 25/75, 33/67 and 50/50.

Analysis of the results of bench tests shows that as the content of safflower oil in blended fuel increases, the engine brake power slightly decreases (Figure 3). For example, when running at nominal mode at crankshaft speed 2200 rpm on blended fuel 20/80, BP reduced from 61 kW to 60.4 kW (by 1%). On blended fuel 50/50 BP reduced to 58.8 kW (by 4%). The obtained reduction of BPcan is explained by the lower calorific value of blended fuel which is less than the LCV of the conventional diesel oil.

During the engine operation on blended safflower-diesel fuel, its fuel economy worsens. As the content biological component in blended fuel increases, the hourly fuel consumption and BSFC are larger. For example, when the engine was running at a rated speed 2200 rpm on fuel 20/80, the hourly fuel consumption increased from 14.6 kg/h to 15.1 kg/h (by 3%). On fuel 50/50 it increased to 15.6 kg/h (by 6%). The growth of HFC, when the portion of safflower oil in the blended fuel is increasing, can be explained by the growth of cyclic fuel supply. It happened due to increasing of mass supply of the blended fuel in over-plunger chamber of the fuel pump.

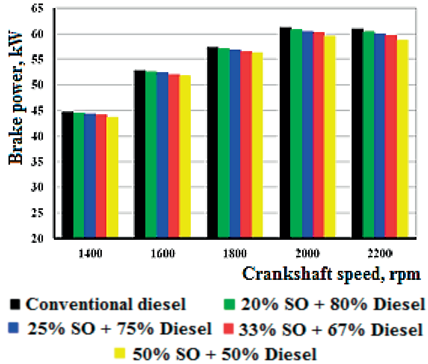

Figure 3. The change of diesel engine brake power depending on the crankshaft speed when running on conventional fuel and blended safflower-diesel fuel

Brake specific fuel consumption increases as the content of safflower oil in the blended fuel is larger (Figure 4).

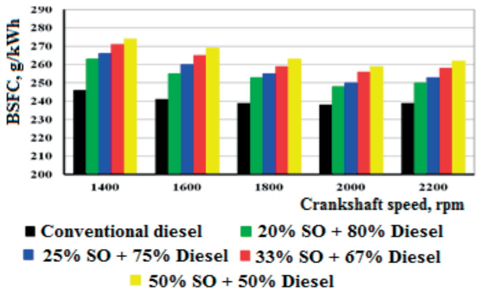

Figure 4. The change of BSFCdepending on the crankshaft speed when running on conventional fuel and blended safflower-diesel fuel

For example, when the diesel engine was running at the rated mode on the blended fuel 20/80, BSFC was 250 g/kWh, on the fuel50/50 it was 264 g/kWh. It was by 5−10% larger than on the conventional diesel fuel (239 g/kWh).

As the crankshaft speed and percentage of safflower oil increase, the exhaust smoke opacity decreases (Figure 5). The maximum value of the smoke opacity (0.6) was noted at the engine operation on the conventional diesel oil and crankshaft speed 1400 rpm. At the maximum torque (crankshaft speed 1600 rpm) the smoke opacity on blended fuel was 0.36-0.43, while on the conventional fuel it was 0.53. The minimum value (0.26) was obtained during the engine operation on blended fuel 50/50 at 2200 rpm. The reduction of the exhaust smoke opacity during the engine operation on safflower-diesel fuel can be explained by less content of carbon compared with conventional diesel oil.

Thus, the greatest deterioration of the power capacity and fuel economy was obtained during the diesel engine operation on safflower-diesel fuel 50/50, but this kind of fuel promoted the maximum reduction of the exhaust smoke opacity.

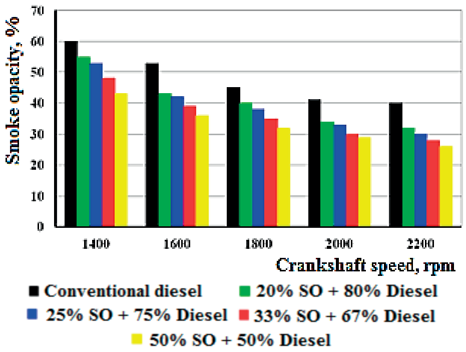

Figure 5. The change of exhaust smoke opacitydepending on the crankshaft speed when running on conventional fuel and blended safflower-diesel fuel

To improve the diesel engine power capacity, fuel economy and ecological parameters, the safflower-diesel fuel 50/50 was processed with an ultrasound treatment by ultrasonic mixer imbedded in the fuel supply system. Due to the cavitation process, the ultrasonic mixer promoted qualitative mixing of biological and petrochemical components. Moreover, in consequence of high-frequency vibrations, radicals of hydrocarbon groups separated from some fatty acids and joined to the other acid's molecules (Ukhanov et al., 2015).

From the analysis of Figure 6 it follows that during the operation on the ultrasonic processed safflower-diesel fuel, the engine efficiency is worse than on the conventional diesel oil, but better than on the unprocessed blended fuel. For example, the brake power at the nominal mode increased from 58.8 kW to 59.7 kW due to the ultrasonic treatment of blended fuel 50/50. It is only 2% less than at the engine operation on the conventional diesel oil.

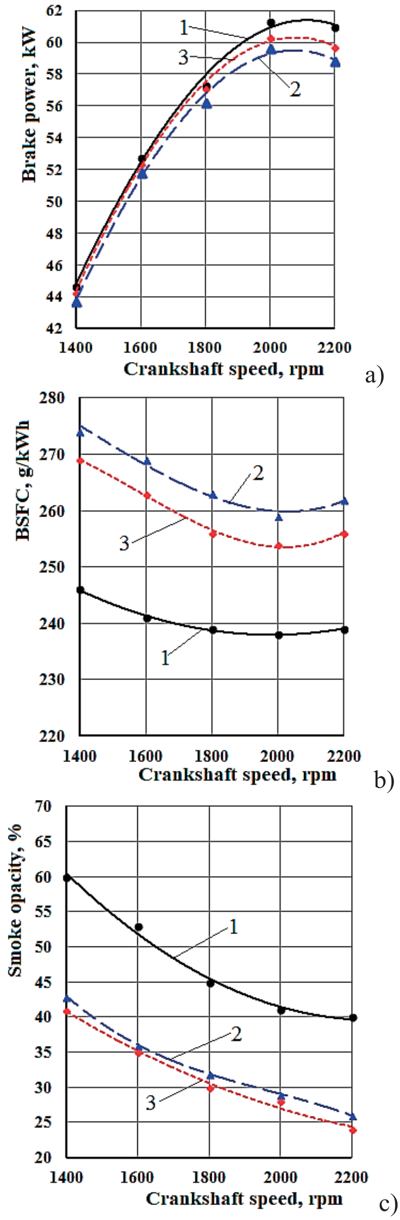

Figure 6. The change of the diesel engine parameters at the external speed characteristic: a) brake power; b) BSFC; c) exhaust smoke opacity;
1 - conventional diesel oil; 2 - unprocessed blended fuel 50/50; 3 - ultrasonic processed fuel 50/50

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The brake-specific consumption of the ultrasonic processed fuel reduced by 3% in comparison with the unprocessed fuel. It was 256 g/kWh, which is 7% more than at the engine operation on the conventional diesel oil.
The exhaust smoke opacity also decreases on ultrasonic processed safflower-diesel fuel. At the nominal mode on fuel 50/50 without ultrasonic, the smoke opacity reduces from 0.4 to 0.26, with ultrasonic - to 0.24.
The obtained results show improvement of the engine power capacity, fuel economy and ecological parameters due to the ultrasonic treatment of the blended fuel.
It should be noted that the blended fuel can be used not only as a motor fuel but also as an activator injected at the intake stroke into the diesel engine's intake manifold for the fumigation of air charge, which promotes improving the environmental parameters (Ukhanov et al., 2019; Ryblov et al., 2018; 2019; 2020).

CONCLUSIONS

The main parameters of physical, chemical and calorific properties of the safflower oil, as a biological component of the blended safflower-diesel fuel, were evaluated. The lower calorific values 36.99 MJ/kg, density 920 kg/m^3, kinematic viscosity 67.3 mm^2/s, dynamic viscosity 58.3 MPa·s (at 20° C).
For blended safflower-diesel fuel with percentage (ratio) of biological and petrochemical components 20/80, 25/75, 33/67, 50/50, these parameters are: the lower calorific value from 39.81 to 41.44 MJ/kg, density from 843 to 867 kg/m^3, kinematic viscosity from 8.2 to 12.2 mm^2/s, dynamic viscosity from 16.8 to 23.6 MPa·s (at 20°C).
The results of the bench dynamometer tests show that during the diesel engine operation on the blended safflower-diesel fuel the brake power decreases by 1−4%, the brake-specific fuel consumption increases by 4-10% in comparison with the engine operation on the conventional petroleum fuel. The greatest decline of the power capacity and deterioration of the fuel economy was obtained during the engine operation on the blended fuel 50/50. However, the maximum reduction of the exhaust smoke opacity was obtained on this kind of fuel.
The ultrasonic treatment of safflower-diesel fuel 50/50 allows improving the power capacity, fuel economy and ecological parameters of the diesel engine during its operation on the blended fuel.

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SOIL CONDITIONS AND STRUCTURAL TYPOLOGIES FOR SEISMIC ISOLATION OF BUILDINGS, IN CITIES EXPOSED TO STRONG EARTHQUAKE HAZARD

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Abstract

Some buildings need special attention in attempting to protect them against strong seismic movements. Seismic isolation comes as a suitable solution to protect the integrity of the construction. For this accomplishment are needed some thorough data about the dynamic characteristics of the structure and site specificity. The characteristics of the buildings can be found from either design data, or from subsequent measurements on its structure. The study of seismic waves has become a design criterion in advanced seismic codes, using design spectra compatible with local conditions differentiated on qualitative stratigraphic description and quantitative waves velocity-based criteria. The results of the later important geophysical measurement campaigns are described and used in this work. To identify whether seismic isolation for buildings is efficient in an earthquakes-prone environment, very important is the analysis of the location they are, or will be. One of the most important elements to be evaluated is the natural period of the site. The conditions for an efficient seismic isolation are presented and discussed with examples. In the paper are also described the different types of seismic isolated structures in Bucharest, and the reason for selecting them.

***Key words**: earthquake, foundation, fundamental period, seismic isolation, structural damage.*

INTRODUCTION

The current seismic design of structures is based on the following safety principles and requirements:
• the structure must withstand minor earthquakes without damage;
• medium earthquakes allow damage to non-structural elements but not to resistance elements;
• structural damage is allowed for major earthquakes, provided that collapse is avoided.
Structure's strength can meet the above requirements if they have sufficient resources to dissipate the seismic energy transmitted by the movement of the foundation ground. This dissipation is the result of the ductility of the structural elements, inelastic and residual deformations (allowed in certain areas provided in the design), to which is added the dissipation of seismic energy given by the degradation of non-structural elements.
The dynamic isolation of the buildings from its foundation is an old desideratum of structural design. Theoretically, if a perfect decoupling between the structure and the supporting ground were achieved, during an earthquake the movement of the ground would not be transmitted to the structure, which in this case could have only a rigid body displacement (Figure 1).

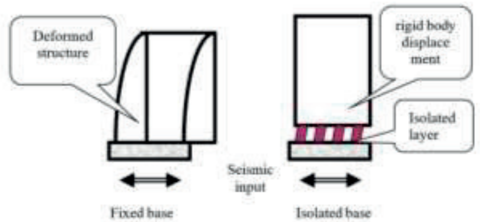

Figure1. Fixed base versus isolated base

In reality, a total decoupling, a total isolation of the structured base is practically not possible. Any isolation layer introduced between the ground and the structure cannot be completely decoupled due to the inherent frictions through which the seismic movement will also interact with the structure, but to a much lesser extent.
However, an insulating layer with low horizontal rigidity reduces the seismic force transmitted to the structure. In this sense, the

notion of seismic isolation is now used. Seismic isolation systems have been developed and applied in order to distribute the deformability and dissipation processes to the isolation layer, thus protecting the structure which in this case has a reduced deformation, practically close to the rigid body behaviour.

How is decided for isolating a structure

In order to apply an isolation method to a structure it is important to understand how this procedure works, because this implies an extra effort from the design and building execution process.

The flexibility introduced by the isolation layer in the structural assembly (foundation + isolation layer + structure) makes the structure's own period suffer a jump to higher values (period shift), a jump that removes the structure from the dangerous area of the fundamental period of the site, thus avoiding destructive effects due to the resonance of the dynamic system.

Isolation of the base by introducing an insulating layer with reduced horizontal rigidity has as a consequence a flexibility of the whole structure-isolation layer-foundation and the new structure acquires its own longer period than the same structure but with a fixed base.

Due to this sense of leap - only for longer periods - base isolation is not a universal remedy applicable to all types of structures and locations. The solution must be adapted to each case according to the dynamic characteristics of the structure, of the terrain on which the structure rests and according to the predominant periods of the seismic input.

In order to illustrate this, in Table 1 is given a classification of structures, based on approximate fundamental periods and in Table 2 a classification of the soil of the sites based also on approximate determinations of own periods.

Table 1. Fundamental periods for some types of structures

Type of the structure	Fundamental period of the building T_0 [s]
Rigid (low, massive constructions, with strong vertical elements such as: ground floor halls, GF + 4, piles, abutment, etc.)	0-0.7
Semi-rigid (reinforced concrete multi-storey buildings, silos, water towers, chimneys, etc.)	0.7-1.5
Flexible (multi-storey buildings with metal frame, towers, radio antennas, etc.)	> 1.5

Table 2. Fundamental periods for some types of soil

Type of the soil	Fundamental period of the soil T_0 [s]
Rocks, consolidated alluvial deposits	0-0.7
Poorly consolidated alluvial deposits	0.7-1.5
Unconsolidated alluvial deposits, fillings	> 1.5

MATERIALS AND METHODS

***M**ethods to determine fundamental period for buildings and soil deposits*

Buildings are not independent elements, they are located on a site, upon which depends their dynamical behaviour in strong earthquakes.

- Fundamental period in buildings.

There are two categories of buildings which could be isolated: i) new and ii) old ones. In both cases, among other parameters, it is necessary to have an evaluation for the fundamental period of each structure.

i) For the new buildings, the fundamental period would be estimated from the design computations.

ii) For the old ones, in order to determine the fundamental period, several methods can be employed, based on vibration measurements.

These techniques are of interest for earthquake-prone areas, case in which monitoring is performed through ambient vibrations recordings, but also through seismic ground motions where they are available.

For both new and old buildings, the dynamic parameters, computed based on numerical models can be validated with experimental data. From the practical view-point, the values of these parameters can be used as a proxy for damage detection or can validate that the construction process has followed the rules prescribed by the design plan. In addition, for the case of the earthquake protection systems (such as seismic base isolation), the improvements in terms of structural response can be quantified and the performance of the isolators can be assessed, based on real data. In Romania, the process of computing the fundamental period of the buildings using seismic sensors is gaining more attention in the last years, given that the building stock consist of a lot of typologies, from different periods and for each of them the engineers should

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assess as best as they can their dynamic parameters in order to estimate its response to strong earthquakes and to prevent their collapse and extend their serviceability.

- Fundamental period in soil deposits

One of the main geophysical characteristics of a site is its fundamental period of vibration. In this sense, some of the most common methods of finding this specific period of each location will be presented.

Geophysical measurements in Romania have developed in the last decades, on a large scale, for acquiring more data about the subsoil mainly by promoting down-hole measurements, in boreholes financed within internal and external collaborations.

Since the 1990s, the profile of seismic waves has become a design criterion in advanced seismic codes, using design spectra compatible with local conditions.

Numerous drillings and down-hole tests have been carried out in the last decades in the Bucharest metropolitan region by UTCB, INCERC, GEOTEC S.A., CNRRS and other institutions. Thus, at INCERC, three reference drillings were made: INCERC 1 at 50 m depth, INCERC 2 at 70 m depth and INCERC 3 at 205 m depth (in 1998 with Romanian (UTCB) and German financing within the joint German-Romanian program of research SFB 461, “Strong earthquakes: a challenge for geosciences and civil engineering”, Karlsruhe University.

The most recent research was carried out within the Science for Peace Project 981882 - “Site-effect analyses for the earthquake-endangered metropolis Bucharest, Romania” (2007-2009), a consortium formed between INCDFP and the University of Karlsruhe (Collaborative Research Centre 461 Strong Earthquakes) (Wenzel, 1997, SFB 461, 2007), UTCB also contributed to the project. (NATO SfP Project).

Within the project, for the study of the basement of the Bucharest Metropolis and the collection of data in areas with little or not at all explored so far, were carried out 10 drillings with a depth of 50 m in which 10 down-hole measurements were performed for longitudinal (Vp) and shear (Vs) seismic waves velocities. Disturbed and undisturbed soil samples (400 in number) were extracted from the 10 boreholes, on which static and dynamic geotechnical investigations were carried out. (NATO SfP Project). This high-quality seismic dataset provides important information useful for the seismic hazard evaluation across the interest area. (Balan et al., 2020a, b) Also, was carried out a continuously monitoring of the buildings, which offer data from the micro tremors, vibration and the noise. (Tiganescu et al., 2019).

In order to identify the buildings that would require seismic isolation, first it is necessary to know the dynamic characteristics of the structure, and then is needed a geotechnical and geophysical analysis of the site they are or will be constructed.

The study of the propagation of seismic waves from the seismic source to a certain point located inside the earth or on the free surface is a fundamental problem in seismology. The main aspects of interest in relation to the phenomenon of seismic wave propagation in a certain area or in a delimited location are the following: the variation of the seismic wave intensity depending on the physical-mechanical and dynamic properties of the propagation environment and the modification of the seismic response of structures depending on the local deformability characteristics of the site-specific soil deposit. Also, the importance of the site conditions is considerable, the effects of earthquakes on constructions can be amplified or dampened significantly compared to those considered in the design if not taken into account all the dynamic characteristics of the foundation -soil and soil stratification above the bedrock.

The use of seismic methods to investigate the soil deposit has proved effective in providing data whose interpretation allows the quantitative evaluation of the elastic-dynamic constants of rocks and soils and assessments of their physical condition.

The evaluation of the dynamic characteristics of the soil deposit involves the determination of the propagation velocities of the longitudinal (V_p) and shear (Vs) seismic waves and of the earth density (ρ), from which the dynamic modules of longitudinal (E_d) and transverse (G_d) deformation can be calculated, function of specific deformation induced by strong seismic movements.

Seismic shear waves define motion parameters that produce the most important dynamic effects on buildings located on the free surface of the land. It is found that the propagation velocities increase both with the degree of compaction and the physical-mechanical qualities of the soil, as well as with the depth measured from the free surface (the thickness of the considered layer) (Kramer,1996). The knowledge of the local geological conditions (subsoil) together with the information related to the distribution of the shear waves velocity in Bucharest layers allowed for upgrade the maps that display distribution of the predominant period of the upper sedimentary layers.

The velocity model constructed upon geophysical measurements indicates soft soil conditions (shear wave velocities V_S< 360 m/s) for several tens of meters underlain by layers of stiffer soils (V_S > 360–700 m/s) down to a depth of several hundreds of meters (Mândrescu et al. 2008).

Following soil classification proposed by Eurocode 8 (EN 1998-1, CEN 2004), the "deep deposits of dense or medium-dense sand, gravel of stiff clay with thicknesses of several tens to many hundreds of meters" are classified as soil type C, and the average shear waves velocity between 180 and 360 m/s.

In general, in the study of the soil deposit response during earthquakes, the importance of seismic shear waves is given, which are strongly influenced by superficial soft sedimentary deposits. However, it should be mentioned that when following the characterization of the movements with periods between 1s and 10s, the consideration of the surface layers is no longer sufficient. In such cases it is necessary to take into account the sedimentary layers up to the "seismic bedrock", which can mean sediment thicknesses that can have several kilometres.

Even in the simplified evaluation of the fundamental period of vibration in the elastic field, the depth considered in the calculation has a significant effect.

In the case of stratified deposits, consisting of n layers with different, but homogeneous properties and thicknesses, the weighted average velocity of the shear seismic waves is calculated according to (P 100-1/2013):

$$\overline{V_S} = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{v_{si}}}$$

n - number of strata, d_i - thickness of every strata and v_{si} - shear velocity in each stratum.

The fundamental period of the soil deposit in a location is an important parameter in the study of the seismic response using recordings of the waves that cross the soil deposit. The fundamental period of a package of "n" layers, of total thickness H depends on the velocity of the seismic shear waves (Vs) through the layers, $T_0 = 4H/V_S$ (Mândrescu et al., 2008).

It is found that the predominant periods are directly proportional to the depth of the H deposit and inversely proportional to the propagation velocity of the shear waves. It is obvious that at equal depths H, the predominant periods will be even smaller as the soil will have higher consistency and degree of compaction.

The highest amplification in the soil deposit occurs at fundamental or lower natural frequencies, which corresponds to the characteristic period of the site.

In situ measurements of the shear wave velocities of the soil and of the thickness ensure the direct determination of the fundamental period of the soil deposit.

Seismically isolated buildings in Bucharest

The seismically isolated buildings currently in Bucharest, with some characteristics (address, number of stories, construction year, and materials) are presented in Table 3 and their photos in Figures 2-4. These buildings are permanently monitored by the National Institute of R-D for Earth Physics (INCDFP) with seismic accelerometers at different levels (status at 31.12.2020) (Table 3).

An analysis of the amplification, in the Fourier domain, from the base to the top of the building was performed, for specific frequency intervals. These three buildings are equipped with base-isolation and damping systems, and the performance of this earthquake-protection system during earthquake was assessed. (Balan et al., 2020a).

The Bucharest City Hall building (PMB) and Victor Slăvescu building (ASE) were constructed at the beginning of XXth century, when no seismic design regulations were in force.

Table 3. Seismically isolated buildings in Bucharest (general characteristics)

No.	Name of building	Address	Number of stations in the building	No. of floors	Year of construction	Structural system
1	General City Hall of Bucharest (Figure 2)	Bucharest; Regina Elisabeta Boulevard no. 47	4 accelerometers, in real time, ground floor, floor 2, 3 and attic, it should be noted that all are placed above the seismic damping system of the building	UG+ GF+3F +Attic	1906. The building was consolidated after 2010 and was equipped with seismic insulators in the basement	Brick masonry with reinforced concrete floors with turned caissons
2	Arch of Triumph (Figure 4)	Bucharest; Arch of Triumph Square	2 accelerometers, one on the ground floor and one on the arch at the top, data are transmitted in real time		1921	Concrete, masonry
3	Victor Slăvescu Building, Academy of Economic Sciences (ASE) (Figure 3)	Bucharest; Calea Griviței 2-2A	monitored with two off-line accelerometers and are located in the basement below / above the seismic insulators	UG + GF+ 2F + Attic	1905	Brick masonry with truss roof

Figure 2. General City Hall of Bucharest

Figure 3. Victor Slăvescu Building, Academy of Economic Sciences (ASE)

On the ASE building, both sensors are located at the ground level, one is under the seismic isolator, coupled with the ground, and the other one is above the isolator, coupled with the structure.

For the Bucharest City Hall all the sensors are installed on the structure and the insulation system is placed under the sensors in the basement (Balan et al., 2020a).

Another structure is the Arch of Triumph (ARC), a unique structure representing a historic monument built back in the 1930s. On this structure two accelerometers are installed, one at the base and one at the top of the structure. Here the insulation system is placed under the sensor in the basement.

Figure 4. Arch of Triumph

RESULTS AND DISCUSSIONS

By comparing data from Table 1 and Table 2 an approximate, but not far from reality, results both the applicability and the limitations of the method of isolating the base:

• Isolation of the base is effective in cases where resonance with the ground can be avoided by increasing the structure's own period (positive period jump);
• The suitable candidates for the application of the method are the rigid or semi-rigid structures at their location on consolidated lands;
• It is not recommended to isolate a structure with its own period different from the predominant periods of the site;
• The inappropriate application of base isolation, when the periods of the structure and the ground are spaced apart, can have an adverse effect, it could transfer the structure from a safe area to a dangerous area.

All the seismic isolated buildings in Bucharest were isolated after construction, in the rehabilitation process, the Town Hall and Arch of Triumph being historical monuments.

The influence of the insulating systems has proved to be a solution for some older structures. The strongest events included in the analysis were one seismic event of M_W = 5.5 (October 2018) and one of M_W = 4.8 (January 2020). The structures dynamic behaviorrevealed a reduction or small amplification of motionabove isolator in comparison to the motion under isolator, and a reduction/amplification of the building base, on different period ranges, when compared with free field recordings. In the latter case the distance from the structure to the free-field station could be an influencing factor. All the data recorded on instrumented structures during seismic events, together with the mentioned analysis, can represent a reference study for future earthquakes with similar or higher magnitude.

Other matters of particular importance in judging the appropriateness of seismic isolation of an existing or future building is the consultation of maps of the fundamental period of the soil and the variation of accelerations on the surface of the city. From these maps it can be evaluated where in the city are most dangerous zones. (Bratosin, 2005; Marmureanu et al., 2010). High accelerations could produce damage to certain buildings, these could be:

a) new ones, buildings important to function after a strong earthquake (hospitals, administrative, first responder's headquarters and storage buildings, etc),
b) old buildings which in the process of rehabilitation the structural engineers decided seismic isolation a method for mitigation seismic risk (the case of isolated constructions in Bucharest).

The spots or certain areas inside the city where the approximate fundamental period of the soil deposit is correlated with the predominant period of the building which is or will be on that site, gives us the possibility to decide, among other criteria, if it is worth to seismic isolate that building or not (Bratosin et al., 2017).

The results of seismic isolation of a structure could mean change in its dynamic behaviour. Extracting the structure from the resonance area by changing upward its own period could bring an appreciable reduction in dynamic amplification. Considering as dynamical characteristics for a test structure, for example at resonance state its own period T_0=0.3 s and a damping ratio $\varsigma = 5\%$, the dynamic amplification factor could reach the value $\Phi = x_{dinamic} / x_{static} = 10$.

Under these assumptions by introducing an insulating layer with certain dynamical characteristics the fundamental period, can get a jump, supposing from $T_0 = 0.3$ s to $T_0 = 0.5$ s, therefore corresponding dynamic amplification decreases dramatically from $\Phi = 10$ to $\Phi = 1.56$, in the conditions in which the excitation period remains the same (Bratosin, 2005).

CONCLUSIONS

The applicability of the base insulation technology is conditioned by the presence of three conditions:

• If the technology is necessary, imposed by the degree of seismic classification of the site and by the requirements of post-seismic functionality;
• If the structure is suitable for base isolation technology, it is a rigid or semi-rigid structure intended to be located on a land with

predominantly short periods and the flexibility introduced by the isolation layer should not endanger the behaviour of non-seismic side loads (powerful winds);

• If the additional cost given by the introduction of the isolation layer and its maintenance is justified by the savings achieved from the reduction of structural requirements, by the reduction of post-seismic rehabilitation costs, by the reduction of material and human losses.

The brief enumeration above shows that the applicability is restricted to regions with high seismic potential and conditioned only by the technical conditions imposed by the dynamic characteristics of the structure and location. It is obvious that once these conditions are met, the base isolation technology also has economic justification even if we refer only to material costs and do not take into account human losses.

The base isolation technology is much more efficient if it is provided from the design stage of some structures to be made. In this case, savings can be made at the initial costs of the structural system, time savings and the achievement of the isolation system is much easier.

If the technology is intended to be applied to existing structures, complications may occur due to the implantation of the isolation layer and the change in the behaviour of the structural system, but these impediments are not insurmountable.

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STRUCTURAL VIBRATION AND FIRE RESISTANCE

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Abstract

The paper presents an assessment approach based on non-destructive and temporary vibration monitoring methods of a reinforced concrete building which is to be structurally and thermally rehabilitated. These methods are in according to the Romanian Code for Seismic Design of Building, Part 3 - Building Assessment, SR EN 1998-3:2008. The results related on dynamic characteristics of this building obtained by ambient vibration monitoring with a data acquisition system are presented. Also, a solution for the thermal insulation of the building is presented, as well as some results obtained from fire testing of this type of system. Where it is not possible to obtain correct information regarding the behaviour of a structural system, due to the lack of data needed to create a reliable model, the contribution of each presented method is consistent, using the advantages of non-destructive methods, ambient vibration monitoring and modal analysis. It is a current internationally practice, with a certain confidence.

Key words*: earthquake, ambient vibration, dynamic characteristics, building assessment.*

INTRODUCTION

In Romania, the seismicity of Vrancea source is very important (Figure 1), with a maximum instrumentally measured magnitude of 7.7, maximum possible magnitude of Mw = 8.0 (it was obtained for 1940, 1977, 1986, 1990 earthquakes), the frequency content showing significant differences in source mechanisms, with a directivity between events and, for soil conditions in Bucharest, a long predominant period of ground vibration of T = 1.4-1.6 s etc. (Lungu et al., 2004) (Radulian and Popa, 1996). In these conditions, reducing the seismic risk of buildings is a complex action, of national interest.

The paper presents an assessment approach based on non-destructive and temporary vibration monitoring methods of a reinforced concrete building from Bucharest, which is to be structurally and thermally rehabilitated. These methods are in according to the Seismic design code, P100-1/2013, Part I - Design prescriptions for buildings and the Code for the seismic design of buildings, P100-3/2008, Part III - Prescriptions for the seismic assessment of existing buildings, SR EN 1998-3:2008.

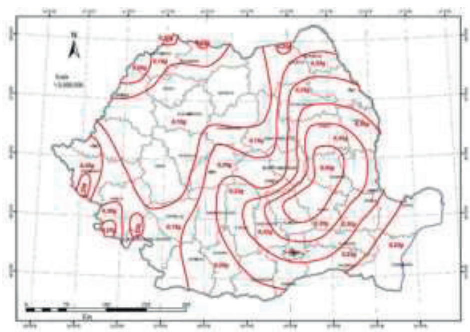

Figure 1. Peak ground acceleration map of the Romanian territory (P100-1/2013)

MATERIALS AND METHODS

1. Structural characteristics of the studied building: The Faculty of Horticulture from 59 Marasti Blvd, Bucharest (Dragomir et al., 2013)

It was built during 1950s with basement + ground floor + 3 storey height regime and two bodies (B1 and B2) separated by an expansion joint (no role as a seismic point) (Figure 2).

The two differ structurally: B1 has a structure consisting partly of structural walls of brick masonry and partly of reinforced concrete

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columns, on which the monolithic reinforced concrete floors are supported; B2 has a structure consisting of structural walls made of brick masonry on which the monolithic reinforced concrete floors are supported.

The thickness of the masonry walls is at least 37.50 cm and can reach up to 50.00 cm at lower levels or in structural elements with high code demands, although currently the supporting walls have been reinforced with reinforced concrete cores. The masonry is made of solid, red brick, double pressed C100 class and lime-cement mortar equivalent to the M10 class.

The partition walls are also made of brick masonry, having thicknesses of 12.5 cm or 25.00 cm and they coincide in most cases with the positions of the beams in the floor made of monolithic reinforced concrete.

The geotechnical study mentions that at the foundation level the ground consists of clay sand. This layer is inferior to the active clay layer with properties specific to the area contracts and due to which in the past certain buildings have suffered. The bearing capacity of the foundation ground at the standard depth of 2.00 m is 280 kPa.

From the accumulated experience it can be said that the foundations of this type of structure, realized between 1950 and 1952, consisted of continuous foundation of simple concrete and reinforced concrete under the structural walls of brick masonry and isolated foundations under the columns of reinforced concrete.

Figure 2. The building with the two sections, B1 and B2

2. Over time, several types of technical studies (approaches) have been developed related to:

- sonic auscultation, ultrasound and percussion with Schmidt hammer (Dragomir et al., 2013);
- evaluation of structural regularity both in plane and vertically (Dragomir et al., 2013), by calculations in order to determine the relative position between the two intrinsic centres (eccentricities e_x and e_y), the centre of gravity - CG and the centre of rotation - CR. Body B1, e_x = 14.0 m, e_y = 6.9 m; Body B2, e_x = 22.8 m, e_y = 1.0 m (Figures 3 and 4).
- determining the dynamic structural characteristics from micro vibrations/ microseisms/ ambiental vibrations instrumentation (Dragomir et al., 2013)

The plan shape of the buildings is irregular, asymmetrical, presenting discontinuities, which lead to the appearance of additional code demands. The values, shown in the above figures, indicate that the plan of the building does not comply with the regularity conditions.

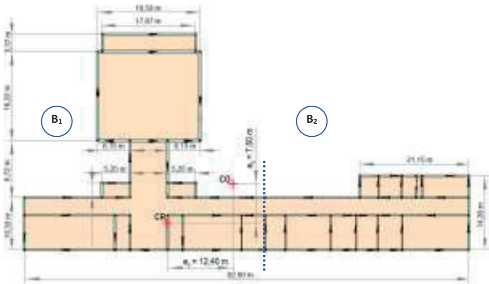

Figure 3. General plan of the Faculty of Horticulture (B1 and B2 bodies without expansion joint)

Figure 4. Eccentricities on the two orthogonal directions

The recording of the dynamic parameters was performed with the micro-seismic data acquisition equipment GeoDAS 12-USB, with 12 channels (Figure 5). Spatial structure velocity was recorded in different locations, in three main directions NS, EW and vertical Z, measured in mm/s.

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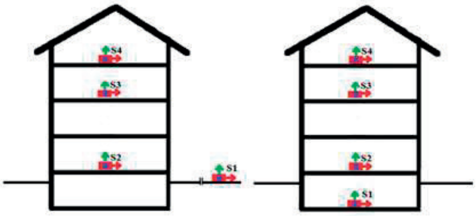

Figure 5. Location schemes of the 4 triaxial sensors. Scheme 1 (left): sensors located on the ground floor, 2nd floor, 3rd floor and near the building. Scheme 2 (right): sensors located on the basement, ground floor, 2nd floor and 3rd floor

The processing of the recording by using specialized software resulted in the Fourier spectra and response spectra. From these spectra, values corresponding to the fundamental period of vibration, for the two transverse and longitudinal directions of the building, were extracted T_{tr} = 0.40 s, T_{long} = 0.28 s (Figure 6). Also, all the velocities values are much lower than the threshold of 5 mm/s, imposed by the norms related to the vibrations in buildings, which means that there are no comfort problems.

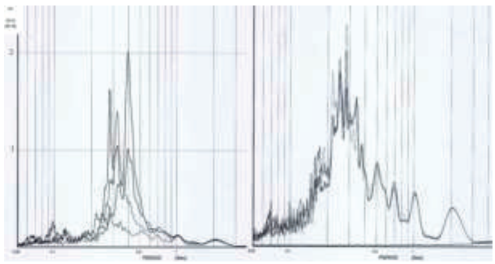

Figure 6. Response spectra on x and y direction (y-axis: maximum values of velocity, x-axis: natural vibration period)

- determining the structural dynamic characteristics from the modal analysis (Dobre et al., 2013). In the following, the dynamic characteristics of the two buildings, B1 and B2; B1 without walls, because the system is a frame structure, B2 with a structure consisting of load-bearing brick walls, mainly (Figure 7).
- determining the dynamic structural characteristics for the B1-B2 assembly (Figure 8), in order to investigate seismic pounding (Dobre et al., 2013); pounding is modelled through a contact element that is activated when the seismic gap between two buildings.

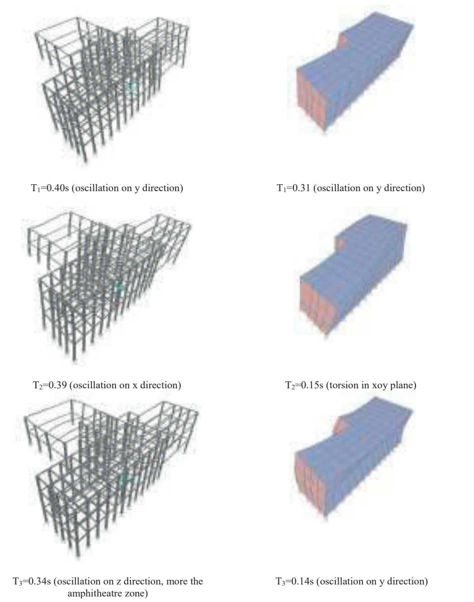

Figure 7. The dynamic characteristics of the two buildings, B1 and B2

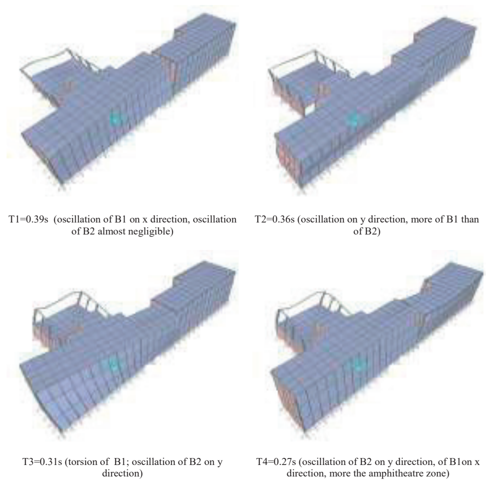

Figure 8. The dynamic characteristics of the system consisting of B1 and B2

- determining the fundamental vibration period, according to the simplified calculation formulas:
For buildings with reinforced concrete structural system (case of B1): T = 0.12N^0.76, thus T (N = 4) = 0.34 s and T (N = 5) = 0.40 s (where N is the number of levels). For buildings with structural brick walls (case of

B2): $T = 0.18N^{0.35}$, thus T (N = 4) = 0.29 s and T (N = 5) = 0.31 s.
The values obtained by applying the formulas and those from the modal analysis, or from vibration recordings are comparable.
- validation of the results obtained through temporary seismic instrumentation, by comparing with the fundamental periods of other existing buildings with reinforced concrete structural system or structural masonry walls (representation based on studies conducted within the INCD URBAN-INCERC, in different time periods) (Figures 9 and 10).

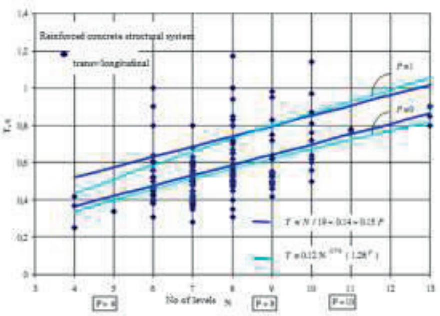

Figure 9. Fundamental periods values for buildings with reinforced concrete structural system.

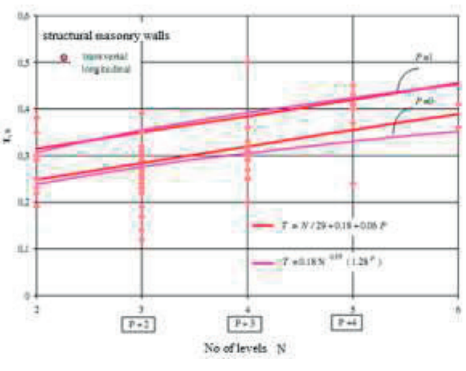

Figure 10. Fundamental periods values for buildings with structural masonry walls

Moreover, for the same building have been also addressed: determination of the response spectra, having represented the pseudo spectral-frequency acceleration, at points of interest, on levels; representations of displacements and accelerations in points of interest; pushover curve and capacity spectrum; the failure mechanism and the development of the plastic joints, with 2D view of one of the x Oz planes; lateral displacements, at service limit state and ultimate limit state; energy charts, taking into account also the control strategies for seismic energy dissipation (Luca et al., 2014; Luca et. al., 2015), establishing the level of structural degradation based on methods of estimating lateral displacements etc. On the other hand, the soil conditions were studied from the perspective of the possibility of consolidation using binders with ecological benefits based on parametric correlations (Dobrescu, 2017).

RESULTS AND DISCUSSIONS

Related to the dynamic characteristics of the two buildings, B1 and B2, as separate systems or in cooperation as a whole, the oscillation periods have close values in the case of modelling, applying a simplified formula, temporary seismic instrumentation, or comparing with the fundamental periods of other existing buildings with reinforced concrete structural system or structural masonry walls.
The presented building is proposed for structural and thermal consolidation, after this another measurement of these characteristics to be realized.
In this case, the capacity to the sheer force of the masonry wall, plated with composite materials, is given also by the contribution of the composite material in addition to the contribution of the masonry (Figure 11).

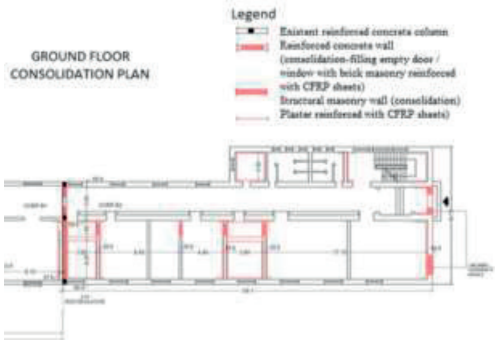

Figure 11. A part of consolidation plan for the ground floor (proposal). Existent reinforced concrete column; Reinforced concrete wall (consolidation-filling empty door / window with brick masonry reinforced with carbon fiber reinforced polymer/CFRP sheets); Structural masonry wall (consolidation); plaster reinforced with CFRP sheets)

The advantages of using this type of intervention are:
- good mechanical properties of composite materials;
- the reduced weight of the composite materials generates permanent loads on the structure; reduced thickness of the coating layers;
- the structural intervention does not alter the initial aesthetic aspect;
- the intervention has a reversible character, the materials can be dismantled from the structure, if the performance levels initially established are not met in the long term.

From the point of view of thermal rehabilitation, a thermal insulation system based on expanded polystyrene (ETICS) could be considered (Kotthoff, 2015) (Figures 12a, 12b), because it is easy to apply on load-bearing or non-bearing exterior walls from masonry or reinforced concrete, does not add loads to the structure, is energy efficient and has low costs compared to mineral dry wool (Simion et al., 2019).

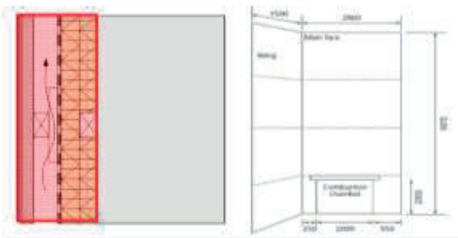

Figure 12a. Thermal insulation system based on expanded polystyrene (ETICS-wall) (Kotthoff, 2015). Large-scale cladding test facility-exposure level two (Simion et al., 2019)

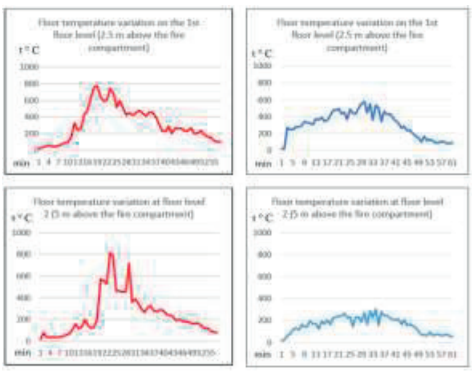

Figure 12b. Temperature-time behaviour on 2 vertical levels of test model (Simion et al., 2019)

The polystyrene sheets can be bonded to the masonry wall by adhesive mortar points or glued to the wall with adhesive mortar, both perimetral (all over the borders) and in the centre by three bonding points (a reinforcement layer consisting of a glass fiber mesh embedded in the glue mortar), with/without protective fire propagation barriers (from basalt mineral wool).

The choice of such a solution could be justified by the results of the tests carried out at the INCD URBAN-INCERC, which highlighted that the perimeter bonding to the support wall of polystyrene sheets with adhesive mortar together with the solution of planking the windows and doors with non-combustible barriers, having a width equal to of polystyrene, provides a high degree of fire safety for the used system in order to obtain the external thermal insulation of a building.

CONCLUSIONS

In the context of national seismicity, it is important to obtain more data on the performance of a structural system, its real resistance, as well as on how a structure behaves after exceeding the elastic limits of behaviour.

There have been presented several types of technical approaches related to an old building in the stage of structural consolidation and thermal rehabilitation, at present.

From the point of view of the dynamic actions, the natural period of vibration, determined experimentally, applying simplified calculation formulas, or from a modal analysis (after the commissioning of a building, before the earthquake, after the action of the earthquake that caused damage, or after carrying out the strengthening works), allows a determination of the rigidity and therefore a very useful assessment on the resistance capacity.

From the point of fire protection measure, some performance characteristics should be considered in the future: spread of fire, maximum flame heights, temperature-time behaviour, progressive smouldering, mechanical behaviour (damage, falling material, collapse of the parts of facade cladding system) etc. in fact, prevention of fire occurring in the insulation layer, or secure restriction of a fire in the insulation layer of every second floor.

Where it is not possible to obtain correct information regarding the behaviour of a structural system, due to the lack of data needed to create a reliable model, the contribution of each presented method is consistent, using the advantages of non-destructive methods, ambient vibration monitoring and modal analysis.

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METHODS AND TECHNIQUES FOR PREVENTION AND CONTROL OF THE WATER EUTROPHYCATION PROCESS IN HILLY LAKES

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Abstract

The paper treats the problem of eutrophication process for some important hilly lakes from Moldavia, Romania. Eutrophycation represents a normal process as time as its evolution is natural, and one of first six major environmental problems from the world lakes and reservoirs. This phenomenon is caused by the over limits increasing of nutrients concentrations (nitrogen, phosphorus) from lake's waters, substances involved through agricultural fields watering, fields on which were applied fertilizers. The paper contains a review of the main methods and techniques for modelling the processes regarding the evolution of lakes water quality. The research took place in the period 2016-2020 and regards main hilly lakes from Moldavia area, Romania.

Key words: *eutrophication, modelling, surface water quality, environmental protection.*

INTRODUCTION

The eutrophication process should not be judged by one criterion or another, but with a set of criteria. In fact, the syntheses elaborated did not subordinate to this vision, reaching the view that this type of organic pollution concerns the abiotic compartment of the ecosystem, at the biotic level, only its effects being felt.

The abundant literature that appears continuously on the concrete cases of eutrophication is increasingly perceived by the difficulties of interpretation and typology of the basins affected by this process.

The process of degradation of environmental factors across the globe has seen a steady ascendant course over the past decades, an increasingly worrying trend, with the amount of pollutants reaching figures that go beyond imagination and continue to grow in almost geometric progression.

A general threat to all surface waters, not spectacular but more dangerous by consequences than acute pollution, is the progressive, often latent, almost unnoticed pollution, but which accumulates the effect of small sources with diffuse pollution and takes chronic forms.

Our paper's subject is such a pollution type: the eutrophication, process of evolution of their quality, especially characteristic of artificial lakes, which brings particular problems from the water treatment technologies point of view.

The eutrophication process should not be judged by one criterion or another, but with a set of criteria.

In fact, the syntheses elaborated did not subordinate to this vision, reaching the view that this type of organic pollution concerns the abiotic compartment of the ecosystem, at the biotic level, only its effects being felt.

Regarding the evolution of the water quality in the lake, a first aspect is related to the initial preparation of the lakes cuvette. These cuvettes include land which, prior to the accumulation, was not in contact with water and may contain deposits of polluting substances. Even in the natural condition, vegetation and other organic substances on these lands can lead to an organic soil pollution of the lakes after their realization.

Therefore, it is necessary to pay special attention to the problem of cleaning the banks and bottom of future storage lakes.

Secondly, during the exploitation, there are some phenomena that did not take place naturally in the natural situation. From the modifying factors that influence or even cause changes in the physical - chemical characteristics of water, we mention: the density difference, which, in different characteristic areas of the complex arrangements, is determined by the difference in temperature, salinity, suspended matter, etc.; speed variations; evaporation, air currents, dissolution or precipitation of various minerals, etc.; biological activity.

These factors are correlated, the variation of one bringing appreciable changes to the others.

Eutrophication process starts when nutrients get into lakes and oceans, nutrients feed algae, which grows and blocks sunlight, plants die without sunlight, eventually, the algae die too.

Protecting water resources starts with sound agricultural and waste management practices (Figure 1).

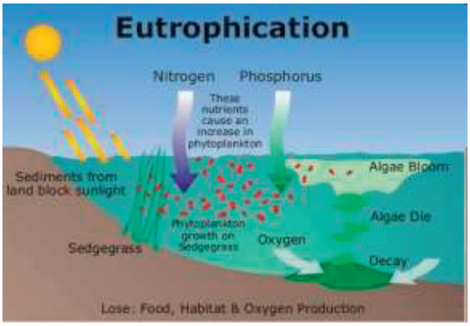

Figure 1. The eutrophication process description

MATERIALS AND METHODS

The analyzed area in this study is located in Moldavian Central Plateau, from Romania (Figure 2).

Figure 2. Moldavian Central Plateau, Romania

From the point of view of anthropical processes, the area of hills and plateaus has undergone increased interventions (urban/rural settlements, communication infrastructures, land use for agricultural crops and animal husbandry, exploitation, mining, forestry) which led to more severe deterioration (through erosion and soil degradation, deforestation, train landslides). Despite these vulnerabilities, the region of hills and plateaus contains a wide range of areas with landscape potential, requiring specific protection (Leinster, P., 2000).

The site under study includes five important lakes in the Central Moldavian Plateau: Lilieci - 262 ha, Bacău II - 217 ha, Galbeni - 1132 ha, Răcăciuni - 2004 ha, and Bereşti - 1800 ha.

All of them are included in a protected natural area of 5,576 ha, located at the confluence of Bistrița with Siret, and downstream of it.

The site represents a natural area (rivers, lakes, swamps, peat bogs, cultivated arable land, alluvial forests, meadows and pastures) in the middle meadow of Siret; ensuring favourable feeding, nesting and living conditions for several species of migratory, migratory or sedentary birds (Figure 3).

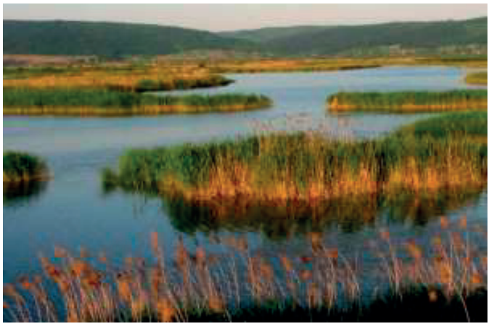

Figure 3. Galbeni Lake from the Moldavian Central Plateau, Romania

The lands bordering the lakes are predominantly arable. On some parts of this area it predominate lands with meadows, often interrupted by clumps of forests or cultivated fields.

The urban areas of the localities are located in the vicinity of the protected natural area Bacău, Iteşti, Siretu, Bazga. In the Northern part of Bacău Lake we find forested plots.

Regarding the property and use of water gloss, due to the fact that the main function of accumulation lakes is the production of electricity, being artificial accumulations, they all are leased to Hydroelectrica S.A.

The space related to the lakes has a special biodiversity, due to the habitat conditions on which offers them; it is also characterized by an active seasonal life.

Mostly of the species, 36% are summer guests and an insignificant number of species are guests of winter; this justifies the special role of the site, especially as a breeding area.

At the same time, the passage species are extremely numerous, providing 47% of the total species encountered.

Calculus of the important factors in the evolution of the trophyc degree of a lake starts from the premise of the use of complex indicators, reflecting not a state of the moment (accidental discharges, thermal pollution, etc.), but a tendency, as well as the influence of several primary indicators (temperature, transparency, lightning, depth, circulation, etc.).

These factors are: saturation in oxygen, chemical consumption of oxygen, appreciated in $KMnO_4$, the mineralization capacity of the lake (CCO-Mn/O_2 report), N_t/P_t report between nutrients, mineral N/PO_4, and phytoplankton biomass.

Also, the application of the “Surface Modelling System” (SMS) software program v. 13.1 of modelling, analysis and design of surface waters in the field conditions specific to the studied lakes, it aims to verify the accuracy of the field and laboratory analyzes performed since 2016 to 2020.

Our research aimed the monitoring of these five lakes water quality, during the mentioned period, regarding the eutrophication process evolution, and was structured on several levels: documentation, field, trophic degree calculus, and a synthesis of results obtained by using the “Surface Modelling System” v. 13.1 software program (Figure 4).

Figure 4. Surface Modelling System (SMS) v. 13.1 software program

The behaviour of these models is well understood and has been studied more intensively than have other parameters.

There are two methods for building models in the SMS program: the direct approach and the conceptual modelling approach. In the first method, the direct approach, the first step is to create a "mesh" or a "grid" (grid).

Model parameters, source data, and background conditions are directly assimilated to networks, nodes, and network elements. This type of approach is only suitable for simple models.

The most effective approach for building realistic, complex, concrete models is the conceptual modelling approach. It creates a conceptual model using GIS objects, including points, arcs, and polygons.

The conceptual model is built independently of the net or grill. It is a high-level description of the area, including geometric features such as channels and dams, bottom conditions of the modelling range, flow rates, etc. and characteristics of the water surface, such as the bottom conditions, the physical, chemical, biological properties of the studied area, etc.

Once the conceptual model is complete, a network of nets or grids is automatically built by the program to fit the conceptual model, and the model data is converted from this model to the elements and nodes of the network of networks.

Basic nutrient indicators such as ammonia, nitrate, and phosphate concentrations can also be predicted reasonably accurately, at least for simpler water bodies such as rivers and moderate-size lakes. Predicting algae concentrations accurately is somewhat more difficult but is commonly done in the United States and Europe, where eutrophication has become a concern in the past two decades. Toxic organic compounds and heavy metals are much more problematic.

Reducing nutrient contributions from sewage treatment works and agricultural sources will be particularly important. In some instances it will be necessary to go beyond the sewage treatment measures set out in the Urban Waste Water Treatment Directive.

With regard to nutrient pollution from agriculture, we will promote a general reduction of nutrient inputs to water from the main sources, complemented by more concerted action in catchments where the impacts or risks justify this approach.

In Galbeni Lake, for instance, the main hydro-chemical parameters of water quality which were analyzed are: air temperature (annual average of 7.5 ÷ 8^{0}C), with warm winters (January's average of 4 ÷ -6^{0}C), and summers with moderate temperatures (July's average of 16 ÷ 17^{0}C); water lake transparency regime, of 3 m in "Lake's Tale" section, in October, because of low precipitations from this period; then between 2 and 10 m in November, so we can say that water of the Galbeni Lake is included in eutrophic - oligotrophic category, with moderate transparency.

We proceeded in the same manner with every studied lake in our research, and their trophic degree is around oligotrophic stage.

Between two sections 1-1 and 2-2 established with Galbeni Lake's data, conform existing norms, at a depth of h = 20 m, for each node (point), SMS knows automate plane coordinates (x, y) of nodes, in function of three points where we have the coordinates to create the program.

Nodes were made in points where we have data for the selected (wanted) field (lake) parameters.

We made the same action for every wanted hydrochemical parameter of our study's lakes. For instance, in the particular case of phosphorus, the network looks like in Figure 5.

We could make the same correlation, using SMS software, for every wanted hydro-chemical or biological parameter of the studied lakes, at every depth and in any section.

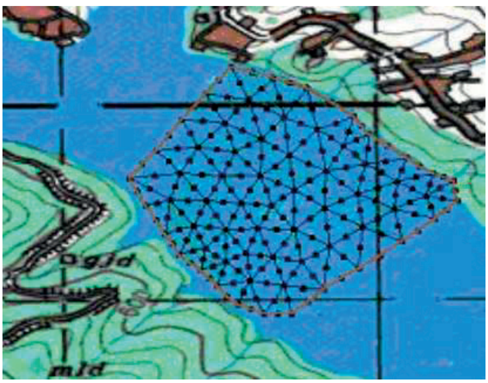

Figure 5. Correlation between points of equal concentration for P total in Galbeni Lake

These graphic correlations, with logarithmic equations to describe relations, permit to establish connections between any two water quality parameters for Galbeni Lake.

Using SMS software, we can establish correlation for points with the same concentration values for any required parameter important for the monitoring of the eutrophication phenomenon in the considered hilly lakes.

For estimate some correlation and logarithmic equations to describe relations between some important water quality parameters from Galbeni Lake, we considered the following parameters, respectively correlation: dissolved oxygen, function of temperature; organic matter, function of dissolved oxygen; nitrogen, function of total phosphorus.

It was used the average values of the considered parameters, for the analyzed period, at h = 20 m depth, in section 1-1 located between two extreme stations.

With these values, it was obtained the correlation, also the logarithmic equations. In the same way, we could establish correlation between every water parameter, and for every lake section we have data, for any depth (Figure 6).

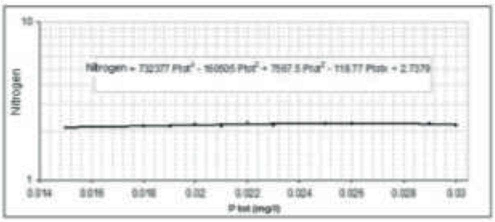

Figure 6. Correlation between nitrogen (mg NO_3/L) and total phosphorus (mg/L) values

Algae cenosis structure modification, with an increase of green algae, especially of *Clorococcalae*, also of blue ones and of *Euglenae*, in our lake's ecosystems, due, in time, to a certain increase of biological productivity and at degradation of water quality, with not-wanted consequences on these, also on the environment (Eilers and Peters, 1988; Scheffer, 1998).

Calculus of trophic degree, following the algorithm proposed by Caraus, I.D. (1986), concluded to integrating the Moldavian Central Plateau's lakes into oligotrophic - mesotrophic lakes category. This result, obtained from mathematical calculus, confirm conclusions made in the experimental field (on lake) after analyzing physical - chemical, biological and bacteriological characteristics observed in land researches, between the researches period.

The objectives proposed by using such a model for the lake under study are the following:

1. Comparison and verification of data taken in the field (on the lakes), and processed in the laboratory;
2. Verification of the result of the calculation of the degree of trophycity with the help of the credit rating system proposed by Caraus, I.D. (1986);
3. The study of the evolution of water quality in the lake through a high-performance program, frequently used by foreign researchers in solving surface water quality problems.

The evolution of the ecological potential, but also of the chemical state in the studied period was followed for the storage lakes from Moldavian Central Plateau, and the three from trace accumulations were evaluated in more detail from the perspective of the evolution of specific indicators eutrophication (total nitrogen, total phosphorus, chlorophyll *a*, transparency) and to establish the trophic stage (Agafiţei, A., Gabor, V., 2018).

The final conclusions regarding the quality of the accumulation lakes from hilly areas combining legislation in the field, theoretical studies, current monitoring and the results of quality models (Agafiţei, A., Agafitei, M., 2002).

CONCLUSIONS

Quality models allow specialists concerned with monitoring the quality of resources to go to the bodies of water most permissible for improvements in ecological and chemical view.

Many of the knowledge gained over the years were based on physical models, but current science focuses mainly on model development mathematics (Ryding and Rast, 1989).

The reduction of nutrient inputs to water and control of eutrophication locally are shared responsibilities, involving a range of stakeholders. In taking forward this strategy, there are working Government departments, other environmental regulators, industry and interest groups (Florescu, M.A., 1983).

Tackling eutrophication will be a long-term commitment, linked to the general objective of contributing to sustainable development.

Starting from the purpose for which the quality of a body of water is modelled, it will decide on the degree of detail of the biological component of the model (the number of parameters of quality and the connections between them), the spatial resolution used for the geometric discretization of the physical system, the type of equations that mathematically render the processes and last but not least the necessary input data used to calibrate the mathematical model (Agafiţei, A., 2000-2002).

Errors between measured and simulated values in the monitoring sections of of the accumulated accumulation lakes, for the two quality indicators - total nitrogen and total phosphorus, may be due to the calculation hypothesis established when running the model, by which the defined section is downloaded directly to the downstream section.

The results should be confirmed by using the model taking into account a possible flow/ exchange between any pair of segments/ sections of the respective storage lake.

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REGULATION OF OXIDATION DITCH TYPE BIOLOGICAL REACTORS

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Abstract

Wastewater treatment plants operate with water flows and characteristics different from those considered in the design stage, the most common differences being found in carbon concentrations that are lower than those of the design, nitrogen concentrations higher than those considered and a disadvantageous C:N:P ratio. This fact means that, during the entire period of operation, decisions are needed leading to wastewater treatment process optimization. The present paper deals with methods of regulating for a nitrification and simultaneous denitrification biological reactor, based on the determinations made for nitrogen concentrations, dissolved oxygen, pH, blowing speed and results obtained related to the treatment efficiency. The analysis proves that the necessary wastewater treatment efficiency is obtained by balancing the nitrification and denitrification processes accompanied by the reduction of energy consumption through recovering oxygen from nitrates, which can be controlled by blowing speed and detecting the operation mode between sequential or continuous ones. Interpretations and conclusions can support operators in finding solutions to optimize the undertaken process.

Key words*: biological reactor, nitrification, denitrification, oxidation ditch, blower.*

INTRODUCTION

Wastewater treatment plants are designed based on data coming from studies and evaluations performed for the served sewerage systems, being a dynamic process, with different efficiencies depending on equipment type and operational practices (Litu et al., 2019).

In most cases, design data, flow rates and concentrations of pollutants are not achieved in operation; there are significant variations both seasonally and hourly, with major technological implications.

Designers must provide technological levers necessary to regulate technological processes and operating scenarios for these different situations.

In exploited wastewater treatment plants, the common situation comprises wastewater inlets having the following characteristics:

- carbon concentrations/carbon amount, CBO5 - lower than those considered in the design phase;
- nitrogen concentrations, ammoniacal nitrogen - higher than those considered in the design phase;
- C: N: P disadvantage ratio (NP-133, 2013).

Wastewater contains significant amount of C, compounds of N, S, P, H and O variable function the treatment cycle phase (Manea and Ardelean, 2016).

MATERIALS AND METHODS

In the present paper it is presented the regulation of the wastewater treatment process for a biological reactor with simultaneous nitrification and denitrification or oxidation ditch type biological reactor (Figure 1).

The biological wastewater treatment process consists in a transfer of materials between water and cells accompanied to the adsorbtion-desorption processes (Iordache et al., 2019).

The advantage of these biological reactors is that they have minimal energy consumption for internal recirculation between aerated areas (for nitrification) and non-aerated areas (for denitrification).

The disadvantage derives from the same aspect, the large recirculation leading to the denitrification process efficiency reduction.

The regulation of these reactors can be done as follows:

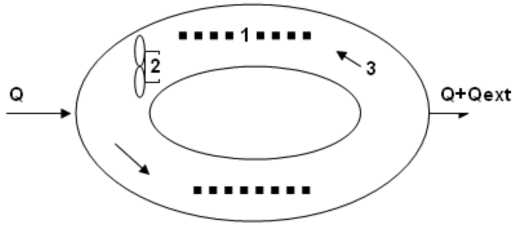

Figure 1. Oxidation ditch type biological reactors, simultaneous nitrification-deintrification;
Q - input flow, Q_{ext} - sludge recirculation flow;
1 - aeration system; 2 - mixing system ; 3 - water - sludge mixture flow into the reactor

1. With continuous operation of the aeration when the blowers are chosen properly: the level of dissolved oxygen in the control section is set and regulated automatically according to the ammonia nitrogen concentration determined in the reactor, usually at the outlet to the secondary decanter; minimum values of dissolved oxygen are set when minimum NH_4 values are recorded. The operator will monitor the evolution of nitrate concentrations and will adjust the aeration program to balance the biological process of nitrification-denitrification.
2. With sequential operation: when minimum NH_4 value is reached, the aeration is stopped to stimulate denitrification on the entire reactor and the aeration is restarted when maximum NH_4 value is reached.

Operating parameters, dissolved oxygen, ammonia nitrogen and nitrate concentrations, pH are determined continuously with specialized equipment (hatch.com, 2020), the values obtained being the basis of process control.

RESULTS AND DISCUSSIONS

The presented results are obtained following the optimization of several similar wastewater treatment plants, which differ in the automation degree and their operating programs.

Figures 2 and 3 show the evolution of oxygen, ammonia nitrogen, nitrates concentrations and the aeration system operation for a fully automated station depending on the nitrogen values determined continuously with the monitoring equipment (hatch.com, 2020). Dissolved oxygen levels below 1 mg/l, stimulation of denitrification at night and creation of a technological reserve for the morning peak are observed.

Figure 3 correlates with Figure 2. The sequential operation highlights the "mirror" evolution of NO_3 and NH_4 concentrations in the reactor but also at the discharge; this is a disadvantage for wastewater treatment plants with continuous supply of biological reactors sequentially operated.

The monitored systems highlight correlations between dissolved oxygen values - blower speed - pH value - nitrates and ammonia nitrogen. The consumption of NH_4 in the reactor (system) corresponds to the decrease of oxygen demand, so the increase of O_2 concentrations, the reduction of the blower speed, the increase of NO_3 concentrations and the pH decrease.

In the absence of NH_4 monitoring or sensors damage, it can be achieved adjustment, balancing of nitrification - denitrification through dissolved oxygen tracking. The increase of dissolved oxygen (obtained by blower speed decreasing) involves NH_4 consumption; when the maximum dissolved O_2 and the minimum blower speed are reached, it is ordered to stop the aeration and to move to the denitrification phase on the entire basin.

For another wastewater treatment plant, the automation system does not allow adjustments according to nitrogen concentrations. In these circumstances, the process regulation is accomplished by blowers timing and operator intervention for fine adjustments.

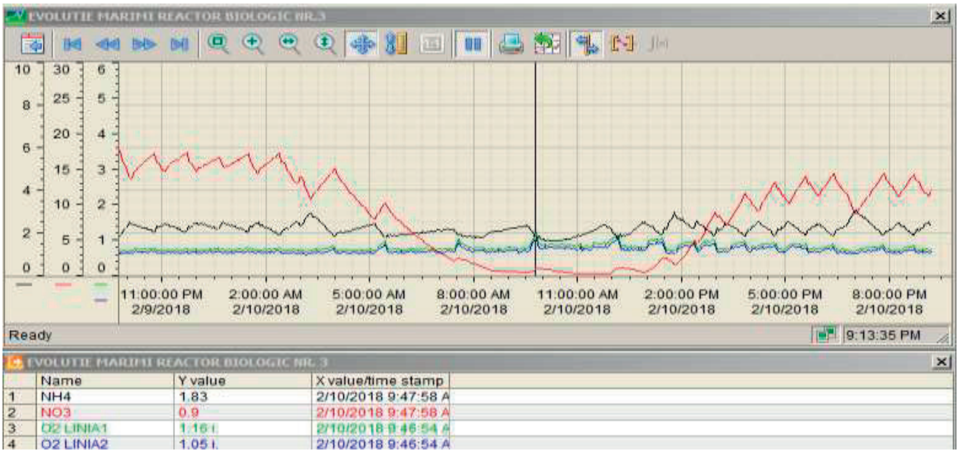

Figure 2. Evolution of nitrogen concentration values in the biological basin sequentially exploited with imposed NH_4 limits

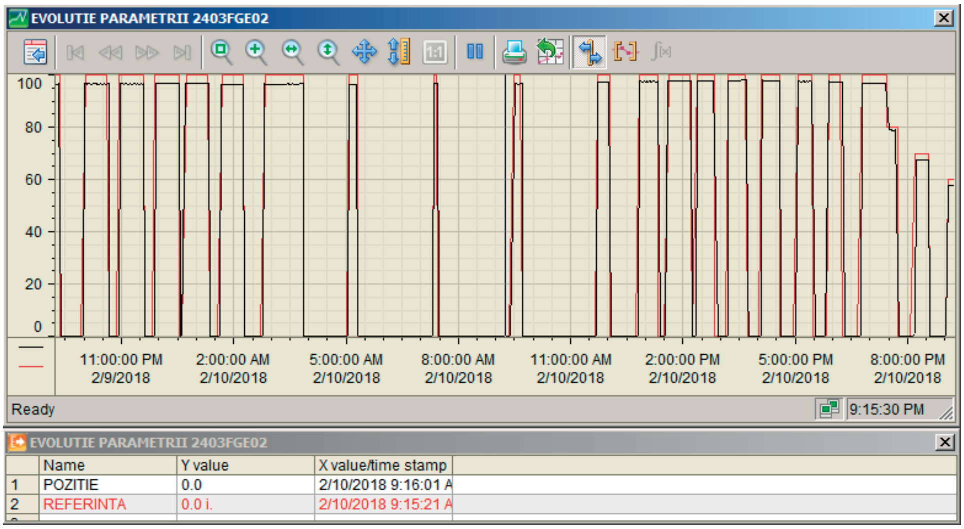

Figure 3. Degree of aeration valves opening of corresponding to timed operation with NH_4 limit

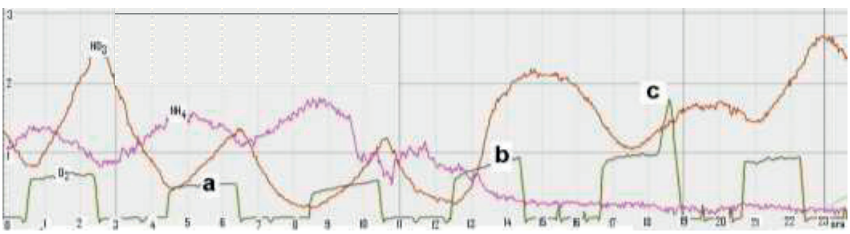

Figure 4. Correlation between dissolved oxygen level and ammonia nitrogen concentration for an oxidation trench type biological reactor sequentially operated; operating situations: a - low NH_4 level, efficient nitrification and denitrification process; b - medium NH_4 level, efficient nitrification, increasing oxygen level, decreasing denitrification efficiency; c - reduced NH_4 level, increasing oxygen level, ineffective denitrification

During the operation period marked “a” in figure 4, in the section of biological reactor output there is observed a correlation between high concentration of ammoniacal nitrogen, low dissolved oxygen concentration (oxygen consumption) and low nitrates concentration, the operation situation corresponds to an efficient denitrification process. During the operation periods marked “b” and “c” in Figure 4, the situation corresponds to a process of excessive nitrification accompanied with ammoniacal nitrogen consumption plus dissolved oxygen and nitrate concentrations increasing; the intervention of the operator and the aeration stopping are required.
Taking into account these correlations, a control program based on dissolved oxygen monitoring can be adopted.

Reaching a maximum set value in the control section corresponds to the oxidation of ammoniacal nitrogen and the transition to the denitrification phase.
The denitrification duration is determined from the NH_4 balance equation on the biological reactor:

Reactor volume x $\Delta c(NH_4) = T_{denitrification}$ x $Q_{intrare}$ x $c(NH_4)_{intrare}$ ....(1)

hypothesized the NH_4 concentration increasing within the reactor:

$\Delta c(NH_4) = (0.5\text{-}1.5)$ mg/l ....(2)

In the case of dissolved oxygen regulation, of aeration process, it is possible to achieve the simultaneous nitrification and denitrification and of a continuous aeration flow.

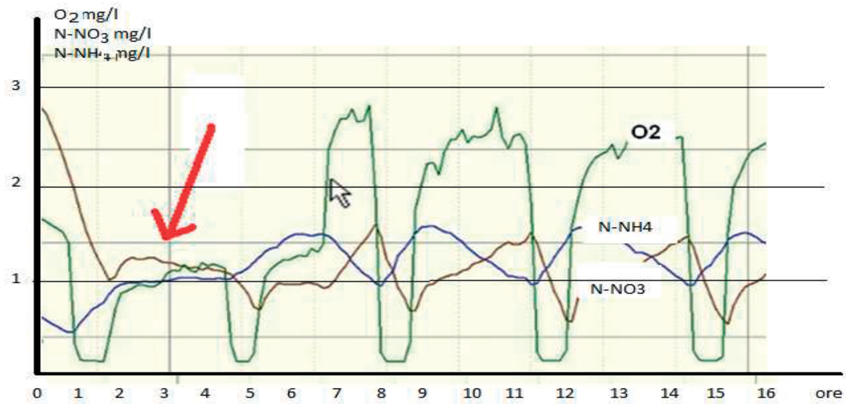

Figure 5. Oxidation trench system with simultaneous nitrification and denitrification operating period (marked area)

The marked period corresponds to the simultaneous nitrification and denitrification process; the achievement of the simultaneity condition derives from the balancing of the entrance nitrogen and carbon quantities with the adopted oxygenation level.
The concentration of ammoniacal nitrogen increasing within the reactor will immediately command the dissolved oxygen concentration reference value growth (Figure 5).

CONCLUSIONS

Ensuring the necessary wastewater treatment efficiencies is achieved by adjusting the technological flow according to the parameters registered at the plant entrance point. Under these conditions, nitrogen is the critical tretament indicator, exceeding nitrates and total nitrogen for treated water being recorded. Balance of nitrification and denitrification processes is required in order to reduce nitrate concentrations for treated water and to reduce energy consumption by recovering oxygen from nitrates.
The principle of elaborating an efficient technological flow is to be changed according to the monitored parameters (technological supply chain, introduction/removal of treatment units/stages, by-pass primary sttling basins, primary settling basins efficiency improvement using coagulants).

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ANALYSIS OF VEGETATIVE AND REPRODUCTIVE GROWTH OF GREENHOUSE TOMATOES CULTIVATED UNDER DRIP IRRIGATION AND FERTIGATION WITH INCREASING FERTILIZER RATES

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Abstract

An experiment was conducted in the experimental field in Chelopechene, Sofia, Bulgaria in 2019-2020 with tomato (Solanum lycopersicum variety "Big Beef" F1) cultivated under drip irrigation and fertigation. Two levels of irrigation (100% ETc and 60% ETc) with four fertilization levels (0, 80 %, 100 %, and 120 % of the fertilizer rate) have been served as treatment. In the phase 4-6th inflorescence, main growth parameters like plant height, stem diameter, number of leaves, number of inflorescences and number of fruits of tomato plants were measured. Analysis of variance (ANOVA) was performed to analyze the effect of irrigation and fertilization on vegetative and reproductive growth of plants. Under full irrigation, the plants have the thickest stems; they are leafier, with more inflorescences and formed more fruits than average. Of all the studied growth parameters, only for the number of inflorescences for both experimental years 2019 and 2020, a statistically proven difference was found for the influence of irrigation.

***Key words**: greenhouse, growth parameters, drip fertigation, tomato.*

INTRODUCTION

Tomatoes are one of the most preferred and consumed vegetable crops in Bulgaria, due to their high nutritional value and content of vitamin C and lycopene, protecting human health. Although the annual production of tomatoes in the country has been declining in recent years, tomatoes have the largest share in greenhouse vegetable growing. In 2019, the greenhouse production in Bulgaria was developed over 9220 acres, with the majority of the production being tomatoes.

Greenhouses used for cultivation of tomato, are usually heated glass or unheated coated with plastic constructions in which the vegetable crop is cultivated directly in the soil (Jinliang Chen, 2013; XING Ying, 2015; Çebi et al., 2018).

Unheated greenhouses rely on sunlight as only source of energy and have a simple structure, making them inexpensive to build and maintain (Yuan et al., 2001). They are coated with polymeric foil materials, which have a relatively short useful life between 6-45 months, depending on the UV stabilizers (Espi et al., 2006). Nevertheless, unheated greenhouses are valuable as cultivation facilities in which some of the adverse weather factors can be eliminated or reduced to plant-tolerable levels, and the yields and quality of production exceed those obtained from the field (Mahajan & Singh, 2006; Mitova et al., 2019).

Tomato is one of the most demanding crops in terms of growing conditions (Sharmasarkar et al., 2001; Kiymaz & Ertek, 2015) and nutrient and water regime are the main factors influencing production during most of the growing season.

Tomato plants require a lot of water, especially during the flowering and fruiting. In greenhouse cultivation, only the irrigation system is relied on to supply the necessary water for the plants, so the question of its effective operation is of particular interest. The application of an irrigation schedule to meet the full water requirements of the crop leads to an increase in yield and product quality (Ankush and Sharma, 2017, Patamanska et al., 2020).

Plant development and fruiting are also strongly influenced by environmental factors, such as light and temperature during different growth stages (Hou et al., 2017; Tijskens et al., 2016).

This study aims to analyse the effect of irrigation and fertilization on the vegetative and reproductive growth of tomatoes cultivated under unheated conditions in a protected environment.

MATERIALS AND METHODS

The study was conducted in the Chelopechene experimental field of the Institute of Soil science, Agrotechnologies and Plant Protection in town of Sofia, Bulgaria in an unheated polyethylene greenhouse with dimensions of 7.9 x 53 m and a total area of 420 m^2 in 2019-2020. The experimental field with geographical coordinates: 42°44′22.8″N, 23°28′3.7″E is a part of the Sofia Field, located at 550 m above sea level. This area has continental climate characterized by cold winter. The soil type of the experimental site is *Chromic Luvisol* which can be defined as moderate to strong water-permeable with an average filtration capacity.

The object of the study are tomato variety *"Big Beef" F1*.

A two-factor experiment was performed with experimental factors - irrigation (V) and fertilization (T).

The factor irrigation was applied in two levels: V1 - full irrigation at irrigation rate estimated by evapotranspiration (100% ETc), V2 - deficit irrigation (60% ETc).

The factor fertilization was applied at four levels: T0 - without fertilizer, T1 - suboptimal fertilization $N_{8.95}P_{11.82}K_{13.87}$, T2 - optimal fertilization $N_{11.59}P_{15.84}K_{17.74}$, T3 - luxury fertilization $N_{14.50}$ $P_{20.13}$ $K_{21.88}$.

The following treatments were tested: V1T0, V1T1, V1T2, V1T3, V2T0, V2T1, V2T2, V2T3.

The experimental treatments were arranged according to the method with long plots. Each plot has a surface of 24 m^2 and consisted of twin rows of tomato with a total of 81 plants. They are planted “checkerboard” at a spacing of 0.6 m and at a distance between rows of 0.5 m.

Irrigation was performed with a drip irrigation system, comprising a command unit and two batteries consisting eight laterals situated next to the each row of tomato. Mulching was applied to further reducing the evaporation. Black polyethylene mulch (UV 15 mic/1.20 m) was used.

Immediately after planting the tomatoes in a permanent place, a watering of 1-2 l per plant was carried out to intercept seedlings and next watering 7 days later. Depending on the growth stage of tomatoes, watering was carried out with a frequency of 3-7 days depending on stage of growth. Deficit irrigation began to be applied from the beginning of fruit setting.

Irrigation rate for the fully irrigated treatments V1T0, V1T1, V1T3 and V1T4 was determined by the sum of daily evapotranspiration for the irrigation interval. The microclimate parameters temperature, relative humidity of the air and the solar radiation required for the calculations of the evapotranspiration using the Penman-Monteith method (Allen et al., 1998) were measured with an automatic weather micro station located in the centre of the greenhouse.

In the autumn, storage fertilization with 450 kg/ha P_2O_5 and 500 kg/ha K_2O was carried out. When planting tomatoes, nitrogen fertilization with ammonium nitrate (450 kg per ha) was performed. During the growing season of tomato simultaneously with irrigation, 100% water-soluble fertilizers were introduced, which contain macronutrients (N, P, K) and micro-elements (Fe, Zn, Mn, Mg, B, Cu, Ca). Depending on the growth stage of tomato were applied: after planting tomato - mineral fertilizer containing 16% N, 69% P_2O_5 and 16% K_2O, during their vegetative development - fertilizer containing 27% N, 27% P_2O_5, and 27% K_2O and in the period of fruiting the applied fertilizer contains 18% N, 11% P_2O_5, and 59% K_2O. In order to apply the exact fertilizer rate, a MixRite 2.5 hydraulic fertilizer injector was used. Fertigation with 120:100:80:0 fertilizer dose was given in the treatments 9 times at 7 days interval beginning 10 days after transplanting.

Biometric parameters of five consecutively planted plants of each repetition of the treatment (4 repetitions) were measured in the morning - between 7^{00} and 9^{00} hours for the analysis.

The following parameters:

- plant height (cm),
- stem diameter (cm),
- number of leaves,
- number of inflorescences,
- number of fruits of tomato plants

were measured.

The obtained results were subjected to analysis of variance (ANOVA) and to Fisher's least significant difference (LSD) procedure for irrigation and fertilization.

RESULTS AND DISCUSSIONS

The average monthly data of the parameters of the microclimate in the greenhouse: solar radiation, relative humidity and maximum and minimum air temperature during the entire growing season from May to September for the two experimental years are shown in Table 1. The conditions are favourable for medium early cultivation of tomato. They are characterized by optimal values of air temperature throughout the growing season.

In May-June during the vegetative development of plants, the average air temperature in the greenhouse is 22-23ºC (2019) and 21-22ºC (2020), and in the period of mature fruiting in the months of July-August is 24-25ºC for both years. The temperature in the greenhouse during the vegetative development of the tomato plant in 2020 was lower than in 2019, but higher in the period of mature fruiting.

Optimal for the good development of tomato plants and fruiting (Genkova, 2009; Shaban, 2014; Shamshiri, 2018), moderate humidity - 60-67% - was registered in the greenhouse in both seasons, except for the months of August - September 2019, when the humidity was lower.

In 2020, tomato plants were subjected to greater temperature differences and have received more light energy. Solar radiation in 2020 is higher for all months of the growing season.

Due to similar climatic conditions in both years, the growing season of tomatoes was the same - 17 weeks.

In the second half of June of the both experimental years in the phase of 4-6th inflorescence the following growth parameters: plant height, stem diameter, number of leaves, number of inflorescences and number of fruits of tomato plants, were measured. The readings were taken for about 60 days after transplanting. The mean values of the biometric parameters of the tomato plants by treatments are shown in Table. 2.

Despite some differences in microclimatic conditions, the tomato plants reacted unidirectional in both experimental years. The higher growth parameters of the plants were observed in 2020 due to more favourable climatic conditions, compared to the previous 2019. With increasing fertilizer rate in both experimental years, the values of the studied parameters increase. In both irrigation regimes, in 2019 tomato plants with T3 fertilization have the highest values of the parameters. Exceptions to the observed trend in 2019, in 2020 make the following parameters: stem diameter of plants under deficit irrigation, height and number of leaves per plant under full irrigation, in which plants with T2 fertilization have optimal development.

At an average plant height of 121.19 cm for both years, those with full irrigation were slightly higher (0.9%) than tomatoes with deficit irrigation. The two-factor dispersion analysis of the average values of the studied parameters (Table 3) showed 70.64% share of fertilization and only 1.01% share of irrigation in the formation of plant height. The combined effect of fertilization and irrigation for the growth of tomatoes is minimal - 2.49%. The performed LSD test by the factor fertilization divides the treatments into 3 homogeneous groups with statistically proven differences between the treatments with luxury fertilization and the other levels of fertilization.

The average stem diameter for the two experimental years in deficit irrigation was only 0.78% larger than that of plants with full irrigation.

From the presented data on the different levels of fertilization it can be seen that with the exception of the deficit irrigation in 2020, in the other treatments the parameter the stem diameter varies greatly, i.e. does not prove reliable enough in this type of research.

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Table 1. Average monthly data of the climatic parameters along the experiment for two experimental years

Parameter / Year / Month	Solar Radiation, W/m²		Temperature Min, °C		Temperature Max, °C		Relative Humidity, %	
	2019	2020	2019	2020	2019	2020	2019	2020
May	108.7	132.98	7.1	2.64	25.80	41.14	62.00	57.77
June	160.05	169.01	13.75	5.26	36.62	43.95	67.57	66.25
July	141.67	190.08	13.63	9.34	36.14	44.91	63.28	60.75
August	134.36	168.85	13.73	10.47	36.99	45.53	54.04	63.79
September	110.34	144.92	5.64	3.99	36.36	42.98	53.46	55.01

Table 2. Growth parameters of greenhouse tomato as affected by irrigation and fertilization

Parameter / Year / Treatment	Plant height, cm		Stem diameter, cm		Leaves number		Inflorescence number		Fruit number	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
V1T0	102.78	134.5	1.12	1.24	19.2	17	4.4	5.4	14.2	7.25
V1T1	112.36	134.8	1.18	1.36	20.6	16.4	5.6	6.4	15.6	8.4
V1T2	110.94	140.2	1.04	1.36	20.6	17.4	6.2	6.6	18	8.8
V1T3	119.52	137.2	1.32	1.43	22.4	18.4	7.6	6.2	18	13
Average	111.4	136.7	1.17	1.35	20.7	17.3	5.95	6.15	16.45	9.4
F-Ratio	11.71	7.61	5.38	2.28	3.25	4.87	5.8	5.03	15.69	30.5
P-Value	0.0000	0.002	0.0094	0.1189	0.0497	0.016	0.007	0.012	0.0001	0
LSD 95.0%	6.0147	2.872	0.1636	0.1586	2.1826	1.146	1.66	0.703	1.4221	1.3368
LSD 99.0%	8.287	3.957	0.2127	0.2185	3.0	1.579	2.28	0.969	1.9593	1.9602
V2T0	93.8	130	1.11	1.18	17.4	17	3.4	5.4	6.8	14
V2T1	99.3	128.6	1.23	1.48	18.4	16.4	4	5.6	8.8	15.2
V2T2	106.2	133.8	1.17	1.5	20.4	17.4	3.6	5.6	8.6	15.4
V2T3	119	136	1.26	1.42	21.6	18.4	4.4	6	11.8	18.4
Average	104.6	132.1	1.19	1.4	19.5	17.3	3.9	5.65	9.0000	15.75
F-Ratio	36.88	14.48	1.95	13.8	22.56	4.87	4.4	1.41	14.55	18.44
P-Value	0.0000	0.0000	0.1626	0.0001	0	0.016	0.0199	0.2771	0.0001	0
LSD 95.0%	5.3593	2.6815	0.1439	0.1189	1.1992	1.146	0.6359	0.636	1.6283	1.31
LSD-99.0%	7.384	3.6945	0.1983	0.1638	1.6523	1.579	0.8762	0.8762	2.2435	1.80

Table 3. Summary of the two-way analysis of variance of average data for two experimental years

Parameter / Year / Treatment	Plant height, cm	Stem diameter, cm	Leaves number	Inflorescence number	Fruit number
	avg 2019-20	avg 2019-20	avg 2019-20	avg 2019-20	avg 2019-20
V1T0	118.64	1.18	18.1	4.9	10.7
V1T1	123.58	1.27	18.5	6	12.0
V1T2	125.57	1.2	19	6.4	13.4
V1T3	128.36	1.375	20.4	6.9	15.5
V2T0	111. 9	1.145	17.4	4.4	10.4
V2T1	113.95	1.355	18.4	4.8	12.0
V2T2	120	1.335	20.4	4.6	12.0
V2T3	127.5	1.34	21.6	5.2	15.1
V	ns	ns	ns	***	ns
T	***	***	***	***	***
VxT	ns	*	*	***	***

*, **, *** indicate significance levels $p<0.05$, $p<0.01$, $p<0.001$, ns denotes no significance

The influence of fertilization is also predominant at this parameter - fertilization has 93.93% share vs 6.06% share of irrigation in the formation of the thickness of stems of tomato plants. The combined effect of the two factors tested was also low, at only 0.03%. The treatments are divided into 4 homogeneous groups by fertilizer factor, and the differences between all treatments are statistically proven.

With an average of 18.992 leaves for the experiment, plants with full irrigation have only 0.9% more leaves than those with deficit irrigation. The performed two way ANOVA of the average data from the two years showed that the share of fertilization in the formation of the number of leaves is 78.83%, and - 0.46% share of irrigation. The combined effect of the two factors in the formation of the leaf structure is higher - 8.5%. The treatments are divided into 3 homogeneous groups by the factor fertilizer, but no statistical difference is proved between treatments by factor irrigation.

By number of inflorescences per plant, tomato plants under full irrigation formed more inflorescences in 2019 than those in 2020, although the climatic conditions were more favourable. In the better climate year 2020, tomato plants under deficit irrigation formed an average of 59.7% more inflorescences compared to 2019. For both experimental years, plants under full irrigation had 16% more inflorescences than those under deficit irrigation. ANOVA shows a high share of participation of both tested factors - 52.55% share of fertilization and 33.8% share of irrigation in the formation of inflorescences. The combined effect of both factors amounts to 9.77%. Regarding the formed inflorescences, the treatments are arranged in three homogeneous groups with proven differences between the treatments by factor fertilization. In addition, there are statistically proven differences between full and deficit irrigation treatments for this parameter.

The number of fruits per plant naturally increases with the fertilizer rate. With an average number of 12.64 fruits formed per plant for the two experimental years, the differences in the number due to the irrigation regime is insignificant - 1.43% in favour of the deficient irrigation. The share of fertilization in the formation of this important parameter is decisive - 91.09%, while the share of irrigation is only 2.42%. The combined effect of both factors on the fruit number is 4.18%. The treatments are arranged in four homogeneous groups with proven differences between all treatments by factor fertilization.

CONCLUSIONS

Obtaining sustainable yields is conditioned by the proper growth and development of tomato plants. The analysis of the growth process of tomato plants showed that the height and diameter of the stems, number of leaves, inflorescences and number of fruits of a plant are variable and are influenced mainly by the fertilization applied in the period of vegetative development. The tomato plants with a luxury fertilisation have the best development under both irrigation regimes.

Of all the studied growth parameters, only for the number of inflorescences for both experimental years 2019 and 2020, a statistically proven difference was found for the influence of irrigation. This finding is of great practical importance, as a priority of research in recent years is a determination of the best practice for the application of irrigation and fertigation for tomatoes to achieve optimal yield with maximum efficiency of fertilizers used and savings of irrigation water.

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WATER QUALITY ASSESSMENTS THROUGH THE APPLICATION OF CAUSE AND EFFECT DIAGRAMS IN CONJUNCTION WITH HACCP AND RISK ASSESSMENT FOR "ROUA APUSENILOR" SPRING WATER BOTTLING PROCESS

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Abstract

In this paper, we approached the two dimensions of water quality assessments. The qualitative dimension which involves the analyses of the physicochemical and microbiological parameters of "Roua Apusenilor" spring water and the application of both HACCP principles and Ishikawa Diagrams as risk analysis steps. The paper highlights the high-quality groundwater parameters of "Roua Apusenilor" spring water according to the European legislation. The hazard analysis was used for risk assessment and for the identification of different types of hazards in a spring water bottling process. To identify the causes that may lead to a potential risk, the Cause and Effect Diagram was used, based on the analysis of the 5M. The paper presents this in detail for the bottling process stage. The main emphasis was put on the quantification of risk assessment by determining the Risk Class (RC) per identified processing hazard. Also, corrective actions were undertaken. For the bottling stage, critical control points have been identified in the Cause and Effect Diagram, based also on the analysis of the 5M. The two methods, HACCP in conjunction with Cause and Effect Diagrams, display enhanced effects on a larger scale when they are used in combination.

***Key words**: HACCP, Ishikawa diagrams, risk assessment, spring water, water bottling process.*

INTRODUCTION

Clean drinking water can sustain every aspect of human life. Spring bottled water may contain lots of contaminants from the environment. The water bottling process also poses risk for spring water contamination. This determines the need to investigate the source, but also the spring water treatment process. Water quality assessments involve laboratory water analysis and a risk analyses methodology to avoid irregularity in the production system (Karnaningroem and Sunaya, 2020).

Water in nature is never pure; given the interactions with the environment, it contains gases, mineral and organic substances, dissolved in suspension (Bătrânescu et al., 1997). Water is a vital resource. Our health depends directly on the drinking water quality (WHO, 2004).

Underground waters are an important resource, considering that they are usually less polluted or even unpolluted compared to surface waters. Therefore, underground waters can be made potable without any treatment or just using minimal measures, sometimes only disinfection. (Negrea et al., 2009).

Water quality assessment is made by measuring certain parameters (physical, chemical and microbiological), whose limits are legally defined (Calisevici et al., 2011). In Romania, water quality drinking is set by Law no. 311/2004 complementary to Law no. 458/2002 which transpose Directive 98/83/EC. Drinking water must be healthy, clean, without microorganisms, parasites or substances which, by number or concentration, can be a potential hazard for human and animal health (Todoran et al., 2010).

Each organization uses various resources to achieve their short- and long-term goals increasing the prospect of their achievement. A general overview of references for some of the primary tools that might be used in quality risk management by industry and regulators include: Basic Risk Management Facilitation Methods (Flowcharts; Check Sheets; Process Mapping); Cause and Effect Diagrams (Ishikawa Diagram, Fishbone Diagram); Failure Mode Effects Analysis (FMEA), Failure Mode, Effects and Criticality Analysis (FMECA), Fault Tree Analysis (FTA), Hazard Analysis and Critical Control Points (HACCP), Hazard Operability Analysis (HAZOP), Preliminary Hazard Analysis (PHA), Risk Ranking and Filtering, Supporting Statistical Tools (Control Charts, Design of Experiments (DOE); Histograms; Pareto Charts; Process Capability Analysis) (Chavda et al., 2015).

Fishbone (Cause and Effect or Ishikawa) diagram may be applied for identification of any phenomena in various life-spheres. It is the tool used to represent relationships between given results and their potential reasons. The graph is based on main reasons, from which detailed reasons stem, in such a way that the graph picture represents a fishbone. Ishikawa graph is most often used for analysis of production processes (Malinowska, 2010)

This method is based on the analysis of main reasons: 5Ms - method, machine, material, man, management. In the 5M+1E variant - environment-related reasons, in 7Ms – measurement, and in 8Ms - finances are additionally considered (Łuczak and Matuszak-Flejszman, 2007; Żuchowski and Łagowski, 2004).

The HACCP method is recognized as a quality risk management tool in different industries (Dahiya et al., 2009). According to article 5(1) of Regulation (EC) No. 852/2004 on the hygiene of foodstuffs, it is a legal obligation in European Union to implement and maintain an institutional food safety system, such as the HACCP.

In the food and pharmaceutical industry, the implementation and certification of the ISO 22000 standard (Food safety management systems), the Global Food Standard (BRC), FSSC 22000, the International Features Standard Food (IFS Food), the Safe Quality Food SQF 2000 and 1000 and the GLOBAL G.A.P. is currently optional (Zaharie Pop et al., 2018).

There are five primary principles in HACCP method: hazard analysis on the system, determination of critical control points and critical limits, establishment of monitoring procedures and organisation of corrective actions in the diversion of critical limits which have surpassed toleration limits. (Karnaningroem and Sunaya, 2020).

The HACCP methodology aims to prevent and reduce known risks that may occur at certain stages of the manufacturing process. It covers both good manufacturing practices (GMP) and safety of employees. HACCP is the systematic method (comprising seven principles) for the identification, assessment and control of safety hazards associated with physical, chemical, and biological hazards. The problems associated with the implementation of HACCP can be overcome by training and continuous education of all employees. The HACCP is proven to be economically efficient, its implementation and maintenance involving lower costs. In the cases involving non-conformities it leads to small scale losses, while ensuring the safety of goods (Tidjani, 2013).

The study aims to make a personal contribution to the possibilities of improving the methodlogy for identifying food safety hazards, assessing their occurrence and severity, establishing control measures for identified risks. To improve the quality of "Roua Apusenilor" spring water, the aim of the present paper is to follow the production steps of bottled water using the Ishikawa "5M" method in conjunction with the HACCP principles.

RESEARCH METHODOLOGY

The risk analysis method introduced in this study was tested on a water bottling company located in Transylvania, in the centre of Romania. The source is "Lucia Cave" in the village of Sohodol, Alba County. The registerred trademark of the product is "Roua Apusenilor" still and carbonated spring water.

The factory has implemented the HACCP system (ISO 22000) for several years. The selection criteria of the enterprise for the study represented the production of a typical, most common and most important element for life – water.

Such a selection criteria allowed to compare the HACCP system and 5M-HACCP functioning in the same enterprises, and to determine risk areas for the production of the most important human product. The study was made in 2020.

The first stage of the research is a qualitative investigation of "Roua Apusenilor" spring water quality at source.

For the qualitative assessment of spring water, one sample (water source for the factory) was

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collected and analysed in September 2020. The assessment was performed in the absence of atmospheric precipitation 7 days before, which could have influenced the results of laboratory analyses. The physicochemical and microbiological analyses were performed according to the working standards specific to each parameter.

The second stage presents the justification of the necessity to implement a management system for food safety according to the HACCP principles in conjunction with the Cause and Effect Diagrams. This can provide control over the technological process, in all stages, through the evaluation of the three possible risks: physical, chemical, and biological, based on the analysis of main reasons: 5Ms - man, method, machine, material, medium. For this, a generic HACCP model was developed.
The risk analysis involves several steps according to Figure 1:

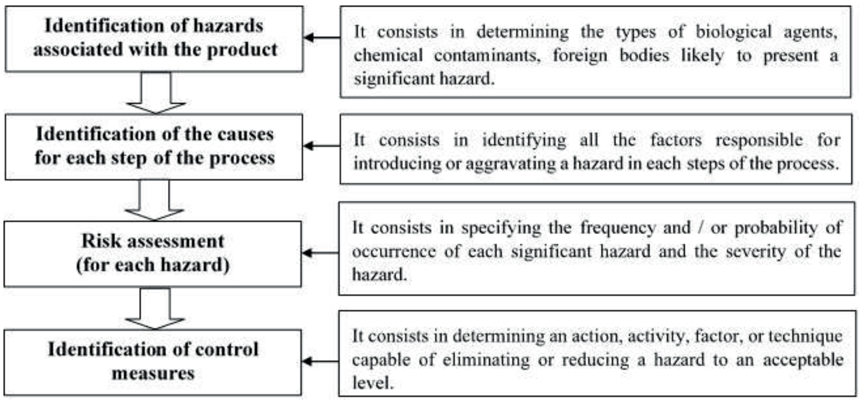

Figure 1. Steps of risk analysis

The proposed methodology identifies, assesses, and classifies all potential risks not only the chemical, physical, and biological (microbial and parasitological), ones as provided by the HACCP system.
Thus, the risk analysis considers the following potential risks that may affect food safety and the health of staff and consumers:
Biological risks represented by micro-organisms, parasites present in water or foodstuffs or that can accidentally contaminate them. These may exceed legal limits and cause diseases for the consumer during handling, processing, storage, and transport.
Chemical risks represented by chemical components or toxic substances specific to water or foodstuffs that are above the legal limit or by foreign chemicals that contaminate food.
Physical risks represented by foreign bodies that are found in water or in foodstuffs or may reach them during food handling.
When identifying the causes that can lead to the appearance of a potential risk, the cause-effect diagram is used, based on the analysis of the 5M; 5 Whys? methods. The diagram, also known as a Fishbone Diagram, is used to illustrate cause and effect relationships, which facilitates the separation of causes from the effects of a given problem and to discern its complexity (Luca, 2016).
The risk assessment is determined for each hazard by identifying the frequency and/or probability of occurrence and the impact of the identified hazard.
Frequency (F) is the probability that the identified risk will occur several times in the product or that the activity carried out will generate this risk several times. It is classified into 4 frequency levels:
- *low*, practically unlikely to occur ("theoretical risk");
- *medium*, it can appear, it happens to appear;
- *high,* occurs systematically, repeatedly;
- *critical*, it will certainly appear in the process, activity.
Severity/gravity (G) is the consequence of the identified risk to the product and food safety or

to the activity carried out in the context in which the department operates.
It is classified into 4 levels:
- *low*, causes low-level damage to products, consumers, and activity;
- *medium*, damage with an impact on the products and the activity carried out;
- *high*, substantial damage to the products and work carried out and/or causing disease for the final consumer;
- *critical,* fatal consequences for the products and activities carried out, serious disease, irremediable damage, manifesting immediately or after a longer period.

Impact (I) is the effect of the identified risk depending on the frequency of occurrence and its severity (as an arithmetic mean) depending on the 5M (man, method, machine, material, medium), on the product and food safety. It is classified into 4 levels:
- *low*, no measures required;
- *medium*, periodic measures are needed, often single actions;
- *high*, requires general control measures (e.g., procedures, working standards);
- *critical*, requires specific control and monitoring measures that are defined for a particular situation (e.g. Operational Prerequisite Programmes - oPRPs, Critical Control Point - CCP).

Risk class (RC) is the final effect of the identified risk on the product, process or activity:
- *low* (between 1 și 2): no special control and monitoring measures required;
- *medium* (between 2,1 și 2,5): single control measures are required;
- *high* (between 2,1 și 3): general control measures are required (e.g., generated by Prerequisite Programs - PRPs);
- *critical*, urgent and specific control and monitoring measures are required which are defined as Operational Prerequisite Programmes - oPRPs; Critical Control Point - CCP.

The "decision tree" model of the HACCP system was used to determine the CCP. The decision tree classifies data elements by asking a series of questions: Q1, Q2, Q3, Q4 (N.G.P. G.F.S., 2007): 1. Do control preventative measure(s) exist? 2. Is the step specifically designed to eliminate or reduce the likely occurrence of a hazard to an acceptable level? 3. Could contamination with identified hazard (s) occur in excess of acceptable level (s) or could this increase to unacceptable levels? 4. Will a subsequent step eliminate identified hazard (s) or reduce likely occurrence to an acceptable level?

RESULTS AND DISCUSSIONS

1. The analysis of "Roua Apusenilor" Spring Water

In Tables 1 and 2 the physicochemical and microbiological results of the sample of "Roua Apusenilor" spring water are presented.

Table 1. Results of the physicochemical analysis of "Roua Apusenilor" spring water

Parameter	Determined	Max. Admissible
pH	6.98	6.5 ÷ 9.5
Permanganate index, mgO_2/L	1.21	5.00
Ammonium, mg/L	<0.025	0.5
Nitrite, mg/L	<0.015	0.5
Nitrates, mg/L	3.95	50
Turbidity, JTU	0.92	5
Total hardness, °dH	11.05	Minimum 5.00
Iron, μg/L	<10	200
Aluminum, μg/L	<0.5	200
Chlorides, mg/L	2.83	250
Conductivity, μS/cm at 20 °C	390	2500
Dry residue at 180°C	192.5	-

Table 2. Results of the laboratory microbiological analysis of "Roua Apusenilor" spring water

Parameter	Determined, CFU	Max. Admissible, CFU
Coliform bacteria	0/250 ml	0/250 ml
Escherichia coli	0/250 ml	0/250 ml
Enterococcus faecalis	0/250 ml	0/250 ml
Total plate count 22 °C	1/ml	100/ml
Total plate count 37 °C	2/ml	20/ml
Pseudomonas aeruginosa	0/250 ml	0/250 ml
Clostridium perfringens	0/100 mL	0/100 mL

Tables 1 and 2 shows that the values of the parameters are within the established limits according to the national and European legislation in force. The quality of "Roua Apusenilor" spring water from "Lucia Cave" source, Sohodol village, is corresponding.

2. Analysis of potential risks through the concomitant use of the Ishikawa diagram and the HACCP principles

The method of verification of HACCP system was designed and tested according to the process map or the 5M-HACCP model presented in Figure 2.

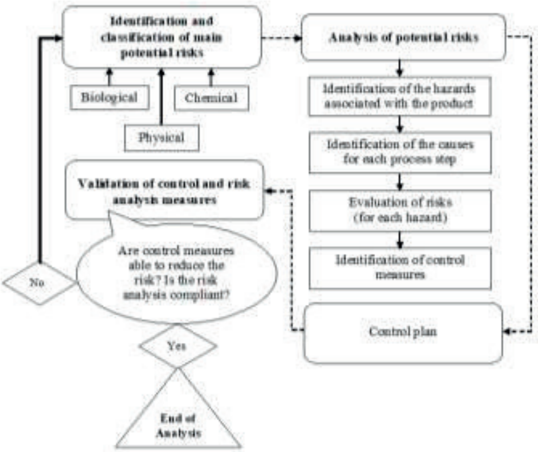

Figure 2. Logigram of the process

To identify the risks associated with food and the safety of staff and consumers the analysis is carried out for each class of hazards (physical, chemical, biological), on each class of products, and on each operation in the technological flow, according to the 5M.

Identification and analysis of the causes for each process operation

The cause is defined as all the practices, all the factors, all the situations responsible for introducing or aggravating a danger in each operation, or in each raw material, etc.

As examples Figures 3 and 4 show the determination of the causes that may generate the risks associated with bottled water, and those associated with the water bottling stage using the Ishikawa diagram based on the analysis of the 5M; 5 Whys? Method.

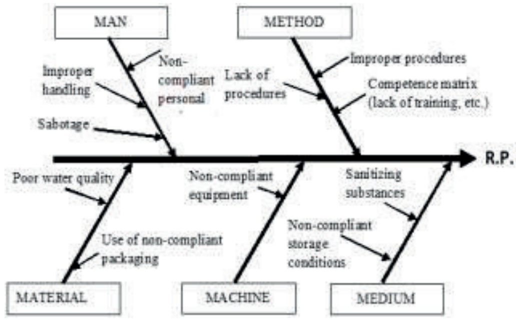

Figure 3. Determination of causes that can generate the risks associated with bottled water (R.P. - root problem)

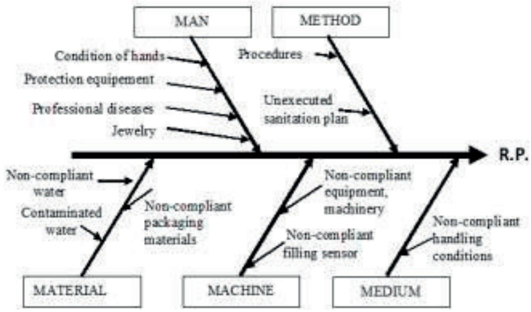

Figure 4. Determination of causes that can generate the risks associated with the water bottling stage

The analysis of the causes is performed for each potential hazard separately, on the 5M, on each operation, to identify all possible sources and then rule some to be negligible.

Table 3 presents the analysis of the causes, based on the 5 Whys? method for each hazard, related to the water bottling stage.

Table 4 shows the assessment of the hazards corresponding to the bottling stage for spring water based on the 5 Whys? method for each hazard, corresponding to the water bottling stage.

Table 3. Analysis of the causes, based on the 5M, for each hazard related to the water bottling stage

Process	Risk	M Type				
		Medium (M1)	Man (M2)	Method (M3)	Material (M4)	Machine (M5)
1. PET unpackaging 2. Placing the containers on the bottle conveyor belts 3. Filling 4. Capping	Physical	-Contamination with foreign bodies from the work environment; -Cross-contamination among handled products; - Air pollution.	-Foreign bodies from workers, work clothes; - Contamination from handling raw materials and packaging; - Contamination due to storage of open vials for filling.	-Lack of knowledge about working and sanitation standards; -Non-compliance with work and sanitation standards. -Unrevised working and sanitation standards.	-Cross-contamination among containers (PET bottles); -Contamination from water with impurities.	-Contamination from transport machinery, and equipment, paper, foils, labels; -Contamination from defective pallets
	Chemical	-Contamination from chemicals (including sanitizers) handled in the same space.	-Contamination from operators, work equipment. -CO_2 / O_3 overdose.	-Lack of knowledge about or non-compliance with work and sanitation standards; - Unrevised working and sanitation standards.	-Contamination with chemicals (including sanitizers) handled or stored in the area. -Use of impure CO_2 / O_3.	-Contamination from defective equipment.
	Biological	-Microbiological contamination from the work environment. -Development of microorganisms due to inadequate hygiene.	-Contamination from sick operators or those who have sick animals, dirty work equipment.	-Lack of knowledge about or non-compliance with work and sanitation standards; -Unrevised working and sanitation standards.	-Water contamination, microbiologically contaminated packaging.	-Contamination from machinery, pallets, unhygienic shelves.

Table 4. Hazards identification and risk class for the bottled stage for still water

Risk	M Type														RC
	Medium (M1)			Man (M2)			Method (M3)			Material (M4)			Machine (M5)		
	G	F	I	G	F	I	G	F	I	G	F	I	G	F	I	
Physical	3	1	2	3	1	2	2	1	1.5	2	1	1.5	3	2	2.5	1.9
Chemical	3	1	2	3	1	2	2	1	1.5	3	1	2	4	1	2.5	2
Biological	3	1	2	3	1	2	3	2	2.5	3	1	2	3	2	2.5	2.2

Table 5. identification of control measures in case of chemical hazard for the spring water bottling stage

M Type	Risk	Measures	Responsible/Period
M1	- Contamination from chemicals (including sanitizers) handled in the same space. - CoVid 19 contamination from the infected environment	- Sanitation check using pH testing. - Removal of chemicals from space. - Sanitation of work environment and disinfection.	- CTC Flow / annually - Production coordinator / daily
M2	- Contamination from operators, work equipment. - CO2 / O3 overdose. - CoVid 19 contamination from infected operators.	- Checking operators and their equipment. - Monitoring dosage using rapid tests. - Monitoring the health of operators	-Production coordinator / daily. -Laboratory technician/ daily
M3	- Ignorance or non-compliance with work and sanitation standards, prevention measures. - Working and sanitation standards, unrevised prevention measures.	- Periodic training of production staff. - Periodic review of standards and procedures.	Operational staff/ at the time of employment quarterly, annually
M4	- Contamination with chemicals (including sanitizers) handled or stored in the area. - Use of impure CO_2 / O_3.	- Handling detergents only at the time of sanitation. - Periodic monitoring of CO_2 / O_3 purity.	Production coordinator / at the time of sanitation and after maintenance Chemical engineer / self-control program
M5	- Contamination from defective or improperly sanitized equipment. - Contamination from machinery, equipment infected with CoVid 19. - Non-calibration of measuring devices.	- Maintenance of equipment. - Compliance with sanitation and prevention standards. - Calibration of measuring devices according to the maintenance program.	Operational staff / according to schedule Production coordinator / at the time of sanitation. Technical manager / according to schedule

Tabel 6. Setting the CCP control plan for the spring water bottling stage

Type M	Risk	Procedures	CCP/PRPs					Corecțions / Corective Activities	Responsible	Record
			Q1	Q2	Q3	Q4	Type			
M1	- Contamination from chemicals (including sanitizers) handled in the same space. - CoVid 19 contamination from the infected environment	PRP	YES	NO	NO	-	none	Product separation, remediation / destruction	Technical and quality control	Sanitation sheets
M2	- Contamination from operators, work equipment. - CO2 / O3 overdose. - CoVid 19 contamination from infected operators.	PRP	YES	NO	NO	-	none	Product separation, remediation / destruction	Technical and quality control	Staff monitoring form.
M3	- Ignorance or non-compliance with work and sanitation standards, prevention measures. - Working and sanitation standards, unrevised prevention measures.	PRP Working standards and prevention	YES	NO	NO	-	none	Testing, retraining	Responsible for quality	Training report
M4	- Contamination with chemicals (including sanitizers) handled or stored in the area. - Use of impure CO_2 / O_3.	PRP Self-control program	YES	NO	NO	-	none	Product separation, destruction	Technical and quality control	Sanitation sheets, Maintenance sheet
M5	- Contamination from defective or improperly sanitized equipment. - Contamination from machinery, equipment infected with CoVid 19. - Non-calibration of measuring equipment	PRP Measuring equipment verification program	YES	NO	NO	-	none	Product separation, remediation / destruction	Technical and quality control	Sanitation sheets, Maintenance sheet

Identification and validation of control measures for each process operation

Control measures are established for the main causes that are determined to possibly lead to potential hazards. These consist of a series of techniques, activities or actions taken to reduce or eliminate a potential risk.

To establish the control measures, one starts from the stage of risk identification and hazard assessment.

Once the main causes generating potential hazards for each raw material/commodity/ process step have been established general control measures are set that can eliminate or reduce this potential risk.

For risk class 3, in addition to the determined control measures, the Preliminary Preparatory Programs will be used, which regulate working conditions, hygiene, production areas and food safety control.

If the analysis identifies potential risks in risk class 4, monitorisation, verification and validation of control measures will also be performed using Operational Prerequisite Program (oPRP) and Critical Control Points (CCPs).

Table 5 presents the identification of control measures in case of chemical hazard for the spring water bottling stage. To control the process of identifying potential hazards and their control measures, the establishment of a control plan is needed, which should define:

- stage of the process (place in the system),
- controlled hazard,
- control measures,
- the procedures controlling it,
- monitoring procedures,
- corrections and corrective actions,
- the person in charge of verifying the process,
- related records.

Table 6 sets out the CCP control plan established for the spring water bottling stage. The control plan is elaborated by the person in charge of the risk analysis from all the departments involved in the material flow.

The validation of control measures and risk analyses is performed by the food safety team measuring the effectiveness and efficiency of the process based on the following indicators:

- no. of risk analyses performed by each department listed in this standard/no. risk analysis required.
- no. of risk analyses validated by ESA/no. of risk analyses performed.

Among the records we can find a sheet for identifying and assessing the causes that may

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generate potential risks, and a sheet for identifying risks, assessing, and establishing control measures.

CONCLUSIONS

The study follows the methods and means of risk investigation to ensure the quality and safety of bottled spring waters, also the introduction of new methodologies and techniques with a good intercalation capacity between them. The superior value of the finished products` quality also implies the rigorous knowledge of their physicochemical and microbiological composition. Thus, the physicochemical and microbiological parameters of the spring water were investigated, and it was determined that the quality characteristics of "Roua Apusenilor" Spring Water were met.
A new perspective was provided in the study of the dynamics of the risk-factor analysis in the bottling process of the spring water "Roua Apusenilor" by the simultaneous use of the Ishikawa diagram and the HACCP principles. The application of Tree diagram led to converging results thus corroborating the validity of conclusions derived from HACCP risk analysis. The synergistic effect of the two methods is observed: HACCP in conjunction with Cause-and-Effect Diagrams.

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ASSESSMENT OF GLOBAL WARMING IMPACT ON AQUATIC ECOSYSTEMS: A STATE-OF-THE-ART PERSPECTIVE

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Abstract

The negative effects of global warming are well recognized globally by scientific communities and governments. Aquatic environments absorb approximately 93% of the excess heat generated by global warming. Aquatic ecosystems sustain fisheries and aquaculture, sectors which provide approximately 17% of animal protein for the global human population. It is imperative to identify the main challenges that will occur within these systems due to global warming, to mitigate the consequences. The aim of the present review is to describe the impact of global warming factors on aquatic ecosystems. The research articles revised within this paper are published in web of science core collection, with high impact factors. The main factors of global warming were identified as: increased water temperature, sea level rise and altered precipitation regime. Each factor was analysed and the influence on aquatic environments was described. The main conclusion of this paper is that global warming will disrupt fisheries and aquaculture activities, through degradation of aquatic ecosystems. Small-scale fishers and aquaculture earthen ponds will be most impacted, due to their geographical location and economic vulnerability.

***Key words**: global warming, sea level rise, aquatic ecosystems, fisheries, aquaculture.*

INTRODUCTION

Warming of the climate system is indubitable (FAO, 2018). Global warming is a direct result of human activity and it is manifested by the rise in global surface temperatures, caused by the increased emissions of carbon dioxide (CO_2) and other greenhouse gases (GHG) such as methane (CH_4) and nitrous oxide (N_2O) (Asakura, 2021; FAO, 2013; Poloczanska et al., 2013). GHG absorb heat and emit it back in the atmosphere as radiant energy, causing the greenhouse effect. The Intergovernmental Panel on Climate Change (IPCC) reported an increase in global average surface temperature, between the years 1880 and 2012, of approximately 0.9°C (Rotman, 2015; Mann et al., 2020). From the total additional heat generated by anthropogenic climate change only 1% is retained in the atmosphere and approximately 93% is absorbed by the global ocean (FAO, 2018). The identified factors of global warming include temperature changes, sea level rise, and altered precipitation regime (Figure 1) (Diop et al., 2018a). The negative effects of this phenomenon extend on aquatic ecosystems, biotic communities, and biodiversity, through loss of habitats (wetlands drainage), aquatic species displacement, loss, and redistribution (Asakura, 2021; Smale et al., 2021; Sunobe et al., 2014). As well, global warming determines extensive and fast sea ice melting, and therefore, a rise in sea levels, which will impact stock dynamics and fish harvest levels in the future (Jorgensen et al., 2020; Diop et al., 2018).

One of the main effects of global warming on fisheries sector is the geographical shifting of target aquatic species (Jorgensen et al., 2020). Several studies have emphasized the influence of global warming on fisheries and the ecological performance of aquatic ecosystems (Diop et al., 2018b; Garza-Gil et al., 2011; Steinmetz et al., 2008; Lehodey et al., 2006). For instance, Diop et al. (2018a) predicted in the future the total collapse of shrimp stocks in the French Guiana region, due to global warming. According to Handisyde et al. (2014), in case of aquaculture activities, the impact of global warming can be either direct (changes in water availability, temperature) or indirect (increased fishmeal costs and thus, increased aquaculture feed costs).

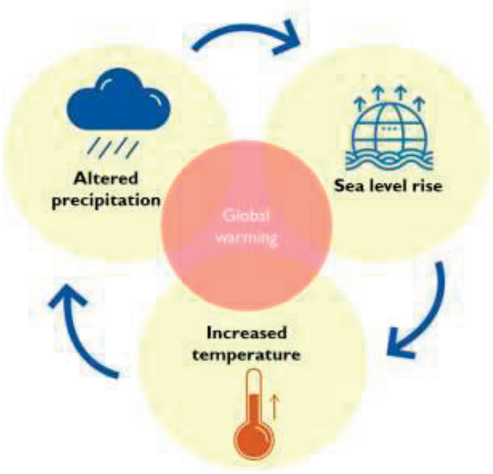

Figure 1. The factors of global warming

Aquatic ecosystems sustain fisheries and aquaculture, sectors which provide approximately 17% of animal protein for the global human population and in coastal areas it can reach even 70% (FAO, 2014). Therefore, it is important to identify the changes that will occur within these systems due to global warming. The influence of global warming on the aquatic environment is a matter of global interest and requires a thorough analysis which should correlate and compare the results of different studies published in peer-reviewed scientific journals (Ciugulea and Bica, 2016).
The aim of the present short review is to describe the impact of the global warming factors on aquatic ecosystems, in order to mitigate the negative effects.

MATERIALS AND METHODS

Increased water temperature
According to FAO (2013), sea surface temperature is expected to increase 0.7°C by 2035, 1.4°C by 2050 and 2.5°C by 2100. Water temperature is expected to manifest an upward tendency, with higher warming rates near the surface, especially in the first 100 m (FAO, 2013). Increasing water temperature can alter water quality, especially in the systems that receive high loads of anthropogenic effluents rich in nutrients and it can enhance eutrophic conditions by stimulating explosive macrophyte growth (Ficke et al., 2005; FAO, 2018). The increased temperature of water bodies leads to water stratification, which can have pronounced negative effects in freshwater systems compared to marine systems, due to shallowness and lower buffering capacity (FAO, 2018). Freshwater systems are more exposed to warming compared to marine ones, due to relatively shallow depths, susceptibility to atmospheric temperature change and an increase of 1.8°C is expected within these systems (FAO, 2018). It is expected that water stratification will be more pronounced in lotic and lentic ecosystem. The different density gradient between the upper and bottom water layer will prevent water mixing. Water mixing is important because the bottom layer contains minerals necessary for algae development, minerals that lack in the upper layer. Nevertheless, the light received from solar radiation and dissolved oxygen (DO) in the water upper layer stimulate photosynthesis of blue-green algae, which can fix nitrogen in nutrient-limited conditions. However, blue-green algae are inedible by most zooplankton species and planktivorous fish species (Ficke et al., 2005). Therefore, a shift in phytoplankton composition can pose a negative impact on fisheries productivity (Ficke et al., 2005). As well, blue-green algae produce alkaloids that are toxic to fish (Ficke et al., 2005). According to Handisyde et al. (2014), the impact of sea surface temperature changes on aquaculture includes: increase of harmful algal blooms that produce fish kills, decreased dissolved oxygen, increased diseases and parasites, change in the location and size of suitable range for target species, altered local ecosystems - competitors and predators, competition, parasitism and predation from exotic and invasive species.
Warming is more prominent in the Northern Hemisphere, especially the North Atlantic, compared to the rest of the globe (FAO, 2018). Negative effects of the rising water temperature include bleaching of corals, redistribution of the northern limit for subtropical and tropical fish species (Asakura, 2021; Wada, 2001).

According to Asakura (2021) the adaptation of tropical animals to temperate regions occurs in 5 stages as it follows: pseudo-population without overwintering (stage 1), pseudo-population with overwintering but no reproductive activity (stage 2), pseudo-population with overwintering and minor reproductive activity (stage 3), complete adaptation of tropical species to temperate environment (stage 4), genetic differentiation and speciation (stage 5). To escape water warming, fish will migrate poleward, phenomenon which will result in species invasion in the Artic, while Artic fish species will migrate further North, altering species composition (Hader and Barnes, 2019). In their study (Kaeriyama et al., 2014) pointed out that global warming decreased suitable areas of habitat for chum salmon in the North Pacific Ocean and loss of migration route to the Sea of Okhotsk. According to Ficke et al. (2005), for temperate fishes (such as carp, freshwater bream, pike, zander) a slight increase in water temperature could be beneficial due to the expansion of the growth season. However, the reproductive success of temperate fishes will be affected by global warming, because low overwinter temperatures are essential for inducing puberty and spawning success (Ficke et al., 2005). In their study, Simionov et al. (2020) pointed out a strong negative correlation between fish species diversity and water temperature. Thus, warming of aquatic ecosystems is associated to low fish diversity.

Another negative effect of rising water temperature is the decrease of DO levels, which will create and expand oxygen minimum zones (FAO, 2018). Oxygen solubility has an inverse relationship with water temperature (Ficke et al., 2005). For instance, at water temperature of 0°C the level of DO is 14.6 mg L^{-1} and at a water temperature of 25°C they DO level is 8.3 mg L^{-1}. The aerobic metabolic rate of most cold-blooded aquatic organisms increases with temperature, therefore global warming reduces oxygen supply in the water column and, at the same time, increases the biological oxygen demand of aquatic organisms (BOD) (Ficke et al., 2005). DO levels of 5 mg L^{-1} are acceptable for most aquatic organisms, however, if DO drops below 3 mg L^{-1} hypoxic conditions are present (Ficke et al., 2005). In aquaculture activities, hypoxic conditions can lead to reduced growth rates and reduced reproductive performance (Ficke et al., 2005).

It is expected that temperate and subarctic fish species will suffer high parasite infestation due to increased transmission opportunity. Higher water temperature during winter season allows parasite survival, and thus, increasing the potential of infection and multiple generations of parasites during a whole year (Ficke et al., 2005). In aquaculture systems, bacterial diseases such as furunculosis are positively associated to increased water temperature (Ficke et al., 2005). Also, it is important to mention that the toxicity of common pollutants such as heavy metals, organophosphates and ammonia increases with high levels of water temperature (Ficke et al., 2005). This phenomenon is related to increased gill ventilation at warmer temperatures, which results in high pollutant uptake (Ficke et al., 2005).

Sea level rise

Sea level rise (SLR) has been defined as one of the worst consequences of global warming (Kibria, 2016). According to FAO (2018), between the years 1901 and 2010, an upward tendency was registered in case of the average global sea level by 0.19 m, with an increased average of 3.1 mm per year. It is expected that by the year 2100 the global mean SLR could be as high as 1 m, if GHG levels continue to increase (Mills et al., 2020). SLR is generated primary by thermal expansion and secondly by melting of glaciers/ice caps (Kibria, 2016). The impact of SLR will expand on wetlands and its biodiversity, water resources, fisheries, and aquaculture (Kibria, 2016). The damage of SLR will affect wetlands included in Ramsar and World Heritage sites (Kibria, 2016). According to Kibria (2016), a 1 m SLR can cause approximately 25-46% loss of the world’s coastal wetlands. The loss of biodiversity caused by SLR includes drowning of coral reefs, loss of breeding and nursery habitats.

Another potential negative effect is the infiltration of saline water in freshwater and brackish ecosystems, which can pose a threat to the aquatic biodiversity. Also, SLR is responsible for progressive salinization of freshwater resources (Hader and Barnes, 2019; Yang et al., 2020). The intrusion of salt can alter the physical properties of deltas and estuaries by increasing water stratification (Mills et al., 2020). Furthermore, according to Zak et al. (2021) the salinization of coastal wetlands enhances sulphate pollution, by increasing SO_4^{2-} concentrations, especially in peat-rich coastal regions.

The impact of SLR on aquaculture includes loss of areas available for aquaculture, loss of areas such as mangroves that provide protection from waves and fish nursery areas, severe flooding, salt intrusion into ground water (Handisyde et al., 2014).

Altered precipitation regime

The warming of the climate has significant implications for the hydrological cycle (FAO, 2018). Global warming tends to enhance the frequency and intensity of precipitation extremes (Li et al., 2021). Surface warming is directly linked with increase in rainfall due to the warming effect, which intensifies evaporation processes over the ocean and water body surfaces, thus increases the water-retention capacity of the atmosphere (Gbode et al., 2021). The rain-induced disasters are manifested through either floods or droughts (Li et al., 2021). Models indicate that zonal mean precipitation is very likely to increase in high latitudes and near the equator, and decrease in the subtropics (FAO, 2018). As well, in the Mediterranean basin and in the already arid zones, droughts are expected to be longer and more frequent, which will lead to reductions in river flows. Intense periods of draughts can lead to wetland drainage, which can expose large areas of SO_4^{2-} reservoirs (Zak et al., 2021). Following the flooding of these areas, due to intense precipitation, sulphate pollution is manifested in the water (Zak et al., 2021).

Changing precipitation alters the quantity, quality and seasonality of water resources (FAO, 2018). Changes in precipitation will substantially alter ecologically important attributes of flow regimes in many rivers and wetlands and exacerbate impacts from human water use in developed river basins (FAO, 2018). Events of droughts will impact aquaculture by inducing salinity changes in the technological water, reducing water quality, limiting water volume, reducing pond levels, altering and reducing freshwater supply (Handisyde et al., 2014). As well, the survival of certain fish species depends on rainfall and runoff from terrestrial landscape, to generate stream flows and the persistence of seasonal ponds (Hader and Barnes, 2019). For freshwater and estuarine ecosystems, changing rainfall patterns can influence water quality and salinity which can then influence the productivity and composition of phytoplankton and aquatic plant communities (Hader and Barnes, 2019).

Heavy rainfall events can lead to increased water turbidity (Bastaraud et al., 2020). In their study, Zhang et al. (2020) demonstrated that increased water turbidity affects the phytoplankton composition in Xiaoqing River. Change in the precipitation regime can influence fish disease prevalence. Increased precipitation was positively correlated with increased parasite (trematode metacercariae) abundance in freshwater fishes (Poulin, 2020). Another study conducted by Smederevac-Lalić et al. (2018) pointed out that high water turbidity, caused by extreme spring flooding, decreases the survival of pontic shad eggs and larvae. Nevertheless, the flooded land near rivers and streams, provide suitable spawning substrate, refuge against predators and high food availability for cyprinid fish species (Janac et al., 2010).

RESULTS AND DISCUSSIONS

It has been pointed out that mangroves can act as a cooling mechanism in coastal areas, due to their wet substrate and despite their large thermal acceptance (Diop et al., 2018a; Bin 2016). Thus, restoring mangrove surface can attenuate the negative effects of global warming. As well, mangrove forests, seagrass beds and marshes act as carbon sequesters, through their vegetation systems (Mcleod et al., 2011). These systems remove and keep carbon from the atmosphere with higher rates compared to the terrestrial systems (rainforests), due to their high productivity and sediments presence (Mcleod et al., 2011). Coastal wetlands provide flood and storm protection, waste assimilation, nutrient cycling functions (Kibria, 2016). To mitigate aquatic biodiversity loss, Saulnier-Talbot and Lavoie (2018) propose the use of anthropohydrocosms (anthropogenic aquatic ecosystems) such as reservoirs, farm ponds, drainage basins, park lakes, storm water ponds, stabilization ponds, artificial wetlands, canals, min void pit lakes, bomb crater ponds, bomb crater lakes etc. These types of anthropogenic aquatic ecosystem can substitute aquatic habitats loss due to global warming and provide new places for species development, reproduction and settlement.

CONCLUSIONS

The main conclusion of this paper is that global warming will disrupt fisheries and aquaculture activities, through degradation of aquatic ecosystems. It is most likely that small-scale fishers and aquaculture earthen ponds will be most impacted, due to their geographical location and economic vulnerability.

More studies such as long-term monitoring of aquatic ecosystems under global warming influence are needed, in order to generate mathematical predictions.

The present review can act as support material for identification of adaptation measurements by governments of coastal countries fighting global warming impact.

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COMPARATIVE STUDY OF NITROGEN MANAGEMENT IN TWO DIFFERENT CYPRINID AQUACULTURE TECHNOLOGIES: INTEGRATED MULTI-TROPHIC AQUACULTURE VS POLYCULTURE

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Abstract

The aquaculture sector registers the fastest growth compared to other food production systems. Most of the Romanian aquaculture production is based on cyprinid species reared in ponds. This technology raises certain concerns related to environment sustainability, because aquaculture effluent contains high concentration of nitrogen, which can cause water pollution and eutrophication. Thus, the objective of this study is to determine if technologies based on integrated multi-trophic aquaculture (IMTA) design can optimize the sustainability of cyprinids pond-based production systems. A number of 4 fish species (common carp - CC; grass carp - GC; bighead carp - BC and silver carp - SC) were used in two rearing technologies (polyculturevs. IMTA). The experimental design includes 2 variants: PCP - polyculture pond (CC + GC + BC + SC) and CP-PP - IMTA partitioned pond (CC monoculture in CP part and CC + GC + BC + SC polyculture in PP part, where no feed was administrated). Total nitrogen (TN) was determined from water, sediments, reed and fish. A main conclusion of this study is that CP-PP variant registered a better TN utilization, fact leads to a reduced environmental impact of cyprinids pond aquaculture.

Key words: *nitrogen balance, IMTA, environmental impact, cyprinids aquaculture, pond partition.*

INTRODUCTION

According to FAO reports, the aquaculture sector registers the fastest growth, compared to other major food production sectors, which provides an important source of protein at a global level (Tenciu et al., 2020).

In aquaculture environments, nitrogen represents a primary concern as the component of waste products generated by rearing fish (Simionov et al., 2016). Expansion and intensification of land-based aquaculture farms can cause the release of a large quantity of wastewater (Simionov et al., 2020). The high nutrients load (such as nitrogen) in the aquaculture effluent can cause water pollution byinducing eutrophication (Herbeck et al., 2014). As well, the discharged nutrients cancause degradation of benthicand pelagichabitats.

Nitrogen is an important nutrient in aquatic ecosystems. It is found in water in many forms: molecular nitrogen, nitrogen oxides, ammonia, nitrates and nitrates (Popa et al., 2020). In the ecosystem, nitrogen enters the biogeochemical cycle, determined by a complex network of interactions of factors in the aquatic ecosystem (Popa et al., 2020). Bacteria have an important role in nitrogen cycle in the aquatic ecosystem and the nitrogen transformations are reversible (Popa et al., 2020).

The present study aims to evaluate the nitrogen dynamics in two aquaculture pond production systems, by applying integrated multi-trophic aquaculture (IMTA) vs. polyculture technologies. Also, this research will evaluate the dynamics of other important nutrients and quality parameters of pond technological water.

MATERIALS AND METHODS

The experiment was conducted at a cyprinid fish farm, located at 24 km from Iasi city, Romania, for 83 days, from June to September. Water inlet and outlet in the farm is effectuated gravitationally.

Two earthen ponds (0.45 ha area and 1.5 m water depth) were used for the present research. The experimental design and sampling areas are represented in Figure 1.

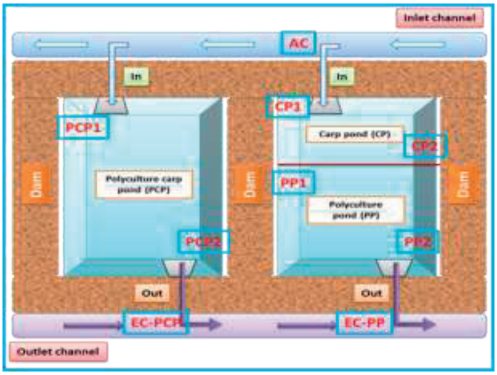

Figure 1. Experimental design and sampling stations (Metaxa et al., 2019)
(AC - inlet channel, EC-PCP - outlet channel from polyculture carp pond, EC-PP - outlet channel from polyculture pond, PCP1 - polyculture carp pond 1, PCP2 - polyculture carp pond 2, CP1 - carp pond 1, CP2 - carp pond 2, PP1 - polyculture pond 1, PP2 - polyculture pond 2) (Metaxa et al., 2019)

The first pond (PCP) was used for polyculture rearing of the common carp with grass carp, bighead carp and silver carp. The second pond (IMTA) was divided, by using a net (Figure 1), as it follows: first part with an area of 0.15 ha CP (carp pond) and the second part with an area of 0.30 ha PP (polyculture pond).
The following fish stocking formula was applied:
- PCP was populated with 2500 specimen of common carp (*Cyprinus carpio*), 40 specimen of silver carp (*Hypophthalmichthys molitrix*), 40 specimen of bighead carp (*Hypophthalmichthys nobilis*) and 100 specimen of grass carp (*Ctenopharyngodon idella)*;
- CP was populated with 2000 specimen of common carp (*Cyprinus carpio*);
- PP was populated with 500 specimen of common carp (*Cyprinus carpio*), 40 specimen of silver carp (*Hypophthalmichthys molitrix*), 40 specimen of bighead carp (*Hypophthalmichthys nobilis*) and 100 specimen of grass carp (*Ctenopharyngodon idella*).
The administered fish feed had a crude protein content of 28% and was represented by a mix of cereals (wheat lees, dry maize dregs and sunflower grouts) in equal amounts. Feed was manually administered twice/day, only in PCP and CP, for five days/week, which makes a total of 59 days of feeding during the entire experimental period. A total quantity of feed of 285.41 kg at CP-PP pond and 756.82 kg at PCP pond was administrated among the experimental period.

Table 1. Individual average length of specimen used in experiment (cm)

Pond	Common carp	Silver carp	Bighead carp	Grass carp
PCP	8.7±0.40	37.9±1.40	35.5±1.70	17.2±0.99
CP	8.5±0.90	-	-	-
PP	8.3±0.7	38.7±1.80	34.7±1.20	17.1±1.00

Table 2. Individual average weight of specimen used in experiment (g)

Pond	Common carp	Silver carp	Bighead carp	Grass carp
PCP	63.0±7.80	2006.3±213.8	1937.0±191.48	200.4±20.01
CP	61.2±11.60	-	-	-
PP	60.0±10.45	2044±289.8	1824.1±182.59	199.4 ± 20.0

Samples of water, sediments, fish and reed were collected from the ponds for analysis. Sampling was undertaken in different timeline stages during the experimental period, as it follows: initial stage (June 2016), intermediary stage (August 2016) and final stage (September 2016).
For the water samples, the following parameters were analysed: dissolved oxygen (DO), temperature (TºC), pH, nitrates ($N\text{-}NO_3$), nitrites ($N\text{-}NO_2$), ammonia nitrogen ($N\text{-}NH_4$), chemical oxygen demand (COD) and total suspended solids (TSS).

Table 3. Determination methods and the equipment used for the analysis of water samples

Analysed parameter	Used method	Used equipment
DO mg/L	Sensor method	HQ40d Portable pH, Dissolved Oxygen, Multi-Parameter (HACH)
TºC		
pH		
$N\text{-}NO_3$ mg/L	Spectrophotometric method, Merk kits	Spectroquant photometer, Nova 400
$N\text{-}NO_2$ mg/L		
$N\text{-}NH_4$ mg/L		
COD mg/L		
TSS mg/L	Total Suspended Solids Procedure, Mass Balance (Dried at 103-105ºC)	

For the samples of sediments, fish and reed the following parameters were analysed: total Kjeldahl nitrogen (TKN), nitrates ($N\text{-}NO_3$) and nitrites ($N\text{-}NO_2$).

The data obtained in the present experimental research was statistically analysed using descriptive statistics and ANOVA test. The programs used to carry out the aforementioned tests were Microsoft Excel 2010 and IBM SPSS Statistics 20.0. The results were presented as minimum, maximum and mean±standard deviation.

Table 4. Determination methods and the equipment used for the analysis of sediments, fish and reed samples

Analysed parameter	Used method	Used equipment
TKN (g % FW)	Macro-Kjeldahl and Acidimetric	Gerhardt Kjeldahl Nitrogen/Protein Equipment
$N-NO_3$ (mg/kg FW)	Spectrophotometric method-Nitrite based on the diazotization-coupling reaction of sulfanilamide with N-(1-naphthyl) ethylenediaminedihydrochloride	SpecordAnalytik Jena 210
$N-NO_2$ (mg/kg FW)	Spectrophotometric method- Nitrate is determined by reduction to nitrite with cadmium	SpecordAnalytik Jena 210

RESULTS AND DISCUSSIONS

A. WATER QUALITY

The concentration of DO in technological water registered a large variation interval (1.07-13.78 mg/L), during the experimental period.

A clear upward tendency in the final stage of the experimental period was observed in most of the investigated stations. In case of inlet and channels, the DO concentration registered lower values compared to the rest of the study stations, during the production cycle.

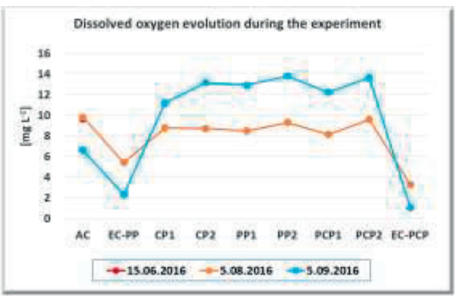

Figure 2. DO dynamics during the experimental period

The outlet channels registered significant lower water average DO concentrations (EC-PP: 3.87±1.54 mg/L and EC-PCP: 2.17±1.10 mg/L), compared with the inlet channel (AC: 8.21±1.60 mg/L). The highest DO average concentrations were recorded in the polyculture carp pond, at PCP2 (11.62±2.02 mg/L), followed by PP2 (11.53±2.25 mg/L) in IMTA pond (Figure 2).

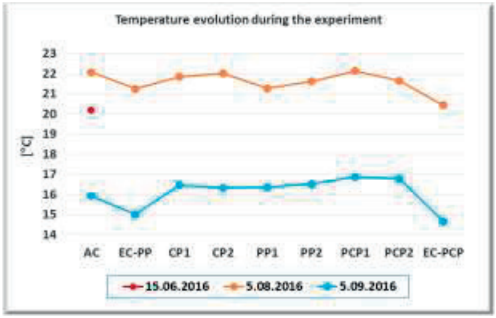

Figure 3. Temperature dynamicsduring the experimental period

The values registered in case of water temperature show a clear downward tendency during the experimental period from an average value of 21.60±0.50ºC (beginning of August) to 16.10±0.72ºC (beginning of September) (Figure 3). No significant differences were registered between the experimental sampling points.

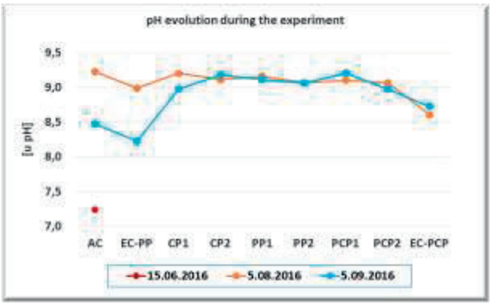

Figure 4. pH dynamics during the experimental period

The pH values registered in the technological water showed a constant trend during the entire production cycle period, in the ponds from both IMTA and polyculture systems, with an average value of 9.09±0.04 u pH, respectively 9.11±0.11u pH. The lowest pH values were registered at the outlet channels (EC-PCP: 8.67±0.06 u pH; EC-PP: 8.61±0.38 u pH), while the highest ones are recorded at PCP1 and CP2: 9.16±0.05 u pH, respectively 9.15±0.03 u pH (Figure 4).

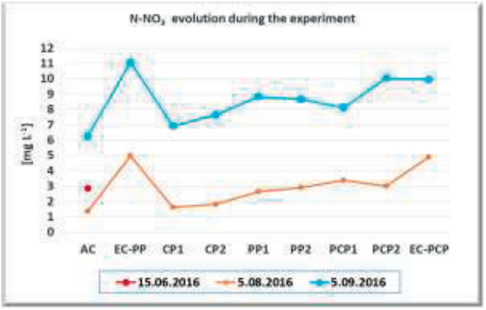

Figure 5. N-NO$_3$ dynamics during the experimental period

The concentration of N-NO$_3$in the technological water registered an accumulation tendency, manifested especially at the end of the production cycle (Figure 5), from an average value of 2.96±1.23 mg/L to 8.61±1.47 mg/L. The outlet channels registered significant higher water average N-NO$_3$ concentrations (EC-PP: 7.03±3.05 mg/L and EC-PCP: 7.43±2.53 mg/L), compared with the inlet channel (AC: 3.81±2.45 mg/L). Regarding the N-NO$_3$ average concentrations from both experimental production systems, the highest values were recorded in polyculture pond, at PCP2 (6.52±3.52 mg/L), while the lowest are corresponding to CP1 (4.27±2.65 mg/L), followed by CP2 (4.73±2.91 mg/L).

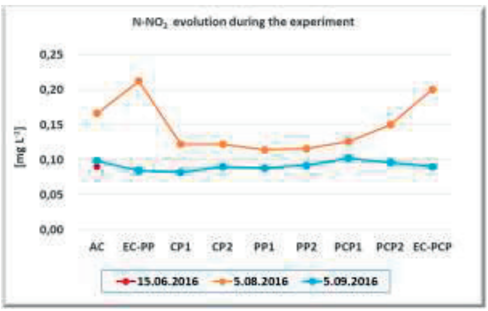

Figure 6. N-NO$_2$ dynamics during the experimental period

The concentration of N-NO$_2$in the technological water had a relatively constant evolution in both experimental production systems, with highest concentrations registered at the end of the intermediary stage of the experimental period (beginning of August). From the intermediary stage to the end of the experimental period, an increase of nitrogen oxidation rate is observed, fact confirmed by the upward tendency of N-NO$_3$ concentrations, correlated with the downward trend of N-NO$_2$ concentrations (Figure 6). The highest values of N-NO$_2$concentrations were registered in the outlet channels, EC-PP and EC-PCP, with average values of 0.15±0.06 mg/L, respectively 0.15±0.05 mg/L (Figure 6).

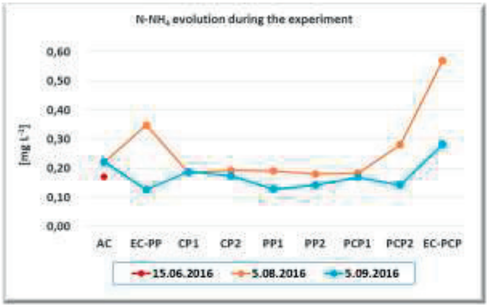

Figure 7. N-NH$_4$ dynamics during the experimental period

The concentration of N-NH$_4$ in the technological water has a relatively constant evolution in both experimental production systems, with highest concentrations registered at the end of the experimental production cycle. Also, the N-NH$_4$ concentrations from the outlet channels sampling points are superior compared to the ones registered in the ponds production systems sampling points, except for EC-PP at the final stage of the experimental period. Therefore, the highest average values during the production cycle are recorded at EC-PCP (0.43±0.14 mg/L) and EC-PP (0.24±0.11 mg/L), while the lowest are corresponding to PP2 (0.16±0.01 mg/L) and PP1 (0.16±0.03 mg/L). Also, PCP2 values of N-NH$_4$ concentration are higher comparing with PP2 values (Figure 7). These results are in direct correlation with the feeding regime applied.

The concentration in COD has an upward tendency during the production cycle, from an average value for all sampling points of 164.4±15.25 mg/L, to 167.89±25.29 mg/L. The COD concentrations registered in PCP (176.77±0.83 mg/L, respectively 192.4±0.8 mg/L) are superior to the ones registered in CP (156.8±6.8 mg/L, respectively 154.4±2.2 mg/L) and PP (155.6±3.2 mg/L, respectively 162.94±10.26 mg/L), fact manifested most probably due to the different feeding management applied (Figure 8).

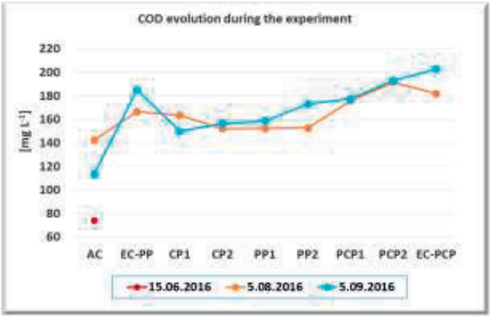

Figure 8. COD dynamics during the experimental period

The TSS dynamics presents an upward tendency during the production cycle, manifested especially at the end of the experimental period. Therefore, the lowest average value of 816.53±362.89 mg/L is registered in case of all nine sampling points in the intermediary stage of the experimental period, while the maximum average value of 2254.13±366.54 mg/L is registered in the final stage of the experimental period (Figure 9). Regarding the ponds sampling points, the IMTA pond registered lower (1390.7±73.82 mg/L) values, comparedto thepolyculture pond (1756.75±68 mg/L).

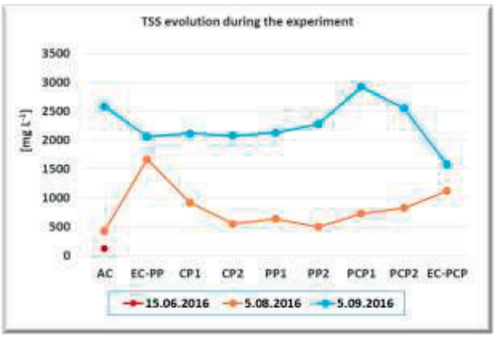

Figure 9. TSS dynamics during the experimental period

B. NITROGEN IN SEDIMENT SAMPLES

In the intermediary stage of the experiment, the TKN concentration in sediments had an average value of 0.50±0.08 g% FW, which was lower compared to the average value in the final stage of the experimental period, respectively 0.83±0.09 g % FW (Figure 10). In the last experimental stage, the TKN concentration in the sediment's samples registered an upward tendency in case of all sampling stations.

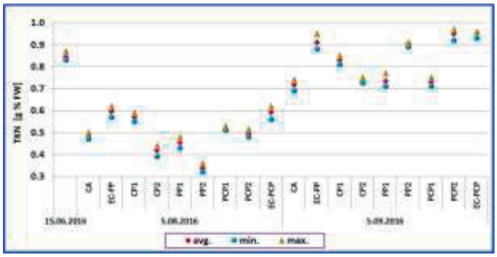

Figure 10. TKN dynamics in sediment samples during the experimental period

The IMTA pond registered significant ($p<0.05$) higher TKN concentrations in sediments only on the inlet area (0.83±0.02 g% at CP1, compared to 0.73±0.02 g% at PCP1). However, comparing the TKN concentrations registered in sediments at the outlet of both ponds, it can be stated that IMTA pond registered significant ($p<0.05$) lower values of TKN, compared to the polyculture pond (Figure 10). Also, by analysing the entire production cycle dynamics of TKN, it can be observed the long-term tendency of this nutrient to accumulate at the level of ponds sediments (Figure 10).

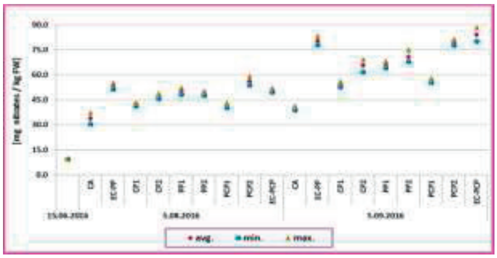

Figure 11. NO_3 dynamics in sediment samples during the experimental period

In the intermediary stage of the experimental period, lower values were registered for each of the sampling points in terms of nitrates concentrations in sediments, compared to the final stage (Figure 11), fact probably due to the change of fish feeding ratio, from 3% BW to 1.5% BW, which seems to stimulate the oxidation processes. The highest concentration of nitrates in sediments is recorded at the outlet of polyculture pond (55.95±2.62 mg/kg FW at PCP2). The IMTA pond had registered significant ($p<0.05$) higher nitrite concentration in sediments on the middle area and also, on the outlet area (47.07±1.63 mg/kg FW at CP2 and 49.98±2.06 mg/kg FW at PP1, respectively 48.96±1.30 mg/kg FW at PP2). However, comparing the nitrates concentrations registered in sediments at the outlet of both ponds, it can be stated that IMTA pond registered significant ($p<0.05$) lower values of nitrates, compared to the polyculture pond (Figure 11). This demonstrates the capacity of IMTA pond to efficiently prevent the eutrophication at the level of pond and moreover, to became more sustainable by reducing the nitrogen outputs.

The final experimental stage registered an upward tendency of nitrates concentration in sediments, for all the sampling points. The IMTA pond had registered significant ($p<0.05$) lower nitrates concentration in sediments on the outlet area (70.64±3.68 mg/kg FW at PP2), compared to the polyculture pond 79.43±1.77 mg/kg FW at PCP2. This confirms the assumption described above. Also, by analysing the entire production cycle dynamics of nitrates, it can be observed the long-term tendency of this nitrogen compound to accumulate at the level of ponds sediments (Figure 11). Also, the highest nitrates accumulation rate was observed in case of both outlet channel sampling points (80.26±2.73 mg/kg FW at EC-PP, respectively 83.97±4.06 mg/kg FW at EC-PCP).

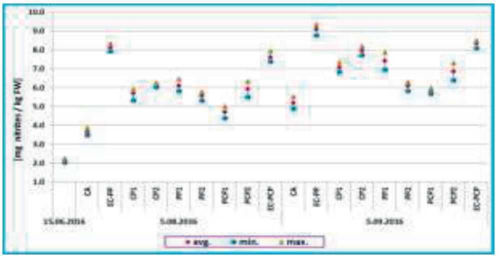

Figure 12. NO_2 dynamics in sediment samples during the experimental period

The highest concentration of nitrites in sediments was recorded in both outlet channel sampling points (8.14±0.21 mg/kg FW at EC-PP, respectively 7.62±0.29 mg/kg FW at EC-PCP). The IMTA pond had registered significant ($p<0.05$) higher nitrite concentration in sediments on the inlet area (5.72±0.33 mg/kg FW at CP1, compared to 4.72±0.32 mg/kg FW at PCP1). However, when comparing the nitrites concentrations registered in sediments at the outlet of both ponds, it can be observed that IMTA pond registered significant ($p<0.05$) lower values of nitrites, compared to the polyculture pond (Figure 12). This demonstrates the capacity of IMTA pond to efficiently prevent the eutrophication at the level of pond and moreover, to became more sustainable by reducing the nitrogen outputs.

C. NITROGEN IN REED SAMPLES

The highest TKN average values were registered in case of the reed samples collected from the outlet channels (4.10±0.14 g% FW in EC-PP and 3.23±0.16 g% FW in EC-PCP), while the lowest values were registered in the IMTA pond, in PP1 (2.0±0.04 g% FW) and PP2 (1.93±0.04 g% FW) (Figure 13).

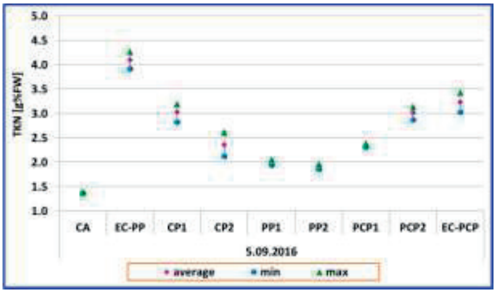

Figure 13. TKN dynamics in reed samples in the final stage of the experimental period

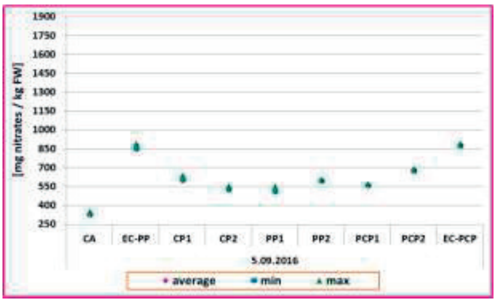

Figure 14. NO_3 dynamics in reed samples in the final stage of the experimental period

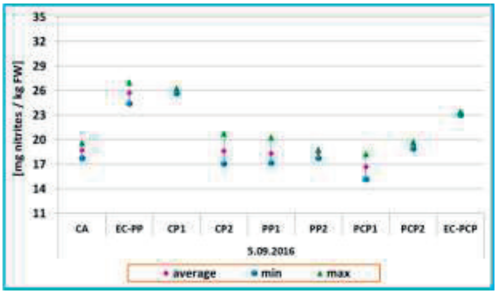

Figure 15. NO_2 dynamics in reed samples in the final stage of the experimental period

The highest NO_3 average values were registered in case of the reed samples collected from the outlet channels (875.62±12.8 g% FW in EC-PP and 880.07±29.5 g% FW in EC-PCP), while the lowest values were registered in the inlet channel, in CA (334.04±8.12 mg/kg FW) (Figure 14).
The highest NO_2 average values were registered in case of the reed samples collected from the outlet channels (25.72±2.25 g% FW in EC-PP and 23.54±1.60 g% FW in EC-PCP), while the lowest values were registered in the polyculture pond, in PCP1 (16.61±1.12 mg/kg FW) (Figure 15).

D. NITROGEN IN FISH SAMPLES

The highest values of TKN registered at the beginning of the experiment, before stocking, are recorded in case of grass carp (2.92 g%), followed by silver carp (2.89 g%) and bighead carp (2.85 g%), while the lowest concentration of TKN in meat is obtained at common carp (Figure 16). This may be due to the fact that common carp has an earlier growth stage, characterized by a lower individual biomass value, comparing with the rest of the experimental fish species.
At the intermediary stage of the experimental period, the CC specimenre ared in the PCP polyculture pond registered the highest TKN concentration in meat (3.07±0.10 g%FW), followed by the IMTA pond specimen CP CC (2.21±0.07 g%) and PP CC (2.01±0.13 g%). Significant differences ($p<0.05$) were observed between IMTA ponds and the polyculture pond CC biomasses. Thus, the IMTA pond production system generates a lower accumulation of TKN in common carp meat, in the intermediary stage of the production cycle, compared to the polyculture pond production system (Figure 17).

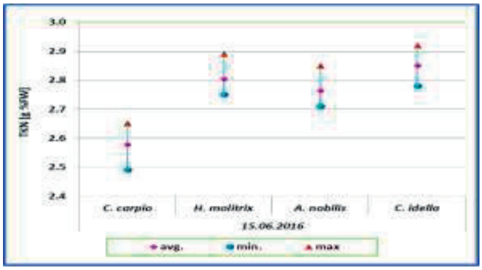

Figure 16. TKN dynamics in fish samples at the beginning of the experimental period

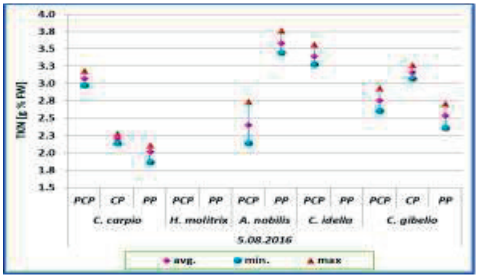

Figure 17. TKN dynamics in fish samples in the intermediary stage of the experimental period

At the intermediary stage of the experimental period, the CC specimenre ared in the PCP polyculture pond registered the highest TKN concentration in meat (3.07±0.10 g%FW), followed by the IMTA pond specimen CP CC (2.21±0.07 g%) and PP CC (2.01±0.13 g%). Significant differences (p<0.05) were observed between IMTA ponds and the polyculture pond CC biomasses. Thus, the IMTA pond production system generates a lower accumulation of TKN in common carp meat, in the intermediary stage of the production cycle, compared to the polyculture pond production system (Figure 17).
The silver carp (SC)catches from both ponds, during the intermediary harvesting, were not enough in order to manage to characterize properly the TKN concentration in meat, therefore no results are available. The same situation is valid also for BC specimen from PP part of IMTA pond.
Regarding the BC meat concentration of TKN, significant ($p<0.05$) higher values can be observed at PP part of IMTA pond (3.59±0.17

g%), compared to PCP polyculture pond (2.40±0.31 g%) (Figure 17).

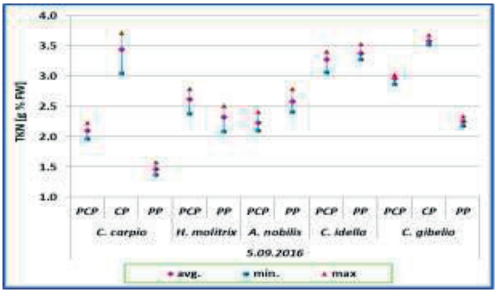

Figure 18. TKN dynamics in fish samples in the final stage of the experimental period

At the end of the experimental period, the CC specimen reared in CP part of IMTA pond registered the highest TKN concentration in meat (3.45±0.35 g%), followed by the PCP CC (2.10±0.13 g%) and PP CC (1.47±0.11 g%). Significant differences ($p<0.05$) were observed between PP CC and PCP CC biomasses.

Thus, the IMTA pond part where feed was administrated generates the higher accumulation of TKN in common carp meat, in the last stage of the production cycle, compared to the polyculture pond production system (Figure 18). However, compared with the previous experimental stage (Figure 17), during this final stage (Figure 18) the TKN meat concentration of CC biomasses from all the experimental ponds registered an upward tendency (Figure 18).

The SC biomass registered a higher TKN concentration in meat ($p>0.05$) in the polyculture pond (2.62±0.21 g%), compared to the PP part of IMTA pond (2.33±0.22 g%) (Figure 18).

The BC and GC biomass registered a higher TKN concentration in meat ($p>0.05$) at PP part of IMTA pond (2.19±0.08 g%, respectively 3.38±0.13 g%), compared with to the polyculture pond (2.23±0.16 g%, respectively 3.28±0.19 g%) (Figure 18).

The TKN meat analysis of this prussian carp reveals the highest values in CP part of IMTA pond (3.58±0.09 g%), followed by the polyculture pond PrC (2.96±0.08 g%) and PP part of IMTA pond PrC (2.26±0.08 g%).

Therefore, it can be concluded that no significant differences ($p>0.05$) were registered between IMTA and polyculture pond systems in terms of meat TKN concentration of SC, BC and GC. However, the differences were significant ($p<0.05$) when it comes to CC meat TKN concentration. Also, the invasive species PrC registered significant ($p<0.05$) differences between PCP vs. CP vs. PP in terms of meat TKN concentration.

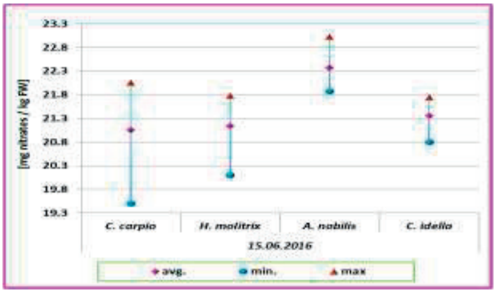

Figure 19. NO_3 dynamics in fish samples at the beginning of the experimental period

The highest values of nitrates concentration registered at the beginning of the experiment, before stocking, are recorded in case of the bighead carp (23.03 mg/kg FW), followed by the rest of three experimental species (22.06 mg/kg FW at CC, 21.78 mg/kg FW at SC and respectively, 21.74 mg/kg FW at GC) (Figure 19).

In the intermediary stage of the experimental period, the CC specimen from the polyculture pond registered the highest nitrate concentration in meat (25.62±2.88 mg/kg FW), followed by the IMTA pond specimen PP CC (14.75±1.59 mg/kg FW) and CP CC (12.52±1.21 mg/kg FW).

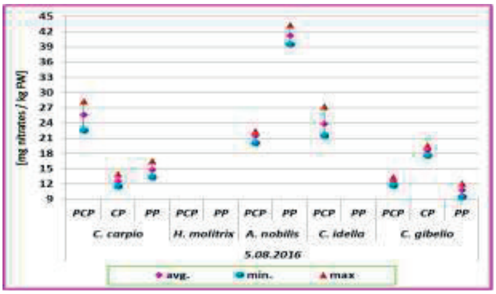

Figure 20. NO_3 dynamics in fish samples in the intermediary stage of the experimental period

Significant differences ($p<0.05$) were observed between IMTA ponds and polyculture pond CC biomasses. Thus, the IMTA pond production system generates a lower accumulation of nitrates in common carp meat, in the intermediary stage of the production cycle (Figure 20), compared to the beginning stage of the experiment (Figure 20).

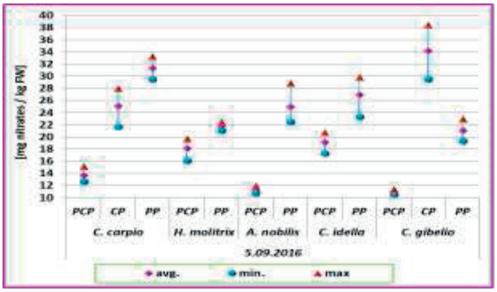

Figure 21. NO_3dynamics in fish samples in the final stage of the experimental period

At the end of the experimental period, the CC specimen from PP part of IMTA pond registered the highest nitrates concentration in meat (31.32±1.89 mg/kg FW), followed by the CP CC (25.09±3.18 mg/kg FW) and PCP CC (13.69±1.30 mg/kg FW). Significant differences ($p<0.05$) were observed between all of the CC experimental variants.

Thus, the IMTA pond part where no feed was administrated generates the higher accumulation of nitrates in common carp meat, in the last stage of the production cycle, compared to the polyculture pond production system (Figure 21). Compared to the previous experimental stage (Figure 20), during this final stage (Figure 21) the nitrates meat concentration of CC biomasses from IMTA pond registered an upward tendency, while a downward tendency was recorded for CC at polyculture pond (Figure 21).

The SC biomass registered a higher nitrates concentration in meat ($p<0.05$) at PP part of IMTA pond (21.73±0.72 mg/kg FW), compared to the polyculture pond (18.16±1.87 mg/kg FW) (Figure 21).

The BC and GC biomasses registered significant ($p<0.05$) higher nitrates concentrations in meat at PP part of IMTA pond (24.97±3.43 mg/kg FW for BC, respectively 26.94±3.32 mg/kg FW for GC), compared to the polyculture pond (11.27±0.61 mg/kg FW for BC, respectively 19.13±1.73 mg/kg FW for GC) (Figure 21).

The nitrates meat analysis of the prussian carp reveals the highest values in CP part of IMTA pond (34.19±4.50 mg/kg FW), followed by PP part of IMTA pond PrC (21.06±1.81 mg/kg FW) and polyculture pond PrC (10.93±0.40 mg/kg FW).

Therefore, it can be concluded that significant differences ($p<0.05$) were recorded when it comes to all experimental fish species meat nitrates concentration from PP part of IMTA pond, compared to the polyculture pond. Also, the invasive species PrC registered significant ($p<0.05$) differences between PCP vs. CP vs. PP in terms of meat nitrates concentration.

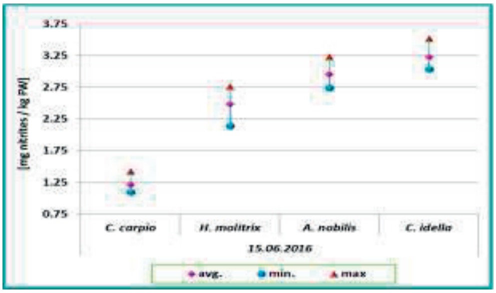

Figure 22. NO_2 dynamics in fish samples at the beginning of the experimental period

The highest values of nitrites concentration registered at the beginning of the experiment, before stocking, are recorded in case of grass carp (3.52 mg/kg FW), followed by bighead carp (3.23 mg/kg FW) and silver carp (2.76 mg/kg FW), while the lowest concentration of nitrites in meat is obtained at common carp (Figure 22). This may be due, same as it was mentioned in case of TKN concentration, to the fact that common carp has an earlier growth stage, characterized by a lower individual biomass value, compared to the rest of the experimental fish species.

In the intermediary stage of the experimental period, the CC specimen from the polyculture pond registered the highest nitrite concentration in meat (8.06±0.48 mg/kg FW), followed by the IMTA pond specimen PP CC (4.09±0.15 mg/kg FW) and CP CC (3.73±0.13 mg/kg FW). Significant differences ($p<0.05$) were observed between IMTA ponds and polyculture pond CC biomasses. Thus, the IMTA pond production system generates a lower accumulation of nitrites in common carp meat, in the intermediary stage of the production cycle (Figure 23).

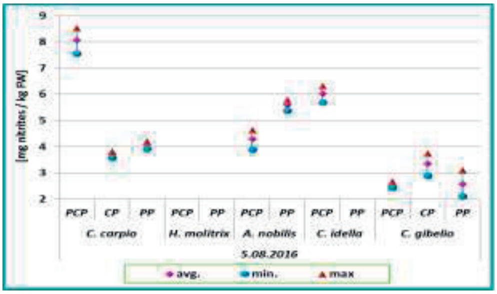

Figure 23. NO_2 dynamics in fish samples in the intermediary stage of the experimental period

The polyculture pond CC registered a notable upward tendency in terms of meat nitrite concentration in intermediary stage (Figure 23), compared to the beginning of the experiment.

The catches of silver carp (SC) specimen from both ponds, during the intermediary harvesting, were not enough in order to manage to characterize properly the nitrite concentration in meat, therefore no results are available. The same situation is valid also for BC specimen from PP part of IMTA pond.

Regarding the BC meat concentration of nitrites, significant ($p<0.05$) higher values can be observed at PP part of IMTA pond (5.59±0.21 mg/kg FW), comparedto the PCP polyculture pond (4.29±0.38 mg/kg FW) (Figure 23).

The grass carp (GC) specimen from PCP pond had an upward tendency in terms of nitrites concentration in meat (Figure 23), compared with the beginning of the experimental stage (Figure 22).

Since at this intermediary harvesting control prussian carp (PrC) specimen was harvested in both experimental ponds, the nitrites meat analysis of this species reveals the highest values in CP part of IMTA pond (3.35±0.43 mg/kg FW), followed by PP part of IMTA pond PrC (2.56±0.50 mg/kg FW).

Therefore, in case of the polyculture pond, after the intermediary stage of the production cycle, it can be concluded that CC and GC registered the highest meat nitrites concentrations, followed by BC. In the IMTA pond, BC registered the highest nitrites concentration in meat, followed by the CC species, between which a small variation interval was registered (Figure 23).

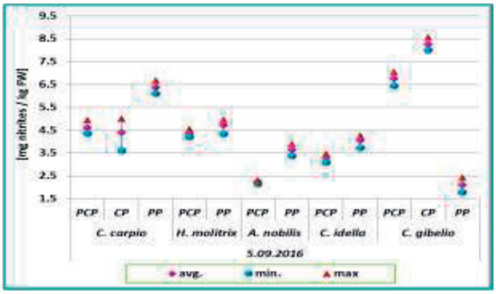

Figure 24. NO_2dynamics in fish samples in the final stage of the experimental period

At the end of the experimental period, the CC specimen from PP part of IMTA pond register-red the highest nitrites concentration in meat (6.36±0.28 mg/kg FW), followed by the PCP CC (4.61±0.60 mg/kg FW) and CP CC (4.38±0.71 mg/kg FW). Significant differences ($p<0.05$) were observed between PP CC and the rest of experimental CC variants.

Thus, the IMTA pond part where no feed was administrated generates the higher accumulation of nitrites in common carp meat, in the last stage of the production cycle, compared to the polyculture pond production system (Figure 24). Comparing with the previous experimental stage (Figure 23), during this final stage (Figure 24), the nitrites meat concentration of CC biomasses from IMTA pond registered an upward tendency, while a downward tendency was recorded for CC in the polyculture pond (Figure 24).

The SC biomass registered a higher nitrites concentration in meat ($p>0.05$) at PP part of IMTA pond (4.70±0.33 mg/kg FW), compared to the polyculture pond (4.35±0.18 mg/kg FW) (Figure 24).

The BC and GC biomasses registered significant ($p<0.05$) higher nitrites concentrations in meat at PP part of IMTA pond (3.63±0.28 mg/kg FW for BC, respectively 4.04±0.28 mg/kg FW for GC), compared to the polyculture pond (2.23±0.12 mg/kg FW for BC, respectively 3.30±0.19 mg/kg FW for GC) (Figure 24).

The nitrites meat analysis of this prussian carp reveals the highest values in CP part of IMTA

pond (8.26±0.28 mg/kg FW), followed by the polyculture pond PrC (6.76±0.31 mg/kg FW) and PP part of IMTA pond PrC (2.10±0.32 mg/kg FW).
Therefore, it can be concluded that no significant differences ($p>0.05$) were registered between IMTA and polyculture pond systems in terms of meat nitrites concentration of SC. However, the differences were significant ($p<0.05$) when it comes to CC, BC and GC meat nitrites concentration from PP part of IMTA pond, compared to the polyculture pond. Also, the invasive species PrC registered significant ($p<0.05$) differences between PCP vs. CP vs. PP in terms of meat nitrites concentration.

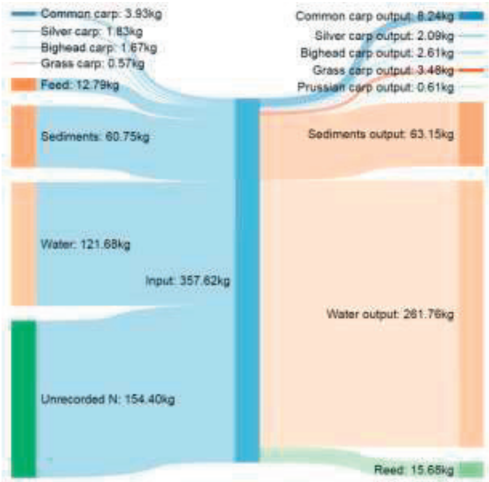

Figure 25. Sankey Diagram for TN in IMTA pond

The TN balance registered a percentage increase of TN recovery, at the end, compared to the beginning of the experimental period, as it follows: for PCP pond - 112.88% in case of fish biomass, 3.95% in case of sediments, 115.12% in case of water, for CP-PP pond – 108.43% in case of fish biomass, 10.06% in case of sediments, 41.78% in case of water. Also, considering the quantity of TN, registered at the end of the experiment:4.76 % - CP-PP, respectively 3.65% - PCP represents the recovered quantity of TN in fish biomass; 17.66% - CP-PP, respectively 14.94% - PCP recovered quantity of TN in sediments; 73.2% - CP-PP, respectively 72.2% - PCP recovered quantity of TN in water; 4.38% - CP-PP, respectively 9.21% - PCP recovered quantity of TN in reed biomass.

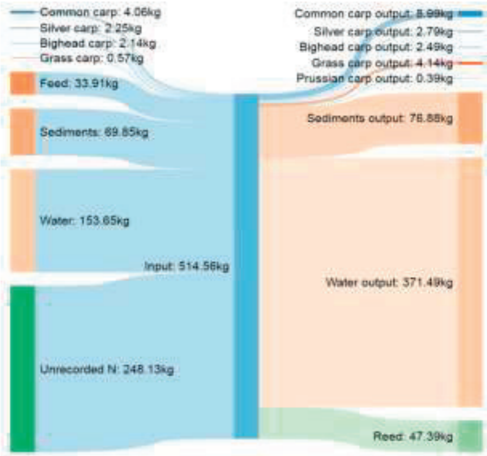

Figure 26. Sankey Diagram for TN in PCP pond

CONCLUSIONS

It can be concluded that the CP-PP feeding management, together with the tested technical solution (pond dividing) generated a higher common carp nitrogen intake and also, better water conditioning performances. Thus, implementing the IMTA technical solution applied in CP-PP generates a reduced loading of nitrogen on the water environment.
Nitrogen compounds dynamics in cyprinids ponds can be significantly influenced by applying the IMTA technology described in this present study.
It is recommended that a long-term monitoring should be made in terms of nitrogen compounds concentration in fish meat, water, sediments and aquatic plants, in order to make a better evaluation of the IMTA technology. Also, future studies on this subject will imply also changes in the fish stocking structure.

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VARIATION OF TURBIDITY OF LIQUID-SOLID MIXTURES IN THE WASTEWATER SETTLING PROCESS

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Abstract

Our paper presents the results of experimental determinations, in the laboratory, on stationary settling columns, in which the process of sedimentation of solid particles from a liquid-solid mixture prepared for this purpose could be followed. Mixtures of distilled water with different concentrations of $CaCO_3$ (2, 4, 6, 8 and 10%) were introduced in the 5 columns of the Armfield apparatus. In bottles of determined volume were prepared solutions from the same liquid-solid mixture, but with fixed concentrations, respectively, of 6, 4, 2, 1, 0.5 mg/mL. These bottles were used as a standard for checking the turbidity of the liquid in the stationary columns in areas of 10 cm on the 940 mm height of the column, for 100 min. The distribution of turbidity of the liquid, in height, in the different zones of the experimental column, was verified with several mathematical functions. The obtained results validated our predictions regarding the variation of the turbidity on the column height according to a power distribution law, and the obtained graphs presented high values of the correlation coefficient. They can be useful for decanter designers and wastewater treatment specialists.

Key words: *liquid turbidity variation, power distribution law, sedimentation, solid-liquid mixture, wastewater.*

INTRODUCTION

Water is the most important resource for life. Many people around the world suffer from a lack of fresh and clean drinking water (Sastry et al., 2013).

The transition of the human community from the traditional lifestyle to modernization and urbanization has involved the destruction of valuable non-renewable natural resources and the disintegration of the environment. Thus, in modern societies, proper wastewater management is a necessity, not an option (Harashit, 2014). Wastewater reuse has become an absolute need.

In order to meet the conditions of use, the improvement of water quality is achieved through a treatment process, which depends on the nature and state of dispersion of the mineral or organic substance obtained.

Minerals or organic substances can exist in three states dispersed in water: dissolved substances, colloidal suspensions and weight suspensions (Ciobanu M.G., 2010).

Demands for industrial and domestic wastewater treatment, in order to avoid environmental pollution and, in particular, contamination of pure water resources, have become national and international problems.

Wastewater treatment is a rather sensitive topic, including health and environmental, sociological and environmental and business sustainability issues for wastewater organizations and companies (Anjum et al., 2016).

In this regard, innovative, inexpensive and efficient methods of purification and cleaning of wastewater before discharge into any other water systems are needed (Moh et al., 2007; Holt et al., 2005; Chen et al., 2000).

One of these methods is the decantation or sedimentation of wastewater, a process by which solid particles with a higher density than water are separated from the liquid-solid mixture under the action of gravitational force (von Sperling, 2007; Adams et al., 1990).

Removal of solids is probably the main method of water purification in treatment plants.

The most significant phase of this process is the separation of sludge and particles suspended in water by gravity (Hasim et al., 2017; Lyn et al., 1992; Bajcar et al., 2011). Sedimentation was seen as a process of changing the concentration of solid particles upwards from the bottom of a settling vessel due to the downward movement of solids. (Concha & Burger, 2002; Cheng, 1997). This can be seen by changing the turbidity of the suspension at various points.

Turbidity in wastewater is caused by suspended matter such as clay, sludge, finely divided organic and inorganic matter, colored soluble organic compounds and plankton and other microscopic organisms (Harashit, 2014).

In stationary wastewater decanters, the liquid begins to clear from top to bottom due to deposits of solid suspensions at the bottom of the decanter. This clarification takes place in stages, in stages, a phenomenon that can be followed by checking the turbidity in several areas of the height of the decanter, at regular intervals (Zabava, 2020).

Total suspended solids (TSS) are the main vector of contaminants in the sewage system (Ashley et al., 2005).

According to the literature, it has been found that there are many different devices and methods used to perform sedimentation tests. Some of these are based on tracing the suspension clarification curve and involve filling a column with a suspension that is allowed to settle without disturbance, called static sedimentation (Gian, 2016; Ipate et al., 2019).

The static sedimentation method is very often applied in the stage of liquid-solid mechanical separation in the treatment of domestic and industrial effluents, but also in the treatment of drinking water (Ipate et al., 2019; Safta et al., 2013).

If a quantity of water is introduced into a column, in which solid particles decantable in suspension are found and left to stand, it is observed, after a period of time, that a clear area appears at the top of the water mass and stratification vertically, depending on the concentration, of the suspended particles that are decanted (Figure 1) (Safta et al., 2012; Sajeev et al., 2002).

In fact, three distinct areas are formed: an area of clear water at the top, a suspension area with particles in the process of settling in the middle and an area with concentrated sludge settled at the bottom.

These areas are separated by two interfaces: a clear water-suspension interface and a suspended-sludge concentrated sediment interface (Safta et al., 2012; Sajeev et al., 2002).

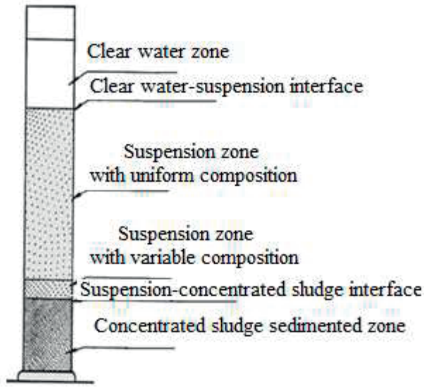

Figure 1. Decantation of a suspension in stationary column (Safta et al., 2012)

The slope of the clarification curve at the critical point represents the speed of the clarified water-suspension interface, when overlapping with the suspension-compacted interface. It should be mentioned that, for a stationary column sedimentation process, the sludge layer in compaction, corresponding to the critical point, has the highest height (Figure 2).

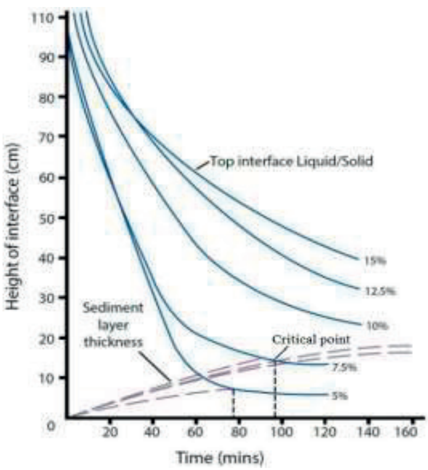

Figure 2. Scheme for determining the position of the critical point in the stationary column (Armfield, 2019)

Among the parameters that influence the behavior of suspended particles in the sedimentation process are the density of solid particles (Droppo et al., 2000), size and shape of solid particles (Florea, 1982; Furumai et al., 2002; Ghawi & Kriš, 2012), but also the temperature (Goula et al., 2008), density (Xiang et al., 2016) and fluid viscosity (Huang, 1981).

Our paper presents the results of experimental determinations, in the laboratory, on stationary settling columns, made of transparent material, in which the sedimentation process of solid calcium carbonate ($CaCO_3$) particles could be followed, from a liquid-solid mixture specially prepared for this purpose.

MATERIALS AND METHODS

The determinations were performed on the laboratory stand W2 Sedimentation Studies Apparatus (ARMFIELD, UK - Figure 3) provided with five graduated glass columns, transparent, with an inner diameter of 50 mm and a useful height of 940 mm, which corresponds to a volume of 1850 mL (Safta et al., 2012). An aqueous suspension of $CaCO_3$ particles was used, having concentrations of 2%, 4%, 6%, 8% and 10%, respectively, corresponding to amounts of 37 g, 74 g, 111 g, 148 g and 185 g of $CaCO_3$. The amount of calcium carbonate corresponding to each concentration was added to each of the 5 columns, adding water to a suspension volume of 1850 mL, corresponding to a height of 940 mm. After placing the stopper, each column was stirred vigorously for a good homogenization of the liquid-solid mixture.

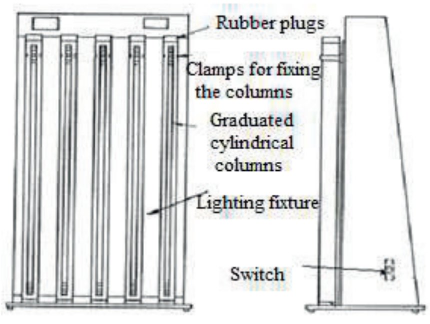

Figure 3. Schematic of the apparatus for the study of sedimentation in stationary column W2 - Armfield

The height of the columns was divided into eight zones of 100 mm, starting from top to bottom, each corresponding to a different zone of sedimentation of $CaCO_3$, as follows: zone 1, 940-840 mm; zone 2, 840-740mm; zone 3, 740-640 mm; zone 4, 640-540 mm; zone 5, 540-440 mm; zone 6, 440-340 mm; zone 7, 340-240 mm; zone 8, 240-140mm, according to Figure 4a.

The concentration of solid suspensions in the 8 zones was analyzed by fluid turbidity expressed in mg / mL.

The turbidity of the 8 zones was tested using standard samples, of different concentrations: 0.2 mg / mL, 0.5 mg / mL, 1 mg / mL, 2 mg / mL, 4 mg / mL and 6 mg / mL, prepared especially for this purpose in bottles of 100 mL. These were stirred throughout the sedimentation experiment prior to testing (verification) to prevent the deposition of solid $CaCO_3$ particles. Experimental recordings were made at 5 min intervals for 100 min, comparing each area in each graduated column with the standard samples (Figure 4b). In fact, it was analyzed how the concentration of the suspension decreases in each of the 8 areas, at intervals of 5 min, for a time of determinations of 100 min.

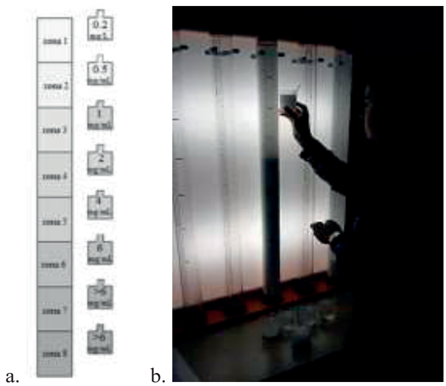

Figure 4. Dividing the column into 8 zones (a) and determining the turbidity of the 8 zones using standard samples (b)

At first, the suspension was placed in the graduated transparent column, provided with a rubber stopper so that the sedimentation process is influenced only by gravitational force.

The column was fixed on the support of the device with the clamps with which it is provided, the timer was turned on to determine at 5 min intervals the turbidity for the 8 established areas and the lighting system of the equipment was turned on for a good determination (test) of turbidity for each area.

Based on the recorded values, the turbidity variation curves over time for each area and

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column were plotted. The experimental data obtained were processed using the Microsoft Excel program, and the decrease of turbidity, the concentration of the suspension in each analyzed area followed a power distribution of the form:

$$Tb = a \cdot t^{-b}, \text{(mg/mL)} \quad (1)$$

where:

- Tb - turbidity of the suspension;
- t is the time, (s);
- a and b are process parameters, determined experimentally.

RESULTS AND DISCUSSIONS

The results obtained after the sedimentation process in a stationary column (100 min), as well as the graphs drawn on their basis, for each zone, in each column, are presented below, in the order of the established concentrations.

a) Distribution of solid particle concentration over time, for the 2% concentration column, analyzing all 8 determined zones (their turbidity)

Table 1 shows the distribution of the concentration of solid particles over time, for the 2% concentration column, determined by analyzing the 8 zones.

Table 1. Experimental data of turbidity in the 8 zones for the concentration of suspension 2%

Time, min	Concentration of zones, mg/mL							
	1	2	3	4	5	6	7	8
0								
5	6							
10	4	6						
15	2	4	6					
20	2	2	4	6				
25	1	2	4	6				
30	1	2	2	4	6			
35	1	2	2	2	4	6		
40	1	2	2	2	4	6		
45	1	2	2	2	2	4	6	
50	1	1	2	2	2	4	4	6
55	1	1	2	2	2	2	4	4
60	0.5	1	1	2	2	2	2	4
65	0.5	1	1	1	1	1	1	2
70	0.5	0.5	1	1	1	1	1	1
75	0.5	0.5	1	1	1	1	1	1
80	0.5	0.5	1	1	1	1	1	1
85	0.5	0.5	0.5	1	1	1	1	1
90	0.5	0.5	0.5	1	1	1	1	1
95	0.5	0.5	0.5	1	1	1	1	1
100	0.5	0.5	0.5	1	1	1	1	1

It can be seen that the liquid begins to clear from top to bottom, in stages, the turbidity having decreasing values over time, for each area analyzed

Figure 5 shows the correlation between the turbidity of the analyzed area and the turbidity change time, for the concentration of 2% $CaCO_3$.

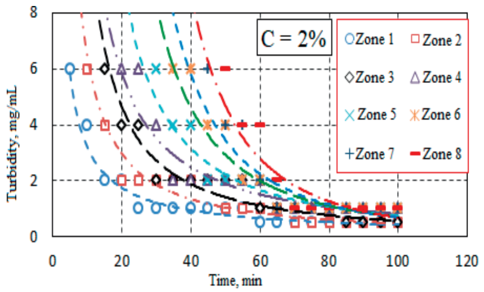

Figure 5. The variation of turbidity in time for the concentration column 2%

The last area to reach a turbidity of 0.5 mg/mL was zone 3. From the eight curves resulting from the representation of the experimental data obtained, it results that the highest value of the regression coefficient R^2 was obtained for the sedimentation zone 1, located in the highest position, 940-840 mm. The correlation coefficient R^2 was higher than 0.770 for all areas, which demonstrates a close link between the two parameters of the sedimentation process.

The correlation with the experimental data given by the coefficient R^2, together with the coefficients of the regression functions a, b, for the 2% concentration column, for the 8 sedimentation zones, is presented in Table 2.

Table 2. The values of the coefficients of the power regression function a, b and of the correlation coefficient R^2

Zone		Coefficients of the eq. (1)		
		a	b	R^2
$C_{2\%}$	1	24.008	0.875	0.936
	2	87.203	1.13	0.905
	3	222.82	1.294	0.905
	4	226.24	1.223	0.895
	5	979.49	1.556	0,887
	6	8936	2.052	0.869
	7	31902	2.335	0.771
	8	234137	2.768	0.796

Analyzing the experimental data, as well as their graphical representation, it can be seen

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that the lowest concentration of solid particles, recorded at 100 min, for the first column had the value of 0.5 mg/mL. The first area that reached this value was sedimentation zone 1, in the 60th minute from the beginning of the determinations. The last zone that reached a turbidity of 0.5 mg / mL was zone 3 (740-640 mm). From the eight resulting curves, following the representation of the experimental data obtained, it results that the highest value of the regression coefficient R^2 was obtained for the sedimentation zone 1, located in the highest position 940-840 mm. In this first area, the correlation coefficient for the power dependence of the turbidity with time was $R^2 = 0.936$.

b) In the case of *the distribution of the solid particle concentration, for the 8 sedimentation zones, for the 4% concentration column*, was proceeded as in the first case.

Using the Microsoft Excel program, analogous to the sedimentation column with 2% suspension, following a power distribution law (eq. 1), the variation of the concentration of solid particles was plotted, expressed by turbidity over time.

From the analysis of the graph (Figure 6) it can be seen that the turbidity in each area decreases over time, the sedimentation zone 8 showing a correlation factor $R^2 = 0.933$. The lowest value of the correlation coefficient with function (1) was the one related to sedimentation zone 1 ($R^2 = 0.878$).

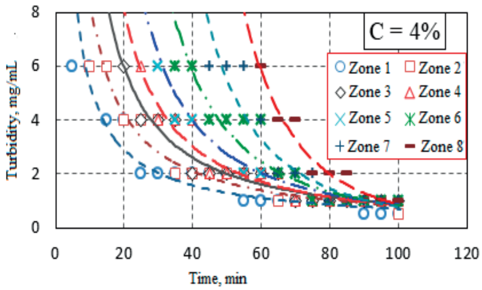

Figure 6. The variation of turbidity in time for the concentration column 4%

It can be seen that only the first two areas of the column reached a low value of the concentration of solid particles of 0.5 mg/mL $CaCO_3$ in suspension in the 100 minutes in which the recordings were made.

In this way, a first conclusion can be drawn, namely, as the concentration of solid particles in the water increases, the time required for their settling increases.

The distribution of the power regression function has the same form as in the case of the 2% concentration column (eq.1), the correlation of the experimental data given by the coefficient R^2, together with the coefficients of the regression functions a, b, for the 4% concentration column, for the 8 sedimentation zones are presented in Table 3.

In none of the zones was reached the turbidity level of 0.5 mg/mL $CaCO_3$ and in zone 8 of sedimentation only after minute 70 the concentration of solid particles decreases to 6 mg/mL.

Table 3. The values of the coefficients of the power regression function a, b and of the correlation coefficient R^2

Zone		Coefficients of the eq. (1)		
		a	b	R^2
$C_{4\%}$	1	40.242	0.878	0.878
	2	86.919	1.01	0.894
	3	207.85	1.187	0.912
	4	529.84	1.401	0.916
	5	1840	1.664	0.910
	6	14135	2.115	0.893
	7	347492	2.826	0.911
	8	2E+07	3.712	0.933

c) *The distribution of the solid particle concentration by zones for the 6% concentration is shown in Figure 7.*

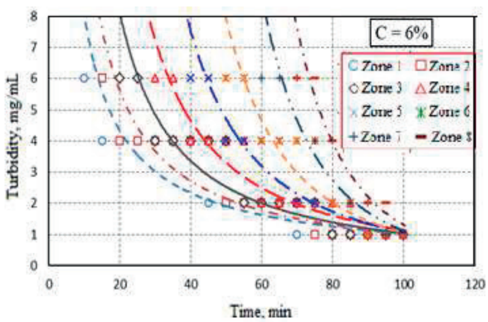

Figure 7. The variation of turbidity in time for the concentration column 6%

The correlation of the experimental data given by the coefficient R^2, is presented in Table 4.

Table 4. The values of the coefficients of the power regression function a, b and of the correlation coefficient R^2

Zone		Coefficients of the eq. (1)		
		a	b	R^2
$C_{6\%}$	1	62.585	0.892	0.837
	2	128.24	1.045	0.846
	3	363.33	1.27	0.879
	4	1328.1	1.533	0,889
	5	18002	2.11	0.896
	6	657470	2.897	0.872
	7	1E+08	3.971	0.884
	8	9E+09	4.914	0.896

Following these results, it can be concluded that even in this case there is a power connection between the parameters turbidity - time.

d) *In the case of the 8% $CaCO_3$ concentration column, the distribution of the concentration of solid particles is shown in Figure 8.*

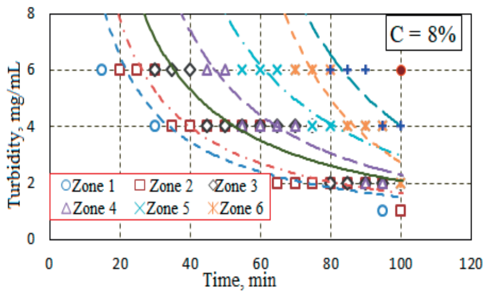

Figure 8. The variation of turbidity in time for the concentration column 8%

It can be seen that in the first sedimentation zone of the graduated column, the concentration level decreased to 6 mg/mL only after 15 minutes from the start of the experiment.

The content of solid particles is quite high, which causes an increase in the clarification time, so it was possible to check the concentration of 6 mg/mL in the sedimentation zone 8 only in minute 100.

According to the experimental data, six of the eight zones do not reach the concentration of 1 mg/mL after the 100 minutes of testing (sedimentation zone 3, zone 4, zone 5, zone 6, zone 7 and zone 8). Moreover, in the sedimentation zone 6 only in minute 100 is reached the concentration level of 2 mg/mL.

It was observed that, at this concentration value, the correlation coefficient had values between 0.701 (sedimentation zone 5) and 0.819 (sedimentation zone 2), decreasing values compared to the other three analyzed concentrations.

For zone 8, no values could be established for these coefficients because the concentration of 6 mg/mL was reached only in minute 100.

In order for wastewater to be discharged into an emissary, that to meet the permissible concentration level in solid particles, regardless of their nature, the settling time needs to be long, especially when the initial concentration is high.

The power distribution has the same shape as in (eq. 1), the correlation of the experimental data given by the coefficient R^2, together with the coefficients of the regression functions a, b for the 8% concentration column, for 7 sedimentation zones, are presented in Table 5.

Table 5. The values of the coefficients of the power regression function a, b and of the correlation coefficient R^2

Zone		Coefficients of the eq. (1)		
		a	b	R^2
$C_{8\%}$	1	98.093	0.906	0.811
	2	140.31	0.965	0.819
	3	230.03	1.022	0.806
	4	812.42	1.274	0.734
	5	2150	1.43	0.701
	6	583487	2.664	0.749
	7	83698	2.158	0.735
	8	-	-	-

e) *The last column analyzed from the point of view of the concentration of solid particles was the one of 10% $CaCO_3$ concentration, its distribution presented in Figure 9.*

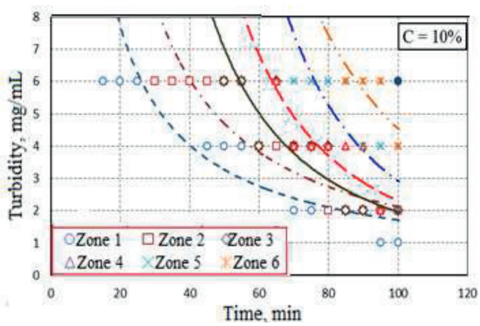

Figure 9. The variation of turbidity in time for the concentration column 10%

In the first sedimentation zone, the solid particle concentration level of 6 mg/mL was reached only in the 15th minute after starting the experiment, and the concentration of 4 mg / mL, also for this area, was reached only after 45 min. It can be seen that only in sedimentation zone 1 the concentration of 1 mg/mL is reached in minute 95, this being the lowest concentration of the suspension recorded in the 100 min.
According to the experimental data, in the sedimentation zone 8 the concentration of 6 mg/mL did not appear after the 100 min of testing. Moreover, it can be observed that, in zone 7 of sedimentation, the appearance of this concentration takes place only at minute 100, fact for which, for zone 7 and 8 could not be represented graphs of variation of turbidity in time, the last the represented area being the sedimentation zone 6.
The correlation of the experimental data given by the coefficient R^2, together with the coefficients of the regression functions a, b for the 10% concentration column, for 6 sedimentation zones, are presented in Table 6. For zones 7 and 8 no values could be set for these coefficients.

Table 6. The values of the coefficients of the power regression function a, b and of the correlation coefficient R^2

Zone		Coefficients of the eq. (1)		
		a	b	R^2
$C_{10\%}$	1	127.69	0.937	0.729
	2	418.25	1.147	0.784
	3	9470.6	1.342	0.806
	4	41721	2.129	0.715
	5	544215	2.635	0.676
	6	116579	2.204	0.578
	7	-	-	-
	8	-	-	-

From the analysis of the graphs made for the five concentrations, it is observed that the lowest values of the correlation coefficient are obtained in this 10% concentration column.
Therefore, it is found that if the initial concentration of solids in the liquid-solid suspension is higher, the level of clear its difficult to achieve, and the sedimentation time is greater.
Thus, the experimental data obtained reinforce the conclusion that as the concentration of solid particles in a suspension increases, the time required to remove them by sedimentation is longer.

CONCLUSIONS

Decantation or sedimentation is the process by which solid particles with a higher density than water is separated from the liquid-solid mixture under the action of gravitational force.
In order for wastewater to be discharged into an emissary, meaning to achieved the permissible concentration level in solid particles, regardless of their nature, the settling time needs to be long, especially when the initial concentration is high.
In stationary wastewater decanters, the liquid begins to clear from top to bottom due to deposits of solid suspensions at the bottom of the decanter. This clarification takes place in stages, meaning in steps, a phenomenon that can be followed by checking the turbidity in several areas of the height of the decanter, at regular intervals.
Research has shown that if the initial concentration of solids in the liquid-solid suspension is higher, the level of clear its difficult to achieve, and the sedimentation time is greater.
The experiment presented shows that the zonal variation of the suspension clarity can be represented by a law of variation of power type (or exponential type), and the parameters of the equation depend on the initial concentration of the suspension, without taking into account the particle size distribution of the solid particles or the temperature at which the settling process takes place.
The experimental results obtained can be useful for decanter designers and specialists in the field of wastewater treatment.

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MISCANTHUS X GIGANTEUS AS A BIOFUEL CROP FOR PHYTOREMEDIATION OF HEAVY METAL CONTAMINATED SOILS

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Abstract

There has been carried out comparative research, which allows determining the quantities and the depots of accumulation of heavy metals, macro, and microelements in the vegetative organs of Miscanthus x giganteus, efficacy for phytoremediation, and quality of biomass as renewable energy sources for the combustion process. The field experiment was performed on an agricultural field contaminated by the Non-Ferrous-Metal Works (MFMW) near Plovdiv, Bulgaria. The experimental plots were situated at different distances (0.5, 3.5, and 15 km) from the source of pollution. Macronutrients (N, P, K, Mg, Ca), microelements (Fe, Mn, Cu), and heavy metal (Cd, Pb, Zn) concentrations in plant materials (roots, rhizomes, stems, and leaves) were determined during the three-year research period, two harvest periods (autumn, spring) per year. Heating value, ultimate and proximate analyses were evaluated at the end of the second growing season. Miscanthus x giganteus is tolerant towards heavy metals and can be grown on highly contaminated soils (2671.6 mg/kg of Zn, 2694.8 mg/kg of Pb, and 84.8 mg/kg of Cd). The depot for accumulation follows the order: roots>stems>leaves>rhizomes. The high concentration of heavy metals in the roots and rhizomes and the low translocation factor indicate the possibility of Miscanthus x giganteus to be used in phytostabilization.
The obtained results have shown that Miscanthus x giganteus can be a significant source of good quality raw material in the production of solids biofuels. The biomass is of good quality (high carbon (47.85-49.92%) and hydrogen (5.37-5.59%) content, and low ash (3.18-3.26%), nitrogen (0.05-0.1%), chlorine (0.056-0.085%), and sulphur (0.006-0.048%) content and high energy potential (17.38-18.32 MJ/kg LHV). The degree of soil contamination did not have a significant influence on heating values, carbon, hydrogen, nitrogen, and sulphur contents but did influence on biomass heavy metal contents. The content of heavy metals in the biomass of Miscanthus x giganteus grown on heavily contaminated soils is significantly higher and exceeds the limit values according to the standard ISO 17225-6:2014. Biomass of Miscanthus x giganteus from highly contaminated soils could be used as a source of energy if the burning of biomass occurs in power plants equipped with purification systems to control dust emissions.

***Key words**: biomass properties, heavy metals, Miscanthus x giganteus, phytoremediation, polluted soils.*

INTRODUCTION

Miscanthus x giganteus is a perennial crop of the Poaceae family to which there has been considerable interest in recent years. *Miscanthus* x *giganteus* is a sterile hybrid between *M. sinensis* and *M. sacchariflorus*, propagating vegetatively through its rhizomes. It is grown as an ornamental and energy crop for biofuel production. In the United States (Colorado and California), it is mainly used for decorative purposes, while in Europe, it is grown as an energy crop and for biofuel. In Europe, the areas with *Miscanthus* are still small, and it is cultivated on 43,000 ha (ABIOM, 2016). Approximately 20,000 ha (Lewandowski et al., 2018) are located mainly in the United Kingdom, Germany, and France, with suitable conditions for Miscanthus growth. The cultivation of *Miscanthus* in Bulgaria started 5-6 years ago with planting material, and a complete technology for propagation and cultivation has been developed.

The plant is characterized by high biomass production, cold tolerance, C4 photosynthesis, non-invasiveness, does not require fertilizers and herbicides, and is easy to harvest (Jorgensen, 2011; Robson et al., 2012). The *Miscanthus* x *giganteus* can be harvested from November (after the early frosts) until the next growing season (March - April). In general, early harvest increases the yield per hectare to maximum, while late harvest leads to a decrease (Lewandowski et al., 2003; Zub et al., 2011). Due to falling leaves and stems, yields decrease by an average of 33-38% from October to February (Dzeletovic et al., 2014). The main use of energy from *Miscanthus* biomass is for direct combustion, but the crop also has significant potential in producing second-generation biofuels (Bilandzija et al., 2017). Phytoremediation is an emerging technology, which should be considered for remediation of contaminated sites because of its cost-effectiveness, aesthetic advantages, and long-term applicability (Chaney et al., 1997). This technology can be defined as the efficient use of plants to remove, detoxify or immobilize environmental contaminants in soils, waters or sediments through the natural, biological, chemical, or physical activities and processes of the plants (Ciura et al., 2005).

The use of biofuel crops for phytoremediation of heavy metal contaminated soils is of increasing interest (Pidlisnyuk et al., 2013). The main reason for this is the increase in demand for biomass as an alternative energy source, as well as the possibility of remediation of contaminated soils. Energy crops include fast-growing varieties of trees and annual and perennial grasses. Among perennial grasses, *Miscanthus* is considered the most promising biofuel plant. Preliminary studies have shown that Miscanthus can be used for phytoremediation of contaminated land after the Chernobyl disaster in Ukraine and contaminated soils from mining in Slovakia (Hauptvogl et al., 2020). The use of *Miscanthus* biomass for energy production seems promising in terms of the costs for phytoremediation and can find actual application in practice compared to the use of expensive conventional methods. Studies have shown that the utilization of biomass obtained as a source of energy is profitable and can make the phytoremediation process profitable (Dornburg et al., 2005).

Direct combustion is the most common way to extract energy from biomass, for which energy crops, agricultural residues, forest residues, industrial and other waste can be used (Elbehri, 2013). In terms of combustion, the most important properties of biomass include proximate analysis, ultimate analysis, heating value (Imam and Capareda, 2012), lignocellulosic composition, and content of micro and macroelements. The standards for solid fuels CEN/TS 14961(2005) and ISO 17225-6(2014) specify the values for Miscanthus x giganteus and other types of agricultural and forest biomass when burned as biofuel. The standards are based on studies conducted in Sweden, Finland, the Netherlands, and Germany. The characteristics of biomass are influenced by its origin, and there is a great variety in the properties of fuels (Garcia et al., 2012).

Insufficient is the information available on the potential of *Miscanthus* for accumulation of heavy metals and its potential for use for phytoremediation. There are no comprehensive studies on the relationship between the total content of heavy metals in the soil, their uptake by the *Miscanthus* biomass and quality of biomass as a biofuel when growing *Miscanthus* on soils with different degrees of heavy metal pollution.

The purpose of this study is to conduct systematic research that will allow us to determine the quantities and the deposits for the accumulation of heavy metals, macro, and microelements in the vegetative organs of *Miscanthus*, the quality of *Miscanthus* biomass as a biofuel, as well as the possibilities to use the plant for phytoremediation of heavy metal contaminated soils.

MATERIALS AND METHODS

The experiment was performed on an agricultural field contaminated by Zn, Pb, and Cd, situated at different distances (0.5, 3.5, and 15.0 km) from the source of pollution, the NFMW (Non-Ferrous Metal Works) near Plovdiv, Bulgaria. Characteristics of soils are shown in Table 1. The soils used in this experiment were slightly alkalic, with moderate content of organic matter and essential nutrients (N, P, and K). The pseudo-total content of Zn, Pb, and Cd are extremely high (2671.6 mg/kg Zn, 2694.8 mg/kg Pb, and 84.5 mg/kg Cd, respectively) and exceeds the maximum permissible concentrations (320 mg/kg Zn, 100 mg/kg Pb and 2.0 mg/kg Cd) in soil 1 (0.5 km from NFMW).

The rapidly-growing energy crop *Miscanthus* × *giganteus* was investigated. The field tests were set after the block method in four replications. The size of the test parcel was 100 m^2. The plants were grown using the conventional technology on areas located at different distances (0.5 km, 3.5 km, and 15 km) from the source of contamination - NFMW Plovdiv. Five plants from each replication were used in the analysis.

The harvest was carried out in autumn and spring when the plants were two years old. The plants were gathered, and the contents of heavy metals, macro, and microelements in their different parts - roots, rhizomes, stems, and leaves, were analysed separately at two harvest periods (autumn and spring). Samples from the rhizomes, roots, stems, and leaves were dried at room temperature to obtain an air-dry mass and then dried at 105°C.

The pseudo-total composition of metals in soils was determined in accordance with ISO 11466. The available (mobile) heavy metals contents were extracted by a DTPA solution (ISO 14780).

The plant samples were treated by the method of microwave mineralization. To determine the heavy metals, micro- and macro elements content in the plant and soil samples, an inductively coupled emission spectrometer (Jobin Yvon Horiba "ULTIMA 2", France) was used.

Proximate analysis: The samples were characterized according to standard methods: moisture content (BDS EN ISO 18134-3:2015), ash (BDS EN ISO 18122:2015), fixed carbon (by difference), and volatile matter (BDS EN ISO 18123:2015).

Ultimate analysis: Total carbon, hydrogen, nitrogen, and sulfur were determined by dry combustion in a Vario Macro CHNS analyser (Elementar GmbH, Germany) (BDS EN ISO 16948:2015). The O content was calculated by difference.

Table 1. Characterization of the soils

Parameter	Soil 1 (0.5 km)	Soil 2 (3.5 km)	Soil 3 (15 km)
pH	7.6	7.6	7.5
Organic carbon, %	3.99	2.24	1.54
N Kjeldal, %	0.24	0.22	0.23
Pseudo-total P, mg/kg	617.2	655.9	1221.1
Pseudo-total K, mg/kg	6108,7	9165.3	9630.8
Pseudo-total Pb, mg/kg	2694.8	186.3	64.1
DTPA-extractable Pb, mg/kg	1088.2	40.5	27.7
Pseudo-total Zn, mg/kg	2671.6	308.3	141.1
DTPA-extractable Zn, mg/kg	249.0	27.4	8.8
Pseudo-total Cd, mg/kg	84.5	4.0	2.1
DTPA-extractable Cd, mg/kg	64.0	0.75	0.67

Heating value: The heating value was determined by ISO method (BDS EN ISO 18125:2017) using an IKA C6000 oxygen bomb calorimeter (IKA Wercke GmbH, Germany).

RESULTS AND DISCUSSIONS

Accumulation of heavy metals in vegetative organs of Miscanthus x giganteus

To clarify the issues of absorption, accumulation, and distribution of heavy metals in vegetative organs of *Miscanthus* x *giganteus* were analyzed samples of rhizomes, roots, stems, and leaves. Table 2 presents the results obtained for the content of heavy metals in the vegetative organs of the study crop at autumn harvest.

Considerably higher amounts were established in the roots of *Miscanthus* x *giganteus* compared to the aboveground parts. The content of Pb in the roots of *Miscanthus* grown at 0.5 km from NFMW reached to 232.7 mg/kg, Zn - 331.8 mg/kg and Cd - 66.9 mg/kg, whereas in the rhizomes Pb reached to 64.9 mg/kg, Zn - 74.0 mg/kg and Cd - 11.2 mg/kg.

Table 2. Content of heavy metals (mg/kg) in vegetative organs of Miscanthus x giganteus

Element	Rhizomes	Roots	Stems	Leaves
S1Pb	64.9	232.7	109.2	93.0
S1Cd	11.2	66.9	5.7	2.1
S1Zn	74.0	331.8	168.4	120.4
S2Pb	4.0	9.8	1.3	3.1
S2Cd	0.39	1.4	0.5	0.2
S2Zn	9.7	38.4	30.7	18.5
S3Pb	0.25	4.9	0.47	0.83
S3Cd	0.04	0.48	0.06	0.02
S3Zn	9.5	36.4	14.9	11.6

This is explained by the fact that during the penetration of heavy metals in the plasma, there is inactivation and disposal of significant quantities of them due to the formation of slightly mobile compounds with the organic substance. This is consistent with the results obtained by Fernando and Oliveira (2004), who found that metals accumulate primarily in the underground parts of *Miscanthus* x *giganteus* rather than in the aboveground parts.

The heavy metals contents in the stems and leaves of the *Miscanthus* were considerably lower than those in the root system, which showed that their movement through the conductive system was strongly restricted. The content of Pb in the stems of *Miscanthus* grown at 0.5 km from NFMW reached 109.2 mg/kg, Zn - 168.4 mg/kg, and Cd - 5.7 mg/kg. The content of Pb in the leaves of *Miscanthus* grown at 0.5 km from NFMW reached 93.0 mg/kg, Zn - 120.4 mg/kg, and Cd - 2.1 mg/kg.

The obtained results show that the content of Pb in the aboveground parts of *Miscanthus* x *giganteus* is low despite the moderate level of bioavailable forms of Pb in the soil. The studies of Pogrzeba et al. (2011, 2013) show that the uptake of metals strongly depends on the level of accessible forms. In the cultivation of *Miscanthus* x *giganteus*, 2 mg/kg Pb, 0.3 mg/kg Cd and 25 mg/kg Zn are accumulated on clean soils, while at cultivation on contaminated soils - up to 200 mg/kg Pb, 5 mg/kg Cd and 700 mg/kg Zn. Barbu et al. (2009, 2010) found that there is a correlation between the Pb content of the aboveground parts of *Miscanthus* x *giganteus* and the Pb content in the soil. Barbu et al., (2009, 2010) found that the number of accumulated metals in leaves and stems of *Miscanthus* x *giganteus*, when grown on contaminated soil (680 mg/kg Pb and 13 mg/kg Cd), is very low. Similar results are obtained by Nsanganwimana et al. (2015), who found that, despite the high content of Pb in the soil, plants accumulate moderate amounts of this element in their aboveground mass, which may be due to the accumulation of Pb in the roots of the plant.

The Translocation Factor (TF) provides information on the ability of plants to digest absorb heavy metals through the underground parts (roots and rhizomes) and to move them to the aboveground mass (stems and leaves). The obtained results show that, concerning Pb, plants' translocation factor varies from 0.25 to 0.68, for Cd from 0.10 to 0.39, and Zn from 0.58 to 1.02.

The effectiveness of phytoremediation is also determined by the bioconcentration factor (BCF), (McGrath and Zhao, 2003). BCF root is a ratio of the content of heavy metals in plant underground (rhizomes and roots) to soil content ($BCF_{underground}$ = $[Metal]_{underground}$ / $[Metal]_{soils}$). The obtained results show that this ratio varies from 0.07 to 0.11 for Pb, from 0.78 to 1.73 for Cd, and from 0.15 to 0.32 for Zn. BCF shoot is defined as the ratio of the metal concentration in the aboveground mass of the plant (stems and leaves) and the soil ($BCF_{aboveground}=[Metal]_{aboveground}/[Metal]_{soils}$) and is a measure of the plant's ability to digest and move the metals to the aboveground mass, which can be easily harvested. In hyperaccumulators, the BCF factor is higher than one, and in some cases, it may reach 50-100 (McGrath and Zhao, 2003).

The obtained results show that, concerning Pb, the bioconcentration factor for plants varies from 0.02 to 0.08, for Cd from 0.09 to 0.26, and Zn from 0.11 to 0.19. The results obtained show that BCF is higher for Zn and Cd than for Pb. Higher values for Zn and Cd are probably a consequence of these elements' more remarkable ability to accumulate in the aboveground mass than in the roots, which is consistent with the results of Korzeniowska et al. (2011) and Yoon et al. (2006). According to McGrath and Zhao (2003), the BCF value for the aboveground parts of the accumulator plants should be higher than that of the plant roots and should exceed 1. The study results show that *Miscanthus* x *giganteus* can be classified as an accumulator type for Cd. The $BCF_{underground}$ for Cd varies from 0.92 to 2.01, whereas BCF aboveground - from 0.09 to 0.78.

Table 3. Translocation factor (TF) and bioconcentration coefficients (BCF underground, BCF aboveground) of *Miscanthus* x *giganteus*

Soil	Coefficient	Pb	Cd	Zn
S1	TF	0.68	0.099	0.71
S1	BCF under	0.11	0.92	0.15
S1	BCF above	0.08	0.09	0.11
S2	TF	0.31	0.39	1.02
S2	BCF under	0.07	2.01	0.16
S2	BCF above	0.02	0.78	0.16
S3	TF	0.25	0.15	0.58
S3	BCF under	0.08	1.73	0.32
S3	BCF above	0.02	0.26	0.19

$BCF_{under}=[Metal]_{under}/[Metal]_{soil,}$ $TF=[Metal]_{above}/[Metal]_{under)},$
$BCF_{\ above}=[Metal]_{shove}/[Metal]_{soil}$

There is a distinct feature in the accumulation of The *Miscanthus* x *giganteus* accumulates a moderate amount of heavy metals in the leaves and has a relatively lower potential for phytoextraction.

According to Pidlisnyuk et al. (2013) and Kocon et al. (2012), *Miscanthus* x *giganteus* can be grown on contaminated soils which are not contaminated with a high concentration of metals.

Miscanthus x *giganteus* accumulates heavy metals through its root system, and most of them are retained by the roots. The quantity of heavy metals in the stems and leaves of the plants was considerably lower than the root system, which showed that their movement through the conductive system was strongly restricted. The results show that *Miscanthus* is a crop that is tolerant to heavy metals and can be successfully grown on highly contaminated soils.

The high concentration of heavy metals in the roots and the low translocation factor indicate the possibility of *Miscanthus* x *giganteus* being used in phytostabilization.

Heating value, ultimate and proximate analysis

Heating value, ultimate and proximate analysis, the content of macro and microelements are among the main parameters in the assessment of biomass in the process of direct combustion. Moisture content (MC), ash content (AC), volatile matter (VM), nitrogen (N), sulfur (S), and oxygen (O) are undesirable components in biomass, as opposed to fixed carbon (FC), carbon (C), hydrogen (H) and lower heating value (LHV), the higher levels of which improve the quality of the biomass when it comes to direct combustion.

The results obtained for the *Miscanthus* x *giganteus* biomass grown at a different distance from NFMW at spring harvest are presented in Tables 4, 5, and 6. The values of the biomass's main parameters are compared with the requirements of the standards CEN/TS 14961 and ISO 17225-6 and the data from other authors for the analysis of the *Miscanthus* biomass grown in different countries.

The term calorific value refers to the energy content of biomass and characterizes biomass as a possible fuel resource. The calorific value can be expressed by higher and lower heating values (McKendry, 2002; Garcia et al., 2012). According to CEN/TS 14961, the standard for solid fuels for HHV and LHV is 19.8 MJ/kg and 18.4 MJ/kg, respectively.

LHV is one of the essential parameters for assessing the potential of biomass as a biofuel. According to the literature, the lower heating values range from 15.31 MJ/kg (Serbia, Cvetkovic et al., 2016) to 17.25 MJ/kg (Croatia, Jurisic et al., 2014). This study shows that the net heat of combustion done on a dry basis varies from 17.45 to 18.32 MJ/kg. Soil contamination does not affect LHV, with the highest values being obtained for biomass grown on heavily contaminated soils that comply with the standard CEN/TS 14961. The obtained results are higher than the presented data for Serbia, Croatia, Spain, the United Kingdom and France (Table 4).

According to this parameter in the standard CEN/TS 14961, *Miscanthus* biomass is characterized as a valuable energy raw material suitable for use in the combustion process.

Table 4. Proximate analyses and lower heating value of *Miscanthus* x *giganteus* biomass

Parameter	Moisture, %	Ash, %	FC, %	VM, %	LHV, MJ/kg
S1	10.38	3.18	8.51	88.31	18.32
S2	8.21	3.26	11.49	85.25	17.38
S3	8.12	4.92	9.99	85.09	17.45
Reference	8.30-8.60	1.50 - 9.60	9.50 - 18.97	74.40-86.52	15.31-17.25
CEN / TS 14961	-	-	-	-	18.4
ISO 17225-6	≤10	≤4	-	-	-

Heating values decrease with higher moisture content, with higher levels leading to lower combustion temperatures and affecting quality (Garcia et al., 2012).

In general, moisture can vary considerably and is an undesirable ingredient in any fuel (Obernberger and Thek, 2004). The moisture content is influenced by the climatic conditions and the period of biomass harvesting. If the average moisture content of M x giganteus biomass is less than 20%, it is considered that the application of a technological process of drying is not necessary before harvesting. Lewandowski and Heinz (2003) and Borkowska and Molas (2013) determined that biomass harvested in the spring is associated with lower moisture content (57.43% - 64.11%) compared to the autumn harvest. The lower moisture content of the spring harvest shows the potential for storing the harvested biomass without the need for additional drying, which is favourable for the energy balance and the economic efficiency of biomass production.

The results from this study show that the moisture content at spring harvest varies from

8.12 to 10.38%, with higher values reported for the biomass of *Miscanthus* grown on contaminated soil, which is by the standard ISO 17225-6:2014 (≤10) (Table 4).

Based on the data presented in Table 4, can conclude that the average moisture content of slightly contaminated and uncontaminated soil is similar to the values obtained in Poland (8.60%) and Germany (8.30%) (Werle et al., 2018).

The content of fixed carbon is considered a positive property of biomass, representing the amount of energy released from a certain amount of biomass (Garcia et al., 2012; Jurisic et al., 2017). Higher fixed carbon values affect the quality of biomass due to the higher heating values (McKendry, 2002; Obernberger and Thek, 2004). The fixed carbon content is the mass remaining after the release of volatile matter, excluding ash and moisture. Fixed carbon leads to the formation of carbon and burns as a solid in the fuel system (McKendry et al., 2002; Khodier et al., 2012). CEN/TS 14961 and ISO 17225-6 do not specify a value for fixed carbon.

Studies by Bilandzija et al. (2017) show that fixed carbon is not significantly affected by the harvesting season or fertilization, and the average value of this parameter is 9.31%. According to the literature, the fixed carbon in the *M.* x *giganteus* biomass is between 9.5% and 14.0% (Vassilev et al., 2010; Jegurim, 2010; Howaniec and Smolinski, 2011). The results show that the fixed carbon varies from 8.51 to 11.49%, with the lowest values found in the biomass of *Miscanthus* grown on highly contaminated soil. The obtained values for fixed carbon in the *Miscanthus* biomass from slightly contaminated and uncontaminated soil are in accordance with the results from other authors. In contrast, its content in *Miscanthus* from heavily contaminated soils is lower.

The ash content is one of the main factors determining the quality of biomass, as more significant amounts of ash reduce fuel quality. The non-combustible content of biomass is called ash content. The high ash content leads to pollution problems, especially if the ash has high metal chloride content. Biomass fuels from crops or residues have higher ash content (Clarke, 2011). Hodgson et al. (2010) and Baxter et al. (2014) determined that higher-quality biomass with lower ash content is obtained by growing *Miscanthus* without fertilization. Lewandowski and Heinz (2003) decided that harvest postponing from autumn to spring leads to reducing ash content.

The results obtained show that the ash content varies from 3.18 to 4.92%. The lowest values are found for biomass grown in the heavily contaminated soil (S1). According to CEN/TS 14961, the ash content of *Miscanthus* x *giganteus* biomass must be ≤ 4. According to the standard for solid fuels EN ISO 17225-6, the ash content for non-wood pellets can vary from 6 to 10%, while for non-wood pellets from *Miscanthus* it should not be higher than 4%. The biomass from the heavily contaminated (S1) and slightly contaminated area (S2) meets the standard, while from the uncontaminated area (S3), it slightly exceeds the permissible value. A probable reason for the higher ash content in *Miscanthus* from the uncontaminated soil is the higher content of macroelements in plant biomass. According to the literature data, the ash content is between 1.4% and 9.6% (Table 4).

Table 5. Ultimate analysis of *Miscanthus* x *giganteus* biomass

	N, %	C, %	S, %	H, %	O, %	Cl, %
S1	0.09	49.92	0.006	5.37	41.44	0.056
S2	0.05	48.27	0.03	5.59	42.83	0.085
S3	0.1	47.85	0.048	5.47	41.66	0.058
Ref.	0.10-2.15	45.40-48.75	0.07-0.2	3.92-7.32	41.69-46.76	-
CEN/TS 14961	0.7	49	0.2	6.4	44	-
ISO 17225-6	≤0.5	-	≤0.5	-	-	≤0.08

The studied biomass from *Miscanthus* grown on soils with different degrees of contamination has qualities suitable for direct combustion. With regard to the solid fuel standard, the ash content is within the standard.

In the combustion process, biomass decomposes into volatile gases and solid residue. Volatile matters are the components released at high temperatures when the fuel is heated, without taking into account the moisture that is part of the combustible gases (CxHy gases, CO, or H_2) and non-combustible gases (CO_2, SO_2, or NO_x) (Garcia et al., 2012). A high percentage of volatile matter is one of the characteristics of biomass (about 75%,

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which can reach 90%, Khan et al., 2009), reducing the energy value (Grubor et al., 2015; Quaak et al., 1999). It was found that the content of volatile matter is not affected by the harvesting season, as well as by fertilization, and the average value of volatile matter reaches 88.88%. Khodier et al. (2012) and Nhuchhen and Salam (2012) determined that the volatile matter content in *M.* x *giganteus* biomass ranges from 70.7% to 87.2%. CEN/TS 14961 and EN ISO 17225-6 do not specify a volatile matter rate in *M.* x *giganteus*. The results obtained show that volatile matters vary from 85.09% to 88.31%, with the highest values found in the biomass of *Miscanthus* grown on highly contaminated soil. The values for volatile matters are in line with the biomass results from Croatia (86.52%). A comparison with studies conducted in Spain, the United Kingdom, and France shows that *Miscanthus* x *giganteus* grown in Bulgaria has a higher volatile matter content.

Table 5 presents the ultimate analysis of *Miscanthus* x *giganteus* grown on soils with different degrees of heavy metal contamination in Bulgaria. The values of the ultimate analysis are compared with the requirements of the standards CEN/TS 14961 and ISO 17225-6 and the data from other authors for the analysis of the *Miscanthus* biomass grown in different countries. The energy value is negatively affected by the oxygen content. Jegurim et al. (2010), Howaniec and Smolinski (2011), and Bilandzija et al. (2017) examined the oxygen content of *Miscanthus* × *giganteus* biomass and determined values ranging from 31.3 to 49.3%. The established values for oxygen of 46.3% are within the previous studies. The main components of solid biofuels are C, H, and O. C and H are oxidized during combustion in exothermic reactions, which leads to the formation of CO_2 and H_2O and affects the gross calorific value of the fuel (Obernberger et al., 2006). Organically bound O provides the part of O required for the combustion process, and O must be added by air injection (Mantineo et al., 2009). Higher C and H content lead to higher HHV. According to CEN/TS 14961 for solid fuels, the values for C, H, O are 49%, 6.4%, and 44%, respectively.

Carbon is the primary and most crucial element in all types of fuels, and its content determines their quality, i.e., higher carbon levels increase fuel quality.

The total carbon content varies from 47.85 to 49.92%, with the highest values found for the biomass of *Miscanthus* from contaminated soil. According to the literature, the carbon content ranges from 45.40 to 48.75% (Table 5), this is in line with this study's results.

The content of total hydrogen varies from 5.37 in heavily contaminated soil to 5.59% in slightly contaminated soil. According to the literature, the hydrogen content varies widely (from 3.92 to 7.32) (Table 5). Similar results similar were determined in Ireland (5.38%, France (5.70%), United Kingdom (5.98%), higher in Serbia (6.11%) and Spain (6.30%), Poland (7.32%) and Germany (7.28%), and lower in Croatia (3.98%).

The oxygen content varies from 41.44 to 42.83%. Slight differences were found in the biomass's oxygen content between the tested plants from the areas with different degrees of contamination, as lower values were found for *Miscanthus* from the highly contaminated soil. According to the literature, O's content varies from 35.52% to 46.80% (Table 5). Similar results were determined in the United Kingdom (41.69%) and higher in France (44.80%), Poland (44.25%), Germany (45.17%) and Spain (46.42%) and Croatia (46.76%).

From an environmental point of view, nitrogen and sulfur contribute to increased greenhouse gases and are considered unfavourable biomass elements. When biomass is burned, NOx and SO_2 are formed, and therefore the nitrogen and sulfur content of the biomass must be as low as possible. The amount of nitrogen in the biomass is the cause of NOx emissions from biomass combustion. The fuel's low nitrogen content leads to lower NOx emissions (Obernberger and Thek, 2004). Sulfur is the element with a minor presence in biomass, but nitrogen is a critical element for the environment (Garcia et al., 2012; Saez Angulo and Martínez García, 2001). The content of S in the biomass largely depends on the macromolecular composition. SOx are formed during combustion and lead to significant contamination with dust particles and acid rain. Also, S can indirectly contribute to increased corrosion (Clarke, 1989; Obernberger et al, 2006). According to CEN/TS 14961, the limit for N is 0.7%, and for S is 0.2%.

The total nitrogen content varies from 0.05% in slightly contaminated soil to 0.09% in heavily contaminated soil and 0.1% in uncontaminated soil, at a nitrogen rate of 0.5%. The content of total sulfur varies from 0.006% for highly contaminated soil (S1) to 0.03% for slightly contaminated soil (S2) and 0.048% for uncontaminated soil (S3), with a sulfur rate of 0.05%. The values obtained are below the permissible values for the limit for solid fuels. According to the literature data, the sulfur content in biomass varies from 0.06% to 0.2% (Collura et al., 2006; Jeguirim et al., 2010). The low N content found increases the quality of biomass in terms of its use for combustion processes. The nitrogen content is much lower than the established values for plant biomass (0.1% to 2.15%), (Table 5), (Jegurim et al., 2010; Garcia et al., 2012; Moss et al., 2013; Bilandzija et al., 2017). The results obtained are similar for sulphur. *Miscanthus* x *giganteus*, grown in Bulgaria, despite the soil contamination, has a lower content of nitrogen and sulphur than *Miscanthus*, produced in Spain (0.1%), Serbia (0.3%), Ireland (0.29%), Croatia (0.48%), France (1.1%), United Kingdom (1.11%), Poland (1.38%) and Germany (2.15%). It was found that the content of elements in biomass is influenced by the harvesting season and treatment of fertilizers. Postponing the harvesting season from autumn to spring had a positive effect on the quality of biomass due to the increased C content and lower content of O, N, and S. A higher C content in the later harvest was determined by Baxter et al. (2014). Lewandowski and Heinz (2003) also determined a positive effect of spring harvest on reducing N and S content. Spring harvest is associated with a higher H content compared to the autumn harvest. Fertilization has a negative effect on the fuel properties of biomass due to the lowest determined content of C and H. Studies by Baxter et al. (2014) show that the quality of biomass is reduced due to nitrogen fertilization.

Table 6 presents the results for the content of heavy metals, micro and macro elements in the biomass of *Miscanthus* x *giganteus* at spring harvest, grown on soils with different degrees of heavy metal contamination in Bulgaria and typical values of CEN/TS 14961 for solid fuels. Statistically significant differences were found when comparing heavy metal concentration in plant shoots harvested during autumn and spring. Spring harvest of *Miscanthus* causes increases in heavy metals content of the biomass. The spring lead concentration was about tenfold lower when compared to the autumn harvest. Cadmium and zinc concentrations were three and tenfold higher when compared to autumn harvest, respectively. The return of ashes from the combustion of biomass to the soil is the most ecological and sustainable disposal method. In this way, a significant part of the plant's macro- and micronutrients returns to the soil, closing the circulation of minerals (Zajac et al., 2018).

The ashes' chemical composition was dominated by the macroelements Ca, Mg, K, and P, which suggests the possibility for their agricultural use. Simultaneously, the high content of toxic elements, such as Pb and Cd, should be a limiting feature in their use. The ash of biomass must be thoroughly analysed before its recommendation for fertilizing purposes.

Contaminated biomass has to be treated as a hazardous material, and its incineration has to be done in facilities equipped with filters for the capture of metal oxides.

Ash-forming elements such as Al, Si, Ca, Fe, K, Mg, Na, and P in the biomass are significant for any thermochemical conversion process. The relatively high content of alkaline elements can lead to serious technical problems when used as a raw material for energy production.

Alkali metals are generally thought to be the main cause of slagging, fouling and sintering (Cuiping et al., 2004). Suppose the values obtained for *Miscanthus* x *giganteus* grown in Bulgaria are compared with CEN/TS 14961 for solid fuels. In that case, it is established that the values for solid fuels, it is established that the values of iron, and calcium, are fully compatible with the limit; potassium, magnesium, nickel, and chromium are lower. At the same time, copper, zinc, lead, and cadmium are significantly higher.

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Table 6. Heavy metals, micro and macro elements (mg/kg) of *Miscanthus* x *giganteus* biomass

	S1	S2	S3	Reference	Standard
Pb	1070.7	42.0	6.3	2-200	≤10*
Cd	15.7	0.76	0.05	0.1-6.6	≤0.5*
Zn	1182.5	115.9	20.3	20.1-700	≤100*
Cu	72.3	4.2	2.4	2.5-5.3	≤20*
Fe	309.9	76.6	330.3	221.9	40-400**
Mn	49.4	65.0	53.5	74.6-502	-
P	116.4	212.2	286.3	-	-
Cr	0.82	0.79	0.55	22.7-34.6	≤50*
Ni	0.79	0.70	0.77	10.2-12.5	≤10*
Ca	2768	2394	3004	1615-4508	900-3000**
Mg	163.2	218.2	429.0	479-703	300-900**
K	266.6	304.2	657.8	819-3700	1000-1100**
Al	90.2	51.0	183.0	-	-

*EN ISO 17225-6, **CEN/TS 14961

The combustion of biomass with higher macroelements content can lead to significant slagging and furnace corrosion (Bilandzija et al., 2017; Cassida et al., 2005).

Significantly lower results are obtained for macro elements in plant biomass from contaminated soils (S1) compared to slightly contaminated (S2) and uncontaminated soils (S3). The established values for contaminated and uncontaminated soils are by the results published by other authors. Bilandzija et al. (2017) found that the sodium content varies from 63.9 to 90.0 mg/kg, Mg from 467.7 to 482.3 mg/kg, K from 833.6 to 887.2 mg/kg, and Ca from 1802 to 1956 mg/kg depending on the time of harvesting. The differences in the content of the studied elements are probably due to the content of the elements in the soil and the time of harvesting.

Biomass used as fuel may contain different pollutants in different concentrations. The biomass data concentration on As, Ba, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, V, and Zn varies depending on the biomass type (Krzyzak et al., 2017). In the biomass of agricultural origin, these elements may accumulate when grown on contaminated soils or the use of fertilizers. As a result, their biomass concentration varies depending on the type of pollutant, distance from the source, and plant age. Values in the range of 60 to 640 mg/kg for Zn and 0.1 to 6.6 mg/kg for Cd are determined (Kajda-Szczesniak, 2014).

A small part of the elements is retained in the bottom ash during combustion, while a more significant amount is carried away along with the volatile ash. Non-volatile elements such as Fe, Cr, Cu, and Al form stable oxides, which are retained by coarser ash particles. Volatile metals (Cd, Pb, and Zn) evaporate during combustion, mostly controlled by fine dust particles. As a result, a significant part of the heavy metals and the fine dust particles are carried away with the gases through the chimney. The presence of chlorine in the biomass leads to a higher evaporation rate of volatile metals, which forms chlorides and oxides. Cd and Pb form $CdCl_2$ and $PbCl_2$ during combustion. Zn can also evaporate as chloride, but a significant amount remains in the ash from combustion due to the formation of a stable oxide form. In the industrial combustion of biomass from fuel, heavy metal emissions are controlled mainly by minimizing dust emissions. Furthermore, steps have been proposed to use adsorbent materials, such as alumina, kaolinite, bauxite, etc., to inhibit heavy metals' evaporation and retention in the fuel ash.

CONCLUSIONS

Based on the results obtained, the following important conclusions can be made:

1. The *Miscanthus* x *giganteus* is a tolerant plant to heavy metals and can be grown in heavy metal polluted soils (2671.6 mg/kg Zn, 2694.8 mg/kg Pb, and 84.5 mg/kg Cd) and can be successfully used in the phytoremediation of heavy metal polluted soils.
2. The heavy metals distribution has a selective character that in *Miscanthus* x *giganteus* decreases in the following order: roots>stems>leaves>rhizomes.
3. The moisture content of biomass in *Miscanthus* is low and is within the standard.
4. Ash as an indicator of fuel quality is also low, emphasizing the studied biomass's excellent quality.
5. The studied biomass of *Miscanthus* x *giganteus* grown on contaminated soils is of high quality (high content of carbon and hydrogen, and low content of ash, nitrogen, chlorine, and sulphur) and high energy potential.
6. The content of heavy metals in the biomass of *Miscanthus* x *giganteus* grown on heavily contaminated soils is significantly higher and

exceeds the limit values according to the standard ISO 17225-6:2014. Biomass of *Miscanthus* x *giganteus* from highly contaminated soils could be used as a source of energy if biomass burning occurs in power plants equipped with purification systems to control dust emissions.

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CARDOON (*CYNARA CARDUNCULUS* L.) AS A BIOFUEL CROP FOR PHYTOREMEDIATION OF HEAVY METAL CONTAMINATED SOIL

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Abstract

There has been carried out comparative research, which allows determining the quantities and the depots of accumulation of heavy metals, macro, and micro elements in the vegetative organs of Cynara cardunculus L., efficacy for phytoremediation and quality of biomass as renewable energy sources for the combustion process. The field experiment was performed on an agricultural field contaminated by the Non-Ferrous-Metal Works (MFMW) near Plovdiv, Bulgaria. The experimental plots were situated at different distances (0.5, and 8 km) from the source of pollution. Macronutrients (N, P, K, Mg, Ca), micro elements (Fe, Mn, Cu) and heavy metal (Cd, Pb, Zn) concentrations in plant materials (roots, and leaves) were determined. Heating value, ultimate and proximate analyses were evaluated at the end of the second growing season. Cardoon is tolerant towards the heavy metals and can be grown on highly contaminated soils (2544.8 mg/kg of Zn, 2429.3 mg/kg of Pb and 51.5 mg/kg of Cd). The depot for accumulation follows the order: roots>leaves. The high concentration of heavy metals in the roots and the low translocation factor indicate the possibility of cardoon to be used in phytostabilization. The obtained results have shown that cardoon has potential to be a significant source of good quality raw material in the production of solids bio-fuels. The biomass is of good quality (carbon (39.3-43.0%), hydrogen (3.8-4.52%), nitrogen (0.72-0.877%), chlorine (4.7-6.8%), and sulphur (0.266-1.12%) content) and high energy potential (14.54-16.09 MJ/kg LHV). The degree of soil contamination did not have a significant influence on heating values, carbon, hydrogen, nitrogen, and sulphur contents but did influence on biomass heavy metal contents. The content of heavy metals in the biomass of cardoon grown on heavily contaminated soils is significantly higher and exceeds the limit values according to the standard ISO 17225-6:2014. Biomass of cardoon from highly contaminated soils could be used as a source of energy if the burning of biomass occurs in power plants equipped with purification systems to control dust emissions.

Key words: *biomass properties, cardoon, heavy metals, phytoremediation, polluted soils*

INTRODUCTION

Cynara is a genus of thistle-like perennial plants of the Asteraceae family. Cardoon (*Cynara cardunculus* L.) is a perennial C3 crop with an annual growth cycle, well adapted to the soil and climatic conditions of Southern Europe. The plant is found primarily in the Mediterranean region, located mainly in Spain, Italy, and Greece, with mild winters, hot, dry summers, and light rainfall, unevenly distributed throughout the year. Cardoon produces significant biomass in spring and summer (Danalatos et al., 2006) and develops again after the first rains in autumn. Dry biomass is harvested in July-August (with a plant moisture content of 15%).

C. cardunculus is a crop with various applications. The aboveground biomass (leaves and stems) can be used as animal feed, energy production (Mancini et al., 2019), and in the food industry. Cardoon, unlike artichoke, is a crop little known in Bulgaria. Cardoon is a crop that is not demanding in terms of soil and can be grown without irrigation because it withstands drought. The climatic conditions in southern Bulgaria are suitable for its cultivation.

The use of cardoon as an energy crop is associated with very low cultivation costs, high yields of dry biomass, low moisture content in the biomass at harvest, biomass composition mainly of lignocellulose type, and high calorific value. As a solid fuel, cardoon can be used to heat or generate energy (for example, co-combustion mixed with coal). The possibilities of using cardoon as a solid biofuel were studied by Fernandez et al. (1997), Piscioneri et al. (2000), Gherbin et al. (2001), and Dahl and Obernberger (2004). Crop management techniques can affect the characteristics of cardoon biomass as a fuel.

For example, the way the harvest is carried out can lead to contamination of the soil's biomass, which leads to a higher ash content and leads to slag problems. Similarly, fertilization with KCl can increase K and Cl's content in the biomass, which can lead to the formation of deposits in the boiler (Dahl and Obernberger, 2004).

Direct combustion is the most common way to extract energy from biomass, for which energy crops, agricultural residues, forest residues, industrial and other waste can be used (Elbehri, 2013). In terms of combustion, the most critical biomass properties include proximate analysis, ultimate analysis, heating value, lignocellulosic composition, and micro-and macro elements. The standard for solid fuels ISO 17225-6 (2014) specifies the values for different agricultural and forest biomass types when burned as bio-fuel.

Phytoremediation is an emerging technology, which should be considered for remediation of contaminated sites because of its cost-effectiveness, aesthetic advantages, and long-term applicability (Chaney et al., 1997). This technology can be defined as the efficient use of plants to remove, detoxify or immobilize environmental contaminants in soils, waters, or sediments through the natural, biological, chemical, or physical activities and processes of the plants (Ciura et al., 2005).

The use of bio-fuel crops for phytoremediation of heavy metal contaminated soils increases interest (Pidlisnyuk et al., 2013). The main reason for this is the increase in demand for biomass as an alternative energy source and the possibility of remediation of contaminated soils. Energy crops include fast-growing varieties of trees and annual and perennial grasses. The phytoremediation potential of cardoon (*Cynara carduncululus* L.) has been studied in several studies (Papazoglou, 2011; Llugany et al., 2012; Pandey et al., 2016; Arena et al., 2017; Domínguez et al., 2017). Arena et al. (2017) and Sorrentino et al. (2018) found that cardoon is tolerant to Cd and Pb and has a significant ability to accumulate heavy metals in pot experiments. It has been found that cardoon does not get toxic metals in As contaminated soils and accumulates toxic metals in Cd or Pb contaminated soils (Papazoglou 2011; Sanchez-Pardo et al., 2015). Domínguez et al. (2017) found that soil contamination did not significantly affect the cardoon's biomass.

Insufficient is the information available on cardoon potential for accumulation of heavy metals and its potential for use for phytoremediation in field experiments. Most publications have focused on evaluating the use of cardoon seeds for biodiesel production. There is insufficient information on the chemical composition of the cardoon biomass and the quality of bio-fuel.

The purpose of this study is to conduct systematic research that will allow us to determine the quantities and the deposits for the accumulation of heavy metals, macro, and microelements in the vegetative organs of cardoon, the quality of cardoon biomass as a biofuel, as well as the possibilities to use the plant for phytoremediation of heavy metal contaminated soils

MATERIALS AND METHODS

The experiment was performed on agricultural fields contaminated by Zn, Pb, and Cd, situated at different distances (0.5 and 8.0 km) from the source of pollution, the NFMW near Plovdiv, Bulgaria.

The soils were slightly neutral to basic with moderate organic matter content and essential nutrients (N, P, and K), (data are not shown). The pseudo-total content of Zn, Pb, and Cd is high and exceeds the maximum permissible concentrations (MPC) in soil 1 (S1) (Table 1).

Table 1. Content of Pb, Zn and Cd in soils sampled from NFMW

Distance	pH	Pb x ± sd	Zn x ± sd	Cd x ± sd
Soil 1 (S1) 0.5 km	7.4	2509.1±6.5	2423.9±6.3	64.3±0.2
Soil 2 (S2) 8 km	7.5	49.4±0.2	172.7±2.1	1.0±0.1

x - average value (mg/kg) from 5 repetitions; sd - mean standard deviation; MPC (pH 6.0-7.4) - Pb - 100 mg/kg, Cd - 2.0 mg/kg, Zn - 320 mg/kg; MPC (pH > 7.4) - Pb - 100 mg/kg, Cd - 3.0 mg/kg, Zn - 400 mg/kg

The study included cardoon (*Cynara carduncululus* L.), grown on areas located at different distances (0.5 km and 8.0 km) from the source of contamination NFMW Plovdiv. Cardoon seeds were sown to a depth of 3-4 cm; between row and within the row, distances were 70 and 30 cm, respectively. Cardoon is grown according to conventional technology. The analyses were made in the second year of the growing of the plants. Five plants of each of the areas were used for the analysis. The test plant was). On reaching commercial ripeness, the plants of cardoon were gathered.

The pseudo-total content of metals in soils was determined in accordance with ISO 11466. The available (mobile) heavy metals contents were extracted following ISO 14870 by a solution of DTPA. The contents of heavy metals, micro- and macro-elements in the plant material (roots and leaves) were determined by the microwave mineralization method. To determine the content in the plant and soil samples, an inductively coupled emission spectrometer (Jobin Yvon Horiba "ULTIMA 2", France) was used. Digestion and analytical efficiency of ICP were validated using a standard reference material of apple leaves (SRM 1515, National Institute of Standards and Technology, NIST).

Proximate analysis: The samples were characterized according to standard methods: moisture content (BDS EN ISO 18134-3:2015), ash (BDS EN ISO 18122:2015), fixed carbon (by difference), and volatile matter (BDS EN ISO 18123:2015).

Ultimate analysis: Total carbon, hydrogen, nitrogen, and sulfur were determined by dry combustion in a Vario Macro CHNS analyzer (Elementar GmbH, Germany) (BDS EN ISO 16948:2015). The O content was calculated by difference.

Heating value: The heating value was determined by the ISO method (BDS EN ISO 18125:2017) using an IKA C6000 oxygen bomb calorimeter (IKA Wercke GmbH, Germany).

RESULTS AND DISCUSSIONS

Soils

The results presented in Tables 1 and 2 show that in the soil samples S1 (taken from the area situated at the distance of 0.5 km from NFMW), the reported values for Pb were exceeding MPC approved for Bulgaria and reached 2509.1 mg/kg. In the area located at a distance of 8.0 km, the contents of Pb significantly reduce to 49.4 mg/kg. Similar results were obtained for Cd and Zn.

The results for the mobile forms of the metals extracted by DTPA show that the mobile forms of Cd in the contaminated soils are the most significant portion of its total content and reached 57,2%, followed by Pb with 33.8% and Zn with 9.8%.

In the soil located at a distance of 8.0 km from NFMW, the mobile forms of Cd are the most significant part of it.

Table 2. DTPA-extractable Pb, Zn and Cd (mg/kg) in soils sampled from NFMW

Soils	Pb		Cd		Zn	
	mg/kg	%*	mg/kg	%	mg/kg	%
S1	849.1	33.8	36.8	57.2	236.8	9.8
S2	21.5	43.5	0.7	70	38.9	22.5

*DTPA -extractable/total content

Content of trace metals in vegetative organs of cardoon

To clarify the issues of absorption, accumulation, and distribution of heavy metals in vegetative organs of cardoon were analyzed samples of roots and shoots. Table 3 presents the results obtained for the content of heavy metals in the vegetative organs of the study crop.

Table3. Content of heavy metals (mg/kg) in vegetative organs of cardoon, translocation factor (TF) and bioconcetration coefficients (BCF root, BCF shoot)

	Root	Leaves	TF	BCFroot	BCFshoot
Pb	520.2	213.0	0.41	0.21	0.09
Cd	27.8	13.4	0.48	0.43	0.21
Zn	531.9	166.2	0.31	0.22	0.07

$BCF_{root}=[Metal]_{root}/[Metal]_{soil}$, $TF=[Metal]_{shoot}/[Metal]_{root}$, $BCF_{shoot}=[Metal]_{shoot}/[Metal]_{soil}$

Considerably higher amounts were established in the roots of cardoon compared to the above ground parts. The content of Pb in the roots of cardoon grown at 0.5 km from NFMW reached 520.2 mg/kg, Zn - 531.9 mg/kg, and Cd - 27.8 mg/kg. This is explained by the fact that during the penetration of heavy metals in the plasma, there is inactivation and disposal of significant quantities of them due to the formation of slightly mobile compounds with the organic substance. The results are consistent with Capozzi et al. (2019) finding that a significant accumulation of heavy metals in the roots of cardoon in the cultivation of cardoon in the pot experiments.

The heavy metals contents in the cardoon shoots were considerably lower than those in the root system, which showed that their movement through the conductive system was strongly restricted. Pb content in the shoots of cardoon grown at 0.5 km from NFMW reached 213.0 mg/kg, Zn - 166.2 mg/kg, and Cd - 13.4 mg/kg.

The obtained results obtained show that the content of Pb in the aboveground parts of cardoon is low despite the moderate level of bioavailable forms of Pb in the soil.

The choice of plant species for phytoremediation purposes is usually based on assessing their ability to accumulate heavy metals and translocate them from the roots to the aboveground mass. Bioaccumulation coefficients (BCFroots and BCFshoots) and translocation factor (TF) were calculated to evaluate the potential of cardoon for phytoremediation (phytostabilization or phytoextraction). Knowledge of such coefficients can provide useful information on the potential for phytostabilization or phytoextraction of cardoon. The Translocation Factor (TF) provides information on plants' ability to uptake heavy metals through the roots and to translocate them to the aboveground mass (stems and leaves). TF values <1 indicate a higher concentration of heavy metals in the roots, typical for plants with phytostabilization potential, while TF> 1 shows a higher content in the aboveground mass, which is typical for plants with potential for phytoextraction. The obtained results show that, concerning Pb, plants' translocation factor reached 0.41, Cd - 0.48, and Zn - to 0.31. Pb, Cd, and Zn accumulate mainly in the roots and translocate poorly in the aboveground mass. Thie results are consistent with the results of other authors who found low TF coefficients for As, Ni, Pb, and Zn in cardoon (Papazoglou, 2011; Sánchez-Pardo et al., 2015; Arena et al., 2017; Sorrentino et al., 2018). According to Garau et al. (2021) cardoon plants show TF <1 (0.09-0.45) for all elements except Cd (TF = 2.93), and TF values follow the order: Cd> Zn> Cu> Pb> As > Sb.

The effectiveness of phytoremediation is also determined by the bioconcentration factor (BCF). BCFroot is a ratio of the content of heavy metals in plant roots to soil content (BCFroots=[Metal]roots/[Metal]soils).

The obtained results show that this ratio reached 0.21 for Pb, 0.43 for Cd, and 0.22 for Zn.

BCF shoot is defined as the ratio of the metal concentration in the aboveground mass of the plant (stems and leaves) and the soil (BCFshoots=[Metal]shoots/[Metal]soils) and is a measure of the plant's ability to digest and move the metals to the aboveground mass, which can be easily harvested. The obtained results show that, concerning Pb, the BCFshoot reached 0.09, for Cd and Zn to 0.31 and 0.07, respectively. The results are consistent with Garau et al. (2021) finding that BCF is quite low (0.01-0.57).

Cardoon accumulates heavy metals through its root system, and most of them are retained by the roots. The quantity of heavy metals in the shoots of the plants was considerably lower than the root system, which showed that their movement through the conductive system was strongly restricted. The results show that cardoon is a crop tolerant to heavy metals and can be successfully grown on highly contaminated soils.

The high concentration of heavy metals in the roots and the low translocation factor indicate the possibility of cardoon being used in phytostabilization.

Heating value, ultimate and proximate analysis

Heating value, ultimate and proximate analysis, the content of macro-and microelements are among the main parameters in the assessment of biomass in the process of direct combustion. Moisture content (MC), ash content (AC), volatile matter (VM), nitrogen (N), sulfur (S), and oxygen (O) are undesirable components in biomass. The higher levels of fixed carbon (FC), carbon (C), hydrogen (H), and lower heating value (LHV) improve the quality of the biomass when it comes to direct combustion.

The results obtained for the cardoon biomass grown at a different distance from NFMW are presented in Tables 4, 5, and 6. According to standard CEN/TS 14961, biomass for solid biofuel is divided into three main groups (wood biomass, grass biomass, and fruit biomass). Cardoon biomass belongs to the group of herbaceous biomass - agricultural and horticultural herbs (others). The values of the biomass's main parameters are compared with the requirements of the standard ISO 17225-6 for herbaceous biomass and the data from other authors for the analysis of the cardoon biomass grown in different countries.

The term calorific value refers to biomass's energy content and characterizes biomass as a possible fuel resource. Higher and lower heating values can express the calorific value. According to ISO 17225-6, the standard for solid fuels for LHV is 14.5 MJ/kg.

LHV is one of the essential parameters for assessing the potential of biomass as a biofuel. According to the literature, the lower heating values range from 15.08 MJ/kg to 18.2 MJ/kg (Table 4). This study shows that the combustion's net heat on a dry basis varies from 14.54 to 16.09 MJ/kg, with higher values reported for the biomass of cardoon grown on uncontaminated soil. According to this parameter in the standard ISO 17225-6, cardoon biomass is characterized as a valuable energy raw material suitable for use in the combustion process. Cardoon biomass can be used as a raw material for heat and energy production. It has a gross calorific value (HHV) between 14.9 and 20.3 MJ/kg (Dahl and Obernberger, 2004; Gravalos et al., 2005, Grammelis et al., 2008). Cardoon biomass has calorific values typical of grassy biomass, i.e., 18–22 MJ/kg HHV (Gominho et al., 2018).

Table 4. Proximate analyses and lower heating value of cardoon biomass

Parameter	S1	S2	Reference	ISO 17225-6
Moisture, %	4.66	4.23	5.72-13.2	≤12 -15
Ash, %	21.45	17.05	6.9-29.6	≤6-10
Fixed carbon, %	8.15	5.55	10.9-14.6	-
Volatile matter, %	70.4	77.4	59.5-75.0	-
LHV, MJ/kg	14.54	16.09	15.08-18.2	≥14.5

Heating values decrease with higher moisture content, with higher levels leading to lower combustion temperatures and affecting quality (Clarke and Preto, 2011). In general, moisture can vary considerably and is an undesirable ingredient in any fuel. The moisture content is influenced by the climatic conditions and the period of biomass harvesting.

This study shows that the moisture content varies from 4.23 to 4.66%, with higher values reported for the biomass of cardoon grown on contaminated soil, which is by the standard ISO 17225-6:2014 (≤12-15) (Table 4).

Based on the data presented in Table 4, the average moisture content of contaminated and uncontaminated soil is less to the values obtained by other authors (5.71-13.2%) (Grammelis et al., 2008).

The content of fixed carbon is considered a positive property of biomass, representing the amount of energy released from a certain amount of biomass. Higher fixed carbon values affect the quality of biomass due to the higher heating values (Clarke and Preto, 2011). The fixed carbon content is the mass remaining after the release of volatile matter, excluding ash and moisture. Fixed carbon leads to the formation of carbon and burns as a solid in the fuel system. ISO 17225-6 does not specify a value for fixed carbon.

This study shows that the fixed carbon varies from 5.55 to 8.15%, with higher values reported for the biomass of cardoon grown on contaminated soil. According to the literature, the fixed carbon in the cardoon biomass is between 10.9% and 14.6% (Grammelis et al., 2008). The obtained values for fixed carbon in the cardoon biomass from contaminated and uncontaminated soils are significantly lower than other authors' results (Table 5).

The ash content is one of the main factors determining the quality of biomass, as more significant amounts of ash reduce fuel quality. The non-combustible content of biomass is called ash content. The high ash content leads to pollution problems, especially if the ash has high metal chloride content. Biomass fuels from crops or residues have higher ash content (Clarke and Preto, 2011).

The results obtained show that the ash content varies from 17.05 to 21.45%. The lowest values are found for biomass grown in the uncontaminated soil (S2). According to the standard for solid fuels EN ISO 17225-6, the ash content for non-wood pellets can vary from 6 to 10%. The biomass from the contaminated (S1) and uncontaminated area (S2) exceeds the permissible value. A probable reason for the higher ash content in cardoon is the higher content of macroelements in plant biomass. According to the literature data, the ash content is between 6.9% and 29.6% (Table 4). High values of ash are characteristic of cardoon biomass (4-17%) (Fernandez et al., 2006; Aho et al., 2008). Significantly higher results were obtained by Bartolome et al. (2008), Damartzis et al. (2011) (15.1-29.6%), and Monti et al. (2008) (19.2-22.2%). Significant lower results were obtained by Toscano et al. (2016) (6.3%), Grammelis et al. (2008) (6.9-7.2%), and Cavalaglio et al. (2020) (9.12%).

The studied biomass from cardoon grown on contaminated soils has qualities suitable for direct combustion. About the solid fuel standard, the ash content is higher than the standard.

In the combustion process, biomass decomposes into volatile gases and solid residue. Volatile matters are the components released at high temperatures when the fuel is heated, without taking into account the moisture that is part of the combustible gases (CxHy gases, CO, or H_2) and non-combustible gases (CO_2, SO_2, or NOx) (Garcia et al., 2012). A high percentage of volatile matter is one of the characteristics of biomass reducing the energy value.

The volatile matter content in cardoon biomass ranges from 60% to 78% (Suarez-García et al., 2002; Bartolome et al., 2008; Grammelis et al., 2008; Damartzis et al., 2011; Abelha et al., 2013). EN ISO 17225-6 does not specify a volatile matter rate in cardoon. The results showed that volatile matters vary from 70.4% to 77.4%, with the higher values found in cardoon's biomass grown on uncontaminated soil. The values for volatile matters are in line with the other authors' biomass results (59.5-75.0%).

Table 5 presents the ultimate analysis of cardoon grown on contaminated and uncontaminated soils. The ultimate analysis values are compared with the requirements of the standard ISO 17225-6 and the data from other authors for the analysis of the cardoon biomass grown in different countries. The main components of solid biofuels are C, H, and O. C and H are oxidized during combustion in exothermic reactions, which leads to the formation of CO_2 and H_2O and affects the gross calorific value of the fuel (Clarke and Preto, 2011). Organically bound O provides the part of O required for the combustion process, and O must be added by air injection. Higher C and H content lead to higher HHV.

Carbon is the primary and most crucial element in all types of fuels, and its content determines their quality, i.e., higher carbon levels increase fuel quality.

The total carbon content varies from 39.3 to 43.0%, with the higher values found for cardoon biomass from uncontaminated soil. According to the literature, the carbon content ranges from 24.1 to 46.7% (Table 4).

The content of hydrogen varies from 3.8% in contaminated soil to 4.52% in uncontaminated soil. According to the literature, the hydrogen content varies widely (from 4.8 to 6.63) (Table 5).

The energy value is negatively affected by the oxygen content. The oxygen content varies from 33.59 to 34.31%.

There were no significant differences in the biomass's oxygen content between the tested plants from the contaminated and uncontaminated soils. According to the literature, O's content varies from 35.52% to 46.80% (Table 5).

From an environmental point of view, nitrogen and sulfur contribute to increased greenhouse gases and are considered unfavourable biomass elements. When biomass is burned, NOx and SO_2 are formed, and therefore the nitrogen and sulfur content of the biomass must be as low as possible. The amount of nitrogen in the biomass is the cause of NOx emissions from biomass combustion. The fuel's low nitrogen content leads to lower NOx emissions (Clarke and Preto, 2011). Sulfur is an element with a minor presence in biomass, but nitrogen is a critical element for the environment. The content of S in the biomass largely depends on the macromolecular composition. SOx are formed during combustion and lead to significant contamination with dust particles and acid rain. Also, S can indirectly contribute to increased corrosion (Clarke and Preto, 2011).

The nitrogen content varies from 0.72% in uncontaminated soil to 0.877% in contaminated soil, at a nitrogen rate of 1.5-2%. The sulfur content varies from 0.268% for contaminated soil (S1) to 1.12% for uncontaminated soil (S2), with a sulfur rate of 0.2-0.3%. The values obtained for contaminated soils are below the permissible values for the limit for solid fuels. According to the literature data, the sulfur content in biomass varies from 0.11 to 0.29% (Table 4). The low N content found increases the quality of biomass in terms of its use for combustion processes. The nitrogen content is much lower than the established values for plant biomass (0.55 to 2.63%) (Table 5) (Grammelis et al., 2008; Toscano et al., 2016; Gominho et al., 2018).

Table 5. Ultimate analysis of cardoon biomass

Parameter	S1	S2	Reference	ISO 17225-6
N,%	0.877	0.72	0.55-2.63	1.5-2
C, %	39,3	43.0	24.1-49.3	-
S, %	0.268	1.12	0.11-0.29	0.2-0.3
H, %	3.8	4,52	4.8-6.63	-
O, %	33.41	33.59	43.0-51.45	-
Cl, %	6.8	4.7	nd- 1.73	0.1-0.3

The chlorine content varies from 4.7% in uncontaminated soil to 6.8% in contaminated soil, at a chlorine rate of 0.1-0.3%. The values obtained for contaminated soils are higher than the permissible values for the limit for solid fuels.

The high content of chlorine and alkaline elements is the reason for the increased deposition of alkaline chlorides, which damage the superheaters and reduce the boilers' life (Aho et al., 2008; Abelha et al., 2013).

Table 6 presents the results for the content of heavy metals, micro and macro elements in the biomass of cardoon, grown on contaminated and uncontaminated soils, and typical values of EN ISO 17225-6 for solid fuels.

The content of Pb in the above ground mass of cardoon grown at a distance of 0.5 km from NFMW reaches 155.9 mg/kg, Zn - up to 166.9 mg/kg, Cd - up to 13.4 mg/kg, Cu - up to 37.9 mg/kg, Fe - up to 183.6 mg/kg, Mn - up to 1780.1 mg/kg, K - up to 15756 mg/kg, P - up to 1780 mg/kg, Mg - up to 1373.9 mg/kg and Ca - up to 12637.2 mg/kg.

Significantly lower values were established in the above ground mass of cardoon when grown on unpolluted soils. The content of Pb reaches 5.6 mg/kg, Zn - up to 28.9 mg/kg, Cd - up to 0.09 mg/kg, Cu - up to 4.8 mg/kg, Fe - up to 117.9 mg/kg, Mn - up to 7.5 mg/kg, K - up to 11596.9 mg/kg, P - up to 888.3 mg/kg, Mg - up to 3146.7 mg/kg and Ca - up to 3146.7 mg kg.

Significantly higher amounts of K (24000 mg/kg), Ca (26620 mg/kg), Mg (1910 mg/kg), Fe (230 mg/kg), and Mn (1910 mg/kg) were established by Petropoulos et al., 2018 in the cardoon leaves cultivated in southern Greece. Higher values for K (31700-34900 mg/kg), Mg (4500 mg/kg), and Ca (17000 mg/kg) in the leaves of hydroponically grown cardoon plants were also found by Rouphael et al. (2012) and Borgognone et al., (2014). Monti et al. (2008) found that the iron content reached to 655 mg/kg, Mg to 1876 mg/kg, K to 4711 mg/kg, Ca to 27802 mg/kg, P to 1459 mg/kg. The variation between results may be due to cultivation conditions (hydroponic, greenhouse, and field trials) and plant age differences. The above studies refer to young plants and 5-year-old plants (Petropoulos et al., 2018).

Table 6. Heavy metals, micro and macroelements (mg/kg) of cardoon biomass

	Biomass (S1)	Biomass (S2)	Reference	EN ISO 17225-6
Pb	213.0	5.7	5.7-552	<10
Cd	13.4	0.09	0.2-204.1	<0.5
Zn	166.2	28.9	11-640	<100
Cu	37.95	4.8	8.93-250	<20
Fe	183.6	117.9	122-655	-
Mn	16.7	7.5	16.0-1910	-
P	1780.0	888.3	819.0-1459	-
K	15756.3	11596.9	3490-4711	-
Ca	12637.2	11676.3	12606-27802	-
Mg	1373.9	3146.7	1320.0-2488.3	-

The return of ashes from the combustion of biomass to the soil is the most ecological and sustainable disposal method. In this way, a significant part of the plant's macro-and micronutrients returns to the soil, closing the circulation of minerals (Zajac et al., 2018).

The ashes' chemical composition was dominated by the macroelements Ca, Mg, K, and P, which suggests their agricultural use. Simultaneously, the high content of toxic elements, such as Pb and Cd, should be a limiting feature in their use. The ash of biomass must be thoroughly analyzed before its recommendation for fertilizing purposes.

Contaminated biomass has to be treated as a hazardous material, and its incineration has to be done in facilities equipped with filters for the capture of metal oxides.

Ash-forming elements such as Al, Si, Ca, Fe, K, Mg, Na, and P in the biomass are significant for any thermochemical conversion process. The relatively high content of alkaline elements can lead to lead to significant slagging and furnace corrosion.

Biomass used as fuel may contain different pollutants in different concentrations. The biomass data concentration on As, Ba, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, V, and Zn varies depending on the biomass type. In the biomass of agricultural origin, these elements may accumulate when grown on contaminated soils or the use of fertilizers. As a result, their biomass concentration varies depending on the type of pollutant, distance from the source, and plant age. Values in the range of 60 to 640 mg/kg for Zn and 0.1 to 6.6 mg/kg for Cd are determined (Kajda-Szczesniak, 2014).

A small part of the elements is retained in the bottom ash during combustion, while a more significant amount is carried away along with the volatile ash. Non-volatile elements such as Fe, Cr, Cu, and Al form stable oxides, which are retained by coarser ash particles. Combustible metals (Cd, Pb, and Zn) evaporate during combustion, controlled mainly by fine dust particles. As a result, a significant part of the heavy metals and the fine dust particles are carried away with the gases through the chimney. The chlorine present in the biomass leads to a higher evaporation rate of volatile metals, which forms chlorides and oxides. Cd and Pb form $CdCl_2$ and $PbCl_2$ during combustion. Zn can also evaporate as chloride, but a significant amount remains in the ash from combustion due to a stable oxide form formation. In the industrial combustion of biomass from fuel, heavy metal emissions are controlled mainly by minimizing dust emissions. Furthermore, steps have been proposed to use adsorbent materials, such as alumina, kaolinite, bauxite, etc., to inhibit heavy metals' evaporation and retention in the fuel ash.

CONCLUSIONS

Based on the results obtained, the following important conclusions can be made:

1. The cardoon is a tolerant plant to heavy metals and can be grown in heavy metal polluted soils (2671.6 mg/kg Zn, 2694.8 mg/kg Pb, and 84.5 mg/kg Cd) and can be successfully used in the phytoremediation of heavy metal polluted soils.
2. The heavy metals distribution has a selective character that in cardoon decreases in the following order: roots > leaves.
3. The studied biomass of cardoon grown on contaminated soils is of high quality (high content of carbon and hydrogen, and low content of ash, nitrogen, chlorine, and sulfur) and high energy potential.
4. The content of heavy metals in the biomass of cardoon grown on contaminated soils is significantly higher and exceeds the limit values according to the standard ISO 17225-6:2014. Biomass of cardoon from contaminated soils could be used as a source of energy if biomass burning occurs in power plants equipped with purification systems to control dust emissions.

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SALIX ACCESSIONS WITH POTENTIAL FOR NEW HYBRIDS. A CASE STUDY FROM BANAT AREA

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Abstract

Willows are fast-growing species with a large capacity for sprouting and easy breeding. In order to identify Salix accessions suitable for different conditions, a willow plantation was established in the Didactic Station of BUASVM from Timisoara, Timis County, Romania. 19 Salix genotypes (nine species: Salix alba L., S. cinerea L., S. caprea L., S. daphnoides L., S. fragilis L., S. incana L., S. purpurea L., S. pentandra L., S. triandra L.) were collected from a polluted area (copper and uranium mining area) but also from old willow farms, all from Caras-Severin County. The sprouting capacity and biometric observations were made in an experimental trial with uncut and cutback shoots and biomass was estimated after one growing season. Large variability was observed in terms of survival rate but also the number of shoots per stool, maximum height, and diameter. To evaluate the tolerance of heavy metal stress, four accessions were selected and a laboratory experiment was developed. The enzymatic activity varied according to with stress abiotic factor and also with genotype.

Key words: *willow, biometric observation, heavy metal stress, abiotic stress.*

INTRODUCTION

In the last decade, the interest for willow short rotation coppice in Romania increased. Willows are fast-growing species with a large capacity for sprouting and easy breeding, high transpiration rate, and a high potential for land reclamation (Landberg and Greger, 1994; Pulford and Watson, 2003). The clones from Europe, dedicated to biomass production were created in a wetter and cooler climate. They are suitable in a breeding program to provide valuable traits, but native germplasm is of special interest, due to the adaptation to regional conditions with hot and often dry summers. Native species of *Salix* were considered valuable sources of resistance genes in many breeding programs (Kopp et al., 2001; Iori et al., 2015; Stolarski et al., 2020). Climate change, due to the greenhouse gas effect will affect in the future the agricultural crops, by water stress (Wolfe et al., 2018). The area, affected by drought will increase in the future decades and breeding efforts has to be focused on crops tolerant to abiotic stress (Fabio et al., 2019). Heavy metals are one of the abiotic stresses that became a major threat to crop production (Hassanuzzman et al., 2020). Many researchers investigated the growth performance of willow and their capability for phytoremediation (Greger and Landberg, 1999; Jensen et al., 2009; Dos Santos Utmazian et al., 2017). The aim of this study was to evaluate the potential of willow accessions to be used in land reclamation or as genitors in a breeding program.

MATERIALS AND METHODS

Field trial. Willows genotypes collected from the Banat area represent the biological material for this research. These genotypes were planted in 2015 in a collection in Experimental Didactic Station from Banat University, in the Western Plain of Romania, with an elevation of 88m (N 45047'06" E 21012'50"). The soil is cambic chernozem with a slightly acidic pH value (6.1). The amount of precipitation is 592 mm (Hernea et al., 2016). 19 willows genotypes have been planted in twin rows 70 cm apart and with 140 cm between each set of twin rows. 46 cuttings from each genotype were established in prepared soil at a distance of 80 cm between them. Because weed control is critical in willow plantation, herbicide and also mechanical weed control were applied. After the first growing season, one row from each genotype was cut back and the survival rates were calculated. Biometrical observations were made: (i) no of shoots per stool; (ii) the maximum height of the shoot using a measuring pole (precision cm); (iii) the diameter at the base of the shoots using an electronic caliper (0.01mm precision). To select genotypes for hybridization, in spring 2016, the biomass was estimated.

Hydroponic experiment. In 2017 one laboratory experiments was initiated. 9 cuttings per experimental variants with 10 cm length, no more than 1cm diameter, and 2-4 buds were used. Cuttings were placed in 150 CMC plastic glasses, in Hoagland solution and were daily aerated. The experiment tested the resistance to heavy metals (cadmium, copper, nickel, and lead) for four genotypes: P3 - *S. fragilis,* A2 - *S. daphnoides,* L1 - *S. purpurea,* L2 - *S.* alba. It was tested two concentration from each metal: Cd (Cd_1=5.0; Cd_2=10.0 mg/l), Cu (Cu_1=250 mg/l; Cu_2=500 mg/l) Ni (Ni_1=200 mg/l; Ni_2=500 mg/l), Pb (Pb_1=250 mg/l; Pb_2=1000 mg/l) and the control (Hoagland solution). Observations were made at the end of heavy metal treatment: (i) initial (green) mass; (ii) initial (green) shoot mass; (iii) initial (green) root mass; (iv) dry shoot mass; (v) dry root mass. The dry mass was determined by putting shoots and roots in metallic boxes and dries until constant weight. The tolerance of studied genotypes to heavy metals have been evaluated at the end of the experiments according to with 5 predefine vitality classes: (5: high, leaves and shoots green; 4: medium, leaves up to 50% necrotic and shoots green ; 3: low, leaves more than 50% necrotic and shoots green; 2: leaves necrotic and shoots partial necrotic; 1: all necrotic, shoot dry mass index (100 x shoots dry mass: cutting initial mass (SDMI)), roots dry mass index (100 x roots dry mass: cutting initial mass (RDMI)), shoots dry mass: roots dry mass (S/R) and vitality in a hydroponic heavy metal experiment (Heike et al., 2014 modified).

Plants metabolic changes to abiotic stress (hydric or heavy metals stress) were evaluated by guaiacol-peroxidase and catalase activities The activity of catalase (CAT) was determined colorimetrically at λ= 570 nm (Sinha, 1972). The activity of guaiacol peroxidase (POX) was determined colorimetrically at λ = 470 nm (Babeanu et al., 2008).

All statistical analyses were conducted with STATISTICA 10.0 software. The variables: survival rate, no of shoots per stool, maximum height of the shoots, the diameter at the base of the shoots, dry matter yield was analyzed statistically by a repeated- measures ANOVA, with genotype and management practice as grouping factors. The statistics F for these analyses are shown in the table of results. Duncan's multiple range test with $p < 0.05$ was used to evaluate the significance of differences between the cut back and uncut groups.

RESULTS AND DISCUSSIONS

Nineteen genotypes have been evaluated in a willow plantation: 1 Pojejena - *S. fragilis* (P1), 2 Pojejena - *S. fragilis* (P2), 3 Pojejena - *S. purpurea* (P3), 4 Pojejena - *S. pentandra* (P4), 5 Pojejena - *Salix purpurea* (P5), 6 Tausani - *S. alba* (T1), 7 Sasca - *S. incana* (S1), 8 Sasca - *S. caprea* (S2), 9 Sasca - *S. purpurea* (S3), 10 Sasca - *S. purpurea* (S4), 11 Agadici - *S. fragilis* (A1), 12 Agadici - *S. daphnoides* (A2), 13 Agadici - *S. daphnoides* (A3), 14 Agadici - *S. caprea* (A4), 15 Agadici - *S. cinerea* (A5), 16 Lisava - *S. purpurea* (L1), 17 Lisava - *S.daphnoides* (L2), 18 Lisava - *S. caprea* (L3), 19 Lisava - *S. fragilis* (L4). One of the most important aspects after the establishment of a culture is the survival rate of the plants. In short rotation coppice, 90% of the survival rates are expected but not less than 75% (Bennick et al, 2008).

A variability in survival rate, during the harvest rotations, as well as the decrease in time was observed also, by other reserchers, in a field trial in Canada (Amichev et al., 2018) and in Poland (Stolarski et al., 2020). Four genotypes had good results (Figure 1), for others, the results were satisfactory according to the fact that all the cutting used were collected from one plant, sometimes with low biometric characteristics (abandoned willow farms) or grown in difficult condition (sterile dumps).

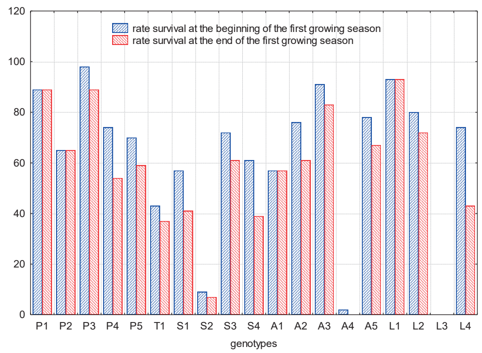

Figure 1. *Salix* genotypes survival rates at the beginning and the end of the first growing season

Three genotypes did not performed at all (S2, A4, and L3), but it is known from the literature how difficult is to reproduce goat willow by cuttings.

The number of shoots per stool was counted, the highest and the thickest shoots were measured and biomass was estimated (Table 1). Diameter at the base of the shoots, height, and also the number of shoots per stool is genetically determined, but also influenced by pedoclimatic conditions (Stolarski et al., 2020). The sprouting capacity increased in all cut back variants, but only a few differences were significant compared to the uncut ones (P4, S1, A2, A3, A5, L1) (Table 1).

The highest mean values were observed for genotypes A2 (7.6 and 17.4) and A3 (7.6 and 15.1) for both uncut and cut back practice. Differences were observed for height and the diameter at the base of the shoots also. The lowest height was registered for genotypes L4 (96 cm for uncut management practice and 111 for cut back management practice) followed by genotypes A5 (111 cm and 103 cm). The highest values were registered for genotype P3 (220 cm and 225). The maximum diameter was registered for genotype A1 (35.6 mm and 18.8 mm) and T1 (30.97mm and 21.74 mm). In terms of biomass, the most productive genotype (initial estimation) was P3 with very good height characteristics and also large diameter values. It should be noted that in most genotypes with significant differences in sprouting, between the cut back - uncut variants, there are no significant differences in the height or diameter of the shoots. Analysis of variance showed that the effect of each factor and also all factors analyzed (genotypes and management practice) is significant (Table 2). This analysis was the base for genotype selection to establish the heavy metal experiment. Some researchers consider that to evaluate the heavy metal tolerance of plants, the hydroponic experiment can be a first step (Torabi et al., 2012) before field experiment, but it is not a certainity that plants will react the same (Zabtudowska et al., 2009).

Hidroponic experiment. In the experiment, the effect of genotypes and heavy metal treatment was analyzed according to shoots and roots dry biomass (Table 3) and the analysis of variance was performed (Table 4).

The experiment reveals the influence of heavy metal on different genotypes. All genotypes react very well on cadmium treatment. It can be seen an increase of SDMI and RDMI value with increasing concentration for all genotypes. For the other variants, it can be seen a decrease of SDMI with increasing the heavy metal concentration. But it not the same in terms of RDMI where the parameters decrease with the increase of copper concentration, increase with the increasing of nickel concentration and it is increasing or decreasing with lead increasing. The best results in terms of vitality were obtained for cadmium and lead treatment and the worst with nickel treatment.

Genotypes P3 and L1 react very well to cadmium, lead, and the lower analyzed concentration of copper but very bad to nickel and the higher analyzed concentration of copper. The genotype A2 shows a very high sensitivity to copper but reacts better than all others to nickel in the lower analyzed concentration. Willows are species with phytoremediation potential having tolerance/resistance to heavy metals from air, water and soil (Watson, 2002)). The importance of genotype in the stress response of the plant is highlighted by the analyses of variance for the shoots and roots dry mass index. The Fisher test applied for each heavy metal reveal the hierarchy of heavy metal toxicity. The most toxic metal is copper followed by nickel and lead on one side and cadmium, with a stimulating effect on the other side. General reduction of willow plant growth under copper concentrations was highlighted by Mleczek et al. (2013).

Table 1. Characteristics of willow plants after two growing seasons according with genotypes and management practice (uncut and cut back) and biomass production after one growing season

Genotypes	Uncut/Cut back	No shoots/stool Mean ± SD	Maxim height (cm) Mean ± SD	Maxim diameter at the base of the shoots (mm) Mean ± SD	Biomass (t/ha)
P1	Uncut	3.8 ± 2.6	205 ± 58	23.98 ± 7.71	2.786
	Cut back	6.6 ± 3.0	203 ± 72	17.28^{0} ± 7.08	
P2	Uncut	2.8 ± 1.3	191 ± 78	26.24 ± 7.60	1.141
	Cut back	5.1 ± 2.7	123** ± 84	13.55^{000} ± 6.65	
P3	Uncut	3.4 ± 1.9	220 ± 52	24.18 ± 7.22	4.211
	Cut back	7.9 ± 3.7	225 ± 55	20.65 ± 5.51	
P4	Uncut	4.0 ± 1.5	199 ± 36	17.72 ± 3.97	1.328
	Cut back	11.8*** ± 5.8	185 ± 22	12.91 ± 3.69	
P5	Uncut	3.0 ± 1.4	235 ± 42	20.78 ± 7.17	1.069
	Cut back	6.2 ± 4.5	211 ± 37	17.22 ± 5.48	
T1	Uncut	3.4 ± 1.2	183 ± 37	30.97 ± 5.94	0.307
	Cut back	5.3 ± 4.6	159 ± 45	21.74^{000} ± 3.95	
S1	Uncut	2.1 ± 0.9	139 ± 39	20.69 ± 5.87	0.589
	Cut back	9.0*** ± 4.8	151 ± 42	19.07 ± 4.04	
S3	Uncut	7.6 ± 4.0	154 ± 28	18.43 ± 3.54	2.903
	Cut back	9.1 ± 4.2	146 ± 50	15.87 ± 1.58	
S4	Uncut	5.9 ± 2.9	197 ± 31	23.03 ± 5.22	1.971
	Cut back	7,9 ± 2.7	186 ± 39	11.78^{000} ± 2.25	
A1	Uncut	4.7 ± 2.9	249 ± 46	35.60 ± 6.73	1.868
	Cut back	9.4 ± 4.0	175^{00} ± 33	18.80^{000} ± 6.40	
A2	Uncut	7.6 ± 3.6	175 ± 40	22.80 ± 8.40	2.958
	Cut back	17.4*** ± 6.7	170 ± 33	14.48^{00} ± 2.72	
A3	Uncut	7.6 ± 4.2	163 ± 41	14.68 ± 5.40	1.978
	Cut back	15.1*** ± 4.0	134 ± 20	12.65 ± 3.18	
A5	Uncut	5.4 ± 2.9	111 ± 21	16.75 ± 4.88	1.039
	Cut back	11.9*** ± 5.4	103 ± 15	11.25 ± 3.05	
L1	Uncut	4.1 ± 2.0	166 ± 54	18.80 ± 7.03	3.698
	Cut back	9.9** ± 4.3	170 ± 43	15.10 ± 3.58	
L2	Uncut	5.4 ± 2.5	189 ± 76	22.07 ± 6.53	2.836
	Cut back	8.7 ± 3.6	180 ± 57	16.93 ± 6.17	
L4	Uncut	2.9 ± 1.0	96 ± 29	16.96 ± 8.09	0.918
	Cut back	6.1 ± 2.6	111 ± 34	15.17 ± 3.61	

Significance of the differences are indicated as * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, positive differences and ^{0} $P < 0.05$, ^{00} $P < 0.01$, ^{000} $P < 0.001$, for the negative ones.

Table 2. The effect of genotype and management practice on main characteristic and biomass of *Salix* sp. plantation (Fisher Test)

Characteristc	Analysis of Variance: Marked effects are significant at p < .05000 Factors: 1- Genotyp; 2- management practice					
	1		2		1x2	
	F	P	F	p	F	p
No shoot	9.73290***	0.000000	141.2449***	0.000000	16.46291***	0.000000
Shoot height	14.41945***	0.000000	8.0453**	0.004761	8.79235***	0.000000
Diameter at the base of the shoot	8.35212***	0.000000	89.8912***	0.000000	11.38638***	0.000000
Dry biomass	2.754475***	0.000642				

Table 3. SDMI, RDMI and vitality in hydroponic heavy metal experiment

Genotype	Characteristic	Control	Cd		Cu		Ni		Pb	
			1	2	1	2	1	2	1	2
P3	SDMI	3.00	2.42	2.86	1.71	0.77	2.05	1.28	3.08	1.90
	RDMI	0.59	0.33	0.45	0.61	0.59	0.28	0.44	0.48	0.61
	Ratio S/R	5.19	9.43	6.41	3.17	1.77	8.22	6.09	6.44	3.29
	Vitality	5	5	5	5	2	2	1	5	5
A2	SDMI	1.04	0.78	0.85	0.41	0.27	0.54	0.45	1.12	0.27
	RDMI	0.32	0.19	0.34	0.53	0.40	0.12	0.14	0.38	0.21
	Ratio S/R	3.39	4.67	2.67	0.87	0.71	5.33	4.78	2.97	1.67
	Vitality	5	5	4	1	1	4	2	5	5
L1	SDMI	2.56	1.96	2.54	1.48	0.61	1.52	1.19	2.62	1.48
	RDMI	0.53	0.29	0.58	0.80	0.58	0.30	0.43	0.55	0.56
	Ratio S/R	4.87	6.76	4.39	1.95	1.07	5.00	4.36	5.00	3.02
	Vitality	5	5	5	5	2	3	2	5	5
L2	SDMI	2.19	2.03	2.42	1.07	0.55	0.90	0.30	2.17	0.45
	RDMI	0.60	0.54	0.61	1.09	0.88	0.24	0.35	0.47	0.34
	Ratio S/R	4.02	5.33	4.72	0.98	0.58	4.00	1.44	4.5	2.22
	Vitality	5	5	5	4	2	1	1	5	3

Table 4. Analysis of variance for hydroponic heavy metal experiment. The effect of genotype and heavy metal treatment on shoots and roots dry biomass

Character	Marked effects are significant at p < .05000 Factors: 1 - Genotype; 2 - Cd treatment; 3 - Cu treatment; 4 - Ni treatment; 5 - Pb treatment; 6 - All treatment													
	1		2		3		4		5		6		1 x 6	
	F	p	F	p	F	p	F	p	F	p	F	p	F	P
IBL	19.618 ***	0.00	0.93	0.405	21.656 ***	0.0	9.907 ***	0.0	8.655 ***	0.00	9.333 ***	0.00	14.74 ***	0.00
IBR	7.082 ***	0.00	2.34	0.112	2.696 *	0.08	5.556 **	0.01	0.613	0.55	5.101 ***	0.00	2.95 ***	0.00

According to the calculated indices (SDBI and RDBI) and plant vitality, an initial selection for tolerant willow clones can be made. All genotypes showed tolerance to cadmium and lead treatment. In other researches it was observed a large variation in willow clones Cd tolerance (Vyslouzilova et al., 2003; Zacchini et al., 2009).

According with Liu et al. (2011) the Cd accumulation increase during a short time course and have a slow absorption rate during a long time course. Zhivotovsky et al. (2011) showed that willow clones exposed to different external lead concentrations can tolerate and accumulate Pb to varied degrees. Except for genotype A2 which showed tolerance for a low concentration of nickel all the others showed no tolerance for this metal. In opposite with treatment with nickel, are the results for treatment with copper. In this case, the genotype A2 showed no tolerance, all the others showed tolerance for the lower copper concentration analyzed.

Heavy metal stress cause various biochemical responses of plants.

For two genotype, P3 and L1, the catalase increase with cadmium concentration increment or it quite similar like in genotype L2. Only genotype A2 does not follow this pattern. The peroxidase decrease with cadmium concentration increment for genotypes A2 and L2. The other genotypes react differently to cadmium increment, increase for P3 and slightly decrease with cadmium increment and decrease with cadmium increment for L2 (Figure 2).

In the copper experiment, for genotype P3 and L2 the catalase increase with metal increment, and the peroxidase decrease. The peroxidase increase also for the lower copper concentration and then decrease with copper increment in the case of A2 and L1 (Figure 3).

The same pattern can be shown for plant reaction to lead increment, a decrease of peroxidase. The catalase increase in case of a small lead concentration and decreases in case of high concentration for P3 and A2 and decreases for others (Figure 4).

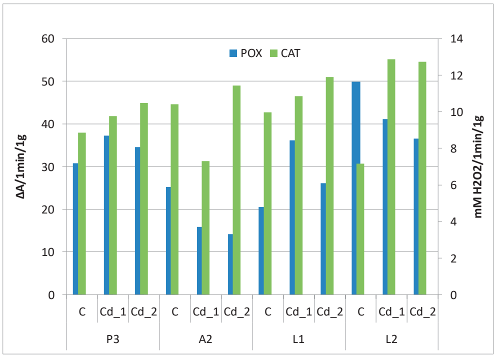

Figure 2. The variation of enzymatic activity, catalase (CAT) and peroxidase (POX) in cadmium experiment

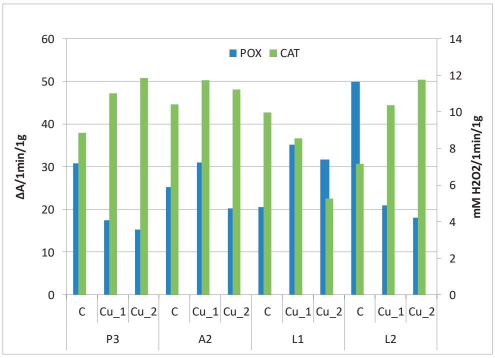

Figure 3. The variation of enzymatic activity, catalase (CAT) and peroxidase (POX) in copper experiment

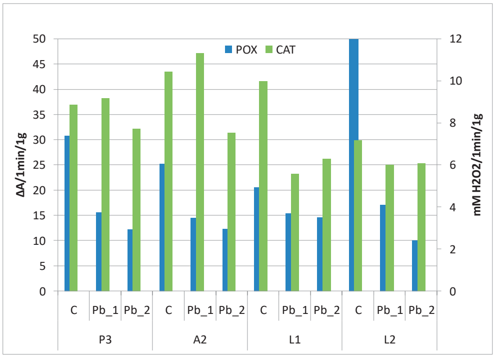

Figure 4. The variation of enzymatic activity, catalase (CAT) and peroxidase (POX) in lead experiment

The enzymatic activity, catalase, and peroxidase decrease with a lead increment for all genotypes and also for P3 and L2 in the copper experiment and L2 in the cadmium experiment. For the other experimental variants, there are no patterns.

CONCLUSIONS

The biometric characters varied significantly with genotype and management practice.
The behavior of willow cuttings varied according to heavy metal (cadmium, copper, nickel ad lead) level.
Cadmium acting like a stimulant for all genotypes. SDMI increase with cadmium increment level and decrease for all other heavy metal.
The enzymatic activity varied according to with stress abiotic factor and also with genotype.

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ECONOMIC EFFICIENCY OF APPLYING MEASURES FOR REDUCTION OF SOIL DEPLETION IN RUSSIAN AGRICULTURAL LAND USE

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Abstract

The current state of Russian land use is characterized by heterogeneity, instability and uncertainty of further development. Its efficiency is affected by the processes of cover destruction, waterlogging, salinization, and desertification. Fertility especially intensely decreases on old-arable lands and under monoculture cultivation. Effective agricultural land management is required and that involves the use of effective administrative and economic tools. The methods of cost optimization described by the process model are recommended, including the classification of costs, identification of ways to reduce them, introduction of a correction factor for determining the amounts of land payments, differentiation of responsibility for the implementation of mandatory measures, and differentiation of the amount of monetary penalties in accordance with the behavior of subjects in land relations. The practical value of the work is that its results contribute to improving the efficiency of agricultural land use in terms of its economic justification, environmental and social adaptation.

Key words: *agriculture, costs, land use, method, process model.*

INTRODUCTION

In the conditions of transformation of land relations, it is necessary to clarify and supplement the methodological framework for the efficiency of agricultural land use. In our opinion, the concept of efficiency in the use of agricultural land is limited and has a contradictory content - the interest in obtaining maximum income while maintaining soil fertility. The economic efficiency of national production depends largely on the fertility of the land, since in infertile countries "a moderate accumulation of capital will be accompanied by a significant decrease in the rate of profit and a rapid increase in rent" (Ricardo, 1955).

Efficient agricultural land use should be systemic and include three main components (Zavorotin et al., 2017; Zavorotin et al., 2018):

- economic, exogenous and endogenous, conditions of which contain a legal-regulatory framework ensuring the equilibrium of market exchange and adequate distribution of the income earned;
- environmental, conditioned by the impact of natural factors (soil fertility, natural environment, farming system) on the agricultural production;
- social, aimed at increasing responsibility for harming the environment and encouraging agricultural producers to rational use of land.

The criteria for the efficiency of agricultural land use are obtaining a concrete volume of output with a minimum cost of labor, production and natural resources, and preserving soil fertility (economic efficiency), preventing environmental degradation and improving the quality of productive land (ecological efficiency) as well as the degree of achieving a standard of living (social efficiency).

To understand the essence of agricultural land use, a careful study of its various definitions is necessary. Narrowly defined, land use is a form of disposal of land for the purpose of extracting useful properties or income from it through free management, rational organization of the territory, and protection from processes of destruction and pollution (Volkov et al., 1992; Masyutenko et al., 2012).

Within the process of research, land use is considered to be not a method of land exploitation but the right of the subject specified by the triune of powers (possession, use, and disposal of lands), assigned by a set of relevant legislative acts.

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Efficient agricultural land use will be understood as an organized use of the functional potential of land with reduced costs and minimal negative consequences, most adapted to legal, economic, environmental and social conditions.

Areas for improving the efficiency of agricultural land use are as follows:

- organizational-and-managerial, involving the intensification of activities of management bodies, impact on public and individual consciousness for land use rationalization (Krylatykh, 1997);
- socio-economic, consisting of measures for financing federal and regional programs, income distribution, optimization of labor conditions;
- environmental, characterized by the level of use of natural resources, reduction of land intensity of products, and improvement of their quality (Bazilevitch et al., 1968; Gordeev et al., 2008);
- technical-and-technological, involving the use of resource-saving machinery and application of the latest achievements in the economy of agriculture, a scientifically based system of farming (Chernyaev et al., 2014).

According to the chosen areas, methods for cost optimization are scientifically based in order to obtain savings as a result of reducing the negative impact of erosion, soil salinization, consequences of continuous cultivation of commercial crops, full or partial reimbursement by the state of the costs for soil protection measures, etc.

The aim of the study is to develop the method of cost optimization, to calculate costs of lost opportunities as reduction in crop yields, to create process model for cost optimization taking into account measures for reduction of agricultural depletion of soils.

MATERIALS AND METHODS

The author's method of cost optimization taking into account measures for reducing agricultural depletion of soil is consigned to determining ways to suspend negative changes caused by violations of the farming system when cultivating crops, improving soil fertility indicators, and strengthening the responsibility of land relations participants for economically inefficient agricultural land use in order to avoid applying monetary penalties.

The idea of the method is in minimization of production costs, imputed costs, land tax, rental payment, costs for conservation, restoration of soil fertility, fines, etc. The following costs are most important (Table 1).

The effect for each type of cost (E_i) is expressed in annual savings:

$$E_i = \Delta C_i \quad (1)$$

where C_i is the cost of the i-th type, RUB/ha.

RESULTS AND DISCUSSIONS

The current state of land use is characterized by heterogeneity, instability, significant deformations, reduced returns to agricultural production, and uncertainty of further development. According to the World Data Atlas (2020), the area of agricultural land in the Russian Federation is 216.2 million hectares. The Food and Agriculture Organization (FAO) defines the category "Agricultural area" as the sum of areas under "Arable land and Permanent crops" and "Permanent pastures". A comparison of the specific weight of agricultural-purpose land in the land area (Table 2), the specific weights of arable land in the total area of agricultural land (Table 3) were made by the fifteen countries bordering on the Russian Federation and the three main European Union states (France, Germany and the United Kingdom) and United States of America and Canada.

In the specific weight of agricultural-purpose land in the land area the Russian Federation is on the 17 places (13.21%).

In the compiled ranking of agricultural land under crops, Finland (98.53%), Japan (93.43%), and Democratic People's Republic of Korea (89.38%) are at the top three places, respectively. In these terms the Russian Federation is on the 14th place (56.24%), all while in contrast to other countries in 2010-2017 the specific weight changes slightly.

In the land legislation of the Russian Federation, the concept of "agricultural-purpose land" is used. They include agricultural land, land occupied by intra-organizational roads, communications, forest plantations designed to protect land from negative impacts,

Table 1. Grouping of costs in the agricultural land use

Cost type	Cost components	Factors of impact on costs
1. Costs for agricultural crops cultivation	Costs for: employee compensation, purchase of material and production stocks, depreciation of fixed assets, maintenance, repair, storage of equipment, other.	Activities and interaction of land relations participants.
2. Costs of lost opportunities (imputed costs)	Lost profit due to the presence of land plots which are abandoned, unused, unsuitable for cultivation of agricultural crops.	Possible crop losses from degraded (highly-eroded, highly-salted, highly-waterlogged), infected (due to unbalanced land use), infertile (with reduced soil fertility under anthropogenic impact) lands.
3. Land payments	Land tax, rental payment.	Land tax and lease rates, cadastral value of the land plot, land rent amount.
4. Costs for agro-technical measures	Costs for measures for conservation, restoration of soil fertility, prevention of soil degradation, as well as monoculture cultivation.	Acidity, humus content, liable phosphorus, exchangeable potassium, the degree of soil degradation (undegraded, slightly-degraded, moderately-degraded, highly-degraded, extremely-degraded), shift of crops in the crop rotation.
5. Monetary penalties	Penalties for damaging the soil fertility.	Land legislation compliance, use of land as intended, the degree of damaging the soil fertility.

Table 2. Agricultural land (% of land area)

Country	2010	2011	2012	2013	2014	2015	2016	2017	On average over 8 years
1. Kazakhstan	80.44	80.38	80.38	80.38	80.38	80.38	80.38	80.38	80.39
2. Mongolia	73.11	73.06	72.99	72.94	72.70	72.67	71.49	71.28	72.53
3. Ukraine	71.23	71.26	71.29	71.68	71.66	71.65	71.67	71.62	71.51
4. United Kingdom	71.19	70.95	71.02	71.30	71.23	70.84	71.71	72.19	71.30
5. Azerbaijan	57.67	57.69	57.68	57.71	57.71	57.71	57.74	57.80	57.71
6. China	54.68	54.90	54.89	54.89	54.89	56.31	56.30	56.30	55.40
7. France	52.83	52.74	52.68	52.55	52.54	52.46	52.45	52.41	52.58
8. Germany	47.91	47.97	47.81	47.86	47.94	47.96	47.68	47.76	47.86
9. Poland	47.18	48.26	47.45	47.06	47.11	46.93	46.94	47.23	47.27
10. Lithuania	44.22	44.77	45.35	46.12	47.12	47.98	47.16	46.86	46.20
11. United States of America	44.86	44.77	44.68	44.61	44.54	44.47	44.40	44.34	44.58
12. Belarus	43.85	43.74	43.35	42.93	42.49	42.24	42.04	41.84	42.81
13. Georgia	35.40	35.14	35.04	35.77	34.77	34.80	34.45	34.32	34.96
14. Latvia	29.00	29.20	29.61	30.18	30.13	30.34	31.08	31.12	30.08
15. Estonia	22.39	22.32	22.55	22.20	22.41	22.84	23.07	23.05	22.60
16. Democratic People's Republic of Korea	22.26	21.84	21.84	21.84	21.84	21.84	21.84	21.84	21.89
17. Russian Federation	13.23	13.21	13.20	13.20	13.20	13.20	13.20	13.20	13.21
18. Japan	12.60	12.51	12.48	12.45	12.39	12.33	12.26	12.19	12.40
19. Finland	7.54	7.53	7.52	7.43	7.46	7.48	7.49	7.47	7.49
20. Canada	6.50	6.44	6.44	6.45	6.46	6.47	6.47	6.44	6.46
21. Norway	2.75	2.74	2.72	2.70	2.70	2.70	2.70	2.70	2.71

Source: Calculated by the authors according to World Data Atlas

Table 3. Arable land (% of agricultural land)

Country	2010	2011	2012	2013	2014	2015	2016	2017	On average over 8 years
1. Finland	98.39	98.43	98.42	98.45	98.41	98.64	98.73	98.77	98.53
2. Japan	93.23	93.27	93.34	93.39	93.45	93.53	93.58	93.63	93.43
3. Democratic People's Republic of Korea	89.55	89.35	89.35	89.35	89.35	89.35	89.35	89.35	89.38
4. Norway	82.11	81.88	81.77	81.86	81.86	81.85	81.81	81.32	81.81
5. Ukraine	78.70	78.73	78.74	78.93	78.94	78.96	78.95	78.99	78.87
6. Lithuania	76.73	77.90	79.56	79.25	79.61	72.26	72.55	71.69	76.19
7. Poland	74.95	75.09	75.19	74.89	75.76	75.76	75.18	75.42	75.28
8. Germany	70.93	71.03	71.02	71.13	70.97	70.80	70.61	70.55	70.88
9. Estonia	67.97	66.81	64.96	66.11	67.15	67.98	69.39	68.26	67.33
10. Canada	64.67	64.62	64.97	65.32	65.67	66.02	66.37	66.17	65.48
11. Latvia	64.99	63.77	63.99	64.36	64.58	65.25	66.70	66.74	65.05
12. Belarus	62.20	62.30	62.78	63.83	65.65	66.21	66.61	67.42	64.63
13. France	63.27	63.28	63.38	63.62	63.73	64.33	63.92	64.34	63.73
14. Russian Federation	56.16	56.24	56.25	56.25	56.25	56.25	56.25	56.25	56.24
15. Azerbaijan	39.52	39.55	39.79	40.36	40.40	40.63	41.88	43.85	40.75
16. United States of America	38.46	38.20	37.95	38.14	38.09	38.53	38.72	38.92	38.38
17. United Kingdom	34.66	35.32	36.15	36.32	36.18	35.07	34.73	34.83	35.41
18. China	20.92	20.79	20.67	20.63	20.63	22.62	22.61	22.61	21.43
19. Georgia	16.06	15.44	15.20	16.73	15.11	15.22	14.37	13.58	15.21
20. Kazakhstan	13.21	13.45	13.52	13.55	13.55	13.55	13.55	13.55	13.49
21. Mongolia	0.54	0.54	0.57	0.50	0.50	0.50	0.51	0.51	0.52

Source: Calculated by the authors according to World Data Atlas

water bodies, as well as buildings and structures used for the production, storage and primary processing of agricultural output (Land Code of Russian Federation, 2001). The specific weight of agricultural-purpose land in the total area of the subjects of the Russian Federation varies from 1.2% (Republic of Karelia) to 94.5% (Nenets Autonomous district (okrug)) (Federal Service for State Registration, Cadastre and Cartography, 2020). More than a third of the soil of the country's agricultural land is subjected to cover destruction, waterlogging, salinization, and desertification. In the Volga Federal district, the main degradation process is erosion, which covers more than three-quarters of the region's area. In many regions and republics, with the exception of separate land uses, they tend to increase. The most developed water erosion processes are in the republics of Tatarstan and Bashkortostan and they are progressing in the Samara, Saratov, and Volgograd regions.

According to the long-term research conducted by the Agricultural Research Institute of South-East Region (2020) and the State Station of Agrochemical Service "Saratovskaya" (2020), water erosion, deflation and their overall impact are noted on 4525.0 thousand hectares, which is 52.7% of the total area of agricultural land in the Saratov region. Distribution of agricultural land area by type of erosion is in Table 4.

Table 4. Distribution of agricultural land area by type of erosion, thousand ha

Natural zone	Type of erosion		
	water	wind	water-wind
Forest-steppe	1319.2	27.4	166.8
Steppe	1365.9	44.7	62.1
Dry steppe	1304.1	64.2	29.5
Semidesert	138.2	0.5	2.6

The processes of water erosion are the most evident in the steppe zone, wind erosion is in the dry-steppe and water-wind erosion is in the forest-steppe natural zone. Water erosion is observed on 4127.4 thousand hectares (48.1%) of the agricultural lands, there is wind erosion on 136.6 thousand hectares (1.6%) and water-wind erosion is on 261.0 thousand hectares, or 3.0%.

In our opinion, cost saving is provided by the correct combination of the proposed methods of impact:

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- reimbursement by the state of part of the costs for agricultural production, taking into account the soil fertility index in the subject of the Russian Federation (reduction of costs of the first type);
- reduction of the specific weight of land unsuitable for cultivation of agricultural crops in their total area, including through conservation (reduction of costs of the second type);
- introduction and use of the correction factor for the area actually occupied by agricultural crops (harvested) (reduction of costs of the third type);
- implementation of measures for prevention of dehumification, soil fatigation, soil depletion (use of grassland crop rotations, application of organic fertilizers), erosions and deflations (non-mouldboard soil cultivation, placement of protective forest belts, contour organization of territories), formation of structurless crusts and over-compacted horizons (use of modern lightweight equipment, reducing the number of treatments, etc.) (reduction of costs of the fourth type);
- advisory engagement, regulation of the agricultural land use (reduction of costs of the fifth type).

The areas of minimizing the lost opportunity costs are considered on the example of soils of different natural zones of the Saratov region, different degrees of their erosion and salinization.

The actual data of eroded lands are used in the calculations: total area of lands - 3443 ha, productivity - 1.87 t/ha, profit - 1117.1 RUB/t. Standard of reduction in crop yields of slight-eroded lands - 18 %, of moderate-eroded lands - 35%, of high-eroded lands - 52% (Masyutenko et al., 2012).

Reduction in crop yields (t/ha) is calculated as productivity (t/ha) multiply by standard of reduction in crop yields. Lost profit (costs of lost opportunities, RUB/ha) is calculated as reduction in crop yields (t/ha) multiply by profit (RUB/t) (Table 5).

The economic effect of agricultural eroded land use depends on conducting subsurface tillage, compliance with requirements for crop rotation. Economic effect, RUB/ha is calculated as reduction in the loss of crop yields (t/ha) multiply by profit (RUB/t) (Table 6).

Table 5. Calculation of the lost profit from grain production on eroded lands (on the example of separate land plots in the Saratov region)

Soil	Reduction in crop yields, t/ha	Lost profit, RUB/ha
slight-eroded	0.337	376.46
moderate-eroded	0.655	731.70
high-eroded	0.972	1085.82

Table 6. Economic effect from the grain production on soils with improved quality indicators (on the example of erodibility reduction of separate land plots in the Saratov region)

Change in the degree of soil degradation (erodibility reduction)	Reduction in the loss of crop yields, t/ha	Economic effect, RUB/ha
moderate → slight	0.318	355.24
high → moderate	0.317	354.12
high → slight	0.635	709.36

Max economic effect from erodibility reduction is 709.36 RUB/ha.

The actual data of salted lands are used in the calculations: total area of lands - 609 ha, productivity - 1.56 t/ha, profit - 918.2 RUB/t. Standard of reduction in crop yields of slight-salted lands - 20%, of moderate-salted lands - 50%, of high salted lands - 70%, of severe-salted lands - 90% (Bazilevitch et al., 1968).

Reduction in crop yields (t/ha) is calculated as productivity (t/ha) multiply by standard of reduction in crop yields.

Lost profit (costs of lost opportunities, RUB/ha) is calculated as reduction in crop yields (t/ha) multiply by profit (RUB/t) (Table 7).

Table 7. Calculation of the lost profit from grain production on salted lands (on the example of separate land plots in the Saratov region)

Soil	Reduction in crop yields, t/ha	Lost profit, RUB/ha
slight-salted	0.312	286.48
moderate-salted	0.780	716.20
high salted	1.092	1002.67
severe-salted	1.404	1289.15

The economic effect of agricultural salted land use depends on conducting melioration and agricultural activities (Table 8).

Table 8. Economic effect from the grain production on soils with improved quality indicators (on the example of salinization reduction of separate land plots in the Saratov region)

Change in the degree of soil degradation (salinization reduction)	Reduction in the loss of crop yields, t/ha	Economic effect, RUB/ha
moderate → slight	0.468	429.72
high → moderate	0.312	286.48
extreme → high	0.312	286.48
high → slight	0.780	716.20
extreme → slight	1.092	1002.67
extreme → moderate	0.624	572.96

Max economic effect from salinization reduction is 1002.67 RUB/ha.

The base for calculating the amount of land payments is the cadastral value of the land plot without taking into account the quality and condition of agricultural land provided for use. To determine the land tax amount accrued for payment, it is multiplied by 0.3%, and for determining the rental amount, cadastral value is multiplied by the corresponding rate and time factors, inflation processes (Zavorotin et al., 2019). This circumstance makes it necessary to apply a substantiated coefficient, excluding the area occupied by communications and roads, disturbed and other lands from the total area not involved in economic turnover.

Reduction the costs for the measures related to improving the soil quality and eliminating monoculture specialization should be achieved by implementing a set of proposed steps supported by the state, performed by owners, land users, landowners, and lessees by themselves (Table 9).

The assistance of the authorities should be specified in the relevant program, and their intervention can be determined by implementing a normative-rent approach to the establishment of marginal lands. This category usually includes agricultural land that has a zero or negative rent value in the following cases:

- anthropogenic impact (uncontrolled, excessive use of fertilizers, pesticides, etc.), leading to degradation of the soil cover;
- establishing payments for land that exceed the income it generates;

Table 9. Expected participation of the state in the implementation of measures on reduction of agricultural land depletion

Circumstance	Degree of participation	Method of influence
Implementation by owners, land users, landowners and lessees of mandatory measures for maintenance and restoration of the normal land condition	Low	Control
The amount of mandatory costs for improving the quality of land does not correspond to the financial capabilities of agricultural producers	Moderate	Subsidizati on
Complete exhaustion of useful properties of land in the use as not intended	High	Removal

- allotment of lands that are unsuitable for profitable production of crop output (erodible, hillside, bushy, stony, swampy, salty, etc.).

The effect of penalties for damaging the soil fertility should be fair towards the owners, land users, landowners, and lessees, so it is necessary to differentiate the number of monetary penalties in accordance with the behavior of subjects.

Inefficient land relations participants who do not use land, use land as not intended, use land in agricultural production irrationally or damage land should be subject to penalties in full in accordance with the current legislation. The same measure of material impact should be applied to the subjects that use land for agricultural production with that unreasonably increasing the anthropogenic load on agricultural land. If they get land that has been subjected to slope, degradation and other natural processes, they have the right to apply for the cancellation or reduction of fines. Penalties in the form of fines should not be applied to effective participants in land relations who use land in agricultural production with restoration measures.

The essence of the developed method can be traced by the model of the process of its functioning, the effect of agricultural land use consists of three components (Figure 1).

Economic block	**Environmental block**	**Social block**
Collecting information about the types and amounts of costs		
The use of traditional methods of reducing the costs for crops cultivation	Aquisition and processing of data on the results of soil bonitet	
Application of the developed set of measures for reducing the costs of different types	Prevention of intensive removal of nutrients in the process of commercial crops growing	Determining the land tax and rent rate
	Conservation, restoration of fertility, prevention of soil degradation	Establishment of differentiated amounts adjusted for the correction factor
		Reduction or cancellation of monetary penalties

Improvement of the efficiency of agricultural land use

Costs minimization	Improvement of soil fertility	Responsible attitude to land use and improvement of living standards

Figure 1. Process model for cost optimization taking into account measures for reduction of agricultural depletion of soils

The system is described by three coordinated stages, which include step-by-step implementation of the proposed actions in the economic, environmental and social areas of improving the efficiency of agricultural land use. Each of them has a significant impact on the process of land management and all together make it possible to optimize the costs of different types, reduce the destructive impact of soil erosion (deflation), avoid variances from crop rotation requirements and recommendations of scientific institutions for placing crops in the crop rotation, contribute to the reproduction of fertile properties of land, raise environmental awareness, etc.

CONCLUSIONS

Methods of cost optimization taking into account measures for protection of soils from depletion, implemented through the use of agro-technical, fiscal, economic, legal and other opportunities to improve the efficiency of agricultural land use, are proposed. Five groups of costs are identified, and the reduction of them creates the necessary prerequisites for the rational activity of agricultural producers; the results for typical farms used for enhancement of anti-erosion resistance and soil salinity are obtained. One of the areas is stimulation of land relations participants, which ensures establishing the degree of state participation in the financing of soil protection measures, expedience of differentiation of the amounts of monetary penalties and other relevant payments to encourage land users who observe the regulations of environmental safety standards.

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FIELD SHELTERBELTS: CURRENT STATE, LAND USE ISSUES AND PERSPECTIVE IN UKRAINE

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Abstract

The paper aimed to present the evolution of policy on the maintenance and preservation of field shelterbelts in Ukraine. Analysis of the current state and dynamics of areas of field shelterbelts indicates an unsatisfactory trend of this type of land use in terms of their ecological and economic suitability and socio-economic needs, and funding for measures to create protective forests and forest shelterbelts is insufficient. It is based on statistical data of the State Statistics Service of Ukraine, the Ministry of Environmental Protection and Natural Resources of Ukraine, the State Service of Ukraine for Geodesy, Cartography and Cadastre, the Accounting Chamber, etc. It is proposed to take into account not only the field shelterbelts on non-agricultural territories of agricultural lands, but also the field protection role of forests in the strategic planning decisions on land use. This approach determines the reflection in the land policy of measures for the maintenance and preservation of field shelterbelts located on agricultural lands, as well as measures to promote protective afforestation.

Key words*: afforestation, field shelterbelt, land use, land policy, land protection.*

INTRODUCTION

One of the key factors that comprehensively determines the productivity of agricultural land, in particular, in areas with high level of agricultural risk, is the presence and condition of field shelterbelts. The protective effect of the field shelterbelts on agricultural lands is explained by the protective properties of forests. Protective stabilizing properties of forests are extremely positive, having a positive impact on objects of special interest to mankind: industrial enterprises, cities and other settlements, transport infrastructure, agricultural lands, water sources and reservoirs, sanitary zones, recreation areas, places with undesirable climate change. However, the problems of environmental protection, as well as increasing the fertility of agricultural land are directly related to the protective impact of forests. For example, reducing the level of forest cover from 5 to 1% causes damage to crops by wind erosion to 55%. Forests play an equally important role in protecting soils from water erosion. There is no soil erosion in the areas adjacent to forests. However, if hydro-technical structures and agro-technical methods can be used to combat water erosion, while forests provide a comprehensive result of wind erosion control. Forests, creating an actual obstacle to the movement of air masses, increase the cross-section (unevenness) of the terrain, reducing wind speed in the surface layer, redistributing air flows at high speeds. By regulating the structure of field shelterbelts and the distance between them, it is possible to provide reliable protection of soils from wind erosion. The protection of agricultural fields by forests is reflected in the fertility of agricultural fields. In protected fields, the yield is higher by 15-25% (Sinitsyn, 1980). The worse the climatic conditions, the higher the increase in crop yields in fields protected by forests or forest shelterbelts, compared with the increase in unprotected fields (Sinitsyn, 1980; Tribunskaya, 1990).

The positive protective effect of field shelterbelts in general should be considered as a set of organizational and economic, agro-technical, forest reclamation, hydro-technical and other measures. The effectiveness of field shelterbelts and the protective function of forests as an organizational and economic measure takes place only under the condition of rational land structure and ecological stability of land use, and only then depends on other factors.

Field shelterbelts are an important factor in stabilizing land use, in particular in arid regions. Thus, field shelterbelts of various designs possess various protective and reclamation properties. The degree of protection of the fields mainly depends on the length of the shelterbelt and the height of the stand in them (Tribunskaya, 1990).

Forest shelterbelts of landscapes Hladun (2004) calls one of the most important parts of the complex of rational land use, which in combination with other measures will ensure the inexhaustible use of the resource potential of the landscape, promote its self-regulation and self-restoration of the biological system of the modified landscape. He points out that protective forest shelterbelts have a clear spatial impact on the agricultural area protected by them. The sphere of the greatest positive influence of shelterbelts extends on distance of 30 heights of planting in system, and as a whole shows the microclimatic influence on 50-100 heights. The main influence is manifested at a height of 2-3 m in the surface layer of air, and in the soil - within its thickness and occasionally - in the parent rock (Hladun, 2004). The optimal area of all forest areas for every 100 hectares of agricultural land should average 17.47 hectares. With such an area of forests, the level of gross output will reach its maximum value (Hladun, 2004; Tovma, Hrechko & Malynska, 2000). Mishenin (1998) notes that a meaningful classification of the functions of forest resources in combination with the long-term target orientation of lands can be used as a basis for optimizing the forest cover of the territory (region). Among the important and global studies that provide data on the dynamics of the area of protective forests, designed primarily for the protection of soils and water resources, is the FAO Global Forest Resources Assessment (FAO, 2020).

Recent trends in research of field shelterbelts and other protective forests take place in the context of the implementation and improvement of opportunities for organic production (Piddubna, 2016).

An interesting perspective on the role of field shelterbelts linked to the appreciation of the cultural function of the landscape, particularly in the Netherlands and Poland, is shown in the paper by Schaller et al. (2018).

Important from the point of view of mitigation and adaptation to climate change and the role of field shelterbelts are the results of the study Amadi, Van Rees and Farrell (2016), where farm shelterbelts are described as a management tool to reduce erosion, conserve moisture, protect crops and buildings, and sequester carbon.

According to the statistical reporting of the State Service of Ukraine for Geodesy, Cartography and Cadastre (form No. 6-land) for 2016, the area of field shelterbelts was 446.7 thousand hectares. Researchers consider official statistics to be unreliable, citing the fact that forest shelterbelts are subject to illegal logging, and state registration of shelterbelts has not been carried out since 1976. Experts currently estimate the actual area of forest shelterbelts is about 350.0 thousand hectares, and to achieve the normative indicators it is necessary to create another 700.0 thousand hectares (Zhelezna, Bashtovy & Heletukha, 2016).

As Yukhnovskiy, Maluga, Shtofel & Dudarets (2009) point out, the existing forest shelterbelts are in unsatisfactory condition. As a result of land reform, agricultural land has been largely transferred to private ownership (unbundled), and unprofitable field shelterbelts are mainly part of reserve lands, reserve fund and public lands.

Also moments of legal gaps in the disposal of land under forest shelterbelts and unsatisfactory regulatory influence in Ukraine are noted (Zhelezna, Bashtovy and Heletukha, 2016; Piddubna, 2016; Dudiak, Pichura & Potravka, 2019; Mykolayko, Kyryliuk & Kozynska, 2020).

The analysis by Stupak (2016) suggests that having destroyed the elaborate Soviet soil protection system, Ukraine did not manage to develop a new set of legal rules, nor their enforcement mechanisms, to enable soil protection in the new political and economic setting.

In unprotected field shelterbelts, protection, care and reproduction are not carried out, which makes it impossible for stand to perform their protective functions. As a result of liquefaction of plantations by unauthorized felling, processes of turfing and compaction of soils, emergence of undergrowth and shrub vegetation develop. Forest shelterbelts often become places for grazing cattle, garbage dumps, weed nurseries, suffer from fires while burning stubble, and so on. Lack of silvicultural care leads to the fact that field shelterbelts lose purge (windbreak) and water-regulating properties (Yukhnovskiy, Maluga, Shtofel & Dudarets, 2009).

Due to underfunding of forestry, work on the creation of new field shelterbelts on unproductive and degraded lands, including protective forest shelterbelts, is being carried out in insufficient quantities (State Agency of Forest Resources of Ukraine, 2020). The afforestation area by stand species in 2019 was only 137 ha, of which pine - 59 ha, oak - 51 ha, other hardwoods - 22 ha, birch - 5 ha (State Statistics Service of Ukraine, 2020). Another aspect of the deterioration of the quality of forest shelterbelts is the spread of diseases and pests. Thus, in 2020 there was a deterioration in the sanitary condition of ash, ash-acacia and ash-oak stands of forest shelterbelts in some districts of Luhansk region due to their population by a dangerous pest - emerald ash borer (*Agrilus planipennis*) (State Agency of Forest Resources of Ukraine, 2021).

The issue of reproduction, use and maintenance of field shelterbelts is inextricably linked with the issues of achieving the Global Sustainable Development Goals by 2030 proclaimed by the Resolution of the United Nations General Assembly of September 25, 2015 No. 70/1 and their adapted version taking into account the specifics of Ukraine's development in the National Report "Sustainable Development Goals: Ukraine", compliance with which is provided by the Decree of the President of Ukraine "On Sustainable Development Goals of Ukraine until 2030" (President of Ukraine, 2019). Thus, the issues of field shelterbelts are directly covered by Sustainable Development Goal No. 15 "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". Although related to the use and operation of field shelterbelts are also Sustainable Development Goal No. 12 "Ensure sustainable consumption and production patterns" (in terms of using a rational model of agricultural production, which includes measures for agroforestry, protection of soils and plantations), and Goal No. 13 "Take urgent action to combat climate change and its impacts" (in terms of preventing adverse climatic effects on soil conditions, etc.). According to the above Decree of the President of Ukraine, the Sustainable Development Goals of Ukraine for the period up to 2030 are guidelines for the development of draft forecast and program documents, draft regulations to ensure a balanced economic, social and environmental dimension of sustainable development of Ukraine. Therefore, the issues of reproduction, use and maintenance of field shelterbelts can be effectively solved if their solution is provided by the documents of the state strategic planning with the use of its inherent scientifically based tools and the implementation of appropriate measures.

MATERIALS AND METHODS

To study the content of the main regulatory and legislative acts, the evolution of policy on the maintenance and preservation of field shelterbelts in Ukraine is used the method of document analysis. The same method is used for retrospective analysis of the creation of field shelterbelts on the territory of Ukraine.

Comparison and content analysis are used to study the implementation of the Sustainable Development Goals in Ukraine, the essence and practice of land use and its planning.

Analysis of the dynamics of land distribution in Ukraine by type of land, assessment of eroded lands of Ukraine in terms of regions and natural areas, characteristics of the ecological state of land use in terms of regions of Ukraine, assessment of the dynamics of arable land in Ukraine are based on statistical data of the State Statistics Service of Ukraine, the Ministry of Environmental Protection and Natural Resources of Ukraine, the State Service of Ukraine for Geodesy, Cartography and Cadastre, the Accounting Chamber, the State Agency of Forest Resources of Ukraine.

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RESULTS AND DISCUSSIONS

In agriculture, there is a complex result of the impact of forests on the quantity and quality of water resources, climate, as well as the anti-erosion effect. This result is a change in crop yields. Most often, this complex effect is referred to as the protective function of the forest.

Agricultural lands are the most valuable lands in Ukraine, which occupy a fairly large share of the total area of the country. Thus, as of January 1, 2019, the largest share is arable land, which occupies 54.2% of the country, conversions - 0.3%, perennial plantations - 1.4%, hayfields - 3.8% and pastures - 8.8% (Table 1).

Table 1. Distribution of land in Ukraine by land as of 2018

Type of land	Land area		± 2018/2016, thousand ha
	thousand ha	%	
Lands for agricultural, including	42,682.0	70.7	-44.4
Agricultural land	41,329.0	68.5	-178.9
arable land	32,697.2	54.2	+155.9
conversions	190.5	0.3	-43.2
perennial plantations	863.0	1.4	-29.4
hayfields	2,294.4	3.8	-112.0
pastures	5,282.6	8.8	-151.5
Under outbuildings and yards	584.4	1.0	-2.7
Under roads and runs	715.1	1.2	+278.7
Forests and other forest areas	10,685.6	17.7	+52.3
Constructed land	2,549.8	4.4	-3.1
Earth under water and open wetlands	3,397.8	5.6	-10.9
Other lands	905.93	1.5	-127.9
Total	60,354.9	100.0	-

Source: Data by the State Service on Geodesy, Cartography and Cadaster of Ukraine.

The data in Table 1 show a significant increase in the area of arable land with a reduction in the area of other agricultural lands. This distribution of land is characterized by agricultural development and high ploughing of the territories of Ukraine, which significantly exceeds the ecologically justified limits.

The situation with the aggravation of tendencies of erosion processes and soil degradation, as well as the decrease of soil fertility is threatening. The main factors reducing soil fertility, to date, include: low rates of mineral and, especially, organic fertilizers; reduction of measures for chemical reclamation of soils (liming, plastering); non-compliance with crop rotations; non-compliance with anti-erosion measures; use of heavy agricultural machinery, etc. (Ministry of Agrarian Policy of Ukraine et al., 2010).

Soil erosion can be caused by soil and landscape characteristics (slope steepness, soil type, rainfall), which are difficult to adjust, and the nature of land use, which can be changed quite quickly through the use of terracing, creating wind barriers (including forest shelterbelts), as well as changes in factors such as type, density and age of vegetation. In turn, soil erosion is the most obvious indicator of the adverse effects of unacceptable agricultural measures, which lead to reduced crop productivity and often irreversible soil losses (UNECE, 2007). The average annual soil loss from water and wind erosion in Ukraine is 15 t/ha. In absolute terms, this is 15.9 million hectares of land, including 12.9 million hectares of arable land. In some oblasts, the percentage of eroded lands is much higher than the national average (Table 2) (Ministry of Agrarian Policy of Ukraine et al., 2010).

Table 2. Areas of eroded lands of Ukraine in terms of regions and natural areas, thousand hectares (excluding Kyiv and Sevastopol)

Oblasts / natural areas	Eroded lands			
	agricultural land	% of agricultural land	of which arable land	the total arable land
Volyn	362.4	34.5	225.4	33.4
Zhytomyr	87.8	5.8	60.7	5.6
Transcarpathian	39.6	8.7	35.5	17.7
Ivano-Frankivsk	133.7	21.2	98.4	25.8
Lviv	525.0	41.4	380.1	47.7
Rivne	323.3	34.6	224.2	34.1
Chernihiv	81.0	3.9	53.3	3.8
Polissya	1,552.8	19.6	1,077.6	20.7
Vinnytsya	687.5	34.1	593.1	34.3
Kyiv	157.9	9.5	128.8	9.5
Poltava	517.7	23.8	420.3	23.8
Sumy	305.1	17.9	176.3	14.3
Ternopil	244.0	23.2	239.7	28.1
Kharkiv	996.3	41.2	791.2	41.1
Khmelnytsky	628.4	40.1	501.9	40.0
Cherkasy	326.6	22.5	286.1	22.5
Chernivtsi	124.2	26.4	88.5	26.5
Forest-steppe	3,987.7	27.5	3,225.9	27.5
Autonomous Republic of Crimea	999.3	55.6	919.3	72.6
Dnipropetrovsk	1,104.8	43.9	914.7	43.0
Donetsk	1,757.4	85.9	1,080.0	65.2
Zaporizhzhya	1,212.5	53.9	640.8	33.6
Kirovohrad	1,102.4	54.0	886.7	50.3
Luhansk	1,372.3	71.8	1,237.9	97.5
Mykolayiv	964.5	48.0	914.8	53.9
Odesa	1,214.0	46.8	1,081.6	52.3
Kherson	686.2	34.8	961.0	54.1
Steppe	10,413.4	54.4	8,636.8	55.6
Total in Ukraine	15,953.9	38.4	12,940.3	39.9

Source: (Ministry of Environmental Protection and Natural Resources of Ukraine, 2017).

According to the operative information of the territorial bodies of the State Service on Geodesy, Cartography and Cadaster of Ukraine, in 2018, 24.76 hectares of land were conserved by afforestation, and 22.7 thousand hectares of land are under conservation.

Despite the measures taken, the characteristics of the ecological state of land use in the context of the regions of Ukraine are defined as stable and not stable with an average level of load. The structure of land use and ecological imbalance of the land fund in Ukraine since 1991 has not changed significantly. Thus, the assessment of ecological stability of land use within the regions of Ukraine by calculating the coefficients of ecological stability and anthropogenic load (Table 3) shows that the ecological stability of land use in Ukraine remains a stable unstable (Kec.st. = 0.40) and the average level of load (Ka.l. = 3).

The following limits of values according to the Methodical recommendations by Tretiak, Tretiak and Shkvyr (2001) are accepted:

coefficient of ecological stability of the territory (Kec.st.): less than 0.33 - the territory is ecologically unstable; 0.34 to 0.50 - the territory is stable unstable; 0.51 to 0.66 - goes to the limit of moderately stability; if it exceeds 0.67 - the territory is ecologically stable;

coefficient of anthropogenic loading of the territory (Ka.l.): 5 points - high degree of anthropogenic loading (lands of industry, transport, settlements); 4 points - anthropogenic loading (arable land, perennials); 3 points - average anthropogenic loading (natural forage lands, tinned beams); 2 points - insignificant anthropogenic loading (forest shelterbelts, shrubs, forests, swamps, underwater); 1 point - low anthropogenic loading (micro-reserves).

Retrospective

The creation of protective forest shelterbelts in Ukraine has a long history, in particular, since Soviet times. Although one of the primary acts that directly regulated the protection of forests, which performed a protective function, can be considered issued by the Government of the Russian Empire in 1888 Regulations on the conservation of forests. In accordance with this Regulation, forest protection committees were formed under the chairmanship of governors, who were in charge of regulating the use of forests (Forestry, 1991b).

Table 3. Characteristics of the ecological state of land use in terms of regions of Ukraine as of 2018

Oblasts	Kec.st.	Ecological stability	Ka.l.	Anthropogenic load
Autonomous Republic of Crimea	0.41	stable unstable	3	average
Vinnytsya	0.33	ecological unstable	4	significant
Volyn	0.57	moderately stable	3	average
Dnipropetrovsk	0.28	ecological unstable	4	significant
Donetsk	0.29	ecological unstable	4	significant
Zhytomyr	0.55	moderately stable	3	average
Transcarpathian	0.71	ecological stable	3	average
Zaporizhzhya	0.27	ecological unstable	4	significant
Ivano-Frankivsk	0.62	moderately stable	3	average
Kyiv	0.43	stable unstable	3	average
Kirovohrad	0.27	ecological unstable	4	significant
Luhansk	0.41	stable unstable	3	average
Lviv	0.53	moderately stable	3	average
Mykolayiv	0.28	ecological unstable	4	significant
Odesa	0.31	ecological unstable	4	significant
Poltava	0.33	ecological unstable	4	significant
Rivne	0.60	moderately stable	3	average
Sumy	0.42	stable unstable	3	average
Ternopil	0.34	stable unstable	4	significant
Kharkiv	0.34	stable unstable	4	significant
Kherson	0.34	stable unstable	3	average
Khmelnytsky	0.35	stable unstable	4	significant
Cherkasy	0.36	stable unstable	3	average
Chernivtsi	0.51	moderately stable	3	average
Chernihiv	0.47	stable unstable	3	average
Ukraine	0.40	stable unstable	3	average

Source: calculated according to the data by the State Service of Geodesy, Cartography and Cadastre of Ukraine in accordance with the Methodical recommendations (Tretiak, Tretiak and Shkvyr, 2001).

By the Regulations of 1888, all the forests of the European part of Russia were divided into protective and unprotected. Protective forests were subject to mandatory protection. Such forests included forests and shrubs, which:

restrained loose sands on the sea coast, banks of floating and other rivers, canals and other artificial reservoirs;

protected from sand drifts of the city, settlements, railways, highways and postal roads, cultivated lands and various lands;

protected the banks of navigable rivers, canals and water sources from cliffs, erosion and damage by ice drift;

grow on mountains and slopes, if they precede the formation of avalanches and rapid flows (Forestry, 1991a).

One example of a planned solution to the problems of reproduction and protection of the environment in the USSR was approved by a government decree in October 1948, the Plan of field-protective afforestation, the introduction of grass-field crop rotations, the construction of ponds and reservoirs to ensure high and stable yields in the steppe and forest-steppe regions of the European part of the USSR (Council of Ministers of the USSR & the Central Committee of the CPSU(b), 1948).

Developed by scientists to implement the ideas of prominent soil scientists Dokuchaev, Kostychev, Williams, this Plan was aimed at combating drought, climate change, increasing soil fertility, obtaining high and sustainable yields, stopping washing and blowing of soils, consolidation of sands and the most correct use of lands. Central to this long-term plan, which covered the period up to 1965, was field afforestation and irrigation (Kovalenko, 2018).

In foreign countries, similar problems are solved by creating green ecological frameworks.

The Forest Fund of the USSR divided forests into categories of protection, in particular, allocated the following categories and the corresponding purposes of forest use:

protective forest shelterbelts of the state (allocated since 1973; in 1973 amounted to 0.1 million hectares, in 1988 - 0.2 million hectares) - the preservation of forests created earlier in the implementation of the Plan for the transformation of nature, providing prevention of development erosion and preservation of field fertility in steppe and forest-steppe areas;

field and soil protection forests, forest shelterbelts, steppe forests, riparian forests (allocated since 1966; in 1973 they amounted to 19.2 million hectares, in 1988 - 20.2 million hectares) - preservation of natural forests that perform preventive functions and the emergence of erosion, preservation of field fertility, improvement of the microclimate of the environment in areas with extreme weather, climatic and hydrological conditions (Forestry, 1991a).

In general, in the USSR from 1971 to 1983 constant observations and researches of degree of influence of field protective (and stock-regulating) forest shelterbelts on productivity of arable land in various regions of the country were conducted (Tribunskaya, 1990). Forest shelterbelts in the structure of production fixed assets of agricultural production in the USSR accounted for about 3% of their value (Spiridonov, Moreva, Sharaeva et al., 1986).

A unique forest reclamation facility in Ukraine is the so-called Dokuchaev field shelterbelts, which by the decision of the Kirovohrad Regional Executive Committee in 1968 were recognized as a botanical natural monument of local significance. According to the data provided by the State Enterprise "Onykiyeve Forestry" (Onykiyeve village, Kirovohrad oblast, Ukraine), the nature protection object consists of 4 field shelterbelts, which were created in 1896-1898 on the idea of Dokuchaev V. and are of great value for the study of the protective properties of the forest, its impact on increasing yields and as an experience of creating field shelterbelts in the steppe:

Field shelterbelts No. 1 - area 14.0 ha, width 46 m, length 3259 m - main species: oak (*Quercus robur* L.), ash (*Fraxinus excelsior* L.), elm (*Ulmus carpinifolia* Suckow).

Field shelterbelts No.2 - area 16.0 ha, width 46 m, length 3492 m - main species: oak, acacia yellow (*Caragana arborescens* Lam.).

Field shelterbelts No.3 - area 9.4 ha, width 40 m, length 2497 m - main species: oak, ash.

Field shelterbelts No.4 - area 4.1 ha, width 40 m, length 1131 m - main species: - oak, ash, elm.

The distance between shelterbelts No. 1 and No. 2 is 1370 m, No. 2 and No. 3 - 700 m and between No. 3 and No. 4 - 700 m. At the time of creation of the land under the shelterbelts belonged to the peasant holdings.

Field protection effect of the Dokuchaev field shelterbelts was studied at different times by many scientists and commissions (for example, the Board of Scientists, 2004). The most complete in the context of our study are the conclusions about the field protective effect of these shelterbelts by Sviridenko (1966), which have not lost relevance. According to Sviridenko (1966), the impact on crop yields in the fields of the collective farm "Pobeda" in the Malovyskiv district is significant on average during the period 1961-1965 (Table 4). It is important to note that during Sviridenko's research in 1961-1965, forest shelterbelts were part of the state forest fund and the agricultural collective farm, the fields of which were affected by the shelterbelts, did not incur any forest protection costs. These costs were covered by revenues from felling in the shelterbelts.

Table 4. Influence on the yield of agricultural crops of the Dokuchaev field shelterbelts, which were created in 1896-1898

Agricultural crops	Fields without forest shelterbelts		Fields with forest shelterbelts		Yield increase in fields with forest shelterbelts, centner/ha
	Area, ha	Yield, centner/ha	Area, ha	Yield, centner/ha	
Wheat winter	557	26.1	768	28.4	2.3
Barley	281	29.8	208	38.1	8.3
Maize for grain	1,403	45.3	584	50.9	7.4
Pea	457	16.7	433	21.8	5.1
Sunflower	413	20.6	566	22.9	2.3
Sugar beet	811	279	817	322	43.0

Source: Sviridenko, 1966.

The general conclusions of Sviridenko (1966) indicate the following. Forest shelterbelts, which are located in Onykiyeve forestry and created during the expedition of Dokuchaev V., in terms of growth efficiency, impact on adjacent fields, location on the territory and valuable selection of trees and shrubs are unique forest reclamation objects. The studied field shelterbelts created during the emergence of field protection afforestation do not meet all the requirements of forest reclamation science, in particular, regarding their design (their effective width can be much smaller). The best areas are 23 meters, oak and ash, with Tatarian maple trees (*Acer tataricum*) and elm in the second tier. Some areas of forest shelterbelts have different growth rates, due to the composition of stand, other things being equal. Sviridenko's research (1966) testifies to the effectiveness of oak in field afforestation. Under the influence of forest vegetation, the physical properties of the soil have changed over the years, the horizon of the humus layer has risen, the soil structure has risen, water permeability under forest strips has increased, and the physicochemical composition of the soil has changed. The forest cover of protected fields with the available width of forest shelterbelts is 3.2%. 31.4 ha of fields are under the protection of 1 ha of forest shelterbelts.

Thus, Ukraine has a long experience of creating and operating the potential of field shelterbelts. However, their legal status and quality are unsatisfactory.

Field shelterbelts

Field shelterbelts within state programs (for example, the Verkhovna Rada of Ukraine, 2000) were also considered in terms of increasing the area of the national ecological network. The National program for the formation of the national ecological network of Ukraine for 2000-2015 (Verkhovna Rada of Ukraine, 2000) provided for the creation of forest shelterbelts and protective forests, land reclamation: forest shelterbelts as land - components of the national ecological network were to be 645.5 thousand hectares, or 1.07% of the total area of the country.

The creation of field shelterbelts and protective forests was also envisaged by the General scheme of planning of the territory of Ukraine in early 2002 within the framework of expanding the area of the national ecological network in order to form it as a component of the Pan-European Ecological Network and maintain vital environmental functions, creating the necessary conditions for restructuring and reducing the anthropogenic impact on it to an environmentally acceptable level (Verkhovna Rada of Ukraine, 2002).

Unfortunately, funding for the National Program for the formation of the national ecological network of Ukraine for 2000-2015 in recent years was insufficient, which does not allow to draw correct conclusions about the effectiveness of its implementation and its achievement of forecast parameters. In addition, it, as well as the above-mentioned the General scheme of planning of the territory of

Ukraine, has now expired and needs immediate updating and continuation, taking into account new principles and objectives.

Creation of 107.7 thousand hectares of forest shelterbelts and protective forests on lands not occupied by forests (degraded, unproductive, etc.) was provided by the State Target Program "Forests of Ukraine" for 2010-2015 as part of the task of increasing forest cover by various managers budget funds-permanent forest users (Cabinet of Ministers of Ukraine, 2009).

A productive attempt to solve the problems of reproduction, use and maintenance of forest shelterbelts by means of state strategic planning was made by the Government approval in 2013 of the Concept of agroforestry development in Ukraine, efficient management in them and will be an ecological prerequisite for the balanced development of agricultural landscapes. In turn, this should allow solving the problems of soil protection from degradation and pollution, increasing crop yields, increasing the production of environmentally friendly products, ensuring food security, preserving landscape and biological diversity, creating environmentally safe living conditions (Cabinet of Ministers of Ukraine, 2013). The strategic nature of this document is ensured by the fact that it has a long-term implementation horizon during 2014-2025. However, the relevant action plan for the implementation of the Concept was approved by the Government only a year later, and one of the documents developed in line with the implementation of the Concept - Rules for maintenance and preservation of field shelterbelts located on agricultural land - was approved by the Government only in 2020 (Cabinet of Ministers of Ukraine, 2020), which slows down the scientifically based conceptual and legislative support of the state strategic planning of reproduction, use and maintenance of field shelterbelts in Ukraine.

Calculations according to the actual data of the form No. 6-lands of the State Service of Geodesy, Cartography and Cadastre of Ukraine for 2016 indicate that the area of field shelterbelts is 0.74% of the total area of the country.

The long history of field afforestation and land reform in Ukraine only in 2019 acquired a fuller institutionalized form of regulatory influence on the use of land under field shelterbelts - the Law of Ukraine (Verkhovna Rada of Ukraine, 2018) regulated the issue of collective land ownership, improved land use rules in agricultural lands, defined the list of lands that are subject to transfer to the communal property of the territorial community of the village, settlement, city on the territory of which they are located, among which lands under field shelterbelts are also marked.

In 2020, the Rules for the maintenance and preservation of field shelterbelts located on agricultural lands were approved (Cabinet of Ministers of Ukraine, 2020). These Rules define the basic concepts:

field shelterbelts are artificially created stands of linear type for protection of agricultural lands from negative influence of natural and anthropogenic factors;

maintenance of field shelterbelts - a set of forestry and agro-technical measures aimed at improving the condition or composition of stands, maintenance of appropriate structures;

preservation of field shelterbelts - a set of measures to organize the protection and protection of plantations from fires, illegal logging, damage, weakening, protection from pests and diseases and other harmful effects (Cabinet of Ministers of Ukraine, 2020).

The Land Code of Ukraine (2002) stipulates that field shelterbelts and other protective forests, except for those classified as lands of other categories, are part of non-agricultural lands and belong to agricultural lands. Land plots under field shelterbelts, which limit the mass of agricultural land, are transferred for permanent use to state or municipal specialized enterprises or leased to individuals and legal entities with mandatory inclusion in the land lease agreement of conditions for maintenance and preservation of such shelterbelts and ensuring that they perform the functions of agroforestry reclamation. The obligation to maintain and preserve field shelterbelts is defined as a restriction on the use of land, which may be established by law, regulations adopted in accordance with it, the contract, the court decision. At the same time, the lease of land plots under field shelterbelts serving an array of agricultural lands is not subject to sale on a competitive basis (land auction) of land

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plots of state or communal ownership or the right to them (Land Code of Ukraine, 2002).
The dynamics of the area of field shelterbelts in Ukraine (Table 5) during 2001-2016 indicates a slight increase in this indicator in the country as a whole. In spatial terms, the dynamics are very uneven. The increase in the area of field shelterbelts by more than 10% during the study period took place only in two oblasts - Luhansk and Odesa (with some reservations about the scale of changes - in Volyn oblast).

Table 5. Dynamics of the area of field shelterbelts in Ukraine, thousand hectares

Regions\oblasts of Ukraine	2001	2010	2014	2015	2016	2016/ 2001 (%)
Autonomous Republic of Crimea	23.7	23.8	23.9	23.9	23.9	100.8
Vinnytsya	17.1	17.5	17.6	17.6	17.6	102.9
Volyn	0.1	0.2	0.2	0.2	0.2	200.0
Dnipropetrovsk	39.5	42.6	42.5	42.5	42.5	107.6
Donetsk	31.4	31.9	31.9	31.9	32.5	103.5
Zhytomyr	5.1	4.7	5.0	5.0	5.0	98.0
Transcarpathian		0.2	0.1	0.1	0.1	
Zaporizhzhya	55.0	52.5	51.8	51.9	51.9	94.4
Ivano-Frankivsk	0.1					0.0
Kyiv	12.3	13.0	12.3	12.3	12.3	100.0
Kirovohrad	28.1	27.9	28.1	28.1	27.9	99.3
Luhansk	26.8	30.2	30.3	30.3	30.4	113.4
Lviv		0.1	0.1	0.1	0.1	
Mykolayiv	34.1	34.3	33.7	33.8	33.8	99.1
Odesa	42.7	49.8	49.9	50.0	50.0	117.1
Poltava	20.3	19.8	20.0	20.0	20.0	98.5
Rivne		0.1				
Sumy	12.1	13.3	13.0	13.0	13.0	107.4
Ternopil	1.2	1.2	1.1	0.9	1.1	91.7
Kharkiv	25.4	26.1	26.6	26.5	26.3	103.5
Kherson	29.8	29.0	29.0	29.0	29.0	97.3
Khmelnytsky	4.2	4.3	4.2	4.2	4.3	102.4
Cherkasy	14.0	14.0	14.1	14.1	14.1	100.7
Chernivtsi	0.1					0.0
Chernihiv	10.1	10.3	10.3	10.3	10.3	102.0
Kyiv city						
Sevastopol	0.5	0.5	0.4	0.4	0.4	80.0
Ukraine	433.7	447.3	446.1	446.1	446.7	103.0

Source: the form No. 6-lands of the State Service of Geodesy, Cartography and Cadastre of Ukraine.

Types of field shelterbelts depending on their location and purpose in accordance with the Rules for maintenance and preservation of field shelterbelts located on agricultural land (Cabinet of Ministers of Ukraine, 2020) are: field protective (longitudinal and transverse) forest shelterbelts; stock-regulating forest shelterbelts; ravine field shelterbelts; balk forest shelterbelts; roadside forest shelterbelts; garden forest shelterbelts; other field shelterbelts.
According to this approach to the classification of types of field shelterbelts located on agricultural lands, the data of quantitative land accounting are currently limited.

Forestry and field shelterbelts

As can be seen from the above, in the Ukrainian legislation there is a division of categories of land by purpose into agricultural and forestry, which includes forested areas that perform a protective function, and field shelterbelts. Due to the fact that forestry measures play a significant role in the creation of field shelterbelts, we consider it necessary to show some aspects of it. No less important argument is that the positive impact on agricultural production is exerted by forests regardless of their distance from agricultural land (Sakal and Vrublevska, 2010), and not only field shelterbelts of a certain structure and shape.
According to the Forest Code of Ukraine (2006), forests are divided into the following categories according to their ecological and socio-economic significance and depending on the main functions they perform: protective forests, recreational and health forests, forests of environmental, scientific, historical and cultural purposes, operational forests.
Protective forests perform mainly water protection, soil protection and other protective functions. All forests on the territory of Ukraine, regardless of the categories of lands for which they grow for the main purpose, and regardless of the right of ownership, constitute the forest fund of Ukraine and are under state protection. The forest fund of Ukraine includes forest plots, including protective stands of the linear type, with an area of at least 0.1 hectares. The forest fund of Ukraine does not include, in particular, individual trees and groups of trees, shrubs on agricultural lands, homesteads, country houses and garden plots. It is important to emphasize that forest lands do not include lands on which field shelterbelts are located (Forest Code of Ukraine, 2006).
The Land Code of Ukraine (2002) clarifies that forest lands do not include lands occupied by field shelterbelts on agricultural lands. This clarification was made only in 2018.
The category of protective forests includes forest areas that perform the function of protection of the environment and engineering objects from the negative impact of natural and anthropogenic factors. In general, the use of

elms in the artificial stands of the Western Forest-Steppe is expedient: on the lands of the water fund - in the riverbed protection shelterbelts along rivers, around ponds and reservoirs, on well-moistened slightly washed steep banks of the ancient hydrographic network; to create shelterbelts along highways; to create artificial forest shelterbelts with the participation of elms of operational direction. The functions of noise absorption and dust absorption of forest shelterbelts along highways, as well as near crops, are manifested due to the roughness of *Ulmus* L. leaves (Skolskyi, 2011).

To create artificial forest stands on the lands of the water fund, it is necessary to use such rock mixing schemes to prevent erosion of the shores in the future, especially after floods and inundations. To this end, tree species with a strong root system, such as elm (*Ulmus* L.), should be incorporated into the shoreline, using a wood-shade type of mix. Another species with a very well-developed root system is oak, to ensure the successful growth of which should be introduced buffer rows of the accompanying species - maple. Protective plantings should be created with 1-2-year-old seedlings of *Ulmus* L. and other species (Skolskyi, 2011).

To reduce the effects of these adverse events, it is recommended to create a coastal forest strip (Kalinin & Melnyk, 1991).

Another important task in terms of improving the environmental situation is the creation of forest shelterbelts along railways and highways. Exhaust gases emitted into the atmosphere by transport contain heavy metals and carcinogenic substances that pollute the adjacent fields 100-150 m on both sides of the road in the absence of forest shelterbelts. Adverse phenomena on highways are also snow and sand deposits, strong winds, water erosion, etc. To combat these adverse phenomena, it is necessary to create forest shelterbelts on highways. They must consist of fast-growing tree species, resistant to gas and dust, and which come into operation in the shortest possible time. An example of shelterbelts with the participation of the elm. The success of the growth of *Ulmus* L. is determined by the participation in the stand of the faster-growing ash. It is also advisable to include oak in the shelterbelts plantings, and the participation of elm should not exceed 60% in the composition of the plantation (Skolskyi, 2011).

CONCLUSIONS

The problem of field shelterbelts in Ukraine has several sections: institutional definition of this land, its assignment to a certain category of lands, ownership (disposal) of lands under the shelterbelts, it forests reclamation properties, positive impact on yield, and forestry aspect of the shelterbelts structure and composition. Thus, increasing the productivity of field shelterbelts and protective forests in general is a cross-sectoral problem, primarily of agricultural and forestry, which has an organizational, economic and financial nature. All these sections for the proper management of field shelterbelts according to a systematic approach should be reflected in the state planning documents.

Solving the problems of reproduction, use and maintenance of field shelterbelts in the context of achieving the Sustainable Development Goals by 2030 and their adapted Ukrainian version is possible through the use of scientifically sound instruments of state strategic planning and taking into account the rich domestic experience of planning and environmental protection. Existing unresolved issues in this area are the need to update the the General scheme of planning of the territory of Ukraine, the legislation on the formation of the national ecological network, as well as the full implementation of the the Concept of agroforestry development in Ukraine.

An important measure to intensify the reproduction of forest shelterbelts is the reconstruction of stands, it is necessary to increase the completeness of destroyed, replace low-value, low-yielding stands and shrubs with resistant species that have a dust-capturing effect and noise protection efficiency.

Skolskiy (2011), studying the experience of cultivating elms (*Ulmus* L.) in Ukraine, which have a good dust-catching effect due to the roughness of the leaves, summarizing the data of Padiy (Padiy, 1955; 1993) and Knyazeva (1978), notes that to create sustainable protective stands, it is required that the share of

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elms in forest and field shelterbelts does not exceed 10% with an even distribution of trees in the area. Care should be taken to ensure that elms do not displace other species. In such plantations there are no favourable conditions for the spread of Dutch disease (drying of elms). On the other hand, even when the elms are completely dry, the plantings will not become noticeably liquefied. At the same time, in addition to protective properties, species of the genus *Ulmus* L. are characterized by valuable wood, are a desirable component of mixed stands, and their precipitation improves the properties of forest soils.

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STUDY REGARDING POLLUTED SOILS WITH HEAVY METALS FROM MARAMURES MINING BASIN, ROMANIA, IN VIEW FOR THE REMEDIATION OF AFFECTED AREAS

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Abstract

Heavy metal contamination of soils is associated to mining activities and has impact on plants, micro-organisms and life support functions such as immobilisation, mineralisation, nitrification. The increasingly frequent contamination of soils with heavy metals represents a serious problem for Maramures county in Romania. The phytoremediation method can recover the infertile soil that has been polluted with excessive concentrations of heavy metals, it is a friendly environment method of remediation, can be applied on large areas, it is an in situ method and conserves topsoil. The objective of this paper consists in creating an objective and concrete image, also detailed and actual about the pollution of soils with heavy metals from different areas of Maramures county, in Romania with the purpose of highlighting the necessity of remediation and protection of the environment due to the magnitude of soil pollution. The paper has a fundamental approach based on data from specific literature and technical documentations.

***Key words**: heavy metals, Maramures, phytoremediation, Romania.*

INTRODUCTION

The industry and the technological processes for extraction and for processing the underground minerals are key factors in producing the materials needed for the development of the society and of the economy.
The heavy metals, through their chemical and physical properties, are non-degradable elements in nature and can easily migrate in all environmental factors trough repeatedly transformations.
Starting with the decline of the Romanian mining industry, from the year 1990, the effects on the environment began to appear by polluted soils such as unmonitored and abandoned mining sites and drainage of the acid mines (Doroțan et al., 2015).
Through The EU Accession Treaty from the 1th of January 2007, Romania made a commitment to close the activity of all mining waste dumps (tailings management facilities), because of the non-compliancy with the environmental Community requests.
The closing of mining perimeters and of mine-sterile heaps, of preparation plants and of tailing ponds continues from the perspective of implementing national regulatory procedures to ensure the compliance with the environment protection requirements. The implementation of measures for making waste dumps safe, also for the ecological reconstruction of the affected areas require solutions, investments and works to ensure their stability and safety.
The technical projects which represent the base of the closing and rehabilitation works solution are submitted to currently specific legal regulations on fields such as health, water, safety in the mining industry, construction, environment etc.
The aim of this paper is to represent the effects of heavy metal pollution of mining activities on the affected terrains in order to restore them to their use by applying the technology of phytoremediation, an innovative technology largely accepted by public, eco-friendly, self-sustained, with a large coverage area and without disturbance of the ecosystem.

MATERIALS AND METHODS

The pollution of soils with heavy metals from Baia Mare mining basin, Maramures County
The mining exploitations from Maramureș county in Romania are found in the vicinity of the regions: Ilba, Nistru, Băița, Baia Sprie, Șuior, Cavnic, Băiuț, Poiana Botizei, Țibleș, Baia Borșa and Vișeu de Sus, (Figure 1).

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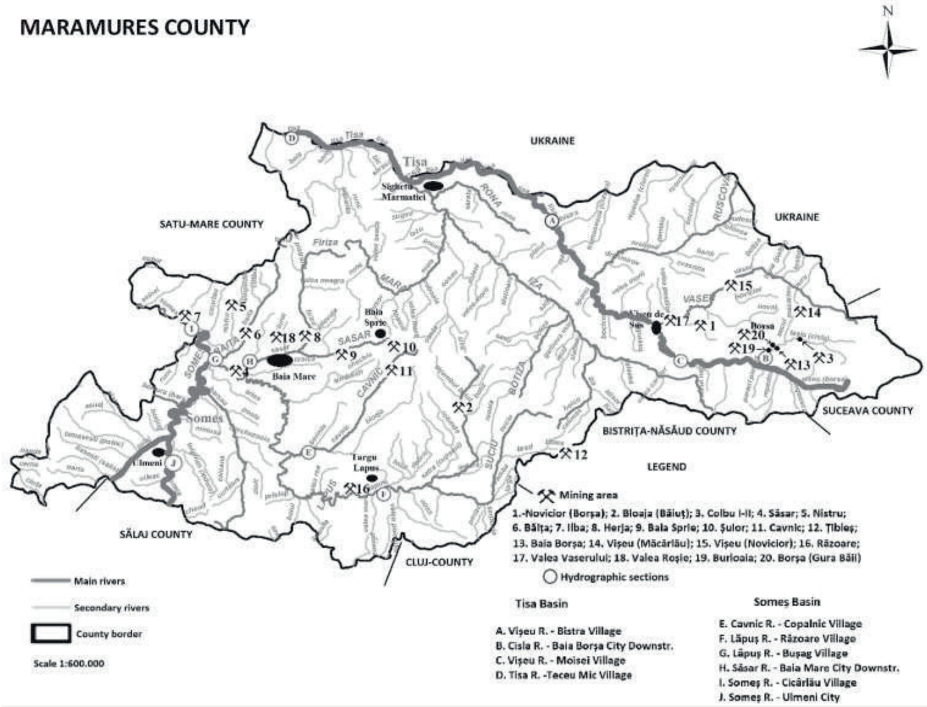

Figure 1. Mining perimeters in Maramureș county (Romania) (Smical et al., 2015)

The propagation and migration of heavy metals in soils could affect the groundwater and also trough contamination by migration and settling on lands.

After some field investigation, was found that depreciated mining concentrates, minerals and flotation sterile were dumped at The Ore Preparation Plants from Baia Sprie, Cavnic, Băiuț, Răzoare, Borșa and Săsar (Figure 2).

Figure 2. Dumps of mining depreciated concentrate and sterile in The Ore Preparation Plant in Băiuț, Maramureș county, Romania (photo: Ioana Petrean)

Because of the surface water entrainment, soil infiltration and because of the oxidation of pyrite from the pyrite dumps it is produced the acidification and heavy metals contamination of soil, underground waters and surface waters (Figures 3 and 4).

Figure 3. Leaks from the sterile dump situated at the exit from Strâmbu-Băiuț village to Lăpuș commune and their path flow on soil and in Lăpuș river, Maramureș county, Romania (photo: Ioana Petrean)

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Figure 4. Mine gallery with the flow of mine water from Băiuț-Văratec metalliferous mining area and the path of the water from the mine in Băiuț valley, Maramureș county, Romania (photo: Ioana Petrean)

To the present day, the technical projects, technical assistance and the implementation of these works did not solve the environmental problems from the mining field (Figure 5).

Figure 5. Destroyed coastal fences and withered saplings on rehabilitated waste mining dump in Nistru mining perimeter, Maramureș county, Romania (photo: Ioana Petrean)

In urban soils of Baia Mare were determined the following values for heavy metal concentrations: 0.3-16.6 mg/kg Cd, 23-404 mg/kg Cu, 151-3261 mg/kg Pb and 180-2695 mg/kg Zn, and in the East part of the area, close to the copper smelter, the concentrations were: 40375 mg/kg Pb, 6122 mg/kg Zn and 5823 mg/kg Cu (Mihali et al., 2013).
Also, close to Baia Mare, in Băiuț-Văratec metalliferous mining area, the following concentrations were determined: Cu from 17.23 to 2184.1 ppm; Pb from 18.98 to 6362 ppm; Zn from 101.12 to 2834.7 ppm; Cd from 0.12 to 20.9 ppm; Ni from 1.52 to 311.4 ppm and As from 0.004 to 266.7 ppm (Chira et al., 2014) (Figure 6).

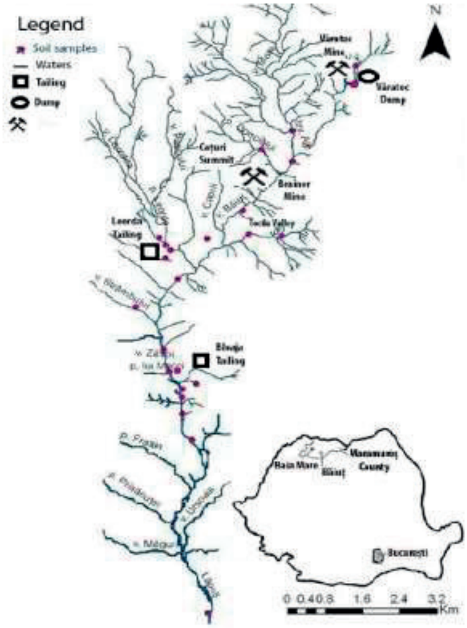

Figure 6. Mining site Băiuț, Maramureș county (Damian et al., 2014)

In agricultural and forest areas from Maramureș county, Romania, the following values for heavy metal concentration were found in soils: 5.6-48 mg/kg Cu, 31-243 mg/kg Zn, 17-639 mg/kg Pb, 0.1-2.0 mg/kg Cd, 45-1265 mg/kg Co, 0.1-31 mg/kg Cr, 1.6-86 mg/kg Ni and 0.2-100 mg/kg Mn (Manea et al., 2018).

The soil remediation

Soil depollution methods can be broadly divided into three categories: physical, chemical and biological (Figure 7). The depollution methods of heavy metals from contaminated soils can be used in combination to remediate contaminated sites. Innovative and cheap technologies are needed to be able to decontaminate soils (Gomes, 2019).
Physical, chemical, biological and combined remediation methods are researched and adopted to address the problems of contaminated soil and contaminated sediments, taking into account the environmental impact assessment and environmental criteria in setting remediation targets.

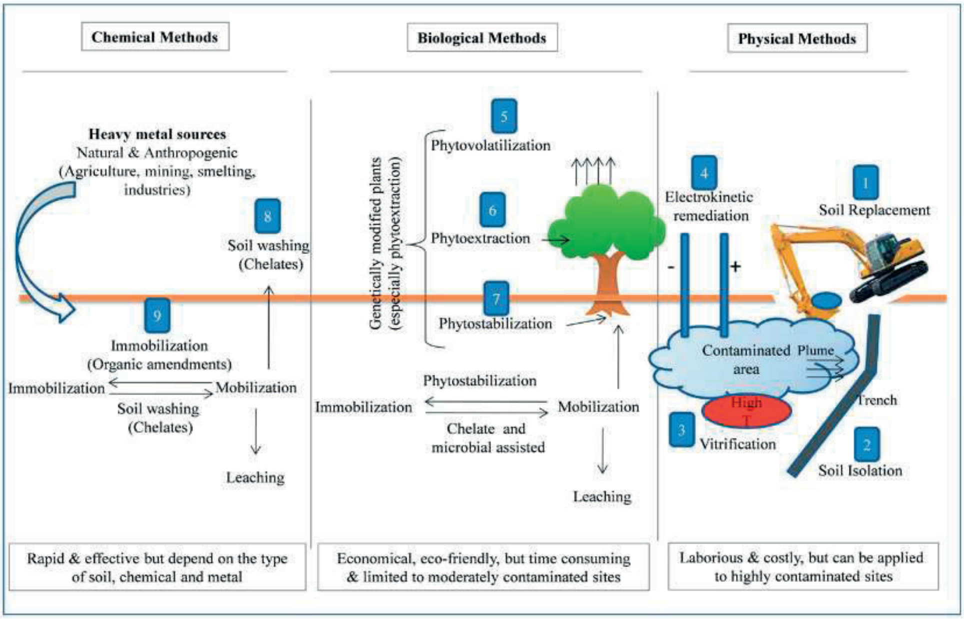

Figure 7. Comparison of different soil depollution methods (Khalid et al., 2017)

Physical remediation methods include: (1) soil replacement, (2) soil insulation, (3) vitrification, and (4) electrokinetics; biological methods include: (5) phytoevaporation, (6) phytoextracttion, and (7) phytostabilization; chemical methods generally include (8) soil washing and (9) immobilization (Khalid et al., 2017).

Physical remediation of soils refers to the partial replacement of contaminated soil with uncontaminated soil and the treatment by heat desorption of the soil. The thermal desorption method involves heating the contaminated soil so that the pollutant volatilizes in the soil. These volatile metals are collected using vacuum pressure and thus removed from the ground. This method is laborious, expensive and has limited applicability, is possible only for small portions of soil (Sidhu, 2016).

Chemical leakage refers to the washing of contaminants from soils with water, reagents, fluids and gases that help the pollutant to drain from the soil, and the recovery of metals extracted in leachate is done by using various chelating agents, surfactants, etc. In the method of chemical fixation, some reagents are added that form insoluble bonds with heavy metals and decrease their mobility in soils. Electrokinetic remediation involves the application of high voltage to the ground to remove the metal. The vitrification process involves heating the soil to very high temperatures (1400-2000°C), so that the pollutant volatilizes or decomposes, but it is an expensive, laborious and complicated process with limited application (Gong et al., 2018). The method performs well in soil with low permeability (Chao et al., 2014).

Biological methods refer to phytoremediation, microbial remediation and animal remediation for the removal of heavy metals from the soil.

Phytoremediation, in situ treatment, consists in growing plants that have hyperaccumulative properties (mainly in the root zone) on soil contaminated with heavy metals. The use of plants and their microcellular absorption system is a new technology, the success of the method consisting in finding suitable plants with affinity for the accumulation and tolerance of heavy metals from over 400 known species (Chao et al., 2014).

Phytoremediation (Figure 8) is advisable for sites contaminated with hydrophobic pollutants such as: benzene, toluene, ethyl benzene, xylenes, chlorinated solvents, PAHs, nitrates, ammonium, phosphate and heavy metals (Suthersan et al., 2017).

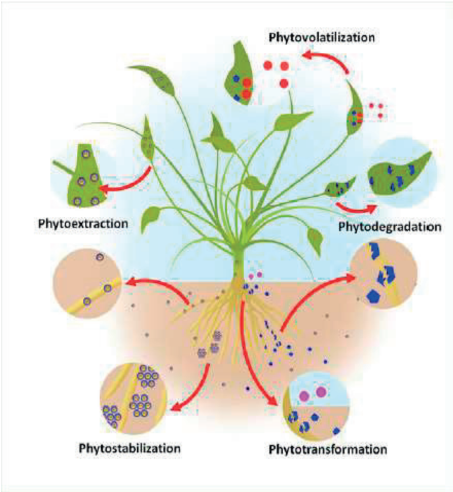

Figure 8. Schematic representation of phytoremediation approaches (Parmar et al., 2015)

Phytovolatization is an approach that involves the absorption and transpiration of metals into their volatile forms and their release or modified forms into the atmosphere through stomata (Tangahu et al., 2011).
Phytoextraction involves the transfer of metals from the soil to parts of the plant, and remediation using microorganisms refers to their ability to change the physical and chemical properties of pollutants, affecting the mobility and transformation of heavy metals in soils.
Plants act as systems for pumping and treating with solar energy, and contaminants solubilized in water are taken up by their roots and transported and translocated through various plant tissues, where they can be metabolized, sequestered or volatilized.
Restoration of polluted soil areas using phytoextraction consists in the in situ cultivation of suitable plant species, harvesting their biomass loaded with heavy metals and treating it (by composting, compaction, drying, thermal decomposition) to reduce its volume and mass, which will later be eliminated as hazardous waste or can be used for the re-extraction of trace elements (Suman et al., 2018).
In phytostabilization or phytoimmobilization, plants are chosen for their tolerance at the sites conditions and the contaminants are sequestered in the lignin of the cell wall of the root tissue (Bansode, 2015).
The mobility of heavy metals is reduced by phytostabilization, through reduced soil erosion and wind dust and low solubility of contaminants. Heavy metals are concentrated due to erosion through sorting and deposition of different sizes of soil fractions (Suthersan et al., 2017).
In phytostabilization, long-term monitoring of mobilization, bioavailability, heavy metal toxicity and ecological impact is necessary.
Microbial remediation refers to the use of microorganisms to achieve the absorption, precipitation, oxidation and reduction of heavy metals in the soil.

The quantification of phytoremediation

The bioconcentration factor (BCF), defined as the ratio between the total concentration of the element in the harvested plant tissue (C_{plant}) and its concentration in the soil in which the plant grew (C_{soil}), is calculated as follows (Favas et al., 2014):

$$BCF = \frac{C_{plant}}{C_{soil}}$$

The translocation factor (TF), defined as the ratio between the total concentration of the elements in the aerial parts of the plant (C_{shoot}) and the concentration in the root (C_{root}), is calculated as follows (Favas et al., 2014):

$$TF = \frac{C_{shoot}}{C_{root}}$$

The metal removal efficiency (ER) is calculated as follows (Gayatri et al., 2019):

$$ER = \left[C_{shoot} + \frac{C_{roots}}{C_{soil}} \right] * 100$$

A hyperaccumulating plant must have BCF>1 or TF>1, and the total concentration of Cu, Co, Cr or Pb>1000 mg/kg, or Fe, Mn or Zn>10000 mg/kg in the aerial parts (Wahsha et al., 2012).

Phytoremediation used plants

In hyperaccumulating plants, the content limits of metal elements in dry biomass are 100 mg/kg for Cd and Se, 1000 mg/kg for Co, Cu, Ni and Pb and 10000 mg/kg for Zn and Mn. These values are up to 100-1000x than in non-hyperaccumulating plants under the same conditions (Suman et al., 2018).
Grasses are the most frequently evaluated plants in phytoremediation because compared to trees and shrubs, herbaceous plants, especially grasses, have characteristics of fast growth, large amount of biomass, strong

resistance, efficiency in soil stabilization and ability to remediate different soil types, are adapted low soil nutrient content, stress environment and to shallow soils (Laghlimi et al., 2015).

Most of hyperaccumulator plant species belong to the plant families: *Brassicaceae* (25%) (Figure 9), *Asteraceae*, *Caryophyllaceae*, *Tiliaceae*, *Cyperaceae*, *Cunouniaceae*, *Fabaceae*, *Scrophulariaceae*, *Myrtaceae*, *Proteaceae*, *Flacourtiaceae*, *Lamiaceae*, *Poaceae*, *Violaceae*, *Euphorbiaceae*, *Rubiaceae, Cruciferae*, including genus *Brassica*, *Alyssums* and pennycress (*Thlaspi*), marigold (*Calendula officinalis*), Mexican marigold (*Tagetes erecta*) (Hassan et al., 2019; P. Ahmad, 2016; Parmar et al., 2015; Chao et al., 2014).

Figure 9. The most important hyperaccumulators from the fam. *Brassicaceae*. (1)*Arabidopsis halleri* (2) *Arabidopsis thaliana*, (3) *Brassica juncea*, (4) *Thalspi caerulescens*, (5) *Thalspi praecox* (Anjum et al., 2012)

Alpine penny grass (*Thlaspi caerulescens*), has been shown to accumulate Zn up to 2000 mg/kg and even 4000 mg/kg. The Indian mustard plant (*Brassica juncea*), has been found to accumulate a significant amount of lead. Indian hemp (*Apocynum* sp.) and common ragweed have also been observed as significant lead accumulators. *Aeollanthus subcaulis* var. *lineris*, a species of the *Lamiaceae* mint family, and bay grass (*Paspalum notatum*) are other hyperaccumulative plants known to accumulate Cu, respectively Cs. Hyperaccumulative plants can access contamination from shallow soils only up to 61 cm deep. If the contamination is between 1.80 m and 3 m, poplar trees can be used for phytoextraction and accumulation of heavy metals by sequestration (Suthersan et al., 2017).

The thale cress plant (*Arabidopsis thaliana*) has a tolerance to Cd without visible signs of toxicity of 1 μm in the soil substrate, but concentrations higher than 5 μm lead to visible morphological changes. The roots of the plant can contain up to 89% Cd under experimental conditions and only a very small part is transported in shoots. Similar results were obtained for *Arabidopsis halleri* plants, with hyperaccumulative root for Cd, but grown in soil have only 20% Cd in the root, the rest of Cd ions are found in the aerial parts (Anjum et al., 2012).

Gayatri et al. (2019) studied the potential of Indian mustard (*Brassica juncea*) for the removal of heavy metals in urban red soil fertilized with manure from cattle, in powder form and found that the metal absorbed in the largest amount by the plant was Pb (151.4 ppm), due to the already available form, followed by Zn (55 ppm) < Cu (15.4 ppm) < Cr (9.6 ppm) < Ni (3.1 ppm) and the percentage of recovery was higher at Zn (51.8%) < Cu (41.6%) < Pb (20.8%) <Cr (11.5%) < Ni (6.1%).

In the study by Ghazaryan et al. (2019) were investigated native species of wild plants that grow in soils contaminated with Cu, the content of Cu (d.s.) determined in the root varied between 55 mg/kg in perforate St John's-wort plant (*Hypericum perforatum*) and 775 mg/kg (*Thymus kotschyanus*). In plant shoots it ranged from 33 mg/kg in Oriental Germander plant (*Teucrium orientale*) to 243 mg/kg in timothy grass (*Phleum pratense*). *Thymus kotschyanus*, *Phleum pratense* and common yarrow (*Achillea millefolium*) had the highest phytostabilization potential.

Cheng et al., (2016) investigated the feasibility of phytoremediation using the silver grass (*Miscanthus floridulus*) on soil contaminated with high concentrations of lead (up to 6000 mg/kg). After one year, the root content reached 806.7 mg/kg, and the plant immobilized 1.13 kg/ha Pb from soil annually (Gong et al., 2018).

In a temperate climate, the best species for vegetating degraded sites belong to the genus: fescue (*Festuca*), ryegrass (*Lolium*), wheatgrass (*Agropyron*), meadow-grass (*Poa*), medick

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(*Medicago*) and vetches (*Vicia*), while the trees that assure a good phytostabilization of the underlayers are: poplar (*Populus*), acacia (*Robinia*), willow (*Salix*), alder (*Alnus*), birch (*Betula)* și maple (*Acer*). Other plants such as: rye (*Secale cereale*), oat (*Avena sativa)*, barley (*Hordeum sativum*), common wheat (*Triticum aestivum*), orchard grass (*Dactylis glomerata*), red fescue (*Festuca rubra)*, Kentucky bluegrass (*Poa pratensis*), annual ryegrass (*Festuca perennis*), perennial ryegrass (*Lolium perenne*), tall meadow oat (*Arrhenatherum elatius*), Timothy grass (*Phleum pratense*) have a major role in nursery culture (Gajić et al., 2018).

In the list of hyperaccumulating plants for Cu are the Indian mustard (*Brassica juncea*), water hyacinth (*Eichornia crassipes*), sunflower (*Helianthus annus*), lentil (*Lemna* sp.), pistachio or marsh lettuce (*Pistia stratiotes*) and *Larrea tridentata* which have a bioconcentration factor of 1000x. The hyperaccumulative species for Zn (and other metals) are: field grass (*Agrostis castellana*), accumulator for Zn, Al, Mn, Pb and hyperaccumulator for As; Indian mustard (*Brassica juncea*), hyperaccumulator for Zn, Cu, Ni, Pb and accumulator for Cd, Cr, U; rapeseed (*Brassica napus*), proposed for phytoextraction of metals Zn, Hg, Cr, Pb, Ag, Se; sunflower (*Helianthus annus*), proposed for phytoextraction of heavy metals, willow (*Salix viminalis*), accumulator for Zn, Ag, Cr, Hg, Se; sage (accumulator for Zn and hyperaccumulator for Cr, Ni, Pb; penny cress (*Thalspi caerulescens*), hyperaccumulator (concentration factor 10000x) for Zn, Cd, Cr, Co, Mo, Ni, Pb. The hyperaccumulators for Cd are a relatively small number of species, including *Thalspi caerulescens*, *Arabidopsis halleri*, *Aramanthus retroflexus* (Oros V., 2011).

Other genres of trees and shrubs that can grow on mining deposits are: wattles tree (*Acacia)*, maples tree (*Acer*), *Azadirachta*, *Albizia*, false indigo shrub (*Amorpha*), *Cassia*, *Dalbergia*, *Eucalyptus*, ash tree (*Fraxinus*), *Grevillea*, leadtrees (*Leucaena*), chinaberry tree (*Melia azedarach)*, mulberries tree (*Morus)*, plane trees (*Platanus*), Indian Beech Tree (*Pongamia pinnata*), Indian gooseberry (*Phyllanthus emblica*), rose (*Rosa*), *Rubus*, tamarisk (*Tamarix*), teak (*Tectona grandis*) (Gajić et al., 2018).

To obtain a stable persistent cover, it is important to use a mixed crop and combinations of grasses, shrubs and trees in phytoremediation of mining soil, as they are types of plants with different roles (Laghlimi et al., 2015).

Cultivation of *L. perenne* with *Alyssum murale* can help the former to accumulate Cu up to 10 mg/kg. Mn mobilization by *Alyssum* hyperaccumulating species can significantly increase Mn levels in *L. perenne* (Anjum et al., 2018).

Among the fast-growing woody plants, in addition to the genus Populus, there are also willow, pine, aspen, birch, beech, eucalyptus.

It is encouraged the selection of native plant species which do not require much maintenance and in time will form self-sustaining communities (Gajić et al., 2018).

The experimental data obtained by Malschi et al. (2013) after tests for phytoextraction, bioaccumulation and bioremediation on samples collected from waste dumps and tailings ponds from mining exploitations in Romania (Rodna, Bistrița-Năsăud, Fundu-Moldovei, Suceava, Aurul in Baia Mare and Târnăveni Chemical Installation platform, Mureș county), indicate that the species of perennial ryegrass (*Lolium perenne* L.), and common water lentils (*Lemna minor* L.), are useful as bioaccumulators and bioindicators for heavy metals and metalloids; *Lolium perene* is a strong bioaccumulator for Mn, Zn, Pb, As, Ba, Cu, Cd and moderate for V, Cr, Co, Ni.

Bacteria-associated plants can improve phytoremediation by altering solubility, bioavailability, and transport of heavy metals and nutrients by altering soil pH, releasing chelates (sideropores, organic acids, biosurfactants, glycoproteins), methylation, P solubilisation, or redox exchange (Ansari et al., 2018).

RESULTS AND DISCUSSIONS

Methods and discussions over the cost and the choice of remediation techniques

Combined remediation involves the application of two or more physical, chemical and/or biological remediation technologies. Thus, the limitations of using a single technology are completed, with various advantages in order to

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improve the efficiency of remediation (such as: chemically assisted phytoextraction, electrokinetic remediation coupled with complexing agents, electrokinetic remediation combined with phytoextraction, heat treatment facilitated by citric acid, soil washing coupled with chemical stabilization, chemical stabilization and phytoremediation (Gong et al., 2018).

Achieving the expected effect of the depollution technology should be based on phytoremediation, supplemented by physical and chemical microbial methods, to increase the bioavailability of heavy metals (Yang et al., 2019).

Despite their high efficiency, most of the depollution methods are expensive, environmentally destructive (do not allow natural recovery) and time consuming (Gomes, 2019).

The choice and applicability of a particular technology depends on the following factors: cost, long-term efficiency and performance, commercial availability, its general acceptance, applicability in cases of mixed soil pollutants (organic and inorganic compounds), reduction of toxicity, reduced mobility, reduced volume (Wuana and Okieimen, 2011).

Phytoremediation is cheaper (60-80%) than the physico-chemical process, because it does not require expensive equipment or exceptionally meticulous recruits (Jan et al., 2016).

The US Environmental Protection Agency (2004) reported that the total value for phytoremediation of the soil varied from 25 USD/t to 100 USD/t, compared to 300-500 USD/t for vitrification and 75-210 USD/t for soil washing. The Federal Remediation Technologies Roundtable (FRTR, in 2007) reported a cost range between 50 USD and 117 USD/m^2 for electrokinetic remediation and 33-32 USD/m^2 for soil washing. Martin and Ruby (2004) estimated a cost of 40-65 USD/m^3 for in situ chemical stabilization. Chang and Yen (2006) estimated a cost of 834 USD/ m^3 for a large-scale thermal desorption process (750°C for 3 hours) for the treatment of mercury-contaminated soil. The cost of landfill for a contaminated site and chemical recycling of contaminants varies between 100 and 500 USD/t, and the cost for electrokinetic monitoring is about 20-200 USD/t, while the costs involved in phytoextraction are 5-40 USD/t (Parmar et al., 2015).

For a large area of contaminated soil or sediment, in situ remediation is more suitable because it causes less disruption to the ecosystem, is simpler as a method and with lower costs than ex situ remediation (Song et al., 2017).

Methods of replacing contaminated soil, removing soil and isolating the soil will cost a large amount of labor and material resources, so they can be applied only on small areas of soil (Chao et al., 2014; Gomes, 2019).

Soil washing is another strategy to depollute soil contaminated with heavy metals, but it has been reported that it is not suitable for plant growth and development due to the impediment of biological and chemical activities. Chemical methods are not preferable due to changes in soil texture and structure, costs and generation of large amounts of sludge (Hasan et al., 2019).

Phytoremediation rejuvenates the vegetal soil layer, does not leave solid wastes and can successfully replace incineration, thermal vaporisation, solvent washing and soil washing, which are procedures that disturb the physico-chemical and biological qualities of the soil and form non-biodegradable waste (Jan et al., 2016).

Phytoremediation depends on climatic and meteorological conditions (Gong et al., 2018).

To reduce the contamination of soils polluted with heavy metals, the planting and harvesting of hyperaccumulating plants must be repeated. Depending on the target metal and the selected plant, the duration of the process can vary from 1 to 20 years (Parmar et al., 2015).

CONCLUSIONS

In Maramureș mining area, with the closure of mining activities near the mines of Cavnic, Borșa, Baia Sprie, as well as around the municipality of Baia Mare, numerous of polluted dumps of sterile remained.

The special problems regarding the quality of the environment in the county are determined by a historical pollution, resulting from the activities of extraction and processing of polymetallic and gold-silver ores deposits, which have affected for a long time with specific pollutants (gases, dusts and heavy metals) the environment factors.

In order to support development and urbanization, the areas used in the past in industry in Baia Mare mining basin must be introduced in use, so it is necessary the implementation of measures for the remediation of the affected areas.

In situ remediation offers a number of potential technical, economic and environmental benefits. In some cases, on-site remediation is the only means of eliminating pollutants when considering the extent of the contaminated area and cost-effectiveness.

The method presented in this article to restore the areas affected by heavy metal pollution is by implementing phytoremediation technology for soils contaminated with heavy metals.

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ECOLOGICAL RESTORATION OF THE POLLUTED SOILS WITH HEAVY METALS. CASE STUDY: CUPROM SA BAIA MARE BRANCH

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Abstract

The paper aimed to present a possible solution for ecological restoration of the soils polluted with heavy metals from the premise of Cuprom SA Bucharest, Baia Mare branch. This premise is famous for a prolonged industrial activity in smelting and refining metallic ores, especially copper, lead and precious metals as gold and silver. The impact over the environment during the production phase was well documented, but after the plant ceased the activity in 2009, the land remained as heavily polluted industrial area in the way of the urban development. The paper presents a possible solution to restore these soils polluted with heavy metals from the premise using an innovative method of soil washing under specific conditions to remove the mobile fraction of the pollutants from the matrices of the soil. The solution presented is minimum invasive, with promising results in the laboratory phase, applicable on site and cost effective.

Key words: *ecological restoration, heavy metals, Cuprom SA.*

INTRODUCTION

The impact of the human activity over the environment is a subject of actuality, largely debated and with influence over all the aspects of the human society. Even if we refer to climate change, deforestation, uncontrolled development or industrialization, environment protection is and provocative and debatable subject of our daily actuality.

Romania has a history, like most of the countries from the former communist bloc, regarding industrial sites largely and uncontrollable developed in the mid XXth century, disregarding any environmental laws and principles, and abandoned from various reasons after 1990.

In Romania has resulted from the former industrial activity a number of 1682 contaminated sites from which 395 represent potentially contaminated sites, whose level of contamination was not determined yet, and the rest of 1287 proved and documented contaminated sites. (National Strategy and National Plan of Action for Management of the Contaminated Sites from Romania, 2015).

In Maramures region the industrial sites were related to mining activity and mineral processing due to the fact that this region is rich in mineral ores.

The activity left behind a series of industrial sites, landfills and mining sites polluted with heavy metals, actually abandoned. These sites still affect the quality of the environmental factors even after 25 years after the activity cease.

The problem with the industrially contaminated sites from the region is that the pollutants identified here are not biodegradable, can be mobilized by the variations in the environmental factors, can accumulate in time.

Cuprom SA Bucharest, Baia Mare branch was an industrial processing plant placed in the industrial zone in the eastern side of Baia Mare which was specialized in producing copper, lead and rare metal (gold and silver) production. The activity was placed on a 58 ha surface and after its closure in 2009 the plan was abandoned, partially demolished and fragmented.

Various remedial approaches were proposed during the years for decontaminating the site and reintroducing the placement in the industrial zone. Many of them were impossible to apply due to the level of contamination and many were more expensive than the value of

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the land itself which leaded to uninterested from the possible investors.

Worldwide a large number of studies were conducted to reduce the risk of potentially toxic elements to human health and the ecosystem (Hasegawa et al., 2019).

These remediation technologies are categorized into three broad groups: physical, chemical, and biological, and have been analyzed and described in several reviews (Shahid et al., 2012; Saifullah et al., 2015; Begum et al., 2016; Rahman et al., 2016; Khalid et al., 2017).

The Cuprom site was analyzed in the possibility of remedial solutions, described in various articles (Boros et al., 2015; Damian et al., 2008; Coman et al., 2010)

A most recent trend in remedial solution for heavy metal polluted industrial soils represents the soil washing method using chelators. The method offered good results in laboratory analysis in specific regions, as reviewed by Hasegawa et al., 2019, for reducing lead, copper and zinc concentrations.

In this study a soil washing method was applied on the soils from Cuprom SA Baia Mare Branch to determine the capability of this method to stabilize and reduce the heavy metal load in a less expensive and non-invasive way.

MATERIALS AND METHODS

Considering the large surface of the industrial site and the legal situation and also the uneven distribution of the pollutants in the land, we decided to survey a well delimited surface of 5000 sqm from the site. The choice of the survey area was delimited so it contains the documented pollution hot-spots based on bibliographic study.

The areal includes objectives as: Oxygen factory, Smelting, Electrolysis and the Copper factory. Geographically the area of research is delimited in the square formed by the coordinates (Table 1, Figure 1).

Table 1. Research area delimitation (coordinates in Stereo 70)

Point	Coord. X	Coord. Y
1	394972.3386	684931.0393
2	395445.3700	685046.7763
3	395480.3657	684897.5287
4	395007.5597	684790.4465

Figure 1. Research area (image source: Google Earth)

Soil samples were collected from 12 points from the research area to characterize the initial load in heavy metals. The soil samples were collected in correspondence with the national law Ord. 184/1997, Appendix A3, from 5 and 30 cm depth. The samples were marked and stored in plastic sealed bags until they arrival in the laboratory. The sample place was identified in geographical coordinated using a GPS in order to identify on the map.

The soil samples were dried to a constant weight in an oven at 65°C, and reduced to a size of 2 mm by separating foreign objects and materials and shredding.

The collected samples were divided quantitatively into two sub-samples, one to analyze the initial load of the site and one for experimenting soil washing technology using chelators.

The metal concentration from the soil samples was determined using atomic absorption spectrometry with Perkin Palmer PinAAcle 900T spectrometer according to the methodology provided by SR ISO 11466:99 and SR ISO 11047:1999.

The researched metal composition was reduced to lead, copper and zinc identified as the main pollutants according to previous documenttations (Damian et al., 2008).

The concentrations of lead copper and zinc in the sampled area at 5 cm depth are presented in the Table 2 and at 30 cm depth in Table 3 comparatively with limit values from the national law Order 756/1997.

For a visual characterization of the distribution of the pollutants in the surveyed area a spatial distribution was performed using software Surfer 16.

The values of concentration were integrated in the software according to sample location and interpolated using Kriging method. The spatial distribution was overlay on the orthophoto plan.

The second batch sample were submitted to a soil washing technology using chelators in a variation of pH conditions.

The performance of chelators in washing processes has been widely assessed, and they have been found to efficiently remove potentially toxic elements and to have less severe effect on the environment (Peters, 1999; Tandy et al., 2004; Begum et al., 2012, Hasegawa et al., 2019). Chelators also have high complex formation constants under weakly acidic to alkaline conditions, and to not require the use of heating or strong acids during extraction. Chelators are thus considered to be suitable extractants for a wide variety of potentially toxic elements and are expected to reduce the cost and the environmental burden of the metal extraction process (Hasegawa et al., 2011; Pinto et al., 2014; Begum et al., 2016, Hasegawa et al., 2019).

In our study we used EDTA (2,2',2",2"' - (ethane-1,2-diyldinitrilo) tetra-acetic acid) in concentration of 0.1 mol/l and 0.01 mol/l.

Seven samples were created from the collected soil, using quarter method and were treated as follows:

Sample 1 - pH correction to neutral and periodic mixing with EDTA solution 0.1 mol/l in a ratio of 5 g soil/1 g EDTA solution;

Sample 2 - pH correction to 3 and periodic mixing with EDTA solution 0.1 mol/l in a ratio of 5 g soil/1 g EDTA solution;

Sample 3 - natural pH and periodic mixing with EDTA solution 0.1 mol/l in a ratio of 5 g soil/ 1 g EDTA solution;

Sample 4 - pH correction to neutral and periodic mixing with EDTA solution 0.01 mol/l in a ratio of 5 g soil/1 g EDTA solution;

Sample 5 - pH correction to 3 and periodic mixing with EDTA solution 0.01 mol/l in a ratio of 5 g soil/1 g EDTA solution;

Sample 6 - natural pH and periodic mixing with EDTA solution 0.01 mol/l in a ratio of 5 g soil/1 g EDTA solution;

Sample 7 - blank sample.

Analytical grade solutions were used during the study without further purification.

The EDTA solutions were created using distilled water produced by a Fistreem Cyclone water distillate. The samples were weight using a Kern laboratory scale with the precision of 0.0001 g. The solutions were prepared using an Unimax 1010 orbital agitator. The pH of the samples was determined using a Hanna HI 99121 pH-meter. For pH correction to neutral a solution of Na (OH) 1 mol/l was used and respective H_2SO_4 1% solution to correct the pH to 3.

Mixing of the samples with the EDTA solutions were performed weekly for a period of 3 moths (91 days). The samples were placed inside vessels from plastic inert materials, perforated at the bottom and with collectors for the washing solution. The chelator was dosed by spraying over the sample in a time span of 5 minutes for letting the chelator to react and absorb in the material.

This method of applying was used to simulate an onsite application without removing the soil. After the experimentation period the samples were analyzed regarding the concentration of heavy metal by atomic absorption spectrometry.

RESULTS AND DISCUSSIONS

The initial contamination of the surveyed area reflected the prepositions of the bibliographical study revealing concentrations 570x higher than normal values for copper, 354x higher than normal values for lead and 292x higher than normal values for zinc. The values reflect a high-level contamination and an uneven distribution of the contamination in the surveyed area, as presented in the tables and figures below.

Table 2. Level of contamination at 5 cm depth

Contamination at 5 cm (mg/kg soil)			
Sample point	*Cu*	*Pb*	*Zn*
Electrolysis	3400	1640	1433
Eastern extremity of Electrolysys	7033	3577	2790
Product Storage	3180	1520	1507
Smelting	2913	1537	2107
Oxygen factory	5776	4243	29166
Normal values (Ord. 756/1997)	*20*	*20*	*100*
Attention level for less sensitive use	*250*	*250*	*700*
Intervention level for less sensitive use	*500*	*1000*	*1500*

A series of hot-spots are identified regarding the spatial distribution of the pollutants, in the extremity of the Electrolysis we observe an accumulation of copper and lead at 5 and 30 cm depth and a surface accumulation of zinc in the area of the Oxygen factory.

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Table 3. Level of contamination at 30 cm depth

Contamination at 30 cm (mg/kg soil)			
Sample point	*Cu*	*Pb*	*Zn*
Electrolysis	2972	1413	1445
Eastern extremity of Electrolysys	11399	7076	7033
Product Storage	3667	1807	1870
Smelting	3533	2127	2297
Oxygen factory	2666	2263	2610
Normal values (Ord. 756/1997)	*20*	*20*	*100*
Attention level for less sensitive use	*250*	*250*	*700*
Intervention level for less sensitive use	*500*	*1000*	*1500*

In all of the samples the concentration is above the normal values indicated by the national legislation and in some cases the values are 20 times higher than the intervention level of contamination for less sensitive use.

Observing the depth of the contamination we decided to sample deeper, at 2 m depth to identify the level of expansion of the heavy metal contamination in the soil. A sample was taken from the depth of 2 m in the middle of the survey area revealing a concentration 2150 mg Cu/kg soil, 1547 mg Pb/kg soil and 753 mg Zn/kg soil, values high above normal concentration according to national standards.

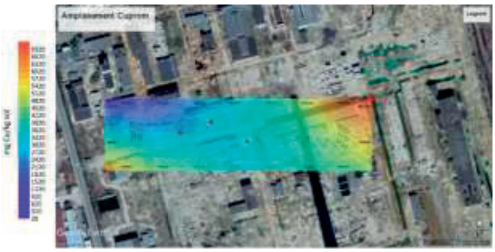

Figure 2. Copper dispersion at 5 cm depth

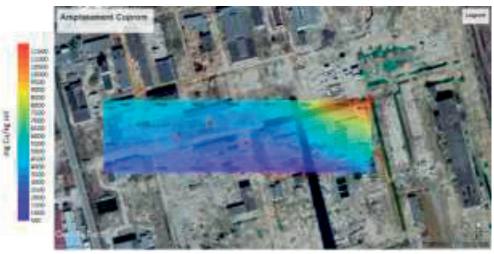

Figure 3. Copper dispersion at 30 cm depth

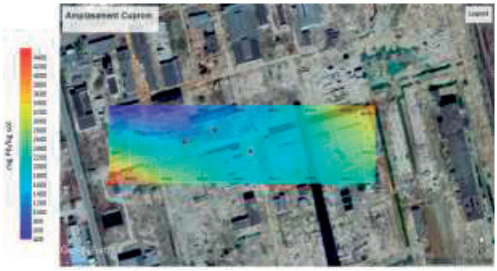

Figure 4. Lead dispersion at 5 cm depth

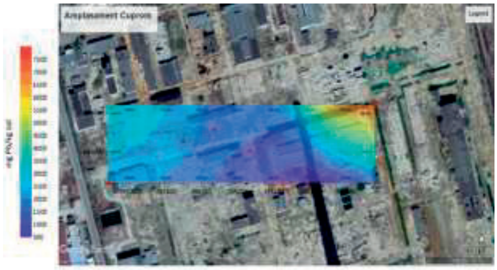

Figure 5. Lead dispersion at 30 cm depth

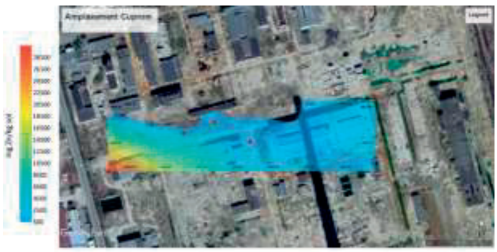

Figure 6. Zinc dispersion at 5 cm depth

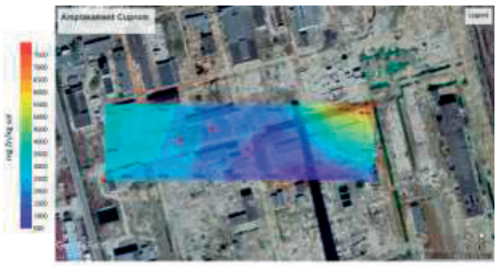

Figure 7. Zinc dispersion at 30 cm depth

The values identified at 30 cm and completed with the 2 m depth sample values proves the migration of pollutants in depth during the almost 100 years of industrial activity o site due to natural leaching or repeated in depth interventions on the site which determined a mixing of the structural composition of the soil.

The soil washing method applied had the goal to reduce the concentration of contaminants under the limit of intervention which will allow to use the site for further industrial development. The results, after applying the method for 3 months, are presented in the Table 4.

Table 4. Contamination after soil washing

	Variation	Cu (mg/kg soil)	Pb (mg/kg soil)	Zn (mg/kg soil)
Sample 1	pH 7, EDTA 0.1 mol/l 5:1	2080	1320	1920
Sample 2	pH 3, EDTA 0.1 mol/l 5:1	2920	1646	1723
Sample 3	pH natural, EDTA 0.1 mol/l 5:1	2290	1376	2056
Sample 4	pH 7, EDTA 0.01 mol/l 5:1	2820	2423	1727
Sample 5	pH 3, EDTA 0.01 mol/l 5:1	2626	2460	1800
Sample 6	pH natural, EDTA 0.01 mol/l 5:1	2743	1706	2256
Sample 7	blank	3256	2680	2306

For comparation a blank sample was made to reflect the initial level of contamination of the sample. All the seven samples were formed from the same type of material, contaminated soil from the site, and equal regarding the quantity and physical characteristics.
The natural pH of the samples, determined at the beginning of the procedure was 8.46. The alkalinity of the sample is due to the fact that the soil is a mixture of imported materials during the functioning of the plant. The pH value varies in the sampled region from 2.5 - strong acidic to 9.2 - alkaline. By mixing the samples to obtain the blank the pH stabilized at the pH of 8.46.
The variation of pH in the determination of chelator efficiency from 3 to the natural pH of 8.46 is due to the variation of the pH of the soil in the sampled region. It is observable from the table above, the most significant results for copper and lead reduction are met at neutral pH with the higher concentration of chelator dosed in the sample.
Regarding the zinc reduction the most satisfying result is in acidic conditions with high concentration of chelator, but almost the same result is obtained at neutral pH with low concentration of the chelator.
The results prove that EDTA chelators work for reducing the concentration of heavy metals in the polluted soils from Cuprom SA Baia Mare and the best results are in neutral pH conditions.
A further research is in progress to determine if a prolonged administration of the chelator can reduce the concentration below the intervention level and an installation is during development for administrating the solution in site and recover the leachate for reusing in the process.
As observed by other researchers (Polettini et al., 2007; Zou et al., 2009; Qi et al., 2011; Hasegawa et al., 2019) the chelator assisted soil decontamination process is highly influenced by the pH value. The solution pH influences several factors e.g., the aqueous species concentration of the potentially toxic elements, the solubilization of the chelators, the sorption and desorption of the pollutants, the ionic exchange and the re-adsorption mechanism of the metal-chelator complexes, among others (Hasegawa et al., 2019). The same influence is clearly observed in the polluted soils from Cuprom SA Baia Mare which determined a variation in the pollutant concentration reduction.

CONCLUSIONS

Chelator assisted decontamination is an experimental method of reducing heavy metal pollutants from the industrially contaminated sites. It is a method which has to be proved for each type of soil due to the fact that it can be very easily influenced by the composition of the soil, the natural conditions, in special the natural pH of the material on which it will be applied.
This technology of decontamination showed significant results for the soils contaminated with heavy metals from the premise of Cuprom SA Baia Mare, by reducing the concentration

of copper with 36%, the concentration of lead with 50% and the concentration of zinc with 25%.

The level of contamination of the site is very high and various and the goal is to reduce the amount of pollution in the limits in which the site can be used as industrial site for further development. In this direction a further research is necessary to determine the limits of the technology and a direct application in the field regarding also the recovery of the chelators and the possibility of recovery also of the metals extracted.

The advantage of the technology is that it is a reduced invasive method and uses available and cheap materials as the chelators. The technology does not involve massive excavations and displacement of the soil. The most important advantage of the technology is that it can be adapted on the level of contamination of the soil.

Heavy metal polluted industrial sites are a national ecological issue in Romania. These sites, even if the activity is ceased, continue to create severe ecological disasters especially in the mining regions. Heavy metal polluted soils, water and the mobilization of dust containing heavy metals from these sites affect the quality of life and the health of population located in the nearby of these premises.

The urban development from the recent years determined the expansion of the cities incorporating the former industrial sites which continue to create a significant impact over the economy and environment.

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GEOCHEMICAL CHARACTERISTICS OF RIVERBED SEDIMENTS IN THE DANUBE DELTA, ROMANIA

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Abstract

Major ($CaCO_3$, TOC, and Fe_2O_3), minor (MnO and TiO_2) and trace (Zr, Cr, V, Zn, Cu, Ni, As, Pb, and Hg) elements from surface riverbed sediments were determined at 66 locations in deltaic environment, along St. George distributary and in the interdistributary depressions of the Danube Delta. The studied area is characterized by terrigeneous, either non-carbonated or low calcareous sediments, quite poor in organic matter. Most of the studied heavy metals showed high spatial variability, generally with higher concentrations in interdistributary depressions and adjacent canals, as well as on the meander Mahmudia (M1). Ni, Cu, and Cr showed concentrations frequently exceeding the quality criteria set in the Romanian legislation. Contamination Factor (CF) and Pollution Load Index (PLI) were used to assess the level of heavy metal pollution in the studied area.

Key words*: major elements, trace elements, Danube Delta, hydrological processes, anthropogenic pressure.*

INTRODUCTION

Geochemical analyses are widely used by the scientists for the determination of the sediment provenance, weathering, diagenesis, heavy-mineral composition, anthropogenic impact and environmental risk assessment (Wu et al., 2013; Babek et al., 2015; Najamuddin et al., 2015; Campodonico et al., 2016; Zhang et al., 2017; Zakir Hossain et al., 2017; Li et al., 2017, Natali & Bianchini, 2017; Mureşan et al., 2019; Bucșe et al., 2020; Ispas et al., 2020; Teaca et al., 2020; Vasiliu et al, 2020). In the fluvial environment, the pollutants are transported by rivers, both as pollutants in solution and adsorbed to suspended solids suspended sediments, under specific flow conditions. The concentration of different pollutants (e.g. heavy metals, pesticides) in the fluvial deposits can be higher due to the remobilization of the older sedimentary deposits of pollutants during the erosion and accumulation processes (Oaie et al., 2005; 2015).

Antropogenic activities, such as construction of dams, hydrotechnical work on the channel planform (e.g. groins, embankments, jetties, meander cut-off) represent important factors in the sedimentary processes by segmentation or even interruption of the sedimentary flow downstream the reservoirs (Tiron Duţu et al., 2019). Two large dams were built at Km 943 (Iron Gates I) and Km 863 (Iron Gates II), in 1973 and 1984, respectively, in the Danube lower segment, having a significant impact on the water and sediment fluxes and, consequently, on the environmental state (Vadineanu, 2001; Panin, 2003; Romanescu, 2013; Romanescu & Stoleriu, 2014; Habersack et al., 2016). Combined with the hydro-technical regulation works along the Danube tributaries, abovementioned dams have dramatically decreased the sediment discharges measured at the Danube's mouths (within 25-30%) (Panin & Jipa, 2002; Panin, 2003; Panin et al., 2016).

Located in the south-eastern part of Romania, the Danube Delta is the largest delta in the European Union covering about 5640 km^2 with a very complex network of canals and lakes (Panin, 2003; Driga, 2004). The Danube input of freshwater supplies the natural lakes and channels through its main distributaries (Kilia, Sulina and St. George). The Danube Delta acts as a natural filter for about 7 to 10% of the total water, sediments and pollutants discharges of the river into the sea (Oaie et al., 2015).

In the Danube Delta, the present hydro-morphological and sedimentological processes are the result of a multiple series of anthropic works located in the Danube Basin but also inside the delta. In the last 200 years, the cut-offs programme of the Sulina and St. George branches brought a redistribution of water and sediment discharges among the delta distributaries (Panin, 1999; Panin & Jipa, 2002; Driga, 2004; Romanescu, 2013). The artificial canals along the St. George branch produced aggradation on the former meanders and erosion of the artificial canals (Popa, 1997; Jugaru Tiron et al., 2009; Tiron Duţu et al., 2014) (Figure 1).

Geochemical studies carried out on the Danube River (Secrieru & Secrieru, 1996; Oaie et al., 2000, 2005; 2015; Catianis et al., 2018) showed many pollution sources resulting from human activities (such as mining exploitations, the hydroelectric power stations, the waste and the sewage, the agriculture farms), and local natural impacts (e.g. geology of the basement; fossil littoral beaches).

A study on the distribution of the geochemical compounds on a rectified meander system of the Danube Delta (three rectified meanders of the St. George branch, Mahmudia, Dunavat de Sus and Dunavat de Jos meanders), realised by Tiron Dutu et al. (2019), concluded that the chemical composition correspond to terrigenous, non-carbonated and low-calcareous, with the occasional presence of calcareous sediments. According to the Order 161/2006, authors have found the quality of the sediments generally as good, with some isolate exceptions for Cr, Cu and Ni.

MATERIALS AND METHODS

This study present geochemical data acquired along the St. George branch in September 2020. The sediments were sampled in high flow period, at a daily discharge of 2,169 $m^3 \cdot s^{-1}$ (measured at Ceatal St. George knot) (Figure 1).

Surface sediment samples were collected with a grab sampler from 66 locations distributed along the branch, on the main channel and former meanders (Mahmudia, Dunavăţ de Sus, Dunavăţ de Jos, Perivolovca, Dranov de Sus, Dranov de Jos, Ivancea meanders, noted here as M1, M2, M3, M5, M5, M6 and M7, respectively); few samples have been collected in the interdistributary depressions (Uzlina and Gorgostel Lakes) and adjacent canals (Dunavat, Uzlina, Mahmudia, Perivolovca and Garla Tuceasca canals) (Figure 1).

Figure 1. Location of the sediment samples along the St. George branch, in the Danube Delta. The lines in red represent the artificial canals of the rectified meanders

Prior to geochemical analysis the sediment samples were oven dried (24-48 h/105°C), ground, and homogenized using a mortar grinder RM 200 (Retsch, Germany) and sieved with a 250 µm stainless steel sieve. The total organic carbon (TOC) and $CaCO_3$ concentrations were determined in accordance with WakleyBlack titration method modified by Gaudette et al. (1974) and Black (1965), respectively. The concentrations of Fe_2O_3, TiO_2, MnO, Zr, Cr, V, Zn, Cu, Ni, As, and Pb were measured by X-ray fluorescence spectrometry using an EDXRF Spectro Xepos spectrometer with a Pd/Co tube and XRF AnalyzerPro software (v. 3.3.2). Total Hg content was determined using an automatic mercury analyzer DMA 80 Milestone (Italy), by solid sample thermal decomposition, identification, and quantification of total Hg by atomic absorption spectrophotometry.

To validate the analytical methodology, a certified reference material (NCS DC 73022) was used. The measured and certified values of element/compound concentrations were compared (Table 1). All of the results obtained for this reference material were statistically similar to the certified values ($p<0.05$), demonstrating the reliability of the methodology and the estimated concentrations. The relative standard deviations of the measured replicates were all within ± 5%.

Table 1. Measured and certified values of standard material NCS DC 73022

Element	Measured value (mg/kg) ± s.d	Certified value (mg/kg) ± s.d	Recovery %
Fe_2O_3	7.13±0.31	7.05±0.11	101.1
MnO	0.11±0.03	0.103±0.03	106.7
Ti	0.50±0.06	0.45±0.02	111.1
Zr	253±3	241±30	104.5
As	289±2	304±20	95
Ni	31.8±0.15	29±1	110
Cu	513±4.8	483±20	106
Cr	75.5±1.8	72±3	104.9
V	97.7±1.9	101±3	96.7
Zn	900±10.9	874±19	103
Hg	0.122±0.005	0.115±0.023	106
Pb	134.0±0.9	126±5	106.3

RESULTS AND DISCUSSIONS

$CaCO_3$ showed relatively low concentrations, ranging within 5.11-16.25% (Table 2). 43% of those values were lower than 10%, while 57% were between 10 and 30%, thus suggesting terrigenous sediments (either non-carbonated or carbonated) according to (Emelyanov & Shimkus, 1986). The highest $CaCO_3$ concentrations were measured in the sampling sites located in the Ceatal St. George area (stations P01 and P02). Concentrations quite close to the maxima were also registered at the entrance of M5 (station P34) and in Gorgoştel Lake (L06).

Total Organic Carbon (TOC) showed very high spatial variability (coefficient of variation >130%), with concentrations varying between 0.002% and 2.60% (Table 2). This high variability is due to the biogenic origin of TOC, in addition to its chemical instability and the dependence of its conservation in sediments both on grain size (fine particles preserve much better the organic matter) and local physical-chemical conditions (Tiron Duţu et al., 2019). Most of the TOC concentrations were lower than 1%, especially on the main channel and meanders, thus suggesting coarse, sandy sediments that are well aerated and allow post-depositional remineralization of organic matter in those sites. TOC concentrations higher than 1% are more frequent in the lakes (Gorgoştel Lake, Uzlina Lake, and Erenciuc Lake) suggesting fine sediments, which allows the conservation of organic matter in sediments, but also a higher primary productivity of the water column.

Another major component of sediments, Fe_2O_3, showed values between 1.17 and 6.26% (Table 2) measured at stations P01 and P44, respectively. The spatial variability of Fe_2O_3 was rather moderate (CV = 43%), higher concentrations being found on meanders (especially on M1 and M6), while the minima were measured along the main channel.

The minor components of surface sediments, MnO and TiO_2, showed moderate to high spatial variability (CVs of 46% and 52%, respectively), with concentrations ranging within 0.02-0.18% and 0.15-2.24%, respectively. MnO showed maxima on meanders M1 (0.11-0.13%) and M6 (stations P40 - 0.13% and P42 - 0.18%), while TiO_2 registered maximum at station P42. Generally, the MnO concentrations were relatively low (0.07 ± 0.03%), suggesting weakly reducing conditions in the sediments (including the sediments from the studied lakes).

Trace elements concentrations showed high spatial variability (coefficients of variation >45%), with maxima for Hg (154%), Cu (104%), and Zr (87%) (Table 2).

The spatial variability of Zr is determined by its presence exclusively in the form of zircon, whose sedimentation depends on the hydro-dynamic environmental factors, which determine the concentration of the mineral in accumulations of heavy minerals, characteristic of coarse sediments. The statistically significant positive correlation between Zr and Ti (Table 3) suggests the association of representative minerals in heavy mineral concentrations.

Table 2. Descriptive statistics for the concentrations of the studied variables

	TOC %	$CaCO_3$ %	F2O3 %	MnO %	TiO_2 %	Cr mg/kg	Zr mg/kg	Ni mg/kg	Cu mg/kg	Zn mg/kg	As mg/kg	V mg/kg	Pb mg/kg	Hg mg/kg
Min.	0.002	5.11	1.17	0.02	0.16	21.59	36.76	13.47	0.15	15.46	1.92	10.64	8.81	0.007
Max	2.60	16.25	6.26	0.18	2.24	356.0	1055	73.5	73.4	141.0	15.79	105	36.93	0.64
Mean	0.34	10.49	3.23	0.07	0.53	95.36	189.0	35.27	18.54	55.3	6.01	48.47	16.87	0.06
St. Dev.	0.46	2.46	1.45	0.03	0.28	62.6	164.0	17.67	19.24	35.81	3.46	28.33	7.65	0.09
CV	135.7	23.4	43.5	46.2	52.9	65.6	86.7	50.1	103.7	64.7	57.7	58.5	45.3	154.2

Table 3. Correlation matrix (Pearson) for the major constituents, minor constituents and heavy metals

Variables	TOC, %	$CaCO_3$, %	MnO, %	Fe_2O_3, %	TiO_2, %	V, mg/kg	Cr, mg/kg	Ni, mg/kg	Cu, mg/kg	Zn, mg/kg	As, mg/kg	Pb, mg/kg	Hg, mg/kg	Zr, mg/kg
TOC, %														
$CaCO_3$, %	**0.45**													
MnO, %	**0.36**	**0.41**												
Fe_2O_3, %	**0.54**	**0.51**	**0.95**											
TiO_2, %	0.14	**0.33**	**0.80**	**0.67**										
V, mg/kg	**0.66**	**0.51**	**0.76**	**0.91**	**0.36**									
Cr,mg/kg	0.06	0.17	**0.60**	**0.49**	**0.65**	0.22								
Ni,mg/kg	**0.66**	**0.49**	**0.73**	**0.89**	**0.33**	**0.98**	0.18							
Cu,mg/kg	**0.81**	**0.40**	**0.63**	**0.79**	**0.25**	**0.90**	0.13	**0.89**						
Zn, mg/kg	**0.74**	**0.41**	**0.74**	**0.87**	**0.36**	**0.94**	0.22	**0.93**	**0.98**					
As, mg/kg	**0.63**	**0.41**	**0.69**	**0.83**	**0.28**	**0.92**	0.16	**0.91**	**0.87**	**0.90**				
Pb, mg/kg	**0.76**	**0.28**	**0.64**	**0.77**	0.24	**0.87**	0.13	**0.87**	**0.97**	**0.97**	**0.89**			
Hg, mg/kg	**0.61**	**0.26**	**0.40**	**0.48**	0.15	**0.54**	0.09	**0.52**	**0.75**	**0.71**	**0.64**	**0.76**		
Zr, mg/kg	-0.01	**0.28**	**0.62**	**0.47**	**0.88**	0.19	**0.48**	0.14	0.08	0.18	0.11	0.05	0.09	

Values in bold are different from 0 with a significance level alpha = 0.05

The very high heterogeneity of Hg is mainly due to an abnormal peak (0.64 mg/kg) observed at station P03, where also Cr (132 mg/kg) and Cu (60.3 mg/kg) showed high concentrations, suggesting a local pollution. Hg concentrations exceeding the quality criteria in effect in Romania (Order 161/2006) were observed mostly in the interdistributary depressions and adjacent canals (0.10-0.24 mg/kg), but also on M1 (0.11-0.15 mg/kg). Cu and As, which showed maximum in the sediments of Gorgostel Lake (L06) and Uzlina Canal (L01), respectively, while the other analysed heavy metals presented the highest concentrations on meanders, specifically M1 (V, Zn, and Pb) and M6 (Ni). The lowest values of heavy metal concentrations were generally measured on the main channel (Cr at station P01, Cu and Pb at station P19, As at station P23 and V, Ni, Zn, and Hg at station P31).

Cu, Ni, Pb, V, As, Zn, and Hg showed significant positive correlations either each other or with TOC and Fe_2O_3 (Table 3), thus suggesting their association in the terrigenous material (sediments). Cr showed significant positive correlations with MnO, Ti, Sr, and Zr

(Table 3), indicating its predominantly natural origin.

Depending on their concentrations in sediments, some chemical compounds can adversely affect benthic organisms, which live on the surface of sediments or in their mass. For such compounds, including some of the heavy metals determined in this study, the Romanian competent authority issued the Order 161/2006, which provides a number of quality criteria (Table 4).

Table 4. Quality criteria for heavy metals in sediments (Order 161/2006) and number of samples exceeding the criteria

Metal	UM	Ord. 161/ 2006	Concentrations exceeding Ord. 161 criteria
Total chromium (Cr^{3+}+Cr^{6+})	mg/kg	100	15
Copper	mg/kg	40	12
Lead	mg/kg	85	0
Zinc	mg/kg	150	0
Nickel	mg/kg	35	30
Arsenic	mg/kg	29	0
Total mercury	mg/kg	0.300	1

Among the analysed metals, Ni, Cu, and Cr showed frequent exceeding of the quality criteria (Table 4). Similar situation was found by Tiron Duţu et al. (2019), who showed the relatively high number of concentrations of Cr, Cu and Ni exceeding the quality criteria is mainly due to their geogenic origin. Hg exceeds the quality criterion only at station P03, while V, As, Pb, and Zn presented all concentrations below the allowed limits.

However, besides the national quality criteria, a pollution index, namely the Contamination Factor (CF) was used for assessing the level of sediment pollution in the studied area. CF is the ratio obtained by dividing the concentration of each metal in the sediment by the background value (concentration in uncontaminated sediment), according to the following formula 1:

$$CF = CF_i = \frac{C_{i,s}}{C_{i,b}} \text{.................................(1)}$$

where:

$C_{i,s}$ is the concentration of metal *i* in the sample;

$c_{i,b}$ is the background concentration of metal *i*. Since no background data for metals in uncontaminated sediments in the study area are available, the concentration of metal *i*, $C_{i,b}$ (mg/kg), in the surface sediments of upper continental crust reported by Rudnick and Gao (2003) was used as a background value (*i.e.*, $c_{As,b}$ = 4.8 mg/kg, $c_{Pb,b}$ = 17 mg/kg, $c_{Cu,b}$ = 28 mg/kg, $c_{Hg,b}$ = 0.05 mg/kg, $c_{Ni,b}$ = 47 mg/kg, $c_{Cr,b}$ = 92 mg/kg, $c_{V,b}$ = 97 mg/kg and $c_{Zn,b}$ = 67 mg/kg).

CF values were interpreted as suggested by Hakanson (1980), where CF < 1 indicates low contamination; 1 < CF < 3 is moderate contamination; 3 < CF< 6 is considerable contamination; and C > 6 is very high contamination.

The CF values were from 0.2-3.9 (Cr); 0.3-1.6 (Ni); 0.1-2.6 (Cu); 0.2-2.1 (Zn); 0.4-3.3 (As); 0.1-1.1 (V); 0.5-2.2 (Pb); and 0.1-12.8 (Hg). Arsenic and total chromium showed the highest mean CF (1.3 ± 0.7 and 1.1 ± 0.7), each of them with ca. 50% of values between 1 and 3, thus suggesting a moderate contamination. The abnormally high CF for mercury is associated with the peak registered at station P03. Although excluding this value, the number of CF_{Hg} > 1 were rather high (ca. 40%), thus suggesting a moderate contamination as well. Cu, Ni, Zn, and Pb showed low to moderate contamination; means < 1 and smaller percentages of the CF value between 1 and 3 (31%, 31%, 18%, and 37%, respectively).

In order to assess the spatial variability in pollution intensity, an empirical index, namely Pollution Load Index (PLI), was used. PLI is determined as the n^th^ root of the product of n CFs, according to the formula 2 below:

$$PLI = \sqrt[n]{(CF1xCF2xCF3x \dots .xCFn} \text{.................(2)}$$

According to Tomlinson et al (1980), PLI values > 1 suggests that pollution exists, while PLI < 1 means that there is no metal pollution.

In the studied are, PLI ranged from 0.2 to 1.9, with 35% of the values >1, suggesting that heavy metal pollution exists some sampling sites. Most of these sites are located in the interdistributary depressions and adjacent canals, as well as on M1.

CONCLUSIONS

The studied area is characterized by terrigenous, non-carbonated and low-calcareous sediments ($CaCO_3$ within 5.11-16.25%), relatively poor in organic matter (TOC within 0.002-2.60%). Only few of TOC concentrations were > 1, mainly in the interdistributary depressions and adjacent canals.

The mean concentrations of heavy metals were 189.02 mg/kg (Zr), 95.36 mg/kg (Cr), 35.27 mg/kg (Ni), 18.55 mg/kg (Cu), 55.31 mg/kg (Zn), 6.01 mg/kg (As), 48.47 mg/kg (V), 16.87 mg/kg (Pb), and 0.06 mg/kg (Hg). Cr, Cu, and Ni frequently exceeded the quality criteria set in the national Order 161/2006, but it does not necessarily mean an intense pollution process.

The heavy metal pollution in the studied area was investigated based on the following indices: CF (contamination factor), and PLI (pollution index load). The highest CF was determined for As, followed by Cr and Hg (moderate contamination), while the lowest CF, suggesting no contamination was observed V. Ni, Cu and Zn showed low to moderate contamination. PLI values showed that the surface sediments are partially polluted (35% of PLI higher than 1), mainly in the interdistributary depressions and adjacent canals, but also on M1.

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ENVIRONMENTAL RISKS IN IRRIGATED AGRICULTURE

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Abstract

The influence of heavy metals content in irrigation waters and irrigated soils on the quality of plant products was studied. In samples of irrigation water, irrigated soil and vegetables (tomato), the content of Cu, Zn, Co, Ni, Pb, Cd, Fe, Mn was determined. The studies were carried out in regions with different levels of technogenic loading.
At a minimum technogenic loading, the heavy metals content in water and soil was estimated as background. The heavy metal contamination wasn't found in the water-soil-plant system. With local pollution, the Pb content in water and soil exceeds the background by 3-5 times, in vegetables it exceeds the Maximum allowable concentrations (MAC). With regional pollution (industrial zone, Donbas), the content of Cd, Co, Pb in water and soil exceeds the background by 3-12 times, the content of Cd, Pb exceeds the MAC in vegetables. At significant technogenic loading irrigation intensifies the hazard of pollutants to accumulate in vegetables and poses serious risks to public health and the environment. The control of heavy metals content in the water-soil-plant system is necessary for ecologically safe agriculture.

Key words*: heavy metals; irrigation; irrigation water; soils; vegetables.*

INTRODUCTION

Land resources of Ukraine are the most valuable national wealth. This is due to the prevalence of fertile chernozem soils in the country's soil cover. However, long-term ecologically unbalanced farming, imperfect management of protection and reproduction of land resources in Ukraine have led to significant degradation of the soil cover (Stashuk et al., 2009; Baliuk et al., 2015). Soil degradation, including soil pollution, has become threatening in the country.
At the same time, sustainable agriculture has an important role to play in achieving many of the 2030 Sustainable Development Goals (SDG) (Transforming our World, 2015). Climate change will put additional pressure on agricultural production systems as they strive to meet the food needs of a growing population (FAO, 2020). Climate change has already caused a seriously disrupting rainfall patterns, increasing the frequency of droughts and emergencies. Agriculture will face the effects of climate change much earlier than society as a whole. The consequence of global warming will most likely be an increase in the area of irrigated land. Under these conditions, irrigated agriculture has an important role to play on the path to sustainability.
However, in large areas of all continents, there is a high degree of degradation of ecosystems. More and more food security depends on soil and water quality. Meeting SDG 2, 3, 6, 13, 15 targets will only be possible if people have enough food to eat and if what they are eating is nutritious and affordable (FAO, IFAD, UNICEF, WFP and WHO, 2020).
Heavy metals (HM) are among the most aggressive harmful substances that enter agricultural landscapes from anthropogenic sources and can negatively affect the quality of plant products and human health. Currently, heavy metals of technogenic origin in significant quantities enter all components of agricultural landscapes (Kabata-Pendias, 2015; Semenov, 2019; Eugenio, 2020; Baliuk et al., 2017; Bambara et al., 2015; Lu et al., 2016; Malakar et al., 2019). It is HMs that has recently been considered indicators of anthropogenic pressure on soils and landscapes (Kabata-Pendias, 2015). In irrigated agriculture, the problem of HM accumulation is exacerbated, since irrigation waters act as an additional source of metals entering the soil and a factor in increasing their migration. Irrigated

water with a high HM content contributes to the accumulation of these elements in soils and plants to dangerous concentrations, which can harm ecosystems and people.

At the same time, researchers are increasingly using the term “potentially toxic elements” in relation to HMs, since they are essential components of the chemical composition of soil, water and plants, and their toxicity manifests itself when the permissible concentrations are exceeded (Kabata-Pendias, 2015; Nematollahi, 2020; Raj, 2020). There are many elements among HM, the physiological role of which has been proven (Vazhenin, 1976; Kabata-Pendias, 2015; Baliuk et al., 2015). In trace amounts, they are vital for plants, animals and humans.

The concentration of these elements in soil, water, plants can be below optimal, which can cause "hidden hunger". Unfortunately, micronutrient malnutrition is currently widespread in both industrialized and developing countries of the world (Guidelines, 2006; Gödecke et al., 2018). Therefore, it is necessary to study the content of HMs from the point of view of their deficiency and the need to use them in the form of micronutrient fertilizers.

The content of HMs is characterized by significant spatio-temporal variation under the influence of global, regional and local pollution, which makes it necessary to constantly monitor their content in irrigation water, irrigated soils and agricultural plants.

Yield increases on irrigated agricultural land should be accompanied by monitoring of pollutants and soil, water and crop quality (Dragović et al., 2008; Baliuk et al., 2017; Bambara et al., 2015; Lu et al., 2016; Malakar et al., 2019).

Irrigated lands are located in all natural zones (Table 1) of Ukraine.

Table 1. Distribution of irrigated lands in Ukraine by natural areas (Stashuk et al., 2009)

Zone, subzone	Irrigated land (%) of total area of irrigation
Polissya	1.0
Forest Steppe	13.6
Step Northern	31.2
Step Southern	30.4
Steppe Dry	23.0
Carpathian mountain region	0.5
Mountain region of Crimea	0.3

In Forest-steppe and Steppe zones of Ukraine are disposed 98% irrigated lands. In Ukraine, irrigation covers various types of soils, but the main areas of irrigation are chernozems - more than 60% of the total area. Irrigated soils of Ukraine are located in regions with different levels of technogenic load. Therefore, it is necessary to study the content of HMs in irrigated soils, irrigation waters and plant products with regional, local pollution and without significant anthropogenic load. This will assess environmental risks in irrigated agriculture and determine if they can be used in an environmentally friendly manner.

The aim of the study was to determine the influence of the content of heavy metals (Cu, Zn, Co, Ni, Pb, Cd, Fe, Mn) in irrigation waters and irrigated soils on the quality of plant products in regions with different levels of technogenic load. Research objectives:

1) heavy metals content in irrigation water and water quality;
2) mobile forms of heavy metals content in irrigated soils and soil quality;
3) heavy metals content in vegetables (tomato) and tomatoes quality.

MATERIALS AND METHODS

Soil samples were selected on an irregular grid with GPS referencing, taking account of soil and lithological heterogeneity. Soil samples were taken on experimental sections from the boreholes. They were collected from the 0-25 cm, 25-50 cm, 50-75 cm and 75-100 cm depth. More than 20 samples from test tomato were collected immediately prior to harvest. Irrigation water samples were tested several times during the growing season. Mobile heavy metals in soils were determined by extraction with ammonium acetate solution at pH 4.8 for one hour using a 1:5 soil: extractant ratio. The heavy metal content of crops was determined by ashing at 550°C for 5 hours and dissolving the ash in 10 per cent HCl. Water samples were analyzed after drying and dissolving the precipitate in M HCl. In all cases, metals were determined by atomic absorption spectroscopy. Statistical processing of the results was performed using Statistica 10 and MapInfo 11.0.

Site 1 - Merefa stationar (Kharkiv district of Kharkiv region) is located in the southern part

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of the Left-Bank Forest-Steppe of Ukraine with a minimum technogenic loading. The studies were conducted in long-term stationary field experience with irrigation of Institute of Vegetable and Melons Growing NAAS. Soil is chernozem typical (Chernozems Chernic, WRB). Vegetables were grown on the site. Irrigation was carried out with using “suitable” waters Mzha River (national classification of the irrigation water quality). Duration of irrigation is 50 years. Mineralization of irrigation water during irrigation was 0.6-0.8 g/l. Irrigation norms in experiment were (depending on the crops grown and weather condition): 350-1350 m^3/ha. Groundwater depth was more than 11 m.

Site 2 - Kharkiv stationar (Kharkiv district of Kharkiv region) is located in the southern part of the Left-Bank Forest-Steppe of Ukraine, near a large industrial city, under local pollution. The studied sites are production areas with vegetable crop rotation. Soil is chernozem typical (Chernozems Chernic, WRB). Water is “limited suitable” for irrigation (due to the risk of HM soil pollution). The source of irrigation was a pond. Duration of irrigation is 20 years. Mineralization of irrigation water during irrigation was 1.1-1.2 g/l. Irrigation norms were (depending on the crops grown and weather condition): 450-1500 m^3/ha. Groundwater depth was more than 5 m.

Site 3 - Maryinka stationar (Maryinsky district of Donetsk region) is located within the northern part of the Left-Bank Steppe of Ukraine under regional pollution (industrial zone, Donbas).

The studied sites are production areas with vegetable crop rotation. Soil is ordinary chernozem (Chernozems Chernic, WRB). Water is unsuitable or limited suitable for irrigation due to the risk of HM soil pollution. The source of irrigation was the Kurakhovskoe water storages. Duration of irrigation is 50 years. Mineralization of irrigation water during irrigation was 2.9-3.1 g/l. The irrigation rate ranged 1500-3000 m^3/ha. Groundwater depth was more than 10 m.

Irrigation was carried out by sprinkling machines at all study sites.

RESULTS AND DISCUSSIONS

The quality of irrigation water is one of the main factors that determine the direction of soil processes and regimes, physical, physicochemical, biological properties of irrigated soil and its ecological and agromeliorative state. Irrigation water quality affects the quality of plants, both directly through the leaf surface, and indirectly through the soil. Therefore we characterize the quality of irrigation water first of all (Table 2).

Table 2. Content of heavy metals in irrigation water, mg/dm^3
(average ± standard deviation)

Site		Content of heavy metals in irrigation water, mg/dm^3							
		Zn	Cd	Ni	Co	Fe	Mn	Pb	Cu
Merefa stationar		0.016 ±0.004	0.002 ±0.0003	0.012 ±0.001	0.008 ±0.0003	0.053 ±0.007	0.011 ±0.003	0.016 ±0.003	0.004 ±0.001
Kharkiv stationar		0.025 ±0.005	0.003 ±0.001	0.025 ±0.008	0.025 ±0.008	0.098 ±0.049	0.038 ±0.012	0.062 ±0.011	0.009 ±0.003
Maryinka stationar		0.007 ±0.005	0.009 ±0.002	0.058 ±0.010	0.055 ±0.011	0.015 ±0.009	0.059 ±0.017	0.065 ±0.013	0.004 ±0.002
Assessment of water quality by									
Background Forest-steppe of Ukraine [1]		0.016	0.002	0.014	0.010	0.072	0.017	0.024	0.013
Background Steppe of Ukraine [1]		0.013	0.005	0.023	0.023	0.065	0.022	0.032	0.008
National classification of the irrigation water quality	Class 1 - Suitable	< 0.5	< 0.005	< 0.08	< 0.02	< 2.0	< 0.50	< 0.02	< 0.08
	Class 2 - Limited suitability	0.5-1.0	0.005-0,01	0.08-0.2	0.02-0.05	2.00-5.00	0.50-1.00	0,02-0.05	0.08-0.2
	Class 3 – Unsuitable	> 1.0	> 0.01	> 0.2	> 0.05	> 5.0	> 1.00	> 0.05	> 0.2

[1] Authors data

The irrigation water used at Merefa stationar is of high quality. The HM content in it does not exceed the background for the forest-steppe. Irrigation water is of good quality according to the National classification of the irrigation water quality, it is suitable for irrigation.
The irrigation water used at Kharkiv stationar is of poor quality due to the high content of Co and Pb. The content of Co in the irrigation water is 1.7-3.5 times higher than the background. Water is limited suitable for irrigation due to the content of this element. The Pb content in the irrigation water exceeds the background 2.1-3.0 times. The water is unsuitable for irrigation due to the content of this element, according to the national classification.
The irrigation water used in Maryinka stationar is of poor quality due to the high content of Cd, Co and Pb.
The content of Cd in the irrigation water exceeds the background by 1.4-2.0 times. Water is limited suitable for irrigation due to the content of this element. Co content in irrigation water exceeds the background by 1.9-2.9 times. The Pb content in the irrigation water exceeds the background 1.6-2.4 times. The water is unsuitable for irrigation in terms of Co and Pb content, according to the national classification.
The assessment of the HM content in the arable soil horizon (0-30 cm) was carried out (Table 3).

Table 3. Contents of heavy metals in the 0-30 cm layer of irrigated soils of Ukraine, mg/kg

Site		Contents of heavy metals in irrigated soils, mg/kg							
		Zn	Cd	Ni	Co	Fe	Mn	Pb	Cu
Merefa stationar	average	1.00	0.07	0.70	0.40	1.90	12.40	0.50	0.20
	min./ max.	0.75/ 1.20	0.05/ 0.10	0.30/ 1.20	0.20/ 0.70	1.00/ 2.50	10.0/ 16.0	0.20/ 1.10	0.10/ 0.60
Kharkiv stationar	average	2.13	0.14	1.15	0.32	2.61	6.19	2.25	0.90
	min./ max.	0.90/ 3.75	0.025/ 0.272	0.50/ 2.75	0.10/ 0.45	1.25/ 4.75	4.50/ 10.10	1.40/ 2.75	0.33/ 2.05
Maryinka stationar	average	0.71	0,95	1.35	2.70	6.35	9.30	6.25	0.95
	min./ max.	0.54/ 1.35	0.49/ 1.15	0.63/ 3.15	0.95/ 3.45	3.65/ 9.45	7.15/ 13.40	4.40/ 8.10	0.48/ 2.20
Background		1.00	0.10	1.00	0,50	2.00	43.00	0.50	0.50
Maximum allowable concentrations (MAC)		23.0	-	4.0	5,0	-	500	6.0	6.0
Level of plants microelements nutrition	lower	<5.0	-	-	<0.3	-	<20.0	-	<0.5
	normal	5.0-10.0	-	-	0.3- 0.7	-	20.0- 40.0	-	0.5- 1.0

The content of mobile HM forms in the 0-30 cm layer of Merefa stationar soils has been studied for 20 years. The average values of the content of mobile forms of most HMs in the studied soils (Zn, Cd, Ni, Co, Fe, Pb) are slightly lower or at the level of the background soils of Ukraine. The average value of the content of mobile Mn in Merefa stationar soils is 3.5 times lower than the background, and Cu - 2.5 times, which may be associated with their lower initial content.
In Merefa stationar soils, the concentration of HM mobile forms is significantly lower than the established MAC and the issue of the supply of plants with the necessary microelements becomes more acute. The studied soils were characterized by a low supply of plants with Zn and Mn mobile forms. Even the maximum content of these elements in soils is significantly lower than the optimum by 4.2 and 1.3 times, respectively. The average Cu content is also insufficient for plants. Plants are provided with Co at an average level. The concentrations of trace elements in the studied soils indicate their deficiency and the need for additional application in the form of micronutrient fertilizers. Thus, despite the fact that chernozems are considered to be soils of optimal chemical composition, they may contain insufficient amounts of mobile forms of microelements necessary for plants.
The content of HM mobile forms in the 0-30 cm layer of the Kharkiv stationar soils has been studied for 10 years. The excess of the maximum values of HM content over the minimum is 2.0-10.9 times. The average values

of mobile forms content (Zn, Cd, Ni, Fe, Pb, Cu) in the studied soils exceed the background content in the soils of Ukraine by 1.1-4.5 times. The average value of mobile Mn content in Kharkiv stationar soils is 6.9 times lower than the background value, and Co - 1.6 times.

In Kharkiv stationar soils, the concentration of HM mobile forms is lower than the established MAC, however, the rather high content of Pb in the soil is alarming (it exceeds the background by 2.8-5.5 times). The question of the provision of plants with necessary microelements remains an acute issue. The studied soils of Kharkiv stationar were characterized by a low supply of plants with Zn and Mn mobile forms. The maximum content of these elements in soils is 3.7 and 1.5 times lower than the optimum, respectively. The Zn and Mn concentrations in the studied soils indicate the need for their additional application in the form of micronutrient fertilizers. The average Cu and Co content is at a level sufficient for plants.

The content of mobile HM forms in the 0-30 cm layer of Maryinka stationar soils was studied for 12 years. The average values of the content of mobile Co, Ni, Fe, Cu forms in the studied soils exceed the background content in soils of Ukraine by 1.4-3.2 times, Cd and Pb content - by 9.5-12.5 times. The average value of mobile Mn content in soils of Maryinka stationar is 4.6 times lower than the background value, and 1.4 times for Zn.

In Maryinka stationar soils, the concentration of most HMs is below the established MAC, the Pb content exceeds the MAC and causes concern about the high content of Cd in the soil (MAC for this element has not been established). The concentration of these elements in soils creates a threat to obtain low-quality plant products.

The question of the provision of plants with necessary microelements remains. The studied soils of Maryinka stationar were characterized by a low supply of plants with Zn and Mn mobile forms. The maximum content of these elements in soils is 1.3 and 2.0 times lower than the optimum, respectively; additional introduction of these elements in the form of micronutrient fertilizers is necessary. The average Cu content is at a level sufficient for plants. The Co content significantly exceeds the optimal content of this element in soils.

The HM content in plants reflects the environmental conditions in which the plants were grown, an excess of HM MPC in the soil or in irrigation water can cause an increase in the HM content to the Maximum allowable concentrations in vegetables (Table 4).

Table 4. Content of heavy metals in tomatoes (raw vegetables), mg/kg

Site		Content of heavy metals, mg/kg							
		Zn	Cd	Ni	Co	Fe	Mn	Pb	Cu
Merefa stationar	average	1.75	0.015	0.06	0.11	2.3	0.19	0.27	0.14
	min./ max.	1.08/ 2.40	0.009/ 0.020	0.05/ 0.10	0.09/ 0.15	1.2/ 4.1	0.11/ 0.34	0.25/ 0.29	0.09/ 0.22
Kharkiv stationar	average	1.72	0.022	0.15	0.22	2.3	0.32	0.53	0.63
	min./ max.	1.62/ 1.77	0.025/ 0.030	0.10/ 0.18	0.20/ 0.30	1.8/ 4.5	0.18/ 0.42	0.24/ 0.65	0.34/ 0.86
Maryinka stationar	average	6.00	0.05	0.34	0.48	14.53	4.40	1.69	0.81
	min./ max.	4.53/ 7.20	0.03/ 0.06	0.16/ 0.54	0.28/ 0.72	8.37/ 16.19	2.86/ 5.71	0.95/ 2.13	0.41/ 1.05
Maximum allowable concentrations in vegetables (MAC in vegetables)		10.0	0.03	0.50	1.00	50.0	20.0	0.50	5.00

In Merefa stationar tomatoes, the TM content (even maximum values) does not exceed MAC in vegetables. Average Pb concentrations in Kharkiv stationar tomatoes were 1.1 times higher than MAC in vegetables. In some sampling periods, the maximum content of Pb and Cd in tomatoes was noted, which corresponded to MAC in vegetables (Cd) or exceeded them by 1.3 times (Pb). The average concentrations of Cd and Pb in Maryinka stationar tomatoes exceed MAC in vegetables by 1.6-3.4 times. The maximum values exceed MAC in vegetables by 2.0 and 4.3 times, respectively. The remaining elements content in tomatoes of Maryinka stationar significantly exceeds the levels of these elements in the

tomatoes of other sites. This may be associated with a significant aerial intake of HM under conditions of significant technogenic load. Therefore, the conclusion about the need for additional application of micronutrient fertilizers does not seem to be relevant for this object.
We found that the objects of study differ significantly in the degree of anthropogenic impact on them:
- Merefa stationar is quite remote from large industrial centers, water suitable for irrigation is used, soils are not contaminated with HM. In these conditions, environmentally friendly, suitable for consumption tomatoes are grown;
- Kharkiv stationar is located in conditions of intense influence of local pollution, irrigation is carried out with waters that are not suitable for irrigation in terms of Pb content, in soils the Pb content exceeds the background by 2.8-5.5 times. Under these conditions, vegetable products do not meet the sanitary and hygienic requirements for the Pb content - the content exceeds MAC in vegetables. Marked individual cases of Cd contamination of tomatoes;
- Maryinka stationar is located in conditions of intense technogenic pollution, irrigation is carried out with waters that are not suitable for irrigation in terms of Co and Pb content, in soils the Pb content exceeds MAC, the Cd content exceeds the background by 5.0-11.5 times. Under these conditions, vegetable products do not meet the sanitary and hygienic requirements for the content of Pb and Cd - the content exceeds MAC in vegetables.
One of the directions of detoxification of contaminated soils and a decrease in the intake of toxicants into plants is the introduction of ameliorants-adsorbents of organic and mineral nature into the soil, which bind metals into sedentary forms. The most promising and economically profitable is the use of local raw materials (industrial waste containing iron and calcium). A phyto-reclamation approach is also used to remove toxic compounds from soils.

CONCLUSIONS

As a result of the work, an assessment of environmental risks in irrigated agriculture in Ukraine under various technogenic loads was carried out on the example of the system "irrigation water-soil-plant".
In Merefa stationar, the content of Cu, Zn, Co, Ni, Pb, Cd, Fe, Mn in irrigation water is at the background level, it is not contaminated with these elements and is suitable for irrigation according to ecological criteria of National classification of the irrigation water quality. The mobile forms of HM content in the plow horizon of the irrigated soil are also at background level, significantly lower than the MAC. The concentrations of Zn, Cu and Mn in the studied soils indicate the need for additional application in the form of micronutrient fertilizers. Tomatoes that are grown under these conditions are good for consumption.
In Kharkiv stationar, the content of Cu, Zn, Ni, Cd, Fe, Mn in irrigation water is at the background level, it is not contaminated with these elements. The Co content in the irrigation water exceeds the background one by 1.7-3.5 times, the Pb content - by 2.1-3.0 times. The water is unsuitable for irrigation due to its Pb content due to ecological criteria. The mobile forms of Zn, Cd, Ni, Fe, Pb, Cu content in the arable horizon exceeds the background content by 1.1-4.5 times. The Mn and Co content in soils is lower than the background content. High maximum concentrations of Pb content in soil are dangerous; they exceed background concentrations by 5.5 times. Concentrations of Zn and Mn in soils indicate the need for additional micronutrient fertilization. Tomatoes grown under these conditions are unsuitable for consumption: the average Pb concentrations in tomatoes were 1.1 times higher than MAC in vegetables, and the maximum - 1.3 times.
In Maryinka stationar, the content of Zn, Fe and Cu in irrigation water is at the background level, it is not contaminated with these elements. The content of most elements in the irrigation water is much higher than the background. The water is unsuitable for irrigation due to the Co and Pb content; high concentrations of Cd are also dangerous. The content in the plow horizon of Co, Ni, Fe, Cu mobile forms exceeds the background content by 1.4-3.2 times, the Cd and Pb content by 9.5-12.5 times. The Mn and Co content in soils is lower than the background content. High maximum concentrations of Pb in soil are dangerous; they exceed background concentrations by 5.5 times. Concentrations of Zn and Mn in soils are lower than background,

however, there is no need for additional application due to the significant aerial intake of these elements. Tomatoes grown under these conditions are not suitable for consumption: the average concentrations of Cd and Pb in tomatoes were 1.6-3.4 times higher than MAC in vegetables, and the maximum - 2.0-4.3 times.

The use of such products poses a threat to human health, therefore, crops resistant to the accumulation of toxicants should be grown on contaminated soils and vegetable crops should be excluded from the crop rotation, which belong to crops with a high ability to accumulate metals.

It has been established that HMs, which to the greatest extent pollute irrigation water and irrigated soils, can accumulate in agricultural products in quantities exceeding MAC in vegetables, which indicates the need for constant monitoring of the levels of HM in the interrelated links: irrigation water - irrigated soil - plants. It is necessary to take measures to reduce the intake of HMs in plants under local and regional pollution. It is necessary to develop an ecologically safe system of irrigated agriculture, including economically feasible measures to improve the quality of irrigation water, the use of soil-protective crop rotations, the introduction of highly profitable agricultural technologies, chemical soil reclamation and the reconstruction of reclamation systems.

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SOLAR CADASTRE IN TIMISOARA, ROMANIA

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Abstract

The topic of the paper refers to solar cadastre regarded from the point of view of choosing the optimal areas for placing photovoltaic panels and the importance for implementing sources energy. In the scientific literature, solar cadastre is also known as roofs cadastre or potential solar cadastre. It is based on the digital terrain model and climate information available for studied areas. Analysis of solar energy and full potential of solar cadastre can be used in various fields as civil engineering or urban planning, also in the projects of research and the investment of energy sources. An important aspect of the presented study case is the decrease of the use of agricultural lands for photovoltaic parks. One way to generate renewable energy in our existing urban environment is to use the solar energy. A method for analysing the potential of existing built environment for obtaining energy sources is by creating solar maps. A solar map or a solar cadastre is a GIS that provides data about yearly solar radiation on the building's surfaces (roof and/ or facade). The current solar maps have different levels of advancement.

Key words*: agricultural lands, Digital Terrain Model, geoportal, renewable energy, solar cadastre.*

INTRODUCTION

Given that pollution is increasingly affecting both the environment and the population, the idea of implementing projects targeting alternative energies that contribute to ensuring a healthy and safer environment for all the factors involved is of great importance. This is also because it represents an international concern, to discover new methods of green energy production.

In highly populated analysed territories, the expansion of construction zones and the pressure imposed on the slopes by housing and transport infrastructure led to the appearance and reactivation of mass movement processes that affect both population and the environment (Sestras, 2019).

In contrast with the past, the energy issue has become a crucial component of ecologically and economically sustainable urban development. The conventional energy sources such as oil, gas and coal are tending to decrease, whereas renewable energy sources such as solar energy, wind power, hydropower, biofuel, biomass and geothermal energy are making a great contribution into producing electric energy, domestic hot water, heating and motor fuels (Chuprikova, 2015).

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.

Solar energy can be used for technologies such as: solar heating, photovoltaic panels, solar thermal energy, solar architecture and artificial photosynthesis. This is an important source of renewable energy and its technologies are generally characterized either by active solar techniques or by passive solar techniques based on how they capture and distribute energy in solar energy.

Active solar techniques include the use of photovoltaic systems, concentrated solar energy and solar energy to heat water for energy recovery.

Passive solar techniques include orienting a building to the Sun, selecting favourable materials for heat or light scattering, and designing spaces naturally ventilated. Renewable energy sources offer a viable alternative with low or no risks that are practically inexhaustible from the point of view of resources.

The most important solution to protect the environment is the regeneration of the energy source: solar, biomass, wind, water, geothermal energy, waves and tidal power. So, one of the ways to reduce CO_2 concentration in the air is to use renewable energy sources, including energy from the Sun.

MATERIALS AND METHODS

The solar cadastre is also called the roofs' cadastre or solar potential cadastre. This type of cadastre consists in a geoportal that allows defining the potential of solar energy for specific locations. It is based on the Digital Terrain Model and climate information available for the studied areas. This type of geoportal is mainly developed as an initiative of the local governments. (Popescu G. et al., 2020)

The data characterizing radiation modelling and energy production on building roofs and integrated vertical facades uses light detection data and measurement data (LiDAR) together with 2D and 3D cadastral data lands is recorded in a webGIS containing geometric details, structures, current situation and property information.

LIDAR (Light Detection and Ranging) technology is an active remote sensing technique with used in order to obtain high accuracy data regarding land topography, vegetation, buildings etc. LIDAR technology represents an effective method of detecting buildings: the larger ones are easy to be identified in contrast to smaller buildings which are harder to identify.

Another method is to combine aerial photographs and existing contours of buildings from the 2D cadastre and even terrestrial laser scanning. In the scientific literature and current practices, facades modelling for solar analysis has received less attention compared to roofs, because it requires much more complex tools based on 3D data. However, these elements from the built environment can be used for assembly solar panels.

An inconvenience for assembly solar panels on facades is the urban vegetation and thus the maximum efficiency of these panels would be obtained only in winter.

The integration of photovoltaic panels (PV panels) on the roofs is still critical from the point of view of the landscape. No impacts on biodiversity or water can be identified. A positive impact on soil preservation is identified on the use of roofs to install the PV panels instead of the occupation of agricultural land.

A very important tool for solar cadastre is represented by 3D cadastre, namely by introducing the third dimension, different situations regarding the built areas can be better illustrated. Also, the introduction of the third dimension and the management of information in a GIS environment for both 3D cadastre and solar cadastre contributes to the clarification of energy consumption and for the development of photovoltaic panel infrastructure (Moscovici et al., 2019)

Solar energy analysis and solar potential maps can be used in various fields such as civil engineering or space planning, as well as in renewable energy research and investment projects.

Cities, which are home to more than half of the Earth's population, consume most of the world's energy. One way to generate renewable energy in our existing urban environment is to use solar energy. A method of analysing the potential of the existing built environment for obtaining renewable energy is through solar maps.

A solar map or solar cadastre represents a webGIS that provides data on annual solar irradiation on building surfaces (roof or facade), mostly accompanied by data regarding the production of solar thermal or photovoltaic systems (Klauser, 2013) (Figure 1).

Current solar maps have different levels of advancement. Sometimes, cities solar maps are part of larger programs implemented in order to obtain data needed for higher renewable energy production. They provide users with direct information on solar system suppliers and installers.

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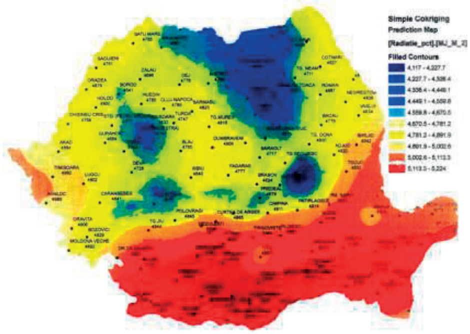

Figure 1. Zoning Romania's territory according to main sunny area

RESULTS AND DISCUSSIONS

Solar energy will play a significant role in order to meet a considerable percentage of its demand for electricity from domestic renewable sources, which means the need for a substantial increase in photovoltaic capacity.

Unfortunatley, at the present moment, there is a lack of knowledge regarding solar cadastre in the urban and rural areas of Romania, in particular in for Timișoara city and the county of Timiș. A solar cadastre on the roof was studied only in urban agglomerations (Figure 2).

At present, the solar cadastre in Timișoara represents a challenge and that is why we considered that it is worth paying attention to this subject.

For the current study, the buildings delimited by the following streets: Plautius Andronescu Street, Oltul Street, Victor Babeș Boulevard and Traian Lalescu Street have been chosen (Figure 3). The studied area includes buildings belonging to the Civil Engineering Faculty and also residential buildings.

After the area for the pilot study was clearly determined, identification of existing roofs on the orthophotoplan followed. For this stage we consulted Eterra's national real estate registration system and we vectorized the buildings that were not registered in the cadastral records (geoportal Eterra, 2020). We also used Google Maps for geospatial data; although it is an online application it could provide useful information for the study (Figure 3).

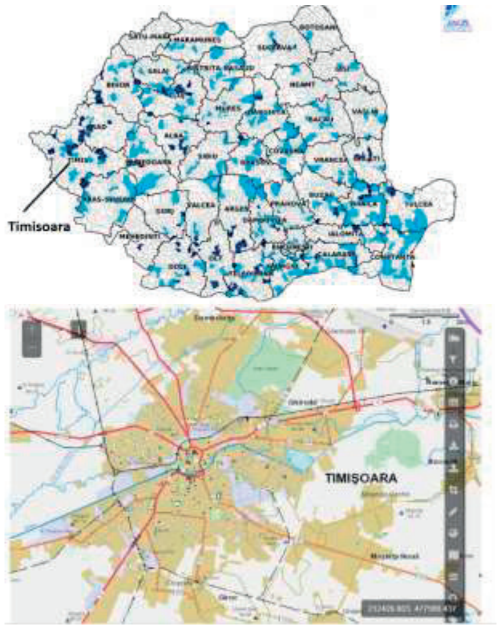

Figure 2. The location of the area studied on the map of Romania (geoportal ANCPI)

Solar technology ensures transforming energy from the sun through sun panels and converting it into heat or, by means of systems photovoltaic (PV) in the energy supply.

When it comes to solar energy, not all roofs have a uniform structure, which is an impediment in the surveyors' activity to identify them only on orthophotoplans.

Each roof, building or structure has its own solar capabilities, depending on the position of the Sun, the season and the nature of its surface. In addition, the shading of elements of the studied area and adjacent objects influence the capacity of solar energy.

The adoption of solar technologies is growing quickly, also thanks to large and urban-scale solar cadastre maps, often available on-line. Identifying suitable surfaces in urban or rural areas plays an important role both for the private investor and the public local community because PV systems need to be properly located and oriented in the environment to meet the required specifications (Agugiaro et al., 2012).

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Figure 3. The area under study

The next step consists in identifying the roof types on orthophotoplanes using all sources Ettera Orthophotoplan, Google Maps. The characteristics of an identified roof included the 2D contour obtained from the orthophotoplan and 3D parameters extracted from the digital terrain model.

Five types of roofs were considered: terrace type roof, pent roof, ridged roof, whole-hip roof and gable roof (Figure 4).

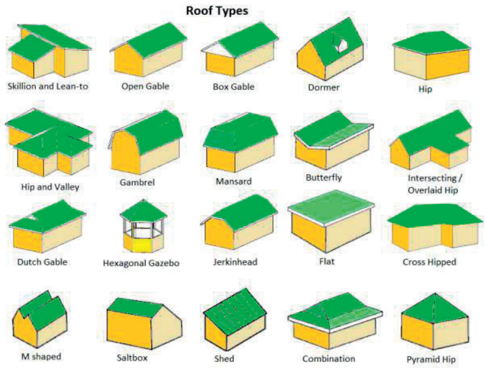

Figure 4. Types of roofs

We performed the vectorization of the roof footprint and at the same time we identified the roof type, taking into account the elements that are of interest for solar cadastre. These are the ridge of the roof, the slope of the roof, the edge of the roof, the skylight, the eaves and the rain shadow as it can be seen in Figure 3.

The parameters of the photovoltaic modules derived from the building characteristics were then combined with data on solar radiation to assess the solar photovoltaic potential. Based on images obtained from Google Earth and the digital terrain model, the buildings were extracted using the object-oriented classification method. The chosen method proposes that after vectoring on layers all identifiable elements, the exclusion of objects including parks and vegetation using shape and texture characteristics. By eliminating them, the active layer of the buildings is subjected to the digital model of the terrain.

Figure 5 illustrates the studied area with the building's geometry and the constructive elements of the roof's identification. A legend was realized in order to explain each type of hatch used.

Figure 5. The studied area for roofs identification

This application can be used to create a database in which the surfaces useful for the location of photovoltaic panels are entered, the calculation of their inclination angles and the distance at which they can be mounted.

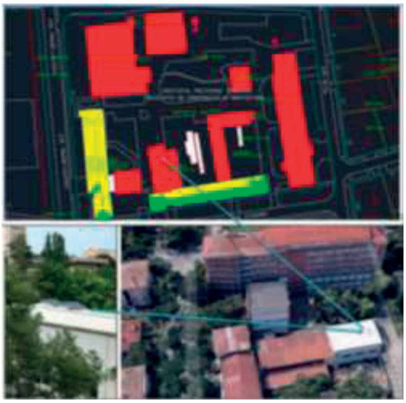

Figure 6. Photovoltaic panels identified on map

The main challenge is to achieve maximum efficiency, but to maintain the necessary accuracy of all points of interest for a solar cadastre. We consider the possibility of using UAV photogrammetry and laser scanning for solar cadastre and whether these methods are practical for such a study. The accuracy of the detailed survey based on UAV technologies was verified on hundreds of points for this study, mainly on the corners of buildings and on the cornices of roofs. Another discussion implies precision work for the location on the rooftop required for mounting solar panels taken into consideration all the 3 dimensions and the angle between the panel and the horizontal line.

On the metal construction assembly room, photovoltaic panels are already installed as we have indicated (Figure 6).

As regards the legislation in force on the studied issue, the Romanian institutions must meet the following directives and laws:

- Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, (Figure 7)
- Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast),
- Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of energy from renewable sources use,
- Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the building's energy performance.

Figure 7. Classes of Energy efficiency

At national level, the main legislative documents, in force in Romania, regarding the promotion of the use of renewable energy sources and the energy performance of buildings are:

- Law no. 159/2013 on amending and supplementing Law no. 372/2005 on the building's energy performance;
- Law no. 220/2008 for establishing the system for promoting the production of energy from renewable energy sources, with subsequent amendments and completions.

CONCLUSIONS

The solar cadastre is a topic of significant interest to the community, authorities and property owners.

Architectural harmony represents an important point in the successful integration of the components of the installation that use solar energy in a building. However, so far, the most common solution has been to install solar collectors on support structures.

On terrace-type roofs or on terraces across Europe, solar panel builders, architects and their customers are working to integrate solar collectors into the environment. Effective solutions for the integration of solar panels in roofs are well known, especially in Northern Europe, in Romania this issue being only in an incipient phase.

In general, the task of identifying suitable surfaces for the installation of photovoltaic panels is not trivial. Therefore, in order to produce estimations of solar potential, several parameters must be taken into account, for example: azimuth, elevation, shadow, sunlight intensity and climate impact. Therefore, solar simulations based on the digital terrain model and the digital model of high-resolution surfaces must be performed, these data will be taken into account in the future to develop this theme.

By using photovoltaic (PV) panels, the received solar energy is transformed into electricity. Identifying suitable areas for the installation of photovoltaic parks in urban or rural areas plays an important role for both the private investor and the local public community, as photovoltaic systems must be properly located and oriented in the environment to meet the required specifications (insulation time, surface orientation).

The solar cadastre can be used to assess the potential of a city or region to produce solar energy. The solar cadastre allows us, in fact, to evaluate the effective energy efficiency of buildings and land in terms of photovoltaic potential and its adequacy to accommodate this type of photovoltaic system.

An increasingly studied problem is represented by the use of good land (from the agricultural point of view) for the construction of photovoltaic parks given that productive agricultural land should be protected even if the purpose of its modification is to produce renewable energy. The solar cadastre in urban areas with the PV panels on rooftops highly supports agricultural land protection policies and complies with the energy production policies.

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MECHANISM OF TRANSFORMATION OF LAND RELATIONS IN THE AGRICULTURAL SECTOR OF RUSSIA

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Abstract

The purpose of the study is to form a mechanism for developing the framework of land relations in agricultural sector based on the designing an institution of land relations management. The theoretical concepts of institutionalism, management, communication as well as situational approach, general scientific and specific scientific methods were used within the study. Mechanism of transformation of land relations in the agricultural sector of Russia is functioning on the basis of the principles of optimality, limited rationality, quality, stability of norms and rules. Integration of the new institution with the existing institutions of legislative authority, federal property management, regulation of real property title, monitoring and supervision, agricultural sector development, land ownership within the framework of the norms are its specific features. The developed mechanism assumes inclusion and application of the mechanism of transformation of the land relations environment as well as the mechanism of supervision over the observance of norms and rules which action is performed with the use of monitoring of agricultural land turnover. The support of management by the functioning and development of institutions and coordination of actors' interaction assume high-quality institutional management. Assessment of efficiency of land relations transformation should be carried out on the basis of the introduced integrated index which includes the coefficients of implementation of managerial decisions, use of authority, compliance of results with the expectations, information collection. The practical relevance of the development lies in the possibility of using the mechanism elaborated by the authors in the areas of targeted measures.

Key words*: actor, agricultural land, development, effective management, institution, monitoring.*

INTRODUCTION

Land relations transformation in agricultural sector of Russia is a complex process which is characterized by inertness, emergence of institutional traps, underdevelopment of the land market, presence of large areas of unclaimed agricultural land. Long-term experience in the reformation of land relations in agricultural sector indicates the failure to achieve the stated goals. Dispersion of management functions into various ministries and departments adversely affects institutional transformation (Dankevych et al., 2017; Shynkaruk et al., 2020; Zavorotin et al., 2015). Often formal institutions of land relations become ineffective and need legislative improvement.

Theoretical and methodological basis for the study of institutional transformation of land relations were the scientific works of Alchian, Demsets (Alchian et al., 2015; North, 1997) and others. North defines institutions as rules, mechanisms ensuring their implementation and standards of behavior which structures repetitive interactions between people. Sukharev (Sukharev, 2014) gives basic definitions of institutions, their dysfunction and types as well as characterizes adaptive efficiency. He understands institutions as formal rules formed by society and government, acquiring the meaning of norms and having legal significance as well as informal rules. Dysfunction is a violation, breakdown in the functions of any organ, system, economic institution, mainly of a qualitative nature. Adaptive efficiency is the efficiency of rules functioning, restructuring of the system is directly related to the possibility of adaptation (Sukharev, 2014). Tambovtsev, in 1997, regards it necessary to consider institutions in terms of changes. Kleiner (Kariuki et al., 2018) considers designing and transplantation of institutions as constituent elements of the institutional change process. In his opinion, the framework of the institution expresses the essence and basic provisions of the norms and rules and is preserved throughout the life cycle of the institution. Aoki (2007) describes some common mechanisms for institutional consistency and change. From Maze's (2007) perspective, in addition to coordination and governance issues, the choice of standards and limits is important to define multilateral governance mechanisms in the agricultural sector. Kariuki, Birner and Chomba (2018) recommend to integrate the mechanisms which coordinate the formal (distribution of title to land) and informal institutions (cultural practices).

Formal and informal institutions affect the efficiency and ability of the market to ensure constructive interaction of economic agents in terms of meeting needs (Shpykulyak et al., 2015). Mamchur (2014) singles out the level of institutional and legal security as an institutional criterion, considers measures of financial regulation, legal, antimonopoly, organizational, production-consumer and other measures as institutional factors of the functioning of the agricultural market.

Bizoza, Opio-Omoding (2021) considered institutional and economic considerations to strengthen long-term impacts in context of theory of change of land tenure security activities. Khlystun (2019) assessed land management system as inefficiency, offered institutional change of system. Ariti, van Vliet and Verburg (2019) studied institutional network which is consists of different administrative levels institutions, showed important of higher administrative level in land management. Kononenko (2019) proved the existence of a strong relationship between the quality of political-legal and land institutions.

In Russia, it is necessary to carry out a qualitative transformation of the institutional environment of land relations (formal and informal institutions), to ensure the transition from an obsolete stage of development to a new one. It must be accompanied by the interaction of institutions in order to comply with the interests of actors in the rational use of agricultural land.

Insufficient development of the issues of land relations transformation in agricultural sector was the basis for the development of a new institution.

MATERIALS AND METHODS

DEVELOPMENT OF THE FRAMEWORK OF LAND RELATIONS INSTITUTION

Designing of a new land relations institution

Designing of a new institution of land relations management elaborated by the authors is aimed at developing the strategy and tactics of the actors' activities (subjects of land relations) in the regulation of the processes of ownership, use and disposal of agricultural land.

For practical use the authors propose the original mechanism for development of the framework of land relations institutions in agricultural sector (Figure 1).

The purpose of the mechanism designing is in the integration of its elements to make them interact and as a result be effective at the final stage of managerial decision-making.

The institutional aspect of land relations should take into account transformation as a process becoming and development rules and regulations. The norms (institutions), which are required to be applied when developing the mechanism of land relations, can be of an imperative, dispositive, encouraging or recommendatory nature.

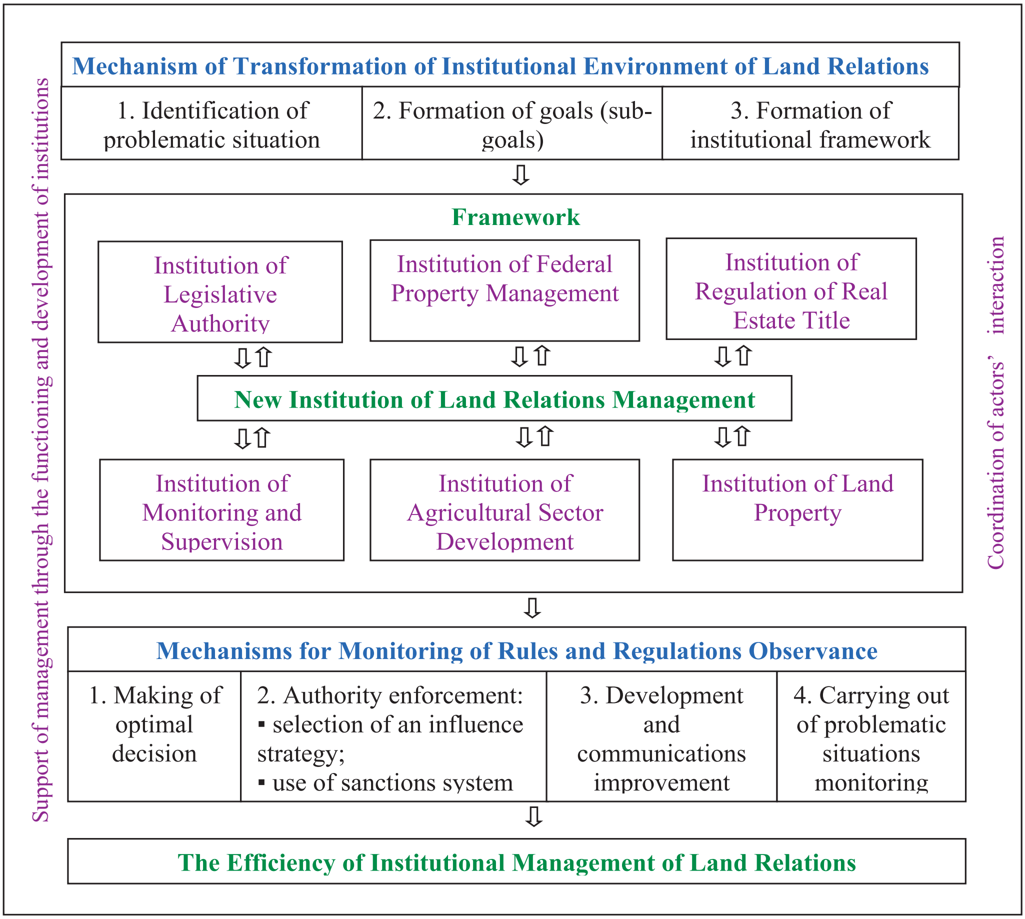

Figure 1. The proposed mechanism for the development of the framework of land relations institutions in agricultural sector and their interactions in Russia Source: Author's own elaboration

The imperativeness is manifested in the strict regulation of normative prescriptions that empower state governing bodies and establish the appropriate legal status and responsibilities of owners, land users, landowners, tenants. Dispositive ness involves informing about the possible lawful behavior of the subject agricultural land use. The use of the incentive system regulates the responsibility of participants in land relations through the approval of special benefits, incentives, etc. The implementation of the recommendations that establish the options for optimal actions is preferable, but not mandatory.

The transformation of the institutional environment involves identification of unstable institutions and sorting of system or emerging problematic situations. For example, the high level of transaction costs in the market and non-market turnover of land shares will prevent the positive institutional changes and the transition of land from inefficient actors to efficiently working owners (Uzun et al., 2019; Zavorotin et al., 2018).

By the significance the situations can be ranked as follows:

1) non-use of agricultural land (first of all - arable land) for the intended purpose accessing by a loss of profit;

2) shrubbing and aforestation of agricultural land characterized by the cost of uprooting and land reclamation;

3) commercial failure of agricultural businesses leading to an increase in the area of unused agricultural land;

4) increase in the prices for material resources, limiting the opportunities of agricultural businesses to involve unused land in economic turnover, etc.

Figure 2 shows the share of arable land in the total area of agricultural land by Russia, European Neighborhood Policy (ENP) countries in Eastern Europe: Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine.

The largest share of arable land in the total area of agricultural land takes Ukraine (79.0%), Russia is in fourth place (56.5%).

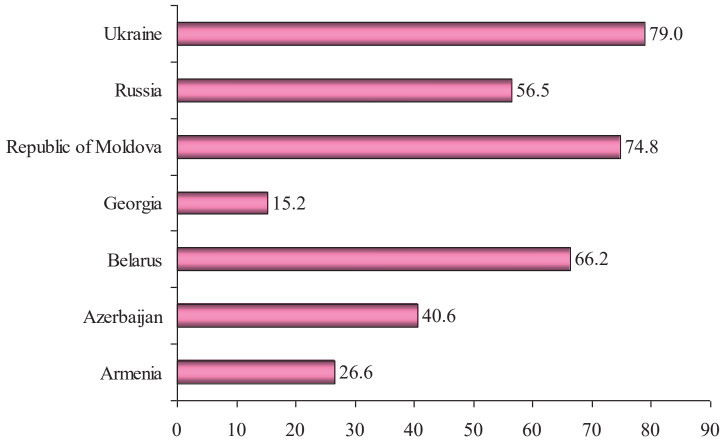

Figure 2. Share of arable land in the total area of agricultural land by Russia and ENP-East countries, %
Source: Author' calculations from FAO (2020)

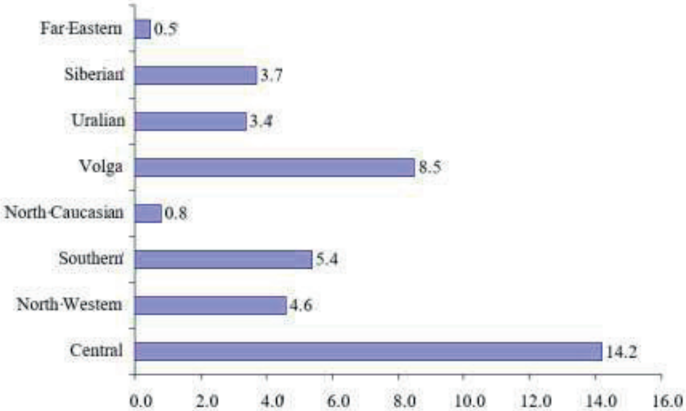

Figure 3. Share of unclaimed arable land in the total area of agricultural land by federal districts of Russia, %
Source: Author' calculations from Report on the status and use of agricultural lands of the Russian Federation, (2015)

Figure 3 shows non-use of agricultural land: the share of unclaimed arable land in the total area of agricultural land by federal districts of Russia. The largest share of unclaimed arable land in the total area of agricultural land takes Central federal districts of Russia (14.2%), the smallest - Far Eastern (0.5%). A certain period should be given to the elimination of the problem within which goals are set and adjusted depending on changes in the internal and external environment of the land relations state and land resources use. It is necessary to apply a situational approach for implementation of these purposes (Zavorotin et al., 2015).

In the mechanism elaborated by the authors, the framework of institutions is formed from interrelated institutions of legislative authority, federal property management, regulation of real property title, monitoring and supervision, agricultural sector development, land property and a new institution of land relations management. With that the principle of differentiation is maintained as institutions perform different functions and have different powers. The solution of the problems coordinated by the institutions is based on the principle of integration of joint managerial activity and use of a dispositive method of legal regulation.

The main element of the framework is the proposed institution of land relations management, which ensures the consolidation of institutions for searching the optimal solutions, the implementation of which stipulates the formation of mechanisms of administrative, judicial, social supervision over observance of norms and rules as well as identification of their violations. For example, in accordance with the regulations a Permanently Functioning Meeting under the Deputy Chairman of the Saratov region Government (Russia) holds meetings for the collegial study of operational issues within the scope of its competence, monitors the implementation of legal acts, federal and regional programs, etc. Members of the Meeting participate in preparation of materials as well as draft resolutions and orders which require a decision of the Governor or the government of the region.

A selection of an influence strategy which involves the formation of new rules and regulations is made for effective management. Constitutional rules include state regulation of land relations, supervision over their observance as well as the imposition of sanctions against inefficient agricultural land users. Economic rules provide motivation and incentives for the rational use of land resources. Interaction of actors and institutions is based on the provisions of the communication theory, which determines the methodological approach to the coordinated solution of problematic issues, monitoring of institutional traps. Communication system is presented by the repeated complementary, met complementary, symmetrical, reciprocating matrices. The first two types of relations are present in the implementation of managerial decisions. For example, in the case of obtaining full, accurate, scientifically valid and up-to-date official statistical information on agricultural land, the communication model will have the form of "economic entity - department of municipal statistics - territorial body of Rosstat - Federal State Statistics Service". Symmetrical communication can be observed at the general meeting of land shares owners. Reciprocating matrices are developed in the non-market turnover of agricultural land.

Within the mechanism of development of the framework of land relations institutions in agricultural sector, support for the management through their functioning and development in conditions of overcoming transformational barriers (high costs, associated risks, opportunistic behavior) is provided.

Monitoring of problematic situations in land relations

The implementation of complex managerial decisions in the sphere of land relations must be accompanied by monitoring of institutional traps. The authors propose an information-analytical system for monitoring of agricultural land turnover, which is a part of the mechanism of land relations management (Figure 4).

Information collection on the state of market and non-market of agricultural land turnover is made at the first stage of monitoring. Market turnover assumes the study of materials on transactions of purchase and sale of state, municipal, private land, right for possession, use, lease, life care contracts; non-market - on land plots, shares of citizens, inheritance, donation, assignment for ownership, use, lease on the basis of contracts.

The second stage stipulates analyzing and forecasting of information, including the identification of risk factors in the land market, risk assessment by the method of developing the weighted average, basic, periodic, operational indices, institutions. The basic index is the level of cadastral valuation of 1 hectare of land. Periodic indexes include the proposal concentration, potential demand, total area of the proposed lands, price level of the proposals by the areas, areas with the largest range of land proposals, areas that are bestselling in potential buyers.

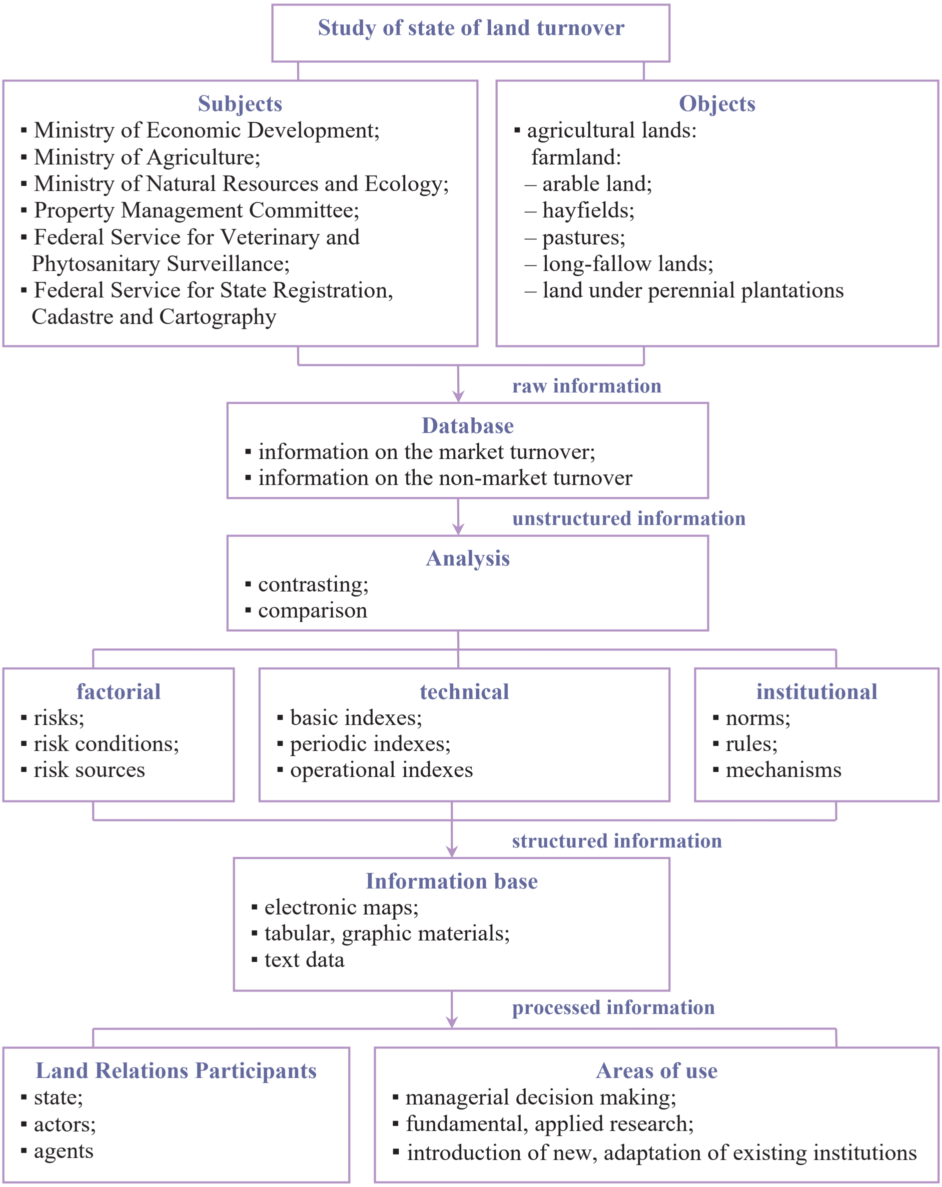

Figure 4. Monitoring of agricultural land turnover in Russia Source: Author's own elaboration

Operational indexes characterize the interest to the plots, sales equivoques, competitiveness of the area by the price, attractiveness and reasonnability of sales, market prospects, possible level of increase in market prices for land. Institutions are analyzed in legal, economic, social aspects: provision with correct, logical, consistent norms and rules; positivity of changes in land legislation; observance of the principles of legal regulation stability, legitimacy, consistency; ratio of actual and nominal carriers; efficiency of mechanisms (Zavorotin et al., 2015).

At the third stage, the results of the survey are interpreted and an information base that facilitates the coordination of actors' interaction is formed. Analysis data on soil profiles, humus content, degree of run-off processes will include in information base, it will possible to model of erosion processes for implementation in precise farming (Koliada et al., 2018; Kucher et al., 2015). Land monitoring allows identifying the main factors of specific crop production, area of agricultural land introduced into economic turnover. It will help evaluate number of implemented of managerial decisions to introduce land into economic turnover, to reduce agricultural depletion. Thus, monitoring enables actors to control enforcement of managerial decisions, make norms (institutions) of land management.

Assessment of efficiency of institutional management of land relations

Institutional management is a targeted impact on the constraints and norms in the activity of organizational systems participants (Novikov, 2005). The integrated index of efficiency of institutional management of the land relations (C_{Int}) is calculated by the formula developed by the authors:

$$C_{Int} = \frac{1}{n}\left(C_{Imd} + C_{AE} + C_{C} + C_{IC}\right), \quad (1)$$

where: C_{Imd} - coefficient of implementation of managerial decisions;
C_{AE} - coefficient of authority enforcement;
C_{C} - coefficient of compliance of results to the expectations;
C_{IC} - coefficient of information collection;
n - total number of management quality coefficients.

This integrated index varies from 0 to 1. The highest value of the C_{Int} is compliant with the optimal values of its components.

Coefficient of implementation of managerial decisions (C_{Imd}):

$$C_{Imd} = \frac{Q_{ID}}{Q_{MD}}, \quad (2)$$

where: Q_{ID} - number of implemented decisions;
Q_{MD} - number of made decisions.

Coefficient of authority enforcement (C_{AE}):

$$C_{AE} = \frac{S_{Ial}}{S_{Ual}}, \ldots \quad (3)$$

where: S_{Ial} - area of agricultural land introduced into economic turnover as a result of the influence of the executive authorities;
S_{Ual} - area of unclaimed agricultural land.

Coefficient of compliance of results to the expectations (C_{C}):

$$C_{C} = \frac{T_{SI}}{T_{SUI}}, \quad (4)$$

where: T_{SI} - number of scheduled inspections;
T_{SUI} - total number of scheduled and unscheduled inspections.

Coefficient of information collection (C_{IC}):

$$C_{IC} = \frac{V_{RI}}{V_{ISA}}, \quad (5)$$

where: V_{RI} - amount of the required information;
V_{ISA} - information-search array.

The criterion of efficiency is the observance of established formal and informal norms and rules (Table 1).

Table 1. Calculation of integrated index of efficiency of institutional management of the land relations in Russia

Indicators	Years	
	2016	2017
Number of implemented decisions (fulfilled the instructions of the state land supervision to eliminate violations of land legislation)	5270	5490
Number of made decisions (issued instructions of the state land supervision to eliminate violations of land legislation)	12441	14559
Area of agricultural land introduced into economic turnover as a result of the influence of the executive authorities, ha	199000	252100
Area of unclaimed agricultural land, ha	51850000	56000000
Number of scheduled inspections	20519	16375
Total number of scheduled and unscheduled inspections	50852	44800
Amount of the required information	819.2	547.5
Information-search array	26800	17000
Coefficient of implementation of managerial decisions (C_{Imd})	0.424	0.377
Coefficient of authority enforcement (C_{AE})	0.004	0.005
Coefficient of compliance of results to the expectations (C_{C})	0.404	0.366
Coefficient of information collection (C_{IC})	0.031	0.032
Integrated index of efficiency of institutional management of the land relations (C_{Int})	0.216	0.195

Source: Author' calculations from Report on the status and use of agricultural lands of the Russian Federation (2015)

According to calculations, in 2016-2017 years there was a weakly expressed degree of efficiency of institutional management of land relations in Russia. This confirms the need to create a mechanism of transformation of land relations in the agricultural sector.

RESULTS AND DISCUSSIONS

The areas of implementation of the developed mechanism are consistent with the Strategy of socio-economic development of the Saratov region until 2030, State program "Development of agriculture and regulation of markets for agricultural products, raw materials and food in the Saratov region", plans for involving the unused land in the economic turnover of municipal districts of the Saratov region.

The materials of the study on the development of the mechanism of transformation of land relations in agricultural sector "Economic aspects of improving the efficiency of agricultural land use" were reported and discussed at the meetings of the Bureau of the Department of agricultural sciences of the Russian Academy of Sciences (Moscow, Russia) and a Permanent Functioning Meeting under the Deputy Chairman of the Government of the Saratov region (Saratov, Russia).

CONCLUSIONS

The institution of land relations management, which is part of the framework of the norms, consolidating sectoral institutions and providing communication of actors, functioning of the mechanism of transformation of the institutional environment, supervision over the implementation of norms and rules was developed on the basis of the conceptual approach.

The process model of problematic situations monitoring was developed and that makes it possible to accumulate, structurize and process the information on the agricultural land turnover.

Monitoring of agricultural land turnover hold great perspectives for more productive analysis and improved data access. Integrate the data in information base will enable to make managerial decision, investigate fundamental, applied research, introduce of new, adapt of existing institutions.

The degree of achieving the efficiency of institutional management from the introduction of the new institution is accessed by the proposed integrated index, including the coefficients of implementation of managerial decisions, authority enforcement, compliance of results to expectations, information collection. There was an assessment of land management to the integrated index. It is equal 0.216 in 2016 year, 0.195 in 2017 year. Consequently, degree of efficiency of institutional management of land relations in Russia character as weakly.

The significant role of new institution of land relations management consists of active development land policy in Russia and move to a higher level of efficiency of institutional management, that confirms the relevance of future research.

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THE METHOD ENSURING SUPPORT OF DEMAND FOR AGRICULTURAL-PURPOSE LAND

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Abstract

A stable institution that ensures coordination of communication between authorities, sellers, and buyers, was designed within the developed method supporting demand for agricultural-purpose land, taking into account the provisions of the system approach. On the example of Saratov region (oblast) of the Russian Federation, the failures of the current land market were determined and taken into account when specifying the objectives, functions, activities, new norms, rules. The block model of the Institution supporting demand for agricultural-purpose land includes the central area of focus, functional purpose, regulatory activities, and expected results. The Institution is aimed at creating the attractiveness of agricultural-purpose land as a commodity, scientific justification of effective agricultural-purpose land use programs. The functions of the Institution supporting demand for agricultural-purpose land are to attract buyers among agricultural producers, to disseminate information on offers and enforcement of concluded contracts. The presented algorithm describes the process of interaction of subjects in land relations with state authorities through the introduced Institution supporting demand for agricultural-purpose land, buyers. The proposed institutional structure will be an effective alternative to a set of disparate initiatives and actions.

Key words: *agricultural-purpose land; auction; demand; land plots; method.*

INTRODUCTION

In the broad sense of the word, "method" is considered as a way of research or cognition, based on the certain body of previously obtained knowledge (Mostepanenko, 1972). In a narrow sense, a method is a systematized set of techniques and procedures of theoretical cognition and practical transformation of an object (Zavorotin et al., 2015; 2017; 2020). This understanding of the method will be used in this study.

The theoretical and methodological basis for developing a method supporting demand for agricultural-purpose land is the institutional theory, in which the structure of incentives is determined by institutions, that is, created by formal and informal constraints, as well as enforcement factors that organize relationships between people.

North (1997) defines institutions as rules, mechanisms that ensure their implementation, and norms of behavior that structure repetitive interactions between people. Sukharev (2014) has an idea of institutions as formal rules formed by society and government, which acquire the meaning of norms that have legal significance, and informal rules.

The conceptual framework of market, market system is contained in the scientific works of Smith (2007), Ricardo (1955), Marx & Engels (1960), Samuelson & Nordhaus (1997), etc. Common definitions of the market are: the sphere of commodity exchange (Marx & Engels, 1960); the system of economic relations between producer and consumer (Kovalenko, 2019); the real space with interaction of supply and demand (Abalkin, 1999).

McConnell & Brue (1992) interpret it as an institution, or a mechanism that brings together buyers ("demanders") and sellers ("suppliers") of particular goods, services or resources. Ciaian, Kancs and Swinnen (2010) take into account demand factors for agricultural-purpose land.

The author's method ensuring support for demand for agricultural-purpose land involves drawing up a set of rational actions that must be taken to improve the efficiency of the development of the agricultural-purpose land market.

MATERIALS AND METHODS

The method ensuring support of demand for agricultural-purpose land involves studying the bidding procedures, sale of agricultural-purpose land by auction, market volatility, and management of regulations, rules, and mechanisms.

RESULTS AND DISCUSSIONS

Analysis of the existing agricultural-purpose land market

Saratov region is the subject of the Russian Federation, which includes 38 municipal districts grouped into 7 natural-climatic microzones: West (Arkadaksky, Balashovsky, Romanovsky, Rtishchevsky, Samoylovsky, Turkovsky districts); Central Pravoberezhye (Atkarsky, Ekaterinovsky, Kalininsky, Krasnoarmeysky, Lysogorsky districts); North Pravoberezhye (Bazarno-Karabulaksky, Baltaysky, Volsky, Voskresensky, Novoburassky, Petrovsky, Khvalynsky districts); Prigorodnaya (Saratovsky, Tatishchevsky, Engelsky districts); North Levoberezhye (Balakovsky, Dukhovnitsky, Ivanteevsky, Marksovsky, Pugachevsky districts); Central Levoberezhye (Ershovsky, Krasnokutsky, Krasnopartizansky, Rovensky, Sovetsky, Fedorovsky districts); South-East (Alexandrovo-Gaysky, Dergachevsky, Novouzensky, Ozinsky, Perelyubsky, Pitersky districts) (Wikipedia, 2020).

In Saratov region, the agricultural-purpose land market operates in two sales areas: agricultural-purpose land for ownership and right for lease.

The main results of the study and analysis of information on the agricultural-purpose land market in the Central Pravoberezhye microzone of Saratov region on public auctions for the sale and lease of agricultural-purpose land plots placed on the official website of the Russian Federation for posting information on the conduct of trades (2020) in accordance with the Federal law of July 24, 2002, No. 101-FZ "On the Turnover of Agricultural Land" (2020) are presented in Table 1.

In 2017-2019 the largest number of offers for the sale of land plots is noted in Kalininsky district (19), for lease - in Ekaterinovsky (45) and Atkarsky (39) districts.

The maximum opening price for the sale of the ownership of 1 ha of land was 822755.1 RUB (Krasnoarmeysky district), and it was 4309.11 RUB (Lysogorsky district) for rental payment.

Market transactions have not been concluded in all areas of the microzone due to the cancellation of auctions, their termination on the initiative of subjects in legal relations, lack of price step-up bids, participants admitted to the auction.

The main problem of functioning of the agricultural-purpose land market is in establishing adequate prices for a specific good. For example, the opening price for a land plot with a total area of 67 hectares for foreclosure sale, carried out through a public offer posted on the Internet by the auction organizers, is 6382872.13 RUB, which is 20 times higher than the price of the winner - 319143.70 RUB (Figure 1).

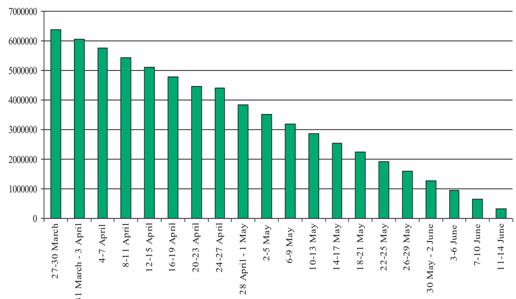

Figure 1. Dynamics of prices for the debtor's land plot in Krasnoarmeysky district of Saratov region, in 2017
Source: Own design based on E-Trade Center (2020)

Thus, there is a difference between the market price and the cadastral value, an imbalance of supply and demand.

Improving the performance of the agricultural-purpose land market by activating norms, rules, and demand support mechanisms

The regional agricultural-purpose land market does not have proper development due to the imperfection of certain normative legal acts regulating land relations, presence of excessive administrative barriers, asymmetric information on prices, which causes an objective need of designing the institute of stimulating demand for land plots (Figure 2).

Incorporation of a new structural component in the existing institutional environment should help to eliminate negative trends that occur in the course of market and non-market turnover.

Table 1. Results of auctions for sale and lease of agricultural-purpose land in municipal districts of the Central Pravoberezhye microzone of Saratov region of the Russian Federation

Indicator		Year 2017	2018	2019
Atkarsky district				
Number of lots, items	for sale	3	1	–
	for lease	10	9	20
	held	3	4	6
Total area of land plots, ha	for sale	7.21	7.00	–
	for lease	301.10	651.04	1289.36
Opening price of the lot, RUB/ha	for sale	12398.37	25573.00	–
	for lease	672.19	511.46	433.95
Ekaterinovsky district				
Number of lots, items	for sale	–	2	5
	for lease	14	7	24
	held	8	–	2
Total area of land plots, ha	for sale	–	3.00	55.20
	for lease	349.05	358.00	581.66
Opening price of the lot, RUB/ha	for sale	–	155820.00	9817.14
	for lease	799.83	1796.86	1490.81
Kalininsky district				
Number of lots, items	for sale	10	1	8
	for lease	6	11	2
	held	7	6	6
Total area of land plots, ha	for sale	772.50	11.00	338.67
	for lease	459.50	1038.35	187.00
Opening price of the lot, RUB/ha	for sale	9190.03	9290.60	11710.38
	for lease	1067.49	1139.70	1240.64
Krasnoarmeysky district				
Number of lots, items	for sale	2	3	–
	for lease	–	5	6
	held	2	–	–
Total area of land plots, ha	for sale	0.43	60.00	–
	for lease	–	78.10	135.63
Opening price of the lot, RUB/ha	for sale	822755.10	3950.00	–
	for lease	–	593.47	1141.86
Lysogorsky district				
Number of lots, items	for sale	2	–	5
	for lease	2	–	10
	held	–	–	4
Total area of land plots, ha	for sale	345.90	–	454.43
	for lease	180.40	–	502.00
Opening price of the lot, RUB/ha	for sale	7091.65	–	8206.69
	for lease	609.76	–	4309.11

Source: Own calculation based on the data from the official website of the Russian Federation for posting information on the conduct of trades (2020) in accordance with the Federal law of July 24, 2002, No. 101-FZ "On the Turnover of Agricultural Land" (2020)

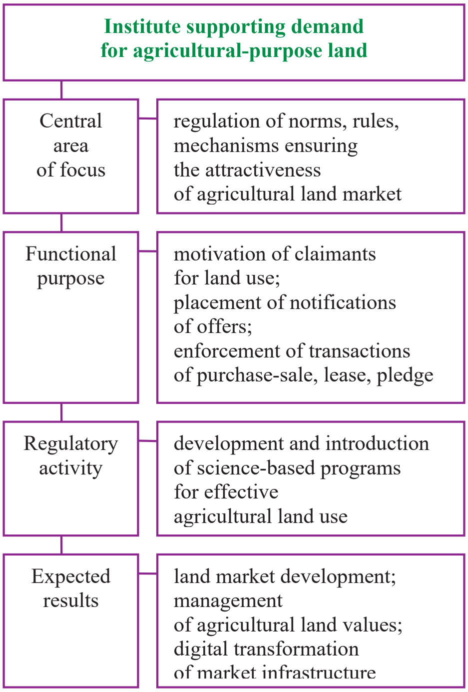

Figure 2. Scheme of the proposed Institute supporting demand for agricultural-purpose land
Source: Own elaboration

This measure will be the most effective when initiated by the authorities.

The Institute supporting demand for agricultural-purpose land is designed to make positive changes in the market situation, to provide the transition of land plots from inefficient to efficient users. Its intended functions are as follows:

- motivation of potential buyers – attraction of agricultural producers through advisory activity (meetings, webinars, etc.) on characteristics of the land plot, legal, financial and other aspects;
- organization of free access to offers - dissemination of information on a possible transaction with land plots;
- transaction enforcement - protection of concluded agreements and fulfillment of obligations stipulated within them.

Interaction of state institutions with modeled norms and rules occurs in a certain sequence (Figure 3).

The practical significance of the method using such institutional structure is the possibility of:

- applying a situational approach to analyze the results of monitoring the preferences of buyers of agricultural-purpose land;
- building systematic relationships with owners, land users, landowners, lessees through the organization of permanent seminars, round tables, including the use of information-and-communication technologies on topical issues of acquisition of land for agricultural production, overcoming the progressing diminishing of soil fertility;
- providing executive authorities with relevant materials for developing doctrines, strategies, concepts, programs;
- encouraging agricultural producers to make transactions for the purchase and sale of land for ownership or rights for lease;
- involving of unused and abandoned agricultural-purpose land in the turnover.

CONCLUSIONS

The developed method ensuring support of demand for agricultural-purpose land allows identifying the problems of the existing market, creating an algorithm for the process stimulating demand for land, and optimizing the market situation by correcting the institutional environment.

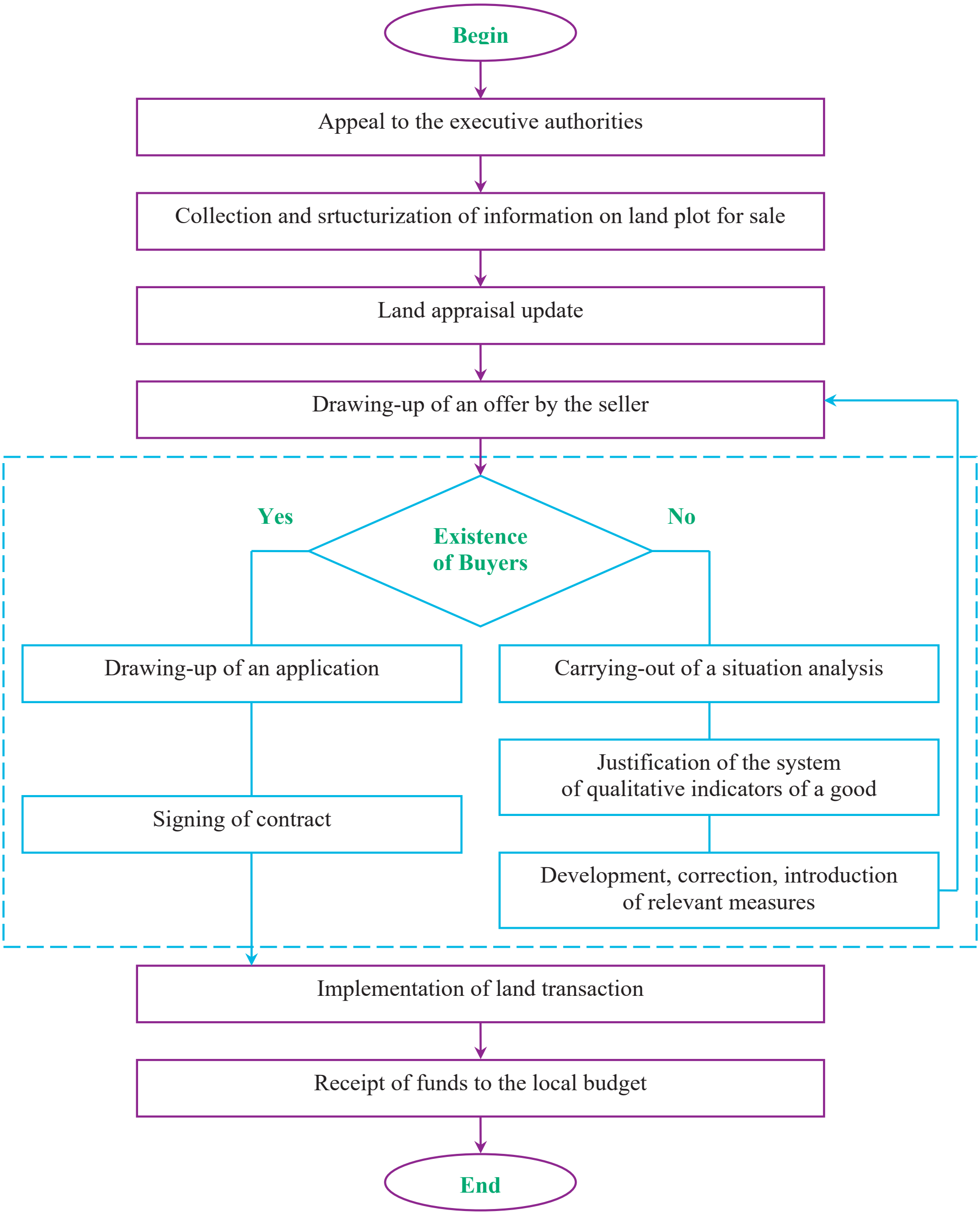

Figure 3. Algorithm of involvement of the Institute supporting demand
in the functioning of the agricultural-purpose land market
Source: Own elaboration
Legend: The dotted line marks the responsibility of the Institute supporting demand for agricultural-purpose land

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THE INFLUENCE OF GIS TECHNOLOGY IN RECLAMATION SOLUTIONS FOR SLOPING LAND AFFECTED BY EROSION

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Abstract

The study was performed on a catchment area of approx. 150 ha, mainly for agricultural use, with steep slopes, with intense erosion and associated processes. The arrangement proposal was made after establishing the erosion risk, the degrees of intensity and the spatial distribution of this process. In order to determine the average annual soil loss and then the alluvial influx, the U.O.R. (Homogeneous Relief Units) procedure was chosen: for each U.O.R. the ROMSEM equation was applied successively, adapted for our country by acad. M. Moţoc. In this approach, the GIS technique was used by using Geo-Graph software, by creating spatial bases and processing by overlay technique (7 information layers were created). The attribute database was created taking into account all the factors involved in the erosion process, the parameters characterizing the climate, the relief, the soil, the land use, the technologies of agricultural exploitation, etc. The main purpose of the paper is to demonstrate that the complex action of monitoring and management of lands affected by various degradation processes can only be done correctly within a Geographic Information System - GIS.

Key words*: Database, erosion, GIS, landscaping, reclamation.*

INTRODUCTION

Soil erosion is one form of soil degradation along with soil compaction, low organic matter, and loss of soil structure, poor internal drainage, salinization, and soil acidity problems. These other forms of soil degradation, serious in themselves, usually contribute to accelerated soil erosion.

Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks, (Haidu I. et al., 2012).

Water erosion's complex hierarchy of processes mean that erosion by water operates over a wide range of spatial scales. Rainsplash redistribution and the initiation of microrills and rills occur at a scale of millimeters. Rill erosion on agricultural hillslopes operates at a scale of meters to tens of meters, while gully erosion can occur on a scale of hundreds of meters, or even kilometers.

The offsite impacts of erosion can affect very large areas, sometimes hundreds or even thousands of square kilometres (Iacobescu O. et al., 2012).

Soil erosion has a range of environmental impacts, including loss of organic matter and nutrients, reduction of crop productivity, and downstream water quality degradation (Berghoff et al., 2014).

Effective control of soil erosion is a critical component of natural resource management when the aim is to achieve sustainable agriculture and acceptable ecosystem integrity (Bilaşco et al., 2018).

Soil conservation on sloping land is carried out through complex measures and works, some of which fully manage water runoffs or intercept and drain water under controlled conditions. They are sized according to hydrological and hydraulic criteria (Arnaudova et al., 2020)

Other measures or works ensure better land coverage and by increasing the ability to infiltrate the soil, prevent erosion. The effect of the set of measures must be assessed, both in terms of water and soil conservation.

In this context, however, it is important that the testing of soil conservation measures, planned for a given territory, is carried out on the basis of average annual soil losses, since their size conditions the level of soil fertility and agricultural production (Irimuș I. et al., 2017).

The planner land reclamation needs to determine the level of soil losses - current and probable ones - after the application of the proposed set of measures. Successive tests must find the combination of measures and works that bring highest anti-erosion and economic efficiency.

Soil erosion control is intended to secure and conserve agricultural land in particular and other social-economic objectives in general, and is called 'conservation works'.

Long-standing practice and scientific study of soil conservation on slopes showed that erosion can be contained if a set of anti-erosion measures is applied, both for preventive purposes and for the improvement of already degraded land (Biali et al., 2020). Taking into account the large area of land that need anti-erosion facilities in Romania (approx. 5.3 million ha), at the rate at which such arrangements have been carried out so far (on approx. 42% of the need), in the future, special financial efforts are required to extend them.

MATERIALS AND METHODS

In Romania, by complying with the structure of USLE equation, but changing the denomination and the determining method of the terms, the formula for computing the soil loss due to surface hydric erosion was used through the form of ROMSEM model-Romanian Soil Erosion Model (Moţoc M., 2002):

$$E = K \cdot S \cdot C \cdot C_s \cdot L^{0,3} \cdot i^n \quad (1)$$

where:

E - the annual soil loss per hectare by means of sheet erosion (t/ha·year);

K - regional erosion (rain erosion) soil loss per rain aggressiveness areas determined based on the rain aggressiveness index $H \cdot I_{15}$; is determined by means of elements extracted from rainfall recorder charts related to torrential rain that generate erosion: H - the quantity of precipitations fallen during the torrential rain (mm); I_{15} - average intensity per 15 minutes of the rain torrential core (mm/ minute).

In this context, the pluvial aggressiveness is expressed through the pluvial aggressiveness coefficient and defines, concomitantly, the erosiveness of rain and the impact on the eroded soil.

The Romanian pluvial aggressiveness zoning map was developed based on the average multiannual values.

L^m - length in the flowing (slope) direction, (m); m = 0.3 for L > 100 m; m = 0.4 for L < 100 m.

i^n - average gradient in the flowing direction, (%); n = 1.4.

S - correction factor for soil erosiveness (non-dimensional).

C - influence factor of purposes, crops and soil works (non-dimensional).

C_S - influence factor of soil protection and preservation actions and works (non-dimensional).

In our project we gave special importance to the "relief" parameter. The relief conditions are characterized by two factors: the length of the slope in the flowing direction (L) and the land gradient (i).

In USLE model, these factors are reunited (Li) and represent the topographic factor. The length of the slope index is defined as the horizontal distance measured from the point of origin of the superficial flow up to one of the following points (Wischmeier and Smith, 1978):

- the point where the slope decreases and the deposit process begins;
- the point where the flow reaches a well-defined channel.

The land gradient factor (i) reflects the influence of the land gradient on the hydric erosion process.

The length of slope factor (L) can be determined through the following formula:

$$L = \left(\frac{\lambda}{22{,}14}\right)^m \quad (2)$$

where:

λ - length of slope (in horizontal projection), (m);

22.14 - length of the standard plot for the control of flow on versants, (m) or (76.2 ft);

m - exponent depending on the land gradient.

By considering the ratio β between erosion in the culverts (through the water currents) and between culverts (caused mainly by the impact of rain drops), the exponent *m* can be determined by means of the following formula (Renard K.G. et al., 1996):

$$m = \frac{\beta}{1+\beta} \quad (3)$$

According to Renard K.G. et al., 1996:

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$$\beta = \left[\frac{\frac{\sin\theta}{0{,}0896}}{3{,}0 \cdot \sin\theta^{0{,}8} + 0{,}56} \right] \quad (4)$$

where θ is the land gradient (radians).

According to researches (Williams J. et al., 1990 and Renard K.G. et al., 1996) the factor (i) which characterizes the size of the land gradient, can be determined through the following formula:

$$i = 10{,}8 \sin\theta + 0{,}03;\ \text{for } i < 9\% \quad (5)$$

$$i = \left(\frac{\sin\theta}{0{,}0896} \right)^{0{,}6};\ \text{for } i \geq 9\% \quad (6)$$

where i is the gradient value (%).

Based on the above, it results the opportunity of determining a single topographic factor Li:

$$Li = \left(\frac{\lambda}{22{,}14} \right)^{m} (10{,}8 \cdot \sin\theta + 0{,}03);\ \text{for } i < 9\% \quad (7)$$

$$Li = \left(\frac{\lambda}{22{,}14} \right)^{m} \left(\frac{\sin\theta}{0{,}0896} \right)^{0{,}6};\ \text{for } i \geq 9\% \quad (8)$$

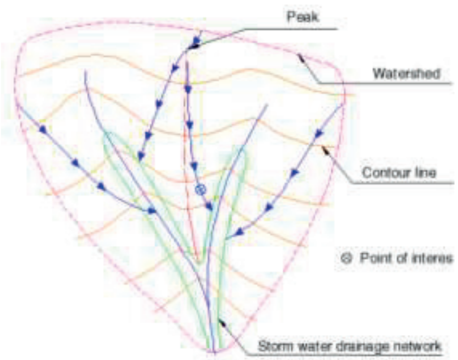

Figure 1. Determination of parameter "length of flow on versants" in model USLE

The flowing/draining directions of the reviewed water catchment area were also laid out by means of the land raster form alphanumeric model. Under this procedure, the draining network of the reviewed area has an arborescent structure, with maximum ramification at source pixel level, where the concentration manner of drainage towards the closing pixel depends on the confluence positioning. By transiting it pixel by pixel, the flow from upstream towards downstream was represented by means of irregular lines, with lengths reduced at the confluence points. In the distributed flowing model, the integration computation organizing manner is based on the determination of associated draining local directions, and the other topographic information was used in particular in order to partially verify the accuracy thereof.

The water flow from a hydrographic unit takes place by means of a complex of paths that unite the high-altitude points with the closing point of the watershed (Haidu I. et al., 2012).

Thus, in the catchment area, one can see the source type pixels - to which no other pixel is drained, the confluence pixels - where at least two upstream pixels are drained, and the closing pixel - passed by all draining paths of the basin (Moore I.D. et al., 1992).

The raster representation considered that the current pixel can be drained based on one of the eight possible directions (Figure 2a), depending on the positioning of the lowest altitude adjacent pixel (Figure 2b). When analysing the vicinities of the central pixel, in order to determine the draining direction thereof (Figure 2c and Figure 2d), the altitude of diagonal ones are reconsidered in order to maintain the same distance from the reference pixel (Burrough P.A., 1988).

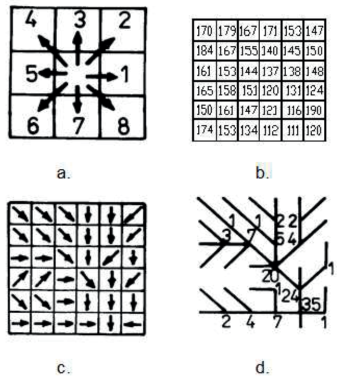

Figure 2. Analysis of versant flow based on GIS raster method:

a) determination of the flowing direction based on one of the eight potential directions;

b) representation of the land surface in raster model (average quotas);

c) flowing directions related to the grid of (b);

d) flowing concentration grid equivalent with (c) and (d)

Research method proposed in the GIS application algorithm

The estimation of average annual soil loss non slopes longer than 400 m by water erosion is based on soil loss accumulation throughout the hill-valley route (highlighted in a land survey), taking into account its constituent landforms.

Assuming that the average amounts of soil reaching the bottom of a slope need to be calculated, on which the following landforms exist: plateau, plateau top (upper/upstream of the plateau), terrace, terrace top (upper/upstream part of the terrace), for the purpose stated, the following steps shall be taken:

a) To calculate the specific average soil loss on the plateau, depending on its elements (L, i, C, Cs, S). Note that a small percentage of the eroded material is deposited in negative landforms (if they exist) or is retained by the vegetation at the slope bottom, as suspension sediments (As) or most of the other types of sediments (Ar).

b) To calculate the specific average loss for the plateau top, which depending on length, tilt, soil, crop, etc. can have much higher values than those on the plateau (generally the tops have small lengths but steep slopes, with low infiltration and short concentration time).

c) To sum up the specific average soil loss at the bottom of the plateau with the loss at the top of the plateau. From this value, the estimated percentage of sediments retained on slope is subtracted, resulting specific average loss from plateau top.

The remaining solid material runs down by draining and accumulates with the rest of terrace soil loss. The value obtained is corrected by removing deposits on slopes, obtaining the specific average loss at the bottom of the terrace.

d) To calculate with the known formula the soil volume on terrace top and to add the soil volume on the terrace. From this value, subtracting the estimated loss due to microrelief and vegetation, the specific average amount of solid material deposited at the base of the slope is obtained.

The more knowledge on erosion alongside the complex slopes and relation between suspended load and pushed load of silts along waterways, the more accurate the results achieved.

For additional insight, mostly within large territories and with a wide variety of geomorphological conditions, soil and slope use, we recommend the implementation of the Technique of Geographical Information Systems (Cochrane et al., 1999).

Estimation of sheet erosion is based on the method developed by acad. M. Motoc (1980), using the calculation relationship (eq. 1).

Land surveys were used to estimate sheet erosion at 1:5000 scale, with relatively homogeneous units in terms of use, slope and slope width. For each relatively homogeneous unit, erosion in t/ha per year is calculated, depending on unit area and then erosion in t/ha.

When summing up erosion of all relatively homogeneous units, the erosion in the entire river basin studied, t/year, is determined.

The measurement unit of sheet erosion is be converted from t/year into m3/year, taking into account the average volumetric weight of the eroded material.

The following chart (Figure 3) presents the organization of operations needed to estimate sheet erosion, in a territory or river basin.

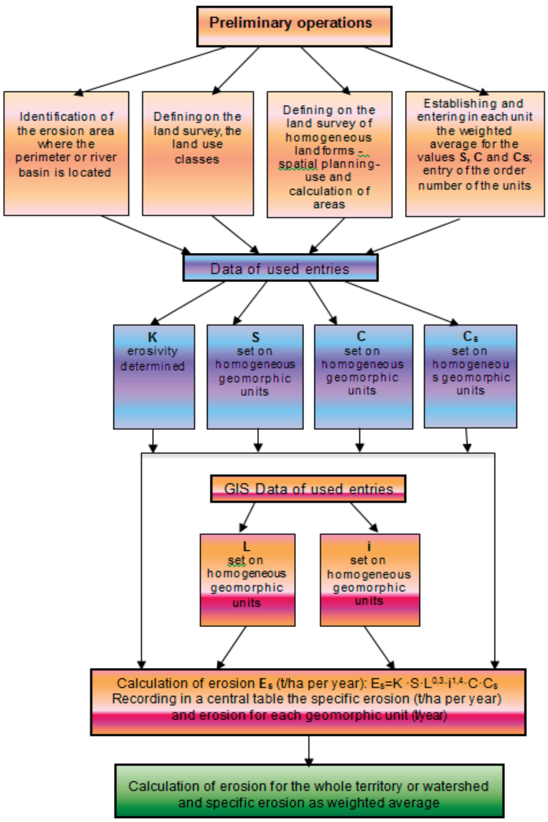

Figure 3. Organising operations to estimate sheet erosion

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RESULTS AND DISCUSSIONS

In our project, the geo-referenced data is represented in the form of layers, fact that enables the analysis of spatial variables and the distribution of entities on the analyzed surfaces, and the overall analysis of acquired information, which implies the concomitant approach of several layers, was enables by the "*overlay"* technique (Biali, 2002).
The application used a Romanian GIS-type software, Geo - Graph, intended for work operations with digital maps and database interrogations with ROMSEM Model.

Research area

The study area is located in the Nicolina river basin (Figure 4), in the lower third of the Bahlui basin, in the vicinity of Iași municipality, being delimited as follows:
- north of the Bahlui river meadow - Iași city;
- east of the Bahlui river basin - Repedea mini-basin;
- east of the Rebricea and Vasluieț river basins;
- west of the Bahlui river basin - Pârâul Mare mini-basin.

The territory of the Nicolina river basin is in administrative terms part of the commune of Miroslava (Iași), having the following limits:
- to the east the Uricani agricultural land
- to the west the Uricani agricultural land
- to the north the Miroslava agricultural land
- to the south Cornești commune

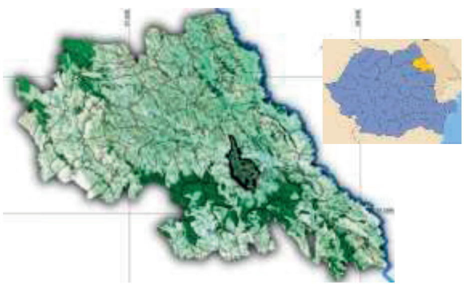

Figure 4. Nicolina river basin, in the lower third of the Bahlui basin, in the area of Iași municipality

Geomorphological data

The studied area is part of the Central Moldavian Plateau. The researched territory is located in the transitional region from the Jijia-Bahlui depression to the high peak of the Central Moldavian Plateau. Consistent valleys: this category includes Nicolina valley with the approximate orientation in the NW-SE direction, with generally open slopes, with a convex profile, and in slippery areas, undulating with an average slope value of 8-12°, (Niacsu L., 2012).

The area under study is 142.70 ha. Following the vectorization from the initial situation plan, it was found that the arable predominates in a percentage of 47.5% equivalent to 67.8 ha, followed by hay 9.9%, pasture 17.4%, orchard 17.1%, the remaining 8.1% being unproductive (gully). The graphical results are presented in the Figure 5.

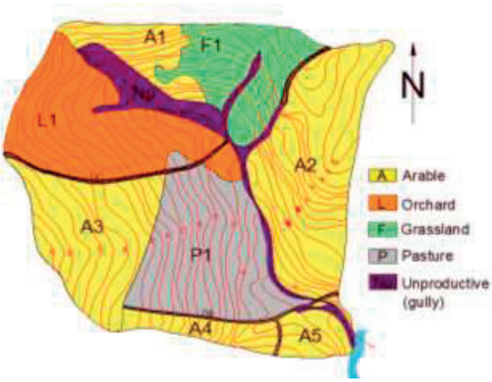

Figure 5. Inventory of use categories (vector)

Climatic data

For the climatic characterization of the studied area, the meteorological data obtained by the Iasi resorts were used. The average annual temperature is 9.6°C, average rainfall 517.8 mm. The average period of frost-free interval is 181 days. The soil is covered with snow for about 60 days, and the average annual thickness is 28 cm in the mentioned period. At Iași resort, there is a deficit of total annual precipitation of 21.2 mm starting in July, August. The microclimate of sunny slopes, which retain less moisture, is often observed the effect of more pronounced drought.

Pedological studies

The lands within the reception area of Ursului Valley (Nicolina Hydrographic Basin) are characterized by a wide range of soils subjected to degradation processes, of different shapes and intensities expressed by sheet erosion, depth and landslide processes (Niacșu L. et al., 2015). The soil type is chernozem in different leaching stages. The studied surface includes the following pedo-amelioration groups (Figure 6), presented briefly:

Group I: Slightly eroded soils. Requires regular cultivation and fertilization. It includes semi-group IA with soil units: US 6.

Soils have good fertility. Hydrological class B/C and C. Erodability coefficient 0.6-0.7.

Group II: Moderately eroded soils. It comprises the US 2,3,4,10,15 moderately-eroded heavily - leached chernozem soil unit. They are located on slopes of 6-12%. Stable structural elements, erosion-resistant soils. Hydrological class C/D. Erodability coefficient 0.6-0.8.

Group III: Moderately to heavily eroded soils. Includes soil unit US 19 medium heavily-leached, heavily-eroded chernozem. Soil permeability is poorly moderate, infiltration coefficient is $1 \cdot 10^5$cm/s. Hydrological class C and D. Erodability coefficient: 0.7-0.8.

Group IV: Excessively eroded soils in the cornice area. It comprises the US 20 soil unit. The texture varies widely from light, medium and fine. The infiltration coefficient is between 10-4-10-5. Erodibility coefficient 1.0-1.1.

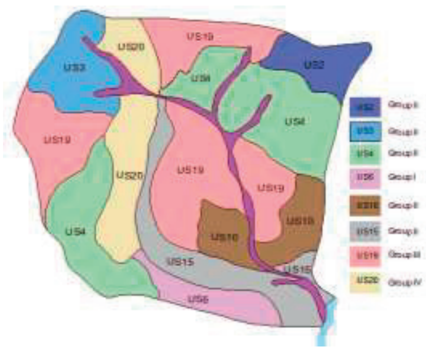

Figure 6. Soil mapping (vector)

Hydrological and hydrogeological studies

Hydrographic regime is characterized mainly by pluvial supply with high waters in spring and floods in summer and autumn. Winter runoff is low, high turbidity due to heavy erosion. Under loessoid deposits, the groundwater is found at a depth of 8-10 m, under the marly clayey deposits on slopes, from 4 to 6 m, and under the deposits of saliferous marls, the canvas varies. On some slopes it is found at 1-2 m and in some areas at 0.6-1.0. On eroded slopes 1-4 m, in meadows, it varies from 0.8 to 1.8 m depth. Following field studies and research, the presence of captive water bodies has been reported, which greatly influences the extent of erosion and landslides.

Proposals for Land Reclamation

Development proposals were made according to results obtained for sheet erosion. Much importance is given to drainage/drainage network/on basin surface, the network obtained by using GIS.

In the GIS application, based on the criteria imposed by maximum lengths and direction, 39 homogeneous relief units (H.R.U.) resulted. Based on equations 2, 6, 8 the parameters length and slope were determined. The graphical results are presented in the Figure 7.

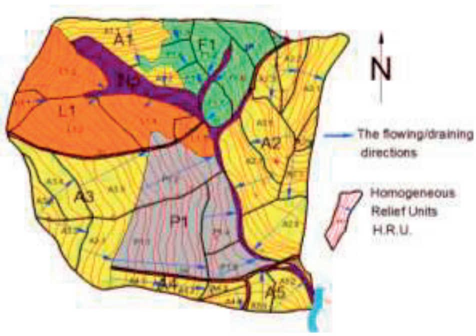

Figure 7. The flowing/draining directions of the reviewed water catchment area (H.R.U)

Based on sheet erosion results in GIS application were proposed the following anti-erosion culture systems on slopes:

a) Cover crops cultivated in the general direction of the level curves, meaning all agricultural crops shall be placed alongside level curve direction on all land with slope under 8%. We proposed this cultivation system on the following homogeneous relief units (H.R.U.): $A_{3.4}$, $A_{4.3}$, $A_{4.4}$, $A_{5.2}$, $A_{5.3}$ (Figure 8).

b) Cover crops cultivated in strips consisting of dividing slope into strips oriented along level curves and growing alternately crops that provide different anti-erosion protection In general, strip width depends on land slope, topsoil type, rainfall characteristics and volume, plants being cultivated etc.

Calculation of strip width (L) cultivated with various plants can be made mainly based on the criterion of critical erosion (tolerable or admissible), according to the equation:

$$L^{0.3} = \frac{E_{cr}}{K \cdot i^{1.4} \cdot S \cdot C \cdot Cs} \quad (9)$$

The interpretation of abbreviations is presented in eq. 1.

In STAS 8390/1980, the following equation is given to calculate cultivated strip width (D):

$D = 10^{2.22} - 0.03 \cdot i,$ (10)

for erosion-resistant soils;

$D = 10^{2.15} - 0.03 \cdot i,$ (11)

for medium erosion-resistant soils;

$D = 10^{2.05} - 0.03 \cdot i,$ (12)

for poorly erosion-resistant soils;

where i is the land slope (%).

Since calculations always show variable strip widths (for the same slope) which depend on cover crop type (each with different roughness, draining coefficients, etc.), for proper exploitation and rotation of crops, approximately equal strip widths will be chosen so that sowers can operate on them.

The calculations in the GIS application resulted in strip lengths between 80 and 280 m.

We proposed the anti-erosion strip system for the following homogeneous relief units (H.R.U.): $A_{1.2}$, $A_{1.3}$, $A_{2.3}$, $A_{2.4}$, $A_{2.5}$.

c) Buffer strip cultivation system is intended to divide the slope (designed for slopes from 12 to 25%) in strips cultivated with the same crop, and interspersed with narrow strips (4-10 m wide) cultivated with grass. According to STAS 8390/1980 we used the following equation to calculate the distance of placing grass strips on tillable land:

$D = C_1 \cdot E_{critic}^{2} \cdot i^{-0.28}$ (13)

where:

D is the distance between two consecutive grass strips (m);

C_1 = 2.90 on topsoil thicker than 0.60 m, formed on loessial sediments.

E - admissible erosion value 4.0...7.0 t/ha per year;

i - land slope (%).

Grass or buffer strip system is proposed for the following plots: $A_{2.2}$, $A_{2.8}$, $A_{3.1}$, $A_{4.2}$.

d) Terrace cultivation system

In areas with high climatic aggression, light soils, long slopes and with a high percentage of hoes, the anti-erosion systems presented above are not enough to contain erosion and keep it within permissible limits, and in such cases the terrace cultivation is promoted. It leads to land slope alteration, soil erosion containment, topsoil changes and higher agricultural production.

We proposed terrace cultivation for the following homogeneous relief units (H.R.U.): $A_{1.1}$, $A_{2.1}$, $A_{2.6}$, $A_{2.7}$, $A_{3.2}$, $A_{3.3}$, $A_{3.5}$, $A_{4.1}$, $A_{5.1}$. The graphical results are presented in the Figure 8.

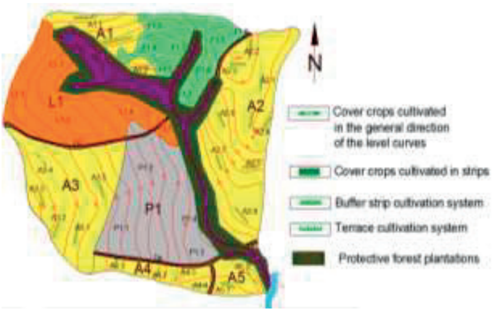

Figure 8. The flowing/draining directions of the reviewed water catchment area (H.R.U)

In the studied river basin, through the application of GIS, anti-erosion works on arable surfaces were proposed. The assessment of the positive effect can be done by determining the anti-erosion efficacy.

The effectiveness of the anti-erosion effect is:

$$E_A = E_a^{*} - E_a^{**} \quad (14)$$

where:

E_a^{*} - alluvial effluence before arrangement;

E_a^{**} - alluvial effluent after arrangement.

E_A = 1978.02 − 600.69 = 1377.33 (m^3/an)

Calculate: K_a - coefficient of anti-erosion effectiveness.

$$K_a = \frac{E_A}{E_a^{*}} \cdot 100 \ (\%) \quad (15)$$

$$K_a = \frac{1377.33}{1978.02} \cdot 100 = 69.63\ \%$$

Because the value of the anti-erosion efficiency coefficient is considerable (K_a = 69.63%), so that it can be concluded that the efficiency of the anti-erosion works in the river basin is significant.

CONCLUSIONS

In the studied catchment area, due to natural and anthropogenic factors, which have contributed to the appearance and development of soil degradation processes through sheet erosion and landslides, it is found that agricultural production on slopes decreased year by year, taking its economic toll on the region.

Annual crop losses, due to sheet erosion, arable land disuse by expanding landslides and deep erosion, led to substantial annual losses taking its economic toll in the region.

In the current situation, 2-3 cm of the fertile topsoil layer is washed off annually, which leads to a decrease, year by year, of the soil production potential. Soil loss on slopes of the studied area (with slopes of 8-22%) amounts to 16-42 t/ha every year.

The land management measures proposed by this project aim to increase the fertility of soils affected by erosion, by improving the soil water storage and chemical characteristics. The objectives of these measures are: managing water runoffs from slopes (Figure 8) restoring disused lands affected by landslides, higher agricultural produce.

This paper presents partial results from a large project of monitoring and management of erosion processes on agricultural slopes and the choice of optimal solutions for the development of these lands.

It is known that the monitoring and management operations of a territory involve a considerable volume of data and means of processing and analysis. In this context, the correct establishment of the land arrangements affected by erosion degradation processes acquires a special importance both for the agricultural owners and for the decision-makers in the field of agricultural management.

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GEOMATIC METHODS FOR MANAGEMENT PLANNING OF PROTECTED AREAS. CASE STUDY: PANIOVA FOREST, TIMIS COUNTY, ROMANIA

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Abstract

Imaging analysis based on satellite images, RapidEye imagery was used to analyse and characterize Paniova Forest, a Natura 2000 Site. The studied perimeter is located in the Lugoj Plain, Timis County, Romania. A RapidEye satellite scene with 5 - multispectral bands was used. From a morphological point of view, the study area was analysed based on the parameters: Altitude, Slope (degree) and Slope exposure. In relation to DEM, 10 classes of the protected area were obtained (14.76 ha and 368.64 ha), in relation to Slope, 10 classes (0.75 ha and 469.29 ha), and in relation to the Slope exposure 11 classes (4.53 ha and 339.9 ha). The relationship between NDVI and MSAVI was described by a linear equation in relation to Altitude derived from SRTM mission, and by polynomial equations of 2nd degree in relations to Slope and Slope exposure. According to PCA, PC1 explained 67.91% of the variance, and PC2 explained 32.033% variance with reference to DEM classes; PC1 explained 80,927% variance, and PC2 explained 18.576% variance with reference to Slope; PC1 explained 66.592% variance, and PC2 explained 33.235% variance with reference to Slope exposure.

Key words: *Agroforestry area, DEM, model, RapidEye, PCA.*

INTRODUCTION

Land and resource management are old human concerns, even if the terminology has undergone evolutionary changes over time (Henley, 2008; Kwok, 2014; Uddin and Hossain, 2015; Epstein, 2019).

Natural resource management and biodiversity conservation are concerns of high importance, due to their importance in today's society and economy and world perspective (Muralikrishna and Manickam, 2017).

The method of studying and managing the environment and resources has evolved, depending on the level of knowledge, purpose, objectives, but also methods, techniques, facilities that people have had at their disposal (Putzel et al., 2015; Sala et al., 2017; Sivarajah et al., 2017). A crucial role now belongs to artificial intelligence, which can manage, in real time, huge amounts of data and facilitate decision-making (Vinuesa et al., 2020).

Also, the organization and management of the territory have changed over time, with reference to quantitative and qualitative territorial landmarks, but also with the requirements and needs of people, with the new reporting of people compared to the environment.

Satellite imagery analysis is used more and more in many domains, from micro - to macro scale.

In the case of land surfaces areas, the imagery analysis is based on satellite images (Landsat, RapidEye, Modis, etc.), aerial systems (UAV) or ground - based sensors (stationary or in-motion, like vehicles equipped with video cameras) and offers multiple information and benefits for the quantitative and qualitative evaluation of surfaces and management decisions (Alvioli et al., 2018; Baena et al., 2017; Gaw et al., 2019; Hamylton et al., 2020; Libran-Embid et al., 2020; Sala et al., 2020).

Satellite imagery allows near real-time or multi-temporal analysis and facilitates prediction analysis based on models built on multispectral images (Geller at al., 2017; Constantinescu et al., 2018; Pasetto et al., 2018).

Land areas can be analysed and characterized in morphological terms, by land cover, land use, quality status (degradation/pollution/ vulnerabilities, etc.), type and quality of resources, crop structure, etc. (Smith et al., 2014; Govedarica et al., 2015; Lawley et al., 2016).

MATERIALS AND METHODS

The study aimed to evaluate, from a land morphology point of view, an agroforestry area, based on a satellite image and the creation of parameters and information useful for analysis and management.

The study area was represented by the Natura 2000 Site, Paniova Forest ROSCI0338, located in the Lugoj Plain (West Plain), Timis County, Romania (Figure 1). The area is located at an altitude between 130-250 m, with an average slope of 10° and an area of approximately 1900 ha.

For the analysis of this site, a RapidEye satellite scene from 22.09.2019 was used. RapidEye imagery is provided in 5 spectral bands, namely Blue (440-510 nm), Green (520-590 nm), Red (630-685 nm), Red Edge (690-730 nm) and Near Infrared (760-850 nm).

Based on the spectral bands of the satellite imagery used, 2 vegetation indices were calculated, NDVI and MSAVI, that are among the most used Vegetation Indices today.

Normalized Difference Vegetation Index (NDVI), relation (1), is useful in order to generate an image displaying greenness (relative biomass) (Rouse et al., 1973), and Modified Soil Adjusted Vegetation Index (MSAVI), based on the SAVI index, relation (2), which is used in order to minimize the effect of bare soil (Qi et al., 1994).

$$\mathrm{NDVI} = \left(\frac{NIR - \mathrm{Re}\,d}{NIR + \mathrm{Re}\,d}\right) \qquad (1)$$

$$MSAVI = \frac{2NIR + 1 - \sqrt{(2NIR+1)^2 - 8(NIR - \mathrm{Re}\,d)}}{2} \qquad (2)$$

From a land morphology point of view, the study area was analyse based on the parameters: Altitude, Slope and Slope exposure (Figure 2).

Statistical analysis and data processing was performed in ArcGIS v.10.6, MS Excel and with PAST software (Hammer et al., 2001).

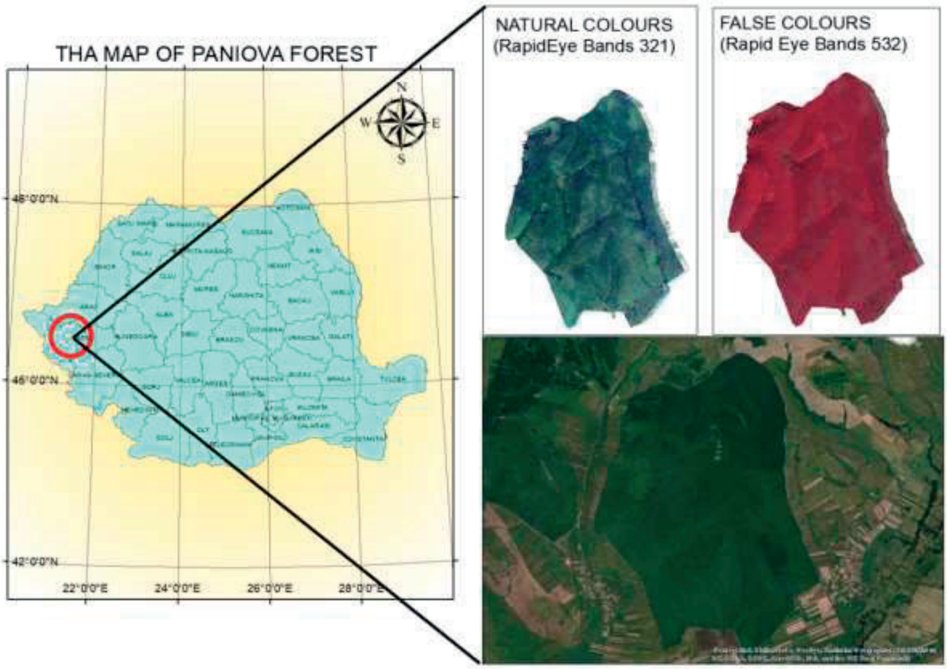

Figure 1. Study area, Natura 2000 Site, Paniova Forest, Timis County, Romania

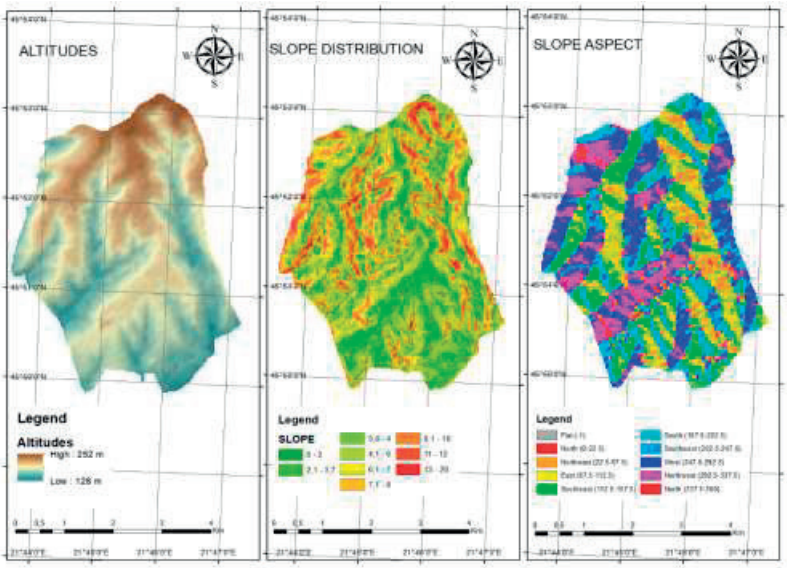

Figure 2. The graphic representation of Altitudes, Slope and Slope exposure for the studied area

RESULTS AND DISCUSSIONS

The land morphology analysis of the studied territory was performed in relation to three important characterization parameters: Altitude, Slope and Slope exposure. In relation to Digital Elevation Model (DEM), 10 arbitrary classes of the protected area were obtained (Figure 3), Paniova forest, with variable areas, between 14.76 ha and 368.64 ha. The NDVI and MSAVI indices (Figure 4) were calculated in relation to the DEM classes obtained, in accordance with the methodology presented in the material and method section, and the results obtained are presented in Table 1. The number of points and related values were generated following the spatial overlapping process.

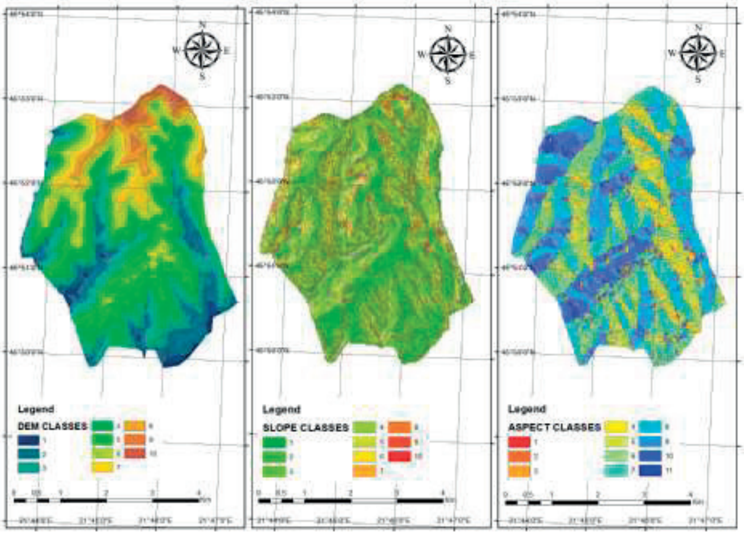

Figure 3. The spatial distribution of the classes

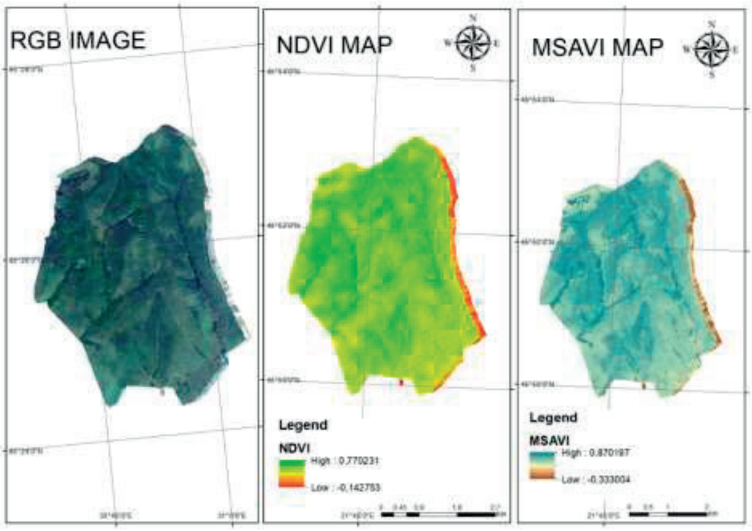

Figure 4. Natural colours RGB image and vegetation indices for the studied area

Table 1. Surface values and indices NDVI and MSAVI on DEM classes, for the protected area Paniova forest

DEM Code	Area		NDVI and MSAVI	NDVI			MSAVI		
	ha	%	Point No	NDVI	Min.	Max.	MSAVI	Min.	Max.
DEM1 <140m	41.97	2.27	17031	0.474282	-0.06424	0.715684	0.63558	-0.13729	0.834275
DEM2 140-152 m	211.01	11.39	86420	0.511829	-0.14275	0.738353	0.673863	-0.333	0.849477
DEM3 152-165 m	313.08	16.90	128614	0.529916	0.079044	0.742211	0.689698	0.146494	0.852025
DEM4 165-177 m	368.64	19.90	151545	0.533219	0.082748	0.770231	0.692206	0.152835	0.870197
DEM5 177-190 m	391.11	21.11	160834	0.546318	0.13221	0.753191	0.704184	0.233526	0.859216
DEM6 190-202 m	228.18	12.32	93835	0.559495	0.070648	0.736411	0.715314	0.131961	0.848191
DEM7 202-214 m	162.90	8.79	66930	0.545339	0.026878	0.742014	0.6989	0.052343	0.851895
DEM8 214-227 m	86.95	4.69	35614	0.552931	0.103157	0.735125	0.706307	0.187006	0.847337
DEM9 227-240 m	33.70	1.82	13807	0.567751	0.122201	0.72336	0.722041	0.217739	0.839466
DEM10 240-252 m	14.76	0.80	6023	0.533198	0.057067	0.684788	0.68757	0.107964	0.812896
TOTAL	1852.30	100.00	760653	0.537538	-0.14275	0.770231	0.695567	-0.333	0.870197

In this regard, based on spatial overlapping, a grouping of NDVI and MSAVI values was made by DEM classes, and the result was an identical number of NDVI and MSAVI points for each DEM class, Table 1. For each DEM class, the average NDVI and MSAVI values were calculated, as well as and the variation interval min - max, and the obtained results are presented in Table 1.

The variation of the vegetation index (NDVI) according to the MSAVI values, in relation to the structuring of the territory on the 10 DEM classes, is described by a linear equation, equation (3), under conditions of R^2=0.992, $p<0.001$, F=1036.2. The graphical distribution is shown in Figure 5.

$$\mathrm{NDVI} = 1.093\,MSAVI - 0.2219 \quad (3)$$

The PCA analysis (Principal Component Analysis) of the distribution of DEM classes, for the studied area Paniova forest, according to Area, MSAVI and NDVI, is shown in Figure 6.

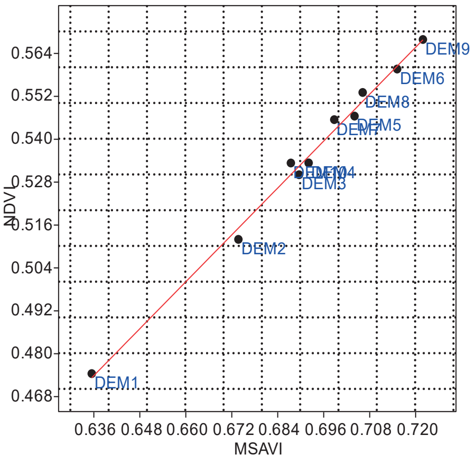

Figure 5. Graphic distribution of values NDVI according to MSAVI, under the conditions of 10 DEM classes

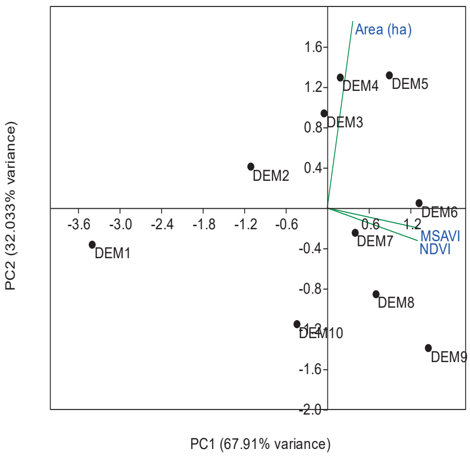

Figure 6. PCA distribution diagram of DEM classes, with reference to Area, NDVI and MSAVI

PC1 explained 67.91% variance, and PC2 explained 32.033% variance.

The cluster analysis, based on Euclidean distances, led to the grouping of DEMs according to MSAVI and NDVI values, in conditions of high statistical accuracy, From the analysis of SDI values (similarity and distance indices) it was found that high levels of affinity were recorded, in descending order, between DEM3 and DEM10 (SDI = 0.003912), followed by DEM10 with DEM4 (SDI = 0.004637), DEM5 with DEM7 (SDI = 0.005374), and between DEM5 and DEM8 (SDI = 0.006946), respectively; Coph.corr = 0.903 (Figure 7).

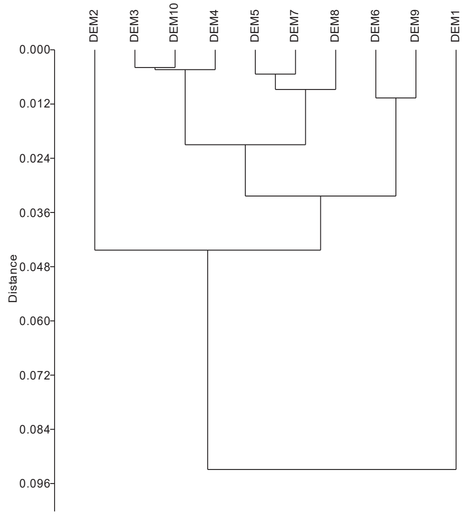

Figure 7. Cluster grouping of DEMs according to MSAVI and NDVI values

In relation to the Slope parameter, for characterizing the land morphology, 10 classes of the protected Area were obtained, Paniova forest, with variable surfaces, between 0.75 ha and 469.29 ha (Table 2).

NDVI and MSAVI indices were calculated in relation to the Slope classes obtained. To this purpose, a grouping of NDVI and MSAVI values was made on the 10 Slope classes, and the result was an identical number of NDVI and MSAVI points, within each Slope class (Table 2).

On each Slope class the average NDVI and MSAVI values were calculated, as well as the variation interval min. - max., and the obtained results are presented in Table 2.

The variation of the vegetation index (NDVI) according to the MSAVI values, in relation to the structuring of the territory analysed on the 10 SLOPE classes, is described by a polynomial equation of 2nd degree, equation (4), in conditions of $R^2 = 0.974$, $p < 0.001$, $F = 132.16$.

$$NDVI = -24.63 MSAVI^2 + 35.71 MSAVI - 12.39 \quad (4)$$

Table 2. Surface values and indices NDVI and MSAVI by Slope classes, for the protected area Paniova forest

Slope Code	Area		NDVI and MSAVI	NDVI			MSAVI		
	ha	%	Point No	NDVI	Min.	Max.	MSAVI	Min.	Max.
SC1 $<1.8^{0}$	200.83	10.84	80347	0.537147	0.114445	0.722472	0.696393	0.20537	0.838869
SC2 1.8^{0}-3.7^{0}	428.18	23.12	171401	0.538453	0.062184	0.735125	0.69732	0.117066	0.847337
SC3 3.7^{0}-5.6^{0}	469.29	25.34	187836	0.53982	0.071918	0.742185	0.697892	0.134174	0.852007
SC4 5.6^{0}-7.5^{0}	392.36	21.18	157098	0.54384	-0.14275	0.748943	0.701088	-0.333	0.856445
SC5 7.5^{0}-9.4^{0}	234.24	12.65	93841	0.54339	0.070648	0.770231	0.70059	0.131961	0.870197
SC6 9.4^{0}-11.3^{0}	88.59	4.78	35592	0.539282	0.079044	0.749304	0.696848	0.146494	0.856681
SC7 11.3^{0}-13.2^{0}	28.16	1.52	11269	0.547272	0.106107	0.740233	0.70404	0.191841	0.85072
SC8 13.2^{0}-15.1^{0}	7.77	0.42	3124	0.541873	0.11385	0.719989	0.698882	0.204409	0.837192
SC9 15.1^{0}-17.00^{0}	2.13	0.11	868	0.552215	0.174248	0.702322	0.708267	0.296761	0.825124
SC10 17.00^{0}-18.9^{0}	0.75	0.04	293	0.548592	0.358688	0.66198	0.707085	0.527967	0.796602
TOTAL	1852.3	100.00	741669	0.540632	-0.14275	0.770231	0.698679	-0.333	0.870197

The graphical distribution is shown in Figure 8. Both from the analysis of equation (4) and from the graphical distribution (Figure 8), an increase was found of NDVI values along with MSAVI values, which indicates a close connection of NDVI index values with MSAVI.

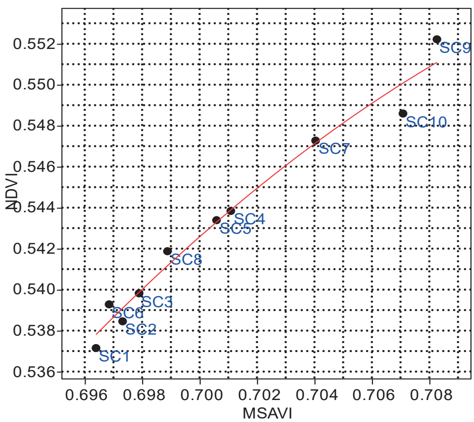

Figure 8. Graphical distribution of NDVI values according to MSAVI, and reference to Slope classes

The PCA analysis of the distribution of SLOPE classes, for the studied area Paniova forest, according to Area, MSAVI and NDVI, is shown in Figure 9. PC1 explained 80.927% of variance, and PC2 explained 18.576% of variance.

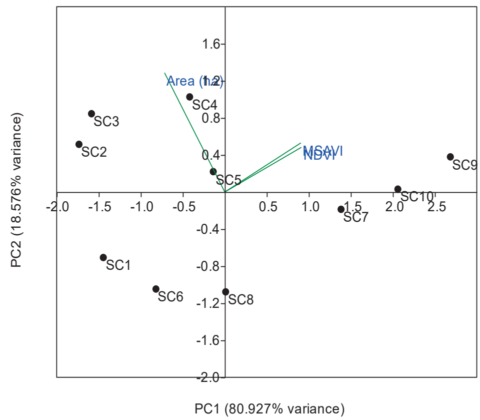

Figure 9. PCA distribution diagram of the Slope classes for Paniova, in relation to Area, NDVI and MSVI

The cluster analysis based on Euclidian distances, led to the association of the 10 Slope groups according to MSAVI and NDVI values, in conditions of high statistical accuracy, Coph.corr = 0.831 (Figure 10). From the analysis of SDI values (similarity and distance indices) it was found that high affinity levels of Slope class (SC) were recorded, in descending order, between SC4 and SC5 (SDI = 0.000671), followed by SC2 and SC6 (SDI = 0.000953), SC6 and SC3 (SDI = 0.001174) and respectively between SC5 and SC8 (SDI = 0.002284).

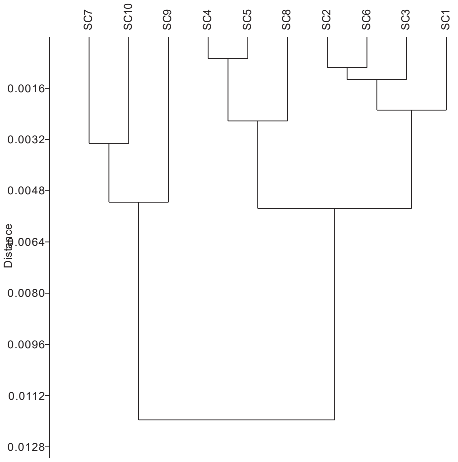

Figure 10. Dendrogram for Slope depending on MDVI/ MSAVI affinity

In relation to the Slope exposure parameter, to characterize the land morphology, 11 classes of the studied area were obtained in Paniova forest, with variable areas, between 4.53 ha and 339.9 ha (Table 3).

Indices NDVI and MSAVI were calculated in relation to the Slope exposure classes obtained. In this purpose, a grouping of NDVI and MSAVI values was made on the 11 Slope espouser classes and the result was an identical number of NDVI and MSAVI points within each class (Table 3).

On each Slope exposure class, the average values NDVI and MSAVI were calculated, as well as the variation interval min - max, and the results obtained are presented in Table 3.

The variation of the vegetation index (NDVI) according to the MSAVI values, in relation to the structuring of the analysed territory on 11 Slope exposure classes, is described by a polynomial equations of 2nd degree, equation (5), in conditions of $R^2 = 0.983$, $p < 0.001$, $F = 226.44$. The graphical distribution is shown in Figure 11.

$$\mathrm{NDVI} = 9.781 MSAVI^2 - 12.61 MSAVI + 4.564 \qquad 5)$$

Table 3. Surface values and NDVI and MSAVI indices by Slope exposure classes, for the protected area Paniova forest

Slope exposure Code	Surface		NDVI and MSAVI	NDVI			MSAVI		
	ha	%	Point No	NDVI	Min.	Max.	MSAVI	Min.	Max.
AC1 Flat	4.53	0.24	1856	0.543548	0.38922	0.716774	0.702654	0.560314	0.835013
AC2 Flat - North	7.84	0.42	3226	0.540295	0.182713	0.715698	0.698706	0.308951	0.834284
AC3 North	15.88	0.86	6458	0.540002	0.162756	0.699042	0.699155	0.279928	0.822856
AC4 Northeast	139.94	7.55	56019	0.548942	0.113901	0.742211	0.706829	0.204492	0.852025
AC5 East	298.71	16.13	119476	0.546056	-0.14275	0.743148	0.703512	-0.333	0.852642
AC6 Southeast	287.37	15.51	114999	0.545795	-0.01442	0.770231	0.703243	-0.02925	0.870197
AC7 South t	238.19	12.86	95366	0.537464	0.103157	0.753191	0.696716	0.187006	0.859216
AC8 Southwest	257.96	13.93	103235	0.529474	0.062184	0.735125	0.687595	0.117066	0.847337
AC9 West t	339.9	18.35	135882	0.539202	0.026878	0.742014	0.696579	0.052343	0.851895
AC10 Northwest	223.33	12.06	89309	0.541187	0.137557	0.723656	0.7002	0.241827	0.839666
AC11 North	38.65	2.09	15600	0.53609	0.132655	0.740799	0.695584	0.234219	0.851093
TOTAL	1852.3	100.00	741426	0.540683	-0.14275	0.770231	0.698733	-0.333	0.870197

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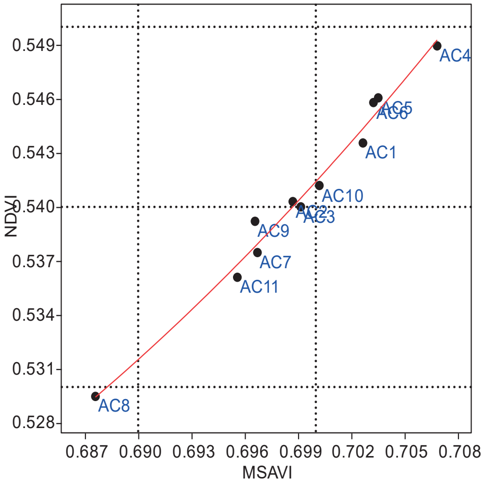

Figure 11. Graphic distribution of NDVI values according to MSAVI, in relation to Slope exposure classes

The PCA analysis of the distribution of the Slope exposure classes, for the studied area Paniova forest, according to Area, MSAVI and NDVI, is presented in Figure 12. PC1 explained 66.592% of variance, and PC2 explained 33.235% of variance.

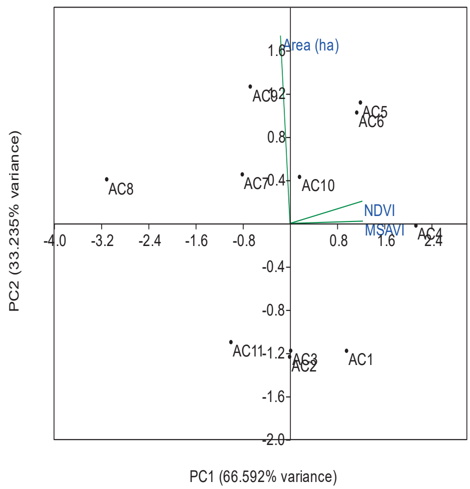

Figure 12. PCA distribution diagram of the Slope expouser classes on the Paniova area, in relation to Area, NDVI and MSVI

The cluster analysis, based on Euclidian distances, led to the association of the 11 Slope exposure classes, depending on the MSAVI and NDVI values, in conditions of high statistical accuracy, Coph.corr = 0.851 (Figure 13).

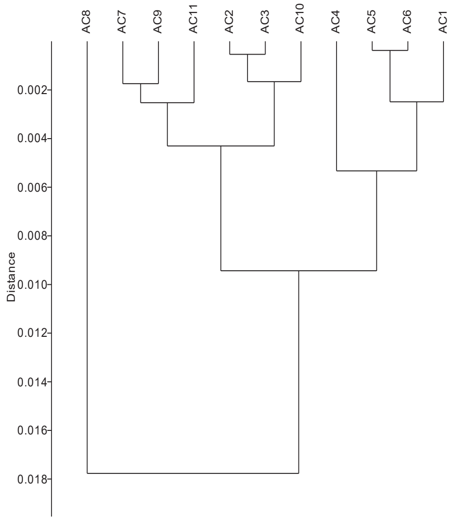

Figure 13. Dendrogram for Slope exposure according to MDVI/MSAVI affinity

From the analysis of SDI values (similarity and distance indices) it was found that high affinity levels of Slope Exposure class (AC) values were recorded, in descending order, between AC5 and AC6 (SDI = 0.000374), followed by AC2 and AC3 (SDI = 0.000536), AC3 and AC10 (SDI = 0.00158), AC7 and AC9 (SDI = 0.001744), and respectively between AC6 and AC1 (SDI = 0.002324).

Imaging analysis based on satellite images is very useful in the analysis and evaluation of the territory for the study of natural or agricultural areas, in order to obtain useful information for monitoring and management of studied areas (Stupen et al., 2018; Todorova and Tcacenco, 2019; Popescu et al., 2020; Stupen et al., 2018).

The morphology of the territory is an important factor of the floristic composition, structure and biomass production of forests. The complex analysis of the data provided information on the landscape heterogeneity of the studied area (Jucker et al., 2018).

The Digital Elevation Model (DEM) has been used in many studies to assess vegetation levels, being considered a very useful parameter especially because the access to certain areas of interest and studied is difficult

(Volarik, 2010). From the point of view of altitude, the studied area is between 130 - 250m, the highest share (approx. 40%) being between altitudes 177-202 m. From the point of view of the inclination (slope), the study area has an inclination between 0°-18°, the highest share (approx. 70%) being in the range of 3°-9°. From the point of view of the slope exposure, the largest share of the area (approx. 16%) is on the East exposure and the lowest on the Nordic and North East exposure.

Paniova Forest, included in the Natura 2000 Site, can also be included in certain objectives and tourist routes, which represents for Romania a high natural potential, reflected by recent studies in the field (Popescu et al., 2020). Similarly, other studies have sought to highlight local resources with high potential for exploitation, broad spectrum or niche (Dobrei et al., 2009; Dobrei et al., 2015).

In relation to the elements of land morphology, Altitudes, Slope, Slope Exposure, characterized in this study, different areas of the studied area can be monitored, regarding aspects of predominant vegetation dynamics (oak), evolution of sub-shrub vegetation, effects of climatic conditions (especially extreme conditions - storms), of current maintenance works (maintenance operation, planting - replanting), interior design, access roads, etc.

This information can be included in the management plan, as benchmarks against which to make a comparative analysis over time, in order to highlight the spatial and temporal variability of the Paniova Forest area.

CONCLUSIONS

Altitudes, Slope and Slope exposure parameters have facilitated the analysis and morphological characterization, on classes with similar properties, of the Paniova Forest area, Natura 2000 Site.

The NDVI and MSAVI indices, associated with the Altitudes, Slope and Slope exposure classes, expressed by the arboreal vegetation in the studied area.

Principal Component Analysis led to the obtaining of distribution diagrams of the classes DEM, Slope, Slope exposure in relation to the indices NDVI and MSAVI, under conditions of statistical accuracy.

The cluster analysis, based on Euclidean distances, facilitated the classification of DEM, Slope and Slope exposure, based on affinity in relation to the values of NDVI and MSAVI indices, and similarity and distance indices (SDI) confirmed the degree of similarity within cluster groups.

This study can be further developed in order to estimate the age of the tree, the biomass of the wood, the health of the trees, the planning of specific interventions in the management of protected areas.

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GIS ANALYSIS OF AREA DETERMINATION METHODS IN FORESTRY

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Abstract

This paper presents a GIS analysis meant to highlight problems regarding area differences in the forest sector, when different determination methods are used. The study's focus is on forest surfaces in the Bran-Moeciu area of Brasov county. These were identified on cadastral plans of forest boundaries and vectorised. These boundaries were then determined using the "Stop & Go" method with Trimble Pro XT and Trimble Pro XH GPS receivers. The analysis was centred on two issues: estimating the boundary differences between the two methods and their implication on area determinations. A simple method of determining boundary differences through their measurement in the AutoCAD software was used, of course taking into account their sign. In addition, a GIS method was developed which, with the aid of VBA code sequences, provides a rapid determination of these differences. The final conclusion was that, based on the analysed data, even if the differences are somewhat significant (sometimes over 75 metres) between the two methods, the implications on area determination is much lower (max. 2-3%), due to their somewhat uniform distribution of positive and negative values.

***Key words**: GIS, GPS, mountainous forests, statistical analysis.*

INTRODUCTION

This paper's purpose is to analyse the area differences which show up when two different methods are used: the one which was exclusively used until the 1990s (based on measurements carried out on cadastral plans with forest boundaries) and the one based on topo-geodetic surveys, which appeared once property laws were put into effect. The study area is located in the Bran-Moeciu region (Figure 1), more specifically in the forest area present here.

Numerous past studies have been carried out in this area, which looked at: the influence of various factors on the precision of coordinate calculation (Teresneu et al., 2014), the precision of coordinate calculation at the canopy's edge (Teresneu and Vasilescu, 2015), the precision of coordinate calculation corroborated with parcel areas (Teresneu et al., 2011), the influence of orography on the coordinate precision (Teresneu and Vasilescu, 2019) etc. Because this study also takes into account various influences which have an effect on the coordinate precision when using GPS receivers, various studies that highlight the strong influence of stand density (Ordonez Galan et al., 2011; 2013; Weilin et al., 2000; Zhang et al., 2014), access to the number of satellites (Wang et al., 2014), the negative influence of snow cover (Janez et al., 2004), the negative impact of decidious species during their vegetation season (Dogan et al., 2014; Sawaguchi et al., 2003) were considered.

Figure 1. Study area

MATERIALS AND METHODS

40 cadastral plans of the study area were used, which had data relating to the boundaries of forest parcels. Also, two GPS receivers were used: *Trimble Pro XT* and *Trimble Pro XH*.

Research methods that were used are: direct measurements, statistical processing and GIS methods.

With regards to the direct measurements, the two GNSS receivers previously mentioned were used to determine the coordinates of forestry parcel boundaries, by measuring the position of over 2700 points. These points were determined in valleys, slopes, forest roads and at the forest's edge. Necessary corrections were taken from the Top Geocart permanent station. Resulting data was then imported in a *.xls file (Figure 2).

1	Comment	Max_PDOP	Corr_Type	Rcvr_Type	Feat_Name	GPS_Height	Vert_Prec	Horz_Prec	Std_Dev
2	borna 58 Mo FM	3.7	Postprocessed Carrier Float	ProXRT	Point_ge	935.349	0.9	**0.6**	0.000000
3	2	11.9	Postprocessed Code	ProXRT	Point_ge	964.581	3.5	**2.5**	24.321031
4	3	4.3	Postprocessed Carrier Float	ProXRT	Point_ge	945.439	1.3	**0.8**	0.000000
5	4	12.3	Postprocessed Code	ProXRT	Point_ge	952.288	2.6	**1.7**	0.748816
6	5	11.6	Postprocessed Code	ProXRT	Point_ge	963.604	1.2	**0.8**	0.270757
7	6	3.7	Postprocessed Carrier Float	ProXRT	Point_ge	971.954	1.2	**0.8**	0.240139
8	7	16.3	Postprocessed Carrier Float	ProXRT	Point_ge	980.461	1.3	**0.8**	0.743607
9	8	7.3	Postprocessed Carrier Float	ProXRT	Point_ge	973.210	1.5	**0.9**	1.326025
10	9	5.0	Postprocessed Carrier Float	ProXRT	Point_ge	978.885	1.2	**0.7**	0.181251
11	10	3.6	Postprocessed Code	ProXRT	Point_ge	976.775	1.1	**0.7**	0.131620
12	11	6.0	Postprocessed Code	ProXRT	Point_ge	974.438	1.4	**0.7**	0.213816
13	12	13.7	Uncorrected	ProXRT	Point_ge	965.080	2.2	**1.1**	1.044148
14	borna 52 Fa FM	3.8	Postprocessed Carrier Float	ProXRT	Point_ge	963.363	1.7	**0.7**	0.000000
15	14	7.0	Postprocessed Carrier Float	ProXRT	Point_ge	966.730	1.9	**0.8**	1.016204
16	15	6.5	Postprocessed Code	ProXRT	Point_ge	973.871	1.7	**0.8**	1.045687
17	16	7.8	Postprocessed Carrier Float	ProXRT	Point_ge	978.559	1.9	**0.8**	0.157612
18	17	9.2	Postprocessed Code	ProXRT	Point_ge	977.109	3.4	**0.9**	0.682035
19	18	7.9	Postprocessed Code	ProXRT	Point_ge	983.867	3.0	**0.7**	0.273256
20	19 pod	4.7	Postprocessed Carrier Float	ProXRT	Point_ge	998.033	1.8	**0.6**	0.000000
21	20 pod	7.2	Postprocessed Carrier Float	ProXRT	Point_ge	998.784	2.5	**1.0**	0.000000
22	21	9.8	Postprocessed Code	ProXRT	Point_ge	999.790	2.4	**0.8**	0.911807
23	22	18.5	Postprocessed Code	ProXRT	Point_ge	1013.038	4.6	**1.2**	1.200337
24	23	9.5	Postprocessed Carrier Float	ProXRT	Point_ge	1037.237	2.2	**0.7**	0.729223
25	24	6.9	Postprocessed Code	ProXRT	Point_ge	1045.839	4.4	**1.7**	2.137337
26	25	15.1	Postprocessed Carrier Float	ProXRT	Point_ge	1061.498	2.7	**0.8**	0.762630
27	26	6.8	Postprocessed Carrier Float	ProXRT	Point_ge	1072.065	2.6	**0.6**	0.000000
28	27	15.4	Postprocessed Carrier Float	ProXRT	Point_ge	1088.858	2.8	**0.6**	0.499122
29	28	13.1	Postprocessed Code	ProXRT	Point_ge	1108.112	2.8	**0.6**	0.319059
30	28	10.0	Uncorrected	ProXRT	Point_ge	1127.898	3.7	**0.9**	0.746053
31	30	10.0	Postprocessed Code	ProXRT	Point_ge	1145.511	4.0	**1.0**	0.767480
32	31	9.6	Postprocessed Carrier Float	ProXRT	Point_ge	1189.852	3.5	**0.8**	1.138058
33	32	11.1	Postprocessed Code	ProXRT	Point_ge	1213.934	3.5	**1.0**	1.621440
34	33	9.1	Postprocessed Code	ProXRT	Point_ge	1229.648	3.3	**0.9**	0.874987

Figure 2. Initial database

Regarding GIS methods, the following steps were carried out: geo-referencing of the cadastral plans, vectorisation of forest boundaries, use of various VBA code sequences for various calculations.

Finally, statistical methods were used to determine the precision of point coordinate calculations (not detailed here), to analyse the boundary differences between the two methods and to compare the parcel areas thus obtained.

RESULTS AND DISCUSSIONS

After geo-referencing all base plans (cadastral plans) the forestry boundaries were vectored. A hybrid AutoCAD-ArcGIS method was used (Tereşneu et al., 2016). Then the *.xls database was completed with additional data, obtained from simple calculations. A particular focus was placed on the quantification of boundary differences resulting from the application of the two methods previously discussed (Figure 3).

The forestry parcels for which boundaries were both vectored and directly measured using GPS were then identified (Figure 4).

These differences were highlighted using two methods. In the first of these, the differences were simply measured in AutoCAD (Figure 5). Measurements were done for the inflection points of the measured boundaries and their corresponding points on the vectored boundaries. In those situations where on the second boundary there were no corresponding inflection points, the differences were measured on the perpendicular line to this boundary.

These differences were then recorded in the *.xls database with a plus or minus sign, depending on their position to the left or right of the marker. The marker is the point determined using direct measurements with GPS equipment. The arithmetical sign was considered based on the technical orientation of valleys and slopes.

Point_ID	Dist_trapez	HP<=0,5	HP<=1	HP<=1,5	HP<=2	HP>2	DT-HP	VP<=0,5	VP<=1	VP<=1,5	VP<=2	VP>2	VP>3
1	4.54	*	0.6	*	*	*	3.94	*	0.90	*	*	*	*
2	0.59	*	*	*	*	2.5	-1.91	*	*	*	*	*	3.50
3	2.32	*	0.8	*	*	*	1.52	*	*	1.30	*	*	*
4	0.30	*	*	*	1.7	*	-1.40	*	*	*	*	2.60	*
5	1.10	*	0.8	*	*	*	0.30	*	*	1.20	*	*	*
6	0.07	*	0.8	*	*	*	-0.73	*	*	1.20	*	*	*
7	9.08	*	0.8	*	*	*	8.28	*	*	1.30	*	*	*
8	9.20	*	0.9	*	*	*	8.30	*	*	1.50	*	*	*
9	1.63	*	0.7	*	*	*	0.93	*	*	1.20	*	*	*
10	0.51	*	0.7	*	*	*	-0.19	*	*	1.10	*	*	*
11	1.97	*	0.7	*	*	*	1.27	*	*	1.40	*	*	*
12	6.04	*	*	1.1	*	*	4.94	*	*	*	*	2.20	*
13	25.85	*	0.7	*	*	*	25.15	*	*	*	1.70	*	*
14	15.13	*	0.8	*	*	*	14.33	*	*	*	1.90	*	*
15	4.21	*	0.8	*	*	*	3.41	*	*	*	1.70	*	*
16	3.84	*	0.8	*	*	*	3.04	*	*	*	1.90	*	*
17	0.38	*	0.9	*	*	*	-0.52	*	*	*	*	*	3.40
18	3.46	*	0.7	*	*	*	2.76	*	*	*	*	3.00	*
19	2.32	*	0.6	*	*	*	1.72	*	*	*	1.80	*	*
20	1.22	*	1	*	*	*	0.22	*	*	*	*	2.50	*
21	1.73	*	0.8	*	*	*	0.93	*	*	*	*	2.40	*
22	5.99	*	*	1.2	*	*	4.79	*	*	*	*	*	4.60
23	4.97	*	0.7	*	*	*	4.27	*	*	*	*	2.20	*
24	3.65	*	*	*	1.7	*	1.95	*	*	*	*	*	4.40
25	0.39	*	0.8	*	*	*	-0.41	*	*	*	*	2.70	*
26	0.62	*	0.6	*	*	*	0.02	*	*	*	*	2.60	*
27	2.28	*	0.6	*	*	*	1.68	*	*	*	*	2.80	*
28	0.47	*	0.6	*	*	*	-0.13	*	*	*	*	2.80	*
29	5.29	*	0.9	*	*	*	4.39	*	*	*	*	*	3.70
30	1.56	*	1	*	*	*	0.56	*	*	*	*	*	4.00
31	1.97	*	0.8	*	*	*	1.17	*	*	*	*	*	3.50
32	5.09	*	1	*	*	*	4.09	*	*	*	*	*	3.50
33	2.44	*	0.9	*	*	*	1.54	*	*	*	*	*	3.30
34	2.19	*	1	*	*	*	1.19	*	*	*	*	*	3.50
35	0.95	*	0.8	*	*	*	0.15	*	*	*	*	2.90	*

Figure 3. Processed database

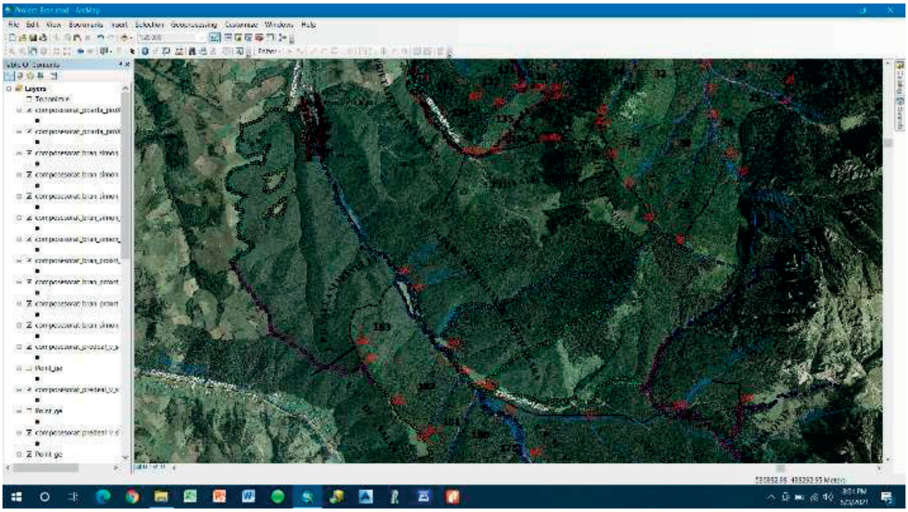

Figure 4. Identification of parcels with boundaries both measured and vectored

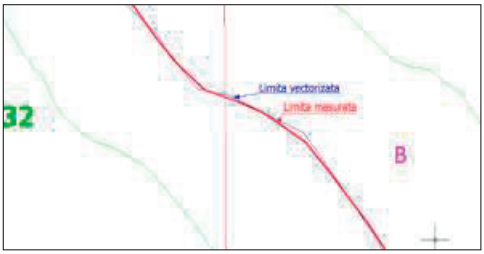

Figure 5. Determining differences in AutoCAD

The second method used involved a VBA code sequence created in ArcGIS to aid in the determination between two arcs. This script also labelled the calculated differences (Figure 6).

In addition, this method also quantifies the areas on both sides of the witness arc and also presents a final result through the summation of the two sides, with their respective signs. Several situations were summarily analyse. In each case, the problem of the deviations between vectorised and measured boundaries was analysed and also the influence these have on the calculation of the global area.

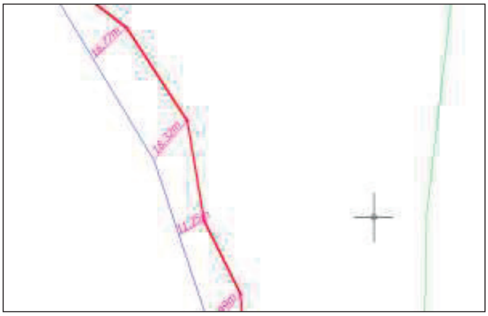

Figure 6. Automatic determination of differences in ArcGIS

In the first case, related to a forest parcel with an area of 115.98 hectares, a mean deviation of 0.98 m between the measured and vectorised boundary was recorded along with a 2.6% difference in terms of area. In the second case, related to a forest parcel with an area of 89.45 hectares, a deviation of 1.12 m between the measured and vectorised boundary was identified and an area difference of 2.8%. Finally, in the third case of a forest parcel with an area of 158.38 ha, a deviation of 0.89 m was recorded and an area difference of 2.5%.

CONCLUSIONS

The problem of correct estimations of forest parcel areas is very important, as on it depend the calculations relating to the harvestable wood quantity (Leahu, 2001). In this paper, a comparison of forest areas as determined through vectorisation of cadastral plans with forest boundaries and through direct measurements using GPS equipment was carried out. Even if the coordinate precision of points located inside the forested areas is not very high (Teresneu et al., 2014), in the sense that millimetre or centimetre-precisions are not achievable, like in the case of the agriculture sector or in residential areas, still a pertinent comparison between the two methods was realised.

The conclusion of this study is that between the two methods there are no significantly large differences, all of them being in the 2.5-2.8% range.

Taking into account the fact that available data was collected exclusively in the mountainous area and only covered an area of a few hundred hectares, the studied problem deserved to be further analysed on larger areas. It is interesting to note that, although individual differences between vectorised and measured boundary are occasionally very large (up to 70-80 m), when their mean is calculated the obtained values are relatively small, hovering around 1 m.

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DOUGLAS FIR (*PSEUDOTSUGA MENZIESII* (MIRB.) FRANCO) FROM BANATULUI MOUNTAINS

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Abstract

The study has identified 844 Douglas fir stand elements in the 12 Forest Districts that cover a total surface of 2544.50 ha. The largest percentages were registered in the following forest districts: Băile Herculane (318.5 ha), Mehadia (266.9 ha), Berseasca (262.5 ha) and Oțelul Roșu (191.4 ha). As such, the purpose of this paper is to analyse the main stand and environment characteristics of areas where Douglas fir species are present. These are followed by the specie's distribution, altitude, relief forms, soils, forest types, mixture, stand structure and productive class. The age of these stands ranges between 1 to 100 years, with approximately 46.6% of stands having ages between 21 to 30 years. The Douglas fir stands show an even-aged stand structure (71%). The majority of Douglas fir stands are situated at altitudes between 601 to 800 m (31%). The slope is the main field configuration, covering a surface of 1987.9 ha. The soils on which this species vegetates are: common eutric cambisol (1546.2 ha), luvisol (220.4 ha), and dystric cambisol (448.4 ha). The most representative forest types are: hill common beech on skeletal soils with mull flora (554.7 ha), mountain common beech on skeletal soils with mull flora (423.6 ha), and normal common beech with mull flora (468.2 ha). The identified Douglas fir stands have average and high productivity classes (1st class = 500.8 ha; 2nd class = 986.5 ha). Green Douglas fir is a forest species that has a special interest for both the European silviculture as well as for the Romanian one.

Key words: *age, altitude, consistency, soil type, Banatului Mountains.*

INTRODUCTION

Douglas fir is an important tree species that originates from North America. The species was discovered in 1792 by Archibald Menzies and introduced in 1826 in Europa by David Douglas (Kleinschmit et al., 1999). The species was used by Indian tribes in treating different illnesses: kidney and urinary problems, venereal diseases, excessive menstruation, intestinal bleeding, stomach problems, coughs or as a cataplasm for cuts, burns, scars or other skin diseases (Pădure et al., 2008). Since then, the species was planted on a large scale in most European countries where it currently covers approximately 750.000 ha (Bastien et al., 2013; Nicolescu et al., 2014; Boiffin et al. 2017).
In present times, Douglas fir covers more than 800.000 ha from which 50% are in France, 25% in Germany, and the rest of 25% are distributed in other European countries. In Germany and Austria, 2% and 0.2% from the country's total forest surface are covered by Douglas fir (Eckhart et al., 2019).
The interest for planting Douglas fir species has increased substantially in the last years as the species is seen as a potential option towards climate change. Due to its growth potential, vigour and wood quality, the species was introduced in many countries around the world, including New Zeeland, Chile, Argentina, Australia and France (Hermann et al., 1999; Hintsteiner et al., 2018; Thurm et al., 2016).
The species was introduced a century ago in Bulgaria, but it became widely spread at the end of the 1950s and 1960s. The plantation surfaces amount to approximately 7.372 ha (Petkova et al., 2014).
In north-west Spain, Douglas fir has become the fourth most important species planted in the last decade (Zas et al., 2003).
In Romania, the species was introduced 100 years ago on considerable surfaces from Aleşd, Marghita, Dobrești, Nădrag basin, Crisbav, Râşnov, Săcele, Fântânele etc. (approximately 30.000 ha). Douglas fir prefers the oceanic, mountain climate, either warm and humid, either cold and humid. The most favourable

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areas are located in West Transylvania and Banat. The species prefers light, airy and drained soils (substratum of crystalline schists, granite, conglomerates).

This tree species is renowned for its durability and superior mechanical properties (Longo et al., 2019). The wood is strong, moderately hard and very rigid. It is easy to process and difficult to impregnate with preservatives (Remeš, 2014). Douglas fir is more resistant to drought than the Norway spruce and it has become known as the "dry Norway spruce" (Vejpustková et al., 2019).

Pseudotsuga menziesii (Mirb.) Franco is a species with a fast and economically valuable growth, being at the same time one of the most beautiful coniferous species (Dorofeeva et al., 2019). It is also one of the most promising exotic tree species from Europe (Castaldi et al., 2020). Furthermore, it has a silvicultural value due to its high quality wood, as well as an ornamental value due to its crown's shape and its needle's smell.

Douglas fir is a valuable resource for flavoured terpenoid products. Because of this fact, Douglas fir forests ensure a valuable resource of non-wood forest products in many areas of the country (Pleșca et al., 2019; Blaga et al., 2019; Cântar et al., 2020; Tudor et al., 2019; Dincă et al., 200; Vechiu et al., 2019).

MATERIALS AND METHODS

Data from management plans from 12 Forest Districts has been used in order to identify and analyse Douglas fir stands. The data was centralized and process through Excel. The following stand and environment characteristics were analysed in areas where Douglas fir is present: spread, altitude, relief forms, soils, forest types, mixture, stand structure, current growth and production class.

RESULTS AND DISCUSSIONS

Based on the realized research, 844 Douglas fir stand elements were identified in 12 Forest Districts that cover a total surface of 2544.50 ha. The largest Douglas fir surface is found in Băile Herculane Forest District (318.50 ha), while the smallest surface is in Văliug Forest District (1.10 ha) (Figure 1).

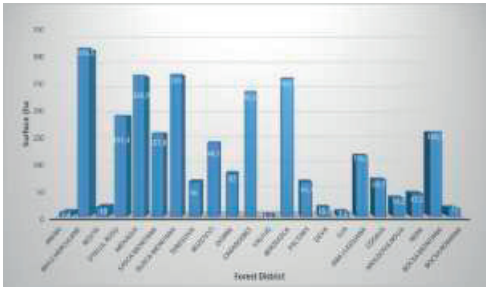

Figure 1. The surface occupied by Douglas fir in Banatului Mountains

The slope is the **relief form** characteristic for these stands, occupying 1987.9 ha (78%) of the total stands' surface (Figure 2).

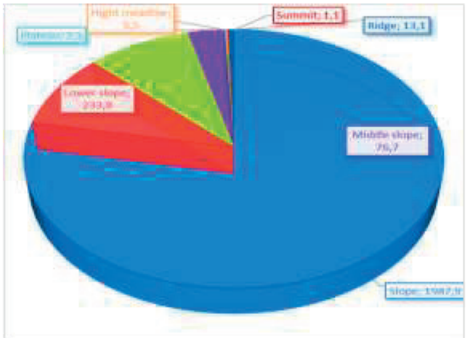

Figure 2. Relief forms characteristic for Douglas fir stands from Banatului Mountains

The most common **field incline** for Douglas fir stands located in Banatului Mountains is of 26-30 degrees (Figure 3).

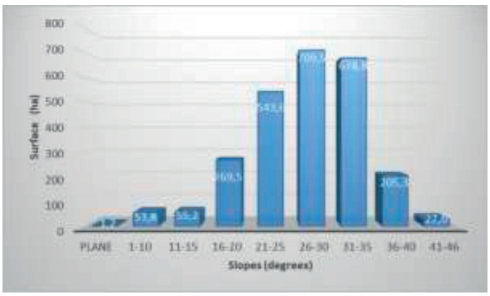

Figure 3. Field incline for Douglas fir stands from Banatului Mountains

The specific **field exposition** for theses stands is north-east, south-east, south-west and north-west (Figure 4).

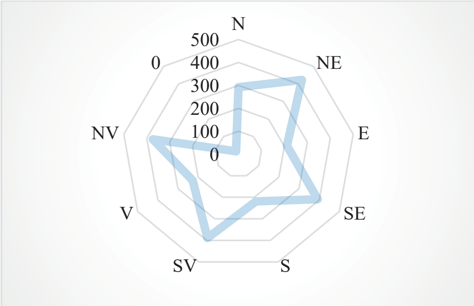

Figure 4. Field exposition for *Pseudotsuga menziesii* stands from Banatului Mountains

The altitude at which these stands are present ranges between 150 m and 1300 m. Our analysis has shown that 31% of the surface occupied by Douglas fir varies between 601 m and 800 m altitude (Figure 5).

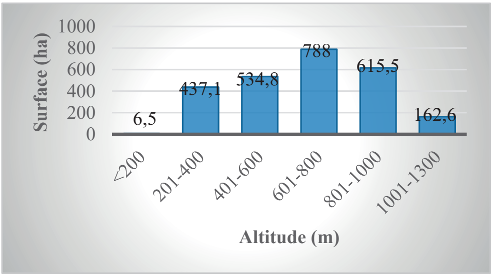

Figure 5. Altitude for Douglas fir stands from Banatului Mountains

The soils on which Douglas fir vegetates are: common eutric cambisol (1546.2 ha), luvisol (220.4 ha) and dystric cambisol (448.4 ha). These soils are rich in humus (Dincă et al., 2017; Oneț et al., 2019), in nutritive elements (Crișan et al., 2017; Dincă et al., 2019) and are well supplied with water (Dincă et al., 2018; Crișan et al., 2020). In Central Europe, Douglas fir was mainly introduced on well-drained, aerated and carbonate-free soils (Eckhart et al., 2019).

The forest soils in which the Douglas fir is present are: hill common beech on skeletal soils with mull flora (554.7 ha), mountain common beech on skeletal soils with mull flora (423.6 ha), and normal common beech with mull flora (468.2 ha).

The age of the Douglas fir stands ranges between 1 and 100 years. Approximately 46.6% of stands have 21-30 years, 26.6% have 11-20 years and 20.5% have 31-40 years (Figure 6).

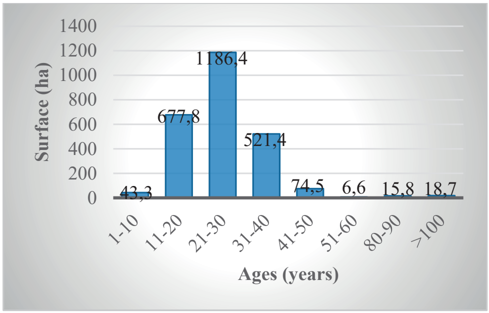

Figure 6. The age of Douglas fir stands from Banatului Mountains

Stand structure is predominantly even-aged (453.3 ha), relatively even-aged (1831.1 ha), relatively uneven-aged (243.2 ha) and uneven-aged (16.9 ha) (Figure7).

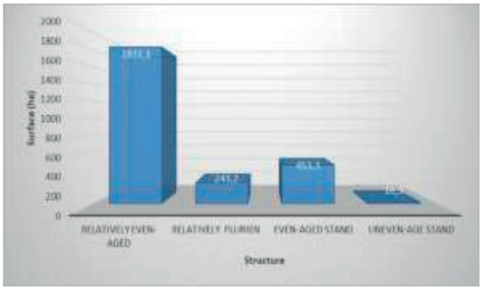

Figure 7. Structure of *Pseudotsuga menziesii* stands from Banatului Mountains

The composition is mixed (intimate + groups = 901.1 ha) and in groups (409.8 ha) (Figure 8).

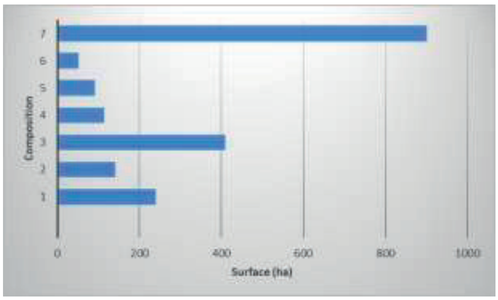

Figure 8. Composition of Pseudotsuga menziesii stands from Banatului Mountains

The stands' production class is average (3[d] class = 1044.7 ha) and superior (1[st] class = 500.8 ha; 2[nd] class = 986.5 ha).

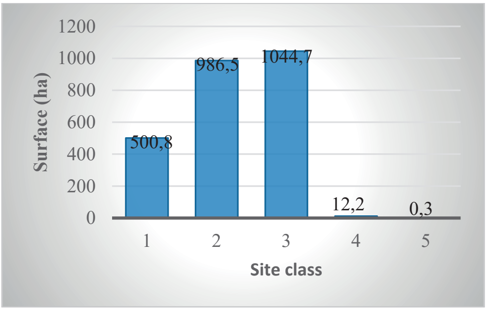

Figure 9. Site class of Douglas fir species from Banatului Mountains

Stand consistency is appropriate (0.7-0.8). However, there are some barrenland stands (0.4-0.5) or that must be thinned (0.9) (Figure 10).

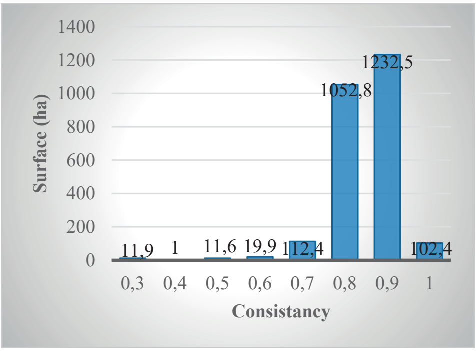

Figure 10. Consistency of Douglas fir stands from Banatului Mountains

CONCLUSIONS

The present study has identified 844 Douglas fir stand elements that cover a total surface of 2544.50 ha. From the identified characteristics, the followings are of special interest: 72% of Douglas fir stands are found on slopes, with common eutric cambisol being the main soil type (1546.2 ha); the age ranges from 1-100 years, approximately 46.6% of stands having 21-30 years; the stands have an average production class (3d class = 1044.7 ha). The majority of Douglas fir stands are situated at altitudes between 600-801 m. The soils on which this species vegetates are: eutric cambisol (1546.2 ha), luvisol (220.4 ha), and dystric cambisol (448.4 ha).

Douglas fir is a forest species that poses a special interest for both European silviculture as well as for Romania's silviculture.

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STUDY OF THE SUCCESSFUL APPROACH TO TRUFFLE GROWING IN EUROPE - REVIEW

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Abstract

Truffle cultivation is an original agroforestry system. Historical data and distribution of truffle species, their characteristics and with which tree species are in symbiosis are indicated. Harvesting truffles is natural and artificial and has specifics in their hunting around the world. Italian entrepreneurs offer successful agriculture, which is related to science, and this is what they rely on in Romania. Truffle plantations on the Balkan Peninsula are an excellent form of alternative high-yield agriculture. The main accents when growing truffles are careful selection of field with appropriate soil and pH, exposure, area, climatic features and quality seedlings. In truffle plantations, yields are planned and quality is guaranteed. The facts about the rich chemical content of truffles and their beneficial effect on human health are objective. This paper aims at turning attention to the species distribution of truffles and the contemporary approach to their cultivation in Europe. As ectomycorrhizal fungi, truffle species also perform many important ecosystem functions, including organic matter decomposition, nutrient cycling and retention, soil aggregation, and transferring energy through soil food webs.

Key words: *agroforestry; ecosystem functions, natural and artificial collection; truffle.*

INTRODUCTION

The genus *Tuber* F.H. Wigg. (Ascomycota, Pezizales, Tuberaceae) is globally famous and historically appreciated for the production of hypogeous ascomata known as 'truffles' (Polemis et al., 2019). Truffles are ectomycorrhizal fungi characterized by hypogeous fruitbodies (Bonito et al., 2010; Lacheva, 2012). Ecologically, Tuber spp. form obligate mycorrhizal symbiosis with the roots of trees, such as oak, poplar, willow, hazel (Harley & Smith, 1983), pecan (Bonito et al., 2013), hornbeam (Ceruti et al., 2003), and some shrubs, such as Cistus (Mello et al., 2006), play important roles in forest functioning and biogeochemical cycles (Smith & Read, 2008; Todesco et al., 2019). In 1881 Carlo Vittadini gave a more elaborate description and was the first to recognize the importance of mycorrhizae to the nutrition of the host tree species (Trappe et al., 2009).

Albert B. Frank first recognized the mycorrhizal symbiosis in 1885 when he showed that fungi in the truffle-forming genus Tuber were found growing on the roots of living plants (Frank, 2005). The survival of truffles is based on their ability to form mycorrhizae from the roots of host trees, and in return the trees receive the nutrients that are important for their survival (Siachoono et al., 2016), as they are therefore in a symbiotic relationship (Trappe et al., 2009). Bonito et al. (2010) point to Paolocci et al. (2006) and Riccioni et al. (2008) who have intensively studied the ecology and host associations of a few commercialized European Tuber spp.

As ectomycorrhizal fungi, truffle species also perform many important ecosystem functions, including organic matter decomposition, nutrient cycling and retention, soil aggregation, and transferring energy through soil food webs. These functions contribute to the overall health, resiliency, sustainability of forest ecosystems (Trappe et al., 2009) and contributes to a stable bioeconomy in rural areas (Hilszczańska et al., 2019).

The protection of forest ecosystems is vital for the hypogeous fungi, such as valuable truffles' conservation (Kaounas, 2020).

This paper aims at turning attention to the species distribution of truffles and the contemporary approach to their cultivation in Europe.

MATERIALS AND METHODS

Recent years have witnessed an upsurge of interest in truffles in particular, thus resulting in information collected from recognized specialists representing the historical development of truffles; their ecosystem functions; as well as that they form obligate mycorrhizal symbiosis with the different ligneous species (pines, oaks, poplars, orchids, and commercially important trees, such as hazelnut, and pecan). Special attention is paid to the species considered most valuable to Europe, such as *Tuber melanosporum* Vittad, *Tuber magnatum* Pico, and *Tuber aestivum* Vittad., their preferences for pH, soils, and reporting the ways for their cultivation and harvesting from natural habitats.

RESULTS AND DISCUSSIONS

The very first uses of truffles date back to 6,000 years ago when ancients believed that truffles had magical powers aphrodisiacs (Ştefan, 2016). The first recorded account of truffles is by the ancient Greeks who used to love and appreciate them. Aristotle declared them an aphrodisiac and Pythagoras agreed, while for the Romans they were simply 'earth fruit'. During the Renaissance they returned to the tables of the wealthy (http://www.trufflegrowers.com.au).

References to edible hypogeous fungi exist in many ancient texts and it seems that the Mesopotamians, Egyptians, Greeks and Romans greatly appreciated truffles (Kaounas, 2020). Francis I of France was the first to bring truffles to rank culinary delicacy, demanding that at its sumptuous banquets he mandatory seasoned with truffles to be the most important preparations. Also, in France Louis XIV commissioned the first scientific research dedicated to cultivating truffles (Ştefan, 2016). Mello et al. (2006) cite Ciccarelli (1564) who points out that the first paper devoted to the nature of truffles appeared in 1564. After the Second World War, due to changes in the social character and forest management, the knowledge about truffles was lost (Hilszczańska et al. 2019)

The genus Tuber is present globally in temperate areas including over 200 species (Bonito et al., 2013; Todesco et al., 2019). The variety of truffles is significant- about 180 species (Bonito et al., 2010), although only about 13 have a commercial interest (Reyna & Garcia-Barreda, 2008; Bonito et al., 2009; Reyna & Garcia-Barreda, 2014), while Ştefan (2016) reports that many of them have only scientific value. Siachoono et al. (2016) reports that 50 genera of hypogeous fungi are recorded for Europe, only two being endemic (Marjanović et al., 2010, 2012). Montecchi & Sarasini (2000) describe 22 European species that belong to the genus Tuber, and Ceruti et al. (2003) lists 32 species from Europe (Iberian and Apennine Peninsulas and Southern France) as regions with the greatest diversity of hypogenic Ascomycota, and especially Tuberaceae.

Truffles in recent years have become increasingly popular around the world. Many truffle species are found in Italy, France, Spain, Australi, and Romania (Ştefan, 2016). Polemis et al. (2019) cite the authors Jeandroz et al. (2008) who point out that the variety of truffles is well documented in Europe, but until recently the Balkan Peninsula was poorly investigated. The geographic distribution of known truffle species (about 100) mainly covers the temperate zones of the northern hemisphere, with at least three differentiation areas: Europe, South-East Asia, and North America (Gajos & Hilszczańska, 2013). Pieroni (2016) cites authors (Mandeel & Al-Laith, 2007; Samils et al., 2008) who point out that truffles have been the focus of very few ethnobiological studies, mainly in desert areas. Trappe et al. (2009) reported that Helen Gilkey specialized in the "true" truffles, i.e., the ascomycetes, whereas Sanford Zeller worked with the basidiomycetes, sometimes called the "false" truffles.

The literature points out that the number of truffles found in nature decreases as a result of environmental pollution and massive deforestation. Truffles mostly grow at various altitudes - from a few meters above sea level to between 800 and 1000 m (Pacioni & Comandini, 1999), as strong ecological relationships exist between *Tuber* spp., host plants and soil type (Lulli et al., 1999; Gajos & Hilszczańska, 2013). Truffles grow best mainly in Rendzic soils (Hilszczańska et al., 2019).

Truffle species present common ecological features, such as a relatively wide range of host species and the need for calcareous soils with a sub-alkaline pH (7 to 8) (Pacioni & Comandini, 1999), except *Tuber borchii* tolerating slightly acidic soils (Mello et al., 2006). Gajos & Hilszczańska (2013) cite author Granetti (1994) who point out that well-aerated and well-drained soils with a good amount of Ca, K and S are suitable for truffles.

Truffles are seasonal wild fungi growing after rain at a depth of 5 to 15 cm under the ground (Rana et al., 2020) or at a depth of 4 to 40 cm (Ştefan, 2016). And because they grow up to 30 cm deep into the soil, they need to be found with the help of trained dogs or pigs (Hilszczańska et al., 2019). In order to find truffles after maturation, the acute sense of smell of certain animals is required. The fine sense of smell of the pig makes it very efficient, but it requires constant vigilance, because of the risk of truffles being damaged, or even swallowed. Moreover, the animal gets tired rather quickly and its transport is difficult. Unlike pigs, dogs are not naturally interested in truffles and can be trained to indicate with their paws the place where the fragrant mushrooms are located. Truffles can also be localized by fly species (genus *Suillia*), which often hover above the place where a truffle is hidden (Talou et al., 1990). The role of the dog in the search for truffles is considered crucial, because the animal works in many cases like a 'translator' for nature, providing essential information for the trifulau, thanks to its keen senses and extensive training (Pieroni, 2016). Polemis et al. (2019) cite authors Hanson et al. (2003), Trappe & Claridge (2010) pointing out that truffles serve as a source of nutrition for the soil micro-fauna and several mammals.

Rana et al. (2020) cite authors (Rota et al., 2008; González & Marioli, 2010) indicating that the weight of truffles is ranges from 30 to 300 g. Ştefan (2016) points out that those truffles are called 'the earth diamonds' due to their high prices when sold on the market, and several of them are highly prized due to their unique aroma (Bonito et al., 2010) and culinary identity (Siachoono et al., 2016; Polemis et al., 2019). Some species, such as *T. magnatum* Pico, and *T. melanosporum* Vittad., are in great demand by the food market in many countries because of their special taste and smell, resulting from a blend of hundreds of volatile compounds (Bellesia et al., 1998; Gioacchini et al., 2005; Mello et al., 2006). The analyzes have proven to contain 9% protein, 13% starchy materials, 1% fat, vitamin B_2, that is rich in vitamin A. It also contains a quantity of nitrogen in addition to carbon, oxygen and hydrogen, which makes the composition similar to the composition of meat (Rana et al., 2020). Truffles are used in the food industry in the development of the luxury gastronomic culture, the pharmaceutical and cosmetic industries (Ştefan, 2016).

There are important differences in the geographical distribution of truffles (Mello et al., 2006). Todesco et al. (2019) point out that the most valuable truffle species are *Tuber melanosporum* Vittad., *Tuber magnatum* Pico, and *Tuber aestivum* Vittad.

The edible fruiting body of *Tuber melanosporum* Vittad. is commonly known as Périgord truffle, 'black truffle' (Kaffsack, 2006) and also locally known as "sweet" truffle (Pieroni, 2016). The Périgord truffle has a much smaller ecological range (Delmas, 1978; Čejka et al., 2020) and is collected in the South and West Europe - Italy, France, and Spain (Mello et al., 2006; Barchfield, 2008; Santelices & Palfner, 2010). The migration of Périgord truffles into higher latitudes in the north of the European Alps (Thomas & Büntgen, 2017; Büntgen, et al., 2019), and the recently documented harvest has declined in the species' southern European habitats (Büntgen et al., 2012), being attributed to global warming (Thomas & Büntgen, 2019; Čejka et al., 2020). Todesco et al. (2019) cites Reyna & Garcia-Barreda (2014) saying that *T. melanosporum* plantations are found not only in the Mediterranean area but also outside their native range, including Australia, South-America, and West USA. Black truffles are grown in symbiosis, especially with oaks, and during its limited harvesting season, mainly winter, one finds them in several regions of southern Europe (Talou et al., 1990). Stobbe et al. (2013) points out that, besides harvests from natural habitats, *T. melanosporum* plantations across the Mediterranean have gained importance over the past decades (Bonet et al., 2009), especially following the application of the technique for artificial mycorrhization of host plants developed in the 1970s, which soon became the standard for truffle cultivation (Hall et al., 2007). The demand for black truffle has stimulated studies on species (Rosa-Gruszecka et al., 2017). *T. melanosporum* was first cultivated in France during the 19th century (Olivier et al., 1996). It is currently cultivated worldwide (mainly in regions with a Mediterranean-like climate) (Reyna & Garcia-Barreda, 2014) and is highly regarded for its culinary properties (Thomas et al., 2016). Thomas (2014) presents a very detailed analysis of the climatic parameters required for growing *T. melanosporum*, including data from Africa, Asia, Australia, Europe, North America, and South America. This study provides information about countries that have a natural population of *T. melanosporum* and those that do not have a history of natural populations but are in the suitable climatic ranges of this species. The author points out that truffle cultivation is successful in areas that have lower temperature and higher rainfall levels than expected. The data compiled are extremely valuable and useful for cultivators in choosing suitable locations for a plantation. Büntgen et al. (2019) cite the authors (Thomas & Büntgen, 2019) reporting that the quality and quantity of truffles are affected by more frequent Mediterranean summer droughts, although many plantations are grown under irrigated conditions.

Tuber magnatum Pico, commonly known as the Italian and the 'white truffle' fruiting bodies have so far been collected in Italy and in East Europe- Croatia, Slovenia, and Hungary- resulting in a limited availability (Mello et al., 2006; Rosa-Gruszecka et al., 2017). According to Murat et al. (2005), for *T. magnatum* there is still a lack of cultivation methodology, although *T. melanosporum*, *T. brumale* and *T. aestivum* have been grown on plantations (Rosa-Gruszecka et al., 2017).

Tuber aestivum Vittad., commonly known as the summer and Burgundy truffle, is an ectomycorrhizal Ascomycete associated with numerous trees and shrubs. Its life cycle occurs in the soil, and thus soil parameters could influence it, such as temperature and water availability (Todesco et al., 2019). Gajos & Hilszczańska (2013) state that according to Chevalier & Frochot (1997) the natural geographical distribution of *T. aestivum* ranges from North Africa to Sweden and from Ireland to Russia. The burgundy truffle is a species with a huge market and a wide geographic spread (https://plantationsystems.com). It is often reported that France, Italy and Spain are home to the Burgundy truffle, and nowadays much of the supply comes from an ancient woodland in a country like Romania. In Romania truffles have spawned a niche in rural tourism. Truffle tourism has a future in Romania because it has environmental management and provides jobs for rural areas (Ştefan, 2016). Currently growing in much of Europe (Stobbe et al., 2013), the Burgundy truffle is expected to offer a great potential to be cultivated in new regions as climate change progresses (Stobbe et al., 2012; Čejka et al., 2020). Romania has large tracts of native woodland that become heavy with truffle collectors from across Europe hunting these fertile grounds. Indeed, Transylvania produces some of the best summer truffles on the market (https://plantationsystems.com).

Kaiser & Ernst (2016) specify that the most highly valued truffles species are native to Europe: the Périgord 'black truffle' and the Italian 'white truffle' dominate the market, and the Burgundy truffle has a lower value.

A new species of truffle- *Tuber pulchrosporum*, was described in Greece and Bulgaria (Polemis et al., 2019) and is not recommended due to its rarity collection (Kaounas, 2020). While *T. borchii* and *T. maculatum* are found throughout Europe (Riousset et al., 2001; Mello et al., 2006), Csorbainé et al. (2008) indicate that *T. macrosporum* mainly occurs on water-affected river banks, temporarily flooded river valleys or in deep and shaded valleys in the Czech Republic, Hungary, Romania, and Ukraine. Gregory et al. (2003) points out that *T. macrosporum* can also have a wider tolerance to drought. Mandić et al. (2018) points out that in personal communication with Ivan Ratoša it is understood that in the '70s the traditionally illegal truffle market, mainly held by Slovenian smugglers, was the only route for selling truffles from Serbia. The author points out that in the early 2000s M. Milenković organized courses and sold written instructions on truffle hunting, as a result of which the number of truffle hunters in Serbia grew rapidly. Truffles currently are gaining attention in Poland, mainly due to the establishment of truffle orchards as a source of benefits in agroforestry, as the grow and collection of truffles stimulates planting oak and hazel (main host-plant species).

Truffles were first found in Bulgaria 15 years ago in Ludogorie, the Shumen Plateau and Strandzha Mountain. History shows that during Socialism there were plenty of planted species of oak, pine tree, and beech, and the development of truffles was furthered by the fact that some nursery gardens had micelle grown in truffles and sapling roots were infected. In the 90s of the XX century Patricio Panfili discovered the first black truffle in the area between Ugarchin and Lovech. There are now also Bulgarian companies offering saplings infected with micelle, as suitable trees here are hazelnut tree, oak, and lime tree. The Italians and the French recommend cultivation on lime tree, oak, and pine tree, as the hazelnut tree is the main tree species used for this purpose in Bulgaria (https://www.duma.bg).

Truffle agroforestry is the original and practical utilization of uncultivated lands with truffle mycorrhizal saplings of the fruit tree Truffle mycorrhizal saplings or forest-ornamental tree species, which form a more stable ecosystem, e.g. truffières. In Bulgaria there is hazelnut truffière, oak and hazelnut truffière, poplar truffière (http://www.kipro-bg.com). A truffle farm near the Balchik village of Obrochishte is one of the newest tourist destinations for tourists in Bulgaria (https://bgtourism.bg).

Plantations of trees where truffles are cultivated, as well as natural truffle forests, are known as truffières (Kaiser & Ernst, 2016). A research on truffle cultivation began in the mid 1800's. However, it was not until the late 1970's that truffles were harvested in French and Italian truffle orchards that had been established with artificially inoculated seedlings. Despite this success, the majority of black truffles and all other species of truffles have been collected over the years from natural areas rather than from artificial truffières. The truffle species most commonly and successfully cultivated is *T. melanosporum*, the famous "French" black truffle. Its hosts include many tree species, but the trees most frequently inoculated are *C. avellana, O. carpinifolia* and *Quercus* spp. (Lefevre & Hall, 2001). In order to cultivate *T. melanosporum*, tree species are inoculated with the fungi and once the mycohrriza is established, these young tree saplings are planted into carefully controlled field sites (Thomas, 2014). Besides forest ecosystems, ectomycorrhizal trees were also implanted in agroforestry ecosystems and in dedicated orchards for producing non-wood products such as edible fungi. The inoculation of tree seedlings with selected ectomycorrhizal fungi in nurseries (i.e., controlled mycorrhization) started a hundred years ago, as this technique has been used extensively since the 1970s to grow truffles (Murat, 2015). Todesco et al. (2019) report that according to the authors Reyna & Garcia-Barreda (2014), Murat, (2015) since the first commercialization of seedlings inoculated with *T. aestivum* and *T. melanosporum* in 1973, considerable progress has been made to improve the quality of the inoculated plants. Santelices & Palfner (2010) point out that according to Ramírez et al. (2004) previous studies carried out in Chile have demonstrated the feasibility of producing mycorrhizal plants of *C. avellana* inoculated with black truffle, matching the highest quality standards demanded on the European markets.

Ştefan (2016), analyzes the different methods of micorrhization used in the truffle culture and their advantages for encouraging the cultivation of truffles. Reyna et al. (2001) have reported attempts to inoculate adult trees with *Tuber* spp. conducted in Italy by Lo Bue et al. (1990), given the extremely painstaking effort required and the costs of their method, it is generally considered impractical and unlikely to have any commercial potential. However, Reyna (1992) have posed the possibility of generating receptive root systems and then inoculating them with a sporal suspension while Chevalier & Frochot (1997) have reported French experiments to replace *T. brumale* infections with *T. aestivum* by surface sporal injection. The experiments reported herein by us have investigated the effects of inoculating established *Q. faginea* and *Q. ilex* with *T. melanosporum* over three years (Reyna et al., 2001). Reyna et al. (2001) point out that nursery inoculation of plants and their cultivation under controlled conditions have resulted in the development of more or less refined techniques. The authors point out that there are many bibliographic references in this direction, some of which describe the most extensively used and practical inoculation techniques (Honrubia et al., 1992), while others analyze the advantages and disadvantages of some of the techniques specifically targeted at *T. melanosporum* (Palazón et al., 1999).

T. melanosporum fruiting bodies are consumed by animals and the spores are dispersed in their excrement. However, when truffles are harvested by man and completely removed from the natural habitat there is little or no opportunity for new trees to become infected by spores. It is possible that this may partly account for decreases in the productivity of natural *T. melanosporum* truffières. Another possible reason for the decline in production is the excessive plant density now found in natural *T. melanosporum* truffières that 100 years ago were kept open by domesticated grazing animals and the collection of firewood (Reyna, 2000; Reyna et al., 2001).

The invasive biology of *Tuber* is of interest, because some of the economically important species are being intentionally introduced into ecosystems around the world (Hall et al., 2007; Bonito, 2009), yet the phenomena of human-mediated long-distance dispersal of mycorrhizal fungi are not well understood (Bonito et al., 2010). Reyna & Garcia-Barreda (2014) cites authors who indicate that *T. aestivum* Vittad., *T. borchii* Vittad. and the *T. indicum* complex have been successfully cultivated (Zambonelli et al., 2000; Hu et al., 2005), whereas without success though by *T. magnatum* (Gregori, 2007; Bencivenga et al., 2009). With a flavor that varies through the season, early summer varieties are often mildly flavored and quite clean on the palate, while those harvested from late summer onwards can be really quite intense - in a similar vein to the Perigord truffle (https://plantationsystems.com).

CONCLUSIONS

Truffles are the icons of the fungal world. Their strong aromatic scent gives them a unique culinary identity, thus becoming in recent years increasingly popular worldwide. The most highly valued truffle species are native to Europe - the Périgord black truffle, the Italian white truffle, and the Burgundy truffle that mainly grows under deciduous trees with host tree species being oaks, hazelnuts, hornbeam, alder, willows, lindens, and poplars.

In recent years a decrease has been observed in the number of truffles found in nature as a result of environmental pollution and massive deforestation. That is why attention is paid to the plantations of trees where truffles are cultivated (truffières) which **is a successful approach to truffle growing in Europe**. Truffle species also perform many important ecosystem functions, including organic matter decomposition, nutrient cycling and retention, soil aggregation, and transferring energy through soil food webs.

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SURVEY OF THE ENTOMOFAUNA ON THE SOIL SURFACE IN AN ORGANIC APPLE ORCHARD

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Abstract

The ecological aspect of organic farming refers to the ability to maintain the resilience of agroecosystems. This paper aims at investigating the species diversity of entomofauna (harmful and beneficial) on the soil surface in an organic apple orchard under the conditions of ecological management approaches. The organic orchard is located on the land of the village of Vodenichane, Yambol region, Bulgaria. Field surveys of entomofauna on the soil surface in the apple orchard were carried out in 2018 and 2019 with monthly reporting of 'pitfall trap' (soil traps) placed in a checkerboard pattern under the crowns of selectd trees. The Dominance index was higher in 2018 in comparison with the dominance index reported in 2019 and showed the capacity of taxons of higher ecological plasticity to increase their number in return for other taxons in the agrocenosis under survey. The other ecological index is the Equitability index, which expresses the uniformity in the distribution of the total number among the separate species and shows a tendency towards striving for achieving optimal development. Equitability was higher in 2018 as compared to the equitability in 2019, which means that the taxons in the complex were more evenly distributed from a systematic point of view.

Key words: *agroecosystem, biodiversity, entomofauna on the soil surface, organic apple orchard.*

INTRODUCTION

Organic farming is one of the forms of sustainable agriculture, in which the care for environmental protection is intertwined with the production of ecologically clean food (Leksono, 2017). The ecological aspect of organic farming refers to the ability to maintain the resilience of agroecosystems (Semos, 2002). Leksono (2017) cites Altieri & Nicholls, (2000) according to whom the concept of organic agriculture is closely related to the concept of agroecology. The concept of agroecosystems is based on the understanding that it is an ecosystem that operates on the basis of complementary relationships between living organisms and their environment, limited within certain limits, which maintain a stable dynamic balance in time and space (Kostadinova et al., 2003; Rusch et al., 2010; Ghosh, 2011). Kostadinova (2017) cites Vandermeer & Perfecto (1995), according to whom there are two main components distinguished in agroecosystems, namely the planned biodiversity of plants and animals, which are purposefully included by the farmer in the agroecosystem, and the associated biodiversity, which includes soil flora and fauna, herbivores, reducers, etc., which are colonized by the environment in the agroecosystem and develop over time depending on its management. It is well known that agriculture can support biodiversity and biodiversity can support agriculture (Bàrberi et al., 2010), yet the importance of balancing these two approaches is rarely taken into account (Altieri, 2004; Bàrberi, 2015). Montañez & Amarillo-Suárez (2014) point out that according to Hole et al. (2005) a dramatic decline was reported in the abundance of several species associated with farms in Europe during the last quarter century. In organic farming, weeds have a positive role in protecting the soil from erosion; most of the flowering weeds (*T. officinale, C. intybus, M. chamomilla*) are honey plants and are a habitat for predators and parasites of the enemies of cultivated plants. In this way they increase biodiversity and help the biological control of the natural enemies of pests (Clements et al., 1994; Rusch et al., 2010; Ghosh, 2011; Diekötter et al., 2016). A number of authors (Franke et al., 2009; Médiène et al., 2011) have pointed out the ecological role of weeds in the agroecosystem, as some of them play the role of a 'buffer' for the development of a large number of aphidophages- predatory species, syrphid flies and others. Weeds are considered an element of pest control because they attract natural predators (Biala et al., 2006; Gaba et al., 2014). Weeds compete with crops for light, water and nutrients, and when they pass a certain level (Economic injury level), there is a reduction in yields, difficulty in harvesting, as some weeds are hosts-source of phytopathogens and pests of crops. Cover crops between rows spacing of perennials are perceived as competition of the main crop in terms of water, light and nutrients (Weibel & Häseli, 2003; Crews, 2005; Moore et al., 2019) as a shelter for the natural enemies of pests (Irvin, 2009; Rodriguez-Saona, 2012; O'Neal, 2014; Snydera, 2019). Kostadinova (2017) cites a number of authors (Vogt & Weigl, 1999; Fitzgerald & Solomon, 2004) who point out that cover crops are attractants of beneficial entomofauna. Many authors (Hooks & Johnson, 2003; Gurr et al., 2004; Poveda et al., 2008; Ratnadass et al., 2012) indicate that the increase in natural pests as a result of the increasing plant species diversity contributes to the biological control in cultivated plants. The maintenance of the soil surface also affects the predatory insects that inhabit the soil surface (Miñarro & Dapena, 2003; Mathews et al., 2004). Kostadinova (2017) cites (Matthey et al., 1990; Steinborn & Heydemann, 1990) who indicate that species from the *Carabidae* family are considered indicative of the habitat quality (Diekötter et al., 2016). As predatory beetles - runners are polyphagous, the species of the genera *Calosoma*, *Carabus* perform natural regulation of many plant pests (Harizanov et al., 2010). Kostadinova (2017) reports that biological diversity and abundance in the biological agrocenosis are the most tangible for species (the families *Carabidae*, *Staphylinidae*, and *Coccinellidae*) known for their benefits for agroecosystems. Pfiffner and Niggli (1996) point out that arthropods are characterized not only by greater diversity and abundance, but also by the fact that they are more evenly distributed. A number of researchers (Harizanov et al., 1996; Andreev, 2012; Harizanov et al., 2010) point out that the family *Coccinellidae* is widespread in biocenoses. In terms of food specialization, ladybugs are divided into 3 groups- phytophagous, mycophages, and zoophages. Species in the group of zoophagous use for food insects with a delicate body (aphids, thrips, cicadas, young larvae of butterflies and beetles, whiteflies) and mites. Though characterized with extensive polyphagia, zoophages have a known preference for certain groups of preys, such as aphids, whiteflies, mites, and others. Arachnids can be used as suitable indicators to monitor the impact of agricultural practices on biodiversity (Mazzia et al. 2015; Kostadinava, 2017). Beneficial species that inhabit the soil surface have a very important role in regulating the density of various pests (Luff, 1983; Nyffeler & Benz, 1987; Mudgal et al., 2010). Birds, mammals, arthropods and plants benefit from organic crop production, which also exhibits better pest control by maintaining natural enemies and pollinators (Hole et al. 2005; Garratt et al., 2011). The Shannon (entropy) index is often used in environmental studies (Townsend et al., 2002; Mouillot et al., 2005; Petrova et al., 2012, Kostadinova et al., 2017). The index of individual species diversity (Shannon H') is one of the most frequently used structural parameters and the most important of all structural indicators. When the ecosystem under survey is in its optimal condition, Shannon H' is high (i.e. there is a large number of species, and a relatively small number of specimens for each species, which is sufficiently aligned in all species) and vice versa (Hristov, 2014). This paper aims at investigating the species diversity of entomofauna (harmful and beneficial) on the soil surface in an organic apple orchard under the conditions of ecological management approaches.

MATERIALS AND METHODS

Location of the study. The orchard is located on the land of the village of Vodenichane, Yambol Region, at an altitude of 117 m. The area, on which the organic fruit orchard has been created, used to be common pasture. The orchard was established in 2008. It has an arable area of 180 dka, including apples of the Aidered variety, Golden Delicious. The rows with a length of 200 meters have a north- south orientation, as the distance between the trees is 90 cm and the formation is free. The distance between the rows is 3.20 meters, and the distances between rows are naturally grassed and periodically mowed.

Organic fertilizers were applied during vegetation- poultry manure and livestock manure, in concentration of 0.6% nitrogen, 0.2% P_2O_5 and 0.6% K_2O, at the following phases of fruit growth - formation of fruitfulness, fruit filling and 60% fruit ripening. The principles of organic fruit-growing were applied in the fruit orchard in conformity with the legislation of the Republic of Bulgaria- Regulation (EC) No 889/2008. Funguran OH 50WP- 0.3; NeemAzal T/S- 0.3%; Madex- 0.01%; Pirethrum- 0.05% were used to fight against pests and diseases.

Soil and climatic characteristics. The soils in this area are Chernozem and are suitable for growing perennial fruits. The typical Chernozem soils are typically micellar-carbonate, with a higher content of humus and carbonates, respectively in the surface and subsurface horizon (Koynov et al., 1998). The climate is continental with Mediterranean influence. Summers are dry and hot, and winters are mild. Rainfalls are unevenly distributed throughout the months. Two maximums are typical (May-June; November-December) and two minimums (August and February) of rainfalls. Figures 1 and 2 present the data regarding the average monthly values of air temperature, and the amount of rainfalls 2018 and 2019. Meteorological conditions are very favorable both for the development of fruit species and for entomofauna, which is an indicator in the agroecosystem under survey.

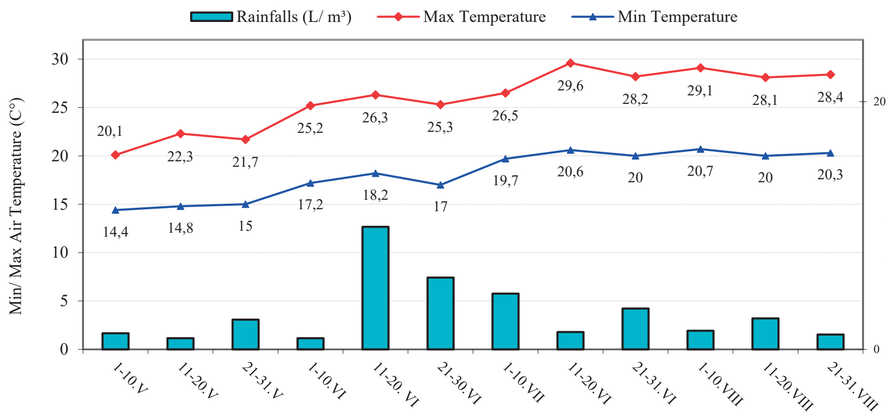

Figure 1. Climatic region characteristics for V-VIII, 2018

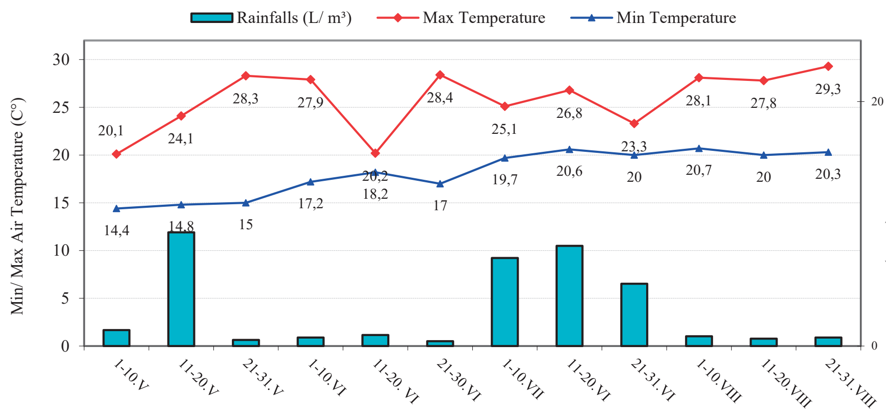

Figure 2. Climatic region characteristics for V- VIII, 2019

Field surveys of entomofauna on the soil surface. Field surveys of entomofauna (harmful and beneficial) on the soil surface in the apple orchard were carried out in 2018 and 2019 with monthly reporting of 'pitfall trap' (soil traps) placed in a checkerboard pattern under the crowns of selected trees. The method of 'pitfall trap' consists in digging plastic cups (with dimensions of d = 9 cm, h = 12 cm) at ground level, in which 100 ml of formalin solution are placed. In order to limit the evaporation of formalin and filling the plastic cups with rainwater, lids are placed 3 cm above the plastic cups. The reports have been prepared on a monthly basis (May, June, July, August) but the presentation of the number of entomofauna has been merged in four months. Specimens are determined to the lowest possible taxons- Family and Order. Ecological indices are calculated using specialized software for statistical analysis Paleontological Statistics, Version 2.15 'PAST' (Hammer et al., 2001). In the surveyed fruit agrocenosis the reported entomofauna is determined by main ecological indicators (total number of species attributed to a family). Some of the indicators for the species structure of the communities recommended by Odum (1975) were used in the study- Shannon, diversity index- H' and Simpson, dominance index- 1-D). The nomenclature of entomofauna is represented by Fauna Europaea [http://www.faunaeur.org.].

RESULTS AND DISCUSSIONS

The results from the survey of the entomofauna on the soil surface from the organic apple agrocenosis in 2018 showed that a total of 108 insect species have been identified in the samples, which are relate to twelve Families and one Order. The results presented in Figure 3 show that the Order *Araneae* is dominant, both quantitatively (23 the number of insects) and in percentage (21%). The other more widespread family in the study was the Family *Tenthredinidae* (17%), followed by the Family *Coccinellidae* (11%) and the Family *Vespidae* (11%). Species from these families definitely play a key role in the agroecosystem. The species from the other reported families (*Cicadelidae*, *Cicadidae*, and *Carabidae*) are less represented, but this does not diminish their role in the agrocenosis. Popov et al., (2017) point out reprentatives of Family *Carabidae* (*Calosoma sycophanta, Carabus convexus dilatatus, Calathus metallicus*), Order *Coleoptera,* which inhabit the soul surface and are beneficial arthropods. According to authors ground beetles are deemed important indicators for the quality of habitats and as such show the sustainability of agroecosystems. Arachnida from Order *Araneae* are polyphagia and are important predatory animals in the regulation of pests in agricultural areas.

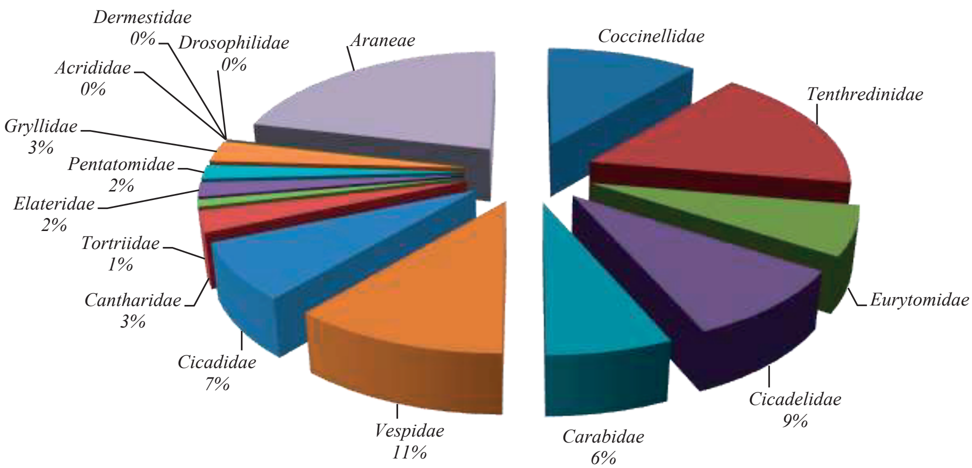

Figure 3. Reporting of entomofauna in V-VIII (2018)
Source: Own survey

The data from the survey on entomofauna conducted in 2019 are presented in Fig. 4, as a total of 124 insects were identified and assigned to fifteen Families and one Order. Figure 4 shows the percentage of families and the Order *Araneae*.

It is noted that the Order *Araneae* and the *Vespidae* Family are equally dominant, both in terms of quantity (19 insects) and percentage (15%). The families *Coccinellidae* (14%) and *Cicadelidae* (10%) are presented in the sample. In this case, the representatives of the family *Carabidae* (7%) are less represented, but their positive role in the agrocenosis has been pointed out by many authors (Kromp, 1989; Andreev, 2012; Harizanov et al., 2010; Kostadinova et al., 2015; Kostadinova et al., 2016; Kostadinova, 2017; Popov et al., 2017; Popov et al., 2018). The other reported families are represented by a smaller number of insects.

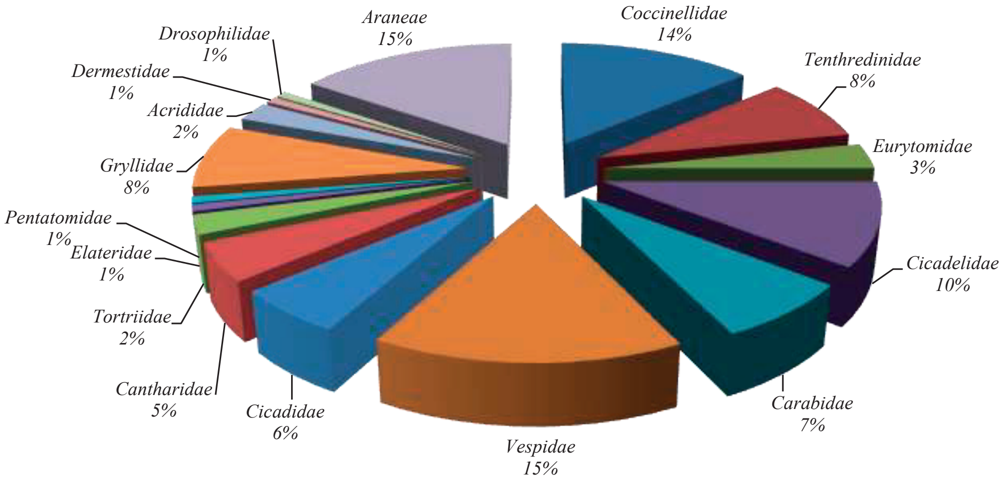

Figure 4. Reporting of entomofauna in V-VIII (2019), Source: Own survey

The survey data obtained during the two-year period have been processed with a specialized software with a calculation of the ecological indices presented in Table 1. In 2018 the Dominance index (D) had a value close to zero (0.123), which means that the number of individuals, which represent the separate taxa in the respective complex, is similar as there are one or two taxons with a predominant number of species. It is noted that in 2019 the Dominance index had a lower value (0.103) as compared to the one reported in the preceding year. The Dominance index (D) definitely demonstrates the capacity of taxons with higher ecological plasticity to increase their number (i.e. to dominate) in return for other taxons in the surveyed agrocenosis. The species characterized with proven, established ecological plasticity in 2018 were the Order *Araneae*, the Family *Tenthredinidae*, the Family *Coccinellidae*, and the Family *Vespidae*. The higher values of the Dominance index established from the results obtained for the year of 2018 show higher dominance or changed conditions in the agroecosystem towards aggravation under the impact of the anthropogenic interference, fluctuation of abiotic factors, etc. There is a situation that is described in the specialized literature as a phenomenon due to the so-called double stress in biocenoses, which is caused by repeated stress of relatively poor in species composition coenoses, such as agrocenosis (Markova & Chardakova, 2009). According to Odum (1975) in case of repeated stress, most often the result is a reduction in the number of the main species, which leads to greater evenness of the species.

The Equitability index (E), expresses the uniformity in the distribution of the total number among the separate species and shows a tendency towards striving for achieving optimal development. The values of the Equitability index (E) are below 1 and vary from 0.887 in 2018 to 0.878 in 2019. It has been established that the equitability was higher in 2018 as compared to the equitability in 2019, which means that the taxa in the complex were more evenly distributed from a systematic point of view. Simpson's index (1-D) and Shannon's index (H) give a more detailed evaluation of the diversity of subspecies in the organic fruit agrocenosis, thus confirming the higher diversity of species from the complex of taxons in 2019 with a value of 0.897 for the Simpson's index, as compared to the value of 0.877 reported in 2018. The higher the value the greater the diversity. This also became clear for the values of the Shannon's index (H), which were 2.435 in 2019 and respectively 2.274 in 2018.

Table 1. Ecological indices

Index	2018	2019
Taxons	13	16
Individuals	108	124
Dominance (D)	0.123	0.103
Simpson (1-D)	0.877	0.897
Shannon (H)	2.274	2.435
Simpson Evenness	0.748	0.714
Equitability (J)	0.887	0.878

Source: Own survey

Biodiversity in species may be used to characterize the "biological health" of a given habitat. However, the values of biodiversity should be interpreted carefully. Some habitats are filled with tension and therefore less organisms adapt to the life there, as all adapted animals are unique. Such habitats are important even if characterized with low diversity. The higher species diversity is conductive to a more stable agroecosystem due to the availability of more ecological niches and the less chance for the environment to be unfavorable, as the combined food networks also contribute to the environmental stability. It is less probable that the potential change of the environment causes any damage to the ecosystem as a whole.

CONCLUSIONS

The Dominance index was higher in 2018 in comparison with the dominance index reported in 2019 and showed the capacity of taxons of higher ecological plasticity to increase their number in return for other taxons in the agrocenosis under survey. The other ecological index is the Equitability index, which expresses the uniformity in the distribution of the total number among the separate species and shows a tendency towards striving for achieving optimal development. Equitability was higher in 2018 as compared to the equitability in 2019, which means that the taxons in the complex were more evenly distributed from a systematic point of view. Biodiversity should be related to the functional features of the agricultural ecosystems. The high level of biodiversity, for example through higher species abundance, does not necessarily mean a high level of functionality of agroecosystems. It is therefore necessary to identify the key functions of biodiversity in agroecosystems and the mechanisms for biodiversity to help the management of organic farming systems.

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TRANSPORT-MANIPULATION TECHNOLOGIES FOR COLLECTION OF VEGETABLE RESIDUES FROM *ROSA DAMASCENE* MILL PRODUCTION IN REPUBLIC OF BULGARIA FOR THE PURPOSE OF FOLLOWING USE FOR ENERGY NEEDS

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Abstract

There are considered three options for harvesting from the field of plant biomass from Rosa damascene Mill after picking the flowers. To limit of Agrilus damage to plantations, the cut biomass must be taken out of the massifs. In order to avoid its rot in the form of energy chips, it is necessary that it has reached an air-dry state before the "shredding" operation. The influence of the field area and its distance from the place for storage of energy chips on the efficiency of the used equipment was observed. Depending on the location and size of the planted areas, it is appropriate to apply one of the considered options.

Key words: *Rosa damascene Mill, technology, energy, transport.*

INTRODUCTION

In the Republic of Bulgaria, the cultivation of a *Rosa damascene* Mill for the production of rose oil, rose water and others is the main livelihood of entire areas, popularly called the Rose Valley or the Valley of Roses. Bulgarian rose oil is well known on international markets (EU, USA, Australia, Japan, Middle East, etc.) https://www.mzh.government.bg/bg/(1February 2021); Zarev, K. (2008), where it has been exported since 1820 to this day.

According to data from the Ministry of Agriculture and Food of the Republic of Bulgaria https://www.mzh.government.bg/ (1 February 2021) the areas occupied with *Rosa damascene* Mill have increased from 3,290 ha (32,900 da) in 2013 to 4,189 ha (41,890 da) in 2018.

According to Implementing Regulation (EU) № 1020/2014, the geographical area of production of "Bulgarian rose oil" includes the municipalities:

- Brezovo, Kaloyanovo, Karlovo, Sopot, Stamboliyski, Saedinenie and Hissarya from the administrative district of Plovdiv,
- Bratya Daskalovi, Gurkovo, Kazanlak, Maglizh, Nikolaevo, Pavel Banya and Stara Zagora from the administrative district of Stara Zagora,
- Belovo, Bratsigovo, Pazardzhik, Panagyurishte, Peshtera and Strelcha from the administrative district of Pazardzhik,
- Ihtiman, Koprivshtitsa and Mirkovo from the administrative district of Sofia.

Apart from this geographical region defined by EU Regulation № 1020/2014, there are other areas in which small areas of *Rosa damascene* Mill are grown.

The *Rosa damascene* Mill are shrubs, branched to varying degrees, and belong to the Rosaceae family (Popov, A. et al., 1968; Terziev, J., 2006; Balinski, K. et al., 2010; Neshev, G. and Landzhev, I., 1994; Staneva, D., 1982). The height of the bushes of the individual species varies in wide ranges from 0.3-0.4 m to 2.5-3.0 m Topalov, V. et al. (1994).

The rose is very resistant to soil and air droughts Nedkov, N. (2014). The culture develops successfully on light, ventilated and deep soils Marinov, H. (1961). There are special requirements for the climate when growing for the production of rose oil Baeva, G. (2018). Only oil-bearing flowers are used, without the rods remaining during pruning Zahariev, I., Kehayov, D. (2015). The stems of *Rosa damascene* Mill has a high energy potential Zahariev, I. and Kehayov, D. (2016), which remains insufficiently studied and not fully used up to the moment \so far\.

The analysis of the areas shows that for 2015 the residual plant biomass after the contour pruning is about 20,000 t and is to increase Zahariev, I. and Kehayov, D. (2015).
According to Zahariev, I. (2018) the leaf-stem mass of *Rosa damascene* Mill enters the air dry state (18-22%) only after the 6965th minute (116th hour) after cutting and drying of atmospheric conditions without precipitation. It is also imperative to end the traditional practice of burning these piles when they reach an air dry state. In this way, thousands of tons (about 20,000 t for 2015) of residual plant biomass to be used for heat production will be saved from destruction every year. At a bulk density of 174.6 kg/m^3 at a humidity of 18% (air dry state) 114,547 m^3 are obtained.
According to Asenov, L. and Vidinova, E. (2007) the technologies for utilization of residual plant biomass can be divided into three subcategories:
- technologies for its collection from the field;
- technologies for its storage and preservation;
- technologies for its utilization as a raw material for obtaining products for energy production.

The purpose of the present study is to determine the techniques and technologies for harvesting from the field of residual plant biomass of *Rosa damascene* Mill in a state of energy fever.
To achieve the above purpose, various publications on technologies for harvesting plant residues and machines of different crops, visited companies producing and/or importers of agricultural machinery to collect the necessary information.

MATERIALS AND METHODS

The residual plant biomass of *Rosa damascene* Mill, after harvesting the oil-bearing flowers and subsequent contour pruning, consists of young shoots, perennial stems, leaves, inflorescences and prickly thorns. In order to be able to collect and utilize this biomass, it must not be crushed and scattered in the field for green manure. It must be extracted at the end of the massif and left in piles until it reaches an air-dry state (Figure 1).
Technologies for harvesting from the massif with *Rosa damascene* Mill of the residual plant biomass in the form of energy chips in air-dry state generated during the contour pruning, after harvesting of the oil-bearing flowers.

Figure 1. Pile of plant remains of *Rosa damascene* Mill reaching an air-dry state to the rose array

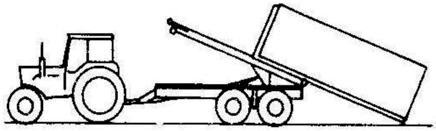
The conversion into energy chips (wood chips) is done with a forage harvester (Figure 2) or a chopping machine.

Figure 2. Shredding of plant residues of *Rosa damascene* Mill with silage harvester KPI-2,4

RESULTS AND DISCUSSIONS

According to Kehayov, D. et al. (2017) have 15 variants of technologies for harvesting residual plant biomass from the field are substantiated. Of interest are mainly three of them:
The proposed technologies are for harvesting the plant residues of *Rosa damascene* Mill generated during contour pruning and chopped into energy chips in air dry condition. These technologies differ in the means of transport used and the type of transport packaging.
<u>The first technology is</u>: *"Direct collection of biomass in the state of energy chips with vehicles for interchangeable bodies\frame\ and containers".*

According to Panayotov, J. (1987) vehicles for interchangeable bodies\frames\ and containers are implemented in the transport systems of developed countries, such as the United States, England, Germany, France, Sweden, Finland and others. They use the latest ways to quickly change bodies\frames\ (Figure 3).



CL

Figure 3. Container system "Multilift",
CL - container vessels with loading and unloading equipment, Panayotov, J. (1987)

When using the container system is appropriate to apply a combination of tractor and road vehicles.
The main advantage is that the container truck can leave an empty container in the field and load itself full, without the need for an additional machine.
Another positive feature of most variants of the Multilift container system is that unloading at recycling points can be done not by removing the container body, but by pouring the energy chips back, as in dump trucks. Thanks to this specific feature of the system, there is no need for an unloading device at the checkpoints.
Due to the fact that a large part of the massifs are located in hard-to-reach places for highway container trucks, the most suitable option for transporting energy chips from the field to the processing centers is a combination of tractor and road transport. In this case, the container is delivered to the base of a rose producer by an ordinary highway container truck. From there it is transported to the massifs with a *Rosa damascene* Mill on a trailer towed by a tractor. Fill up and vice versa. According to https://freeline.bg/shema-na-tovarene (1 February 2021), the volume of a 20-footcontainer is 28-30 m^3, which makes 4.9-5.2 t.
Second technology: *"Transportation of oil rose residues in the form of energy chips with specialized vehicles for the transport of containers with gantry cranes."*
The technological scheme is shown in Figure 4.

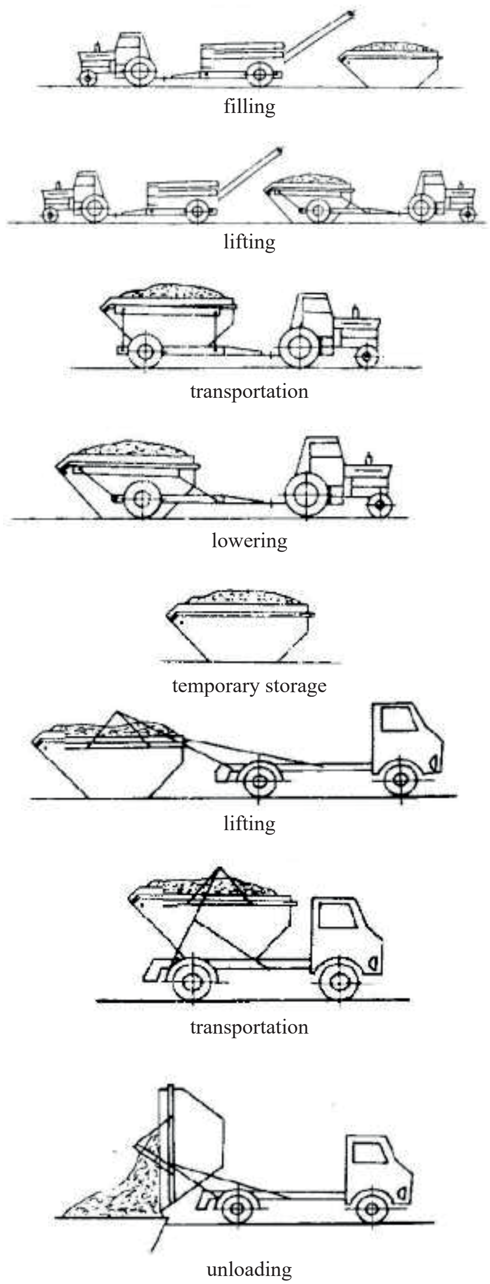


Figure 4. Technological scheme of container system.

This type of transport has been introduced in agriculture, construction and utilities since the 1970s. The gantry crane is characterized by a simple and reliable construction. The containers used have a capacity of 5.1 m^3, with dimensions 2,580 x 2,195 x 1,150 mm and are made of steel sheet with a thickness of 3 mm.

At a bulk density of 174.6 kg/m^3 at 18% moisture content, 174.6 x 5.1 = 890.5 kg will fit in one container.

Another advantage is that the container truck can load 2 or 3 empty containers. Such an organization reduces the downtime of the vehicle waiting for the container to be filled with energy chips.

Glushkov, S. et al. (2015) found that with prolonged storage, the cods subside. For this reason, the storage time of energy chips in the container needs to be limited to reasonable limits.

In this organization, empty containers can be delivered in advance to the rose grower's farm and lifted from there at a time convenient for the transport company.

According to https://agri.bg/agrosaveti/lozarstvo/beritba-na-vineni-sortove-grozde–2(1February 2021)the grapes are harvested at the end of September - beginning of October. The grapes are transported from the vineyards to the wineries \wine factory\ in special containers. During the rest of the year, these containers are stored \ are not used\.

The plant remains of a *Rosa damascene* Mill in the form of energy chips are transported at the end of July - the beginning of August.

From the above, it is clear that the containers for wine grapes can also be used to transport energy chips, because at that time they are in standby mode.

The main disadvantage is the need for equipment for lifting and pouring these wine grape containers in the processing centers when they are loaded on platform cars without the possibility of self-unloading.

Third technology: *"Transportation of oil rose residues in the form of energy splinters by dump trucks and dump trailers".*

The technology includes the following operations: bringing in the form of energy chips and loading of the cut plant remains of *Rosa damascene* Mill in a highway car dump truck and dump trailer, transportation to the collection point for further processing.

The main disadvantage of this technology is the fact that many of the arrays are located in places inaccessible to highway dump trucks.

In order to eliminate the need for stopping and to minimize the downtime of the forage harvester or chopping machine, it is necessary to provide the so-called buffer trailer. It is an intermediate link between the shredder and the vehicle (trailer, dump truck or container). Thanks to it, the chopping machine does not have to stop when filling the vehicle and wait for the arrival and positioning of another one, as shown in Figure.5.

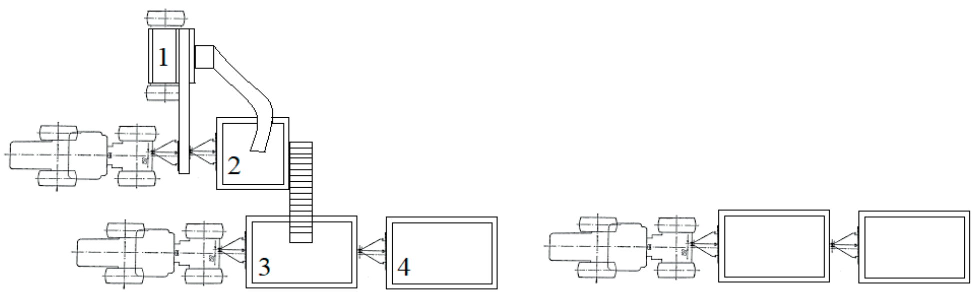


Figure 5. Technological scheme of loading of tractor trailers using an intermediate unit-buffer trailer;
1 - crushing machine; 2 - buffer trailer; 3 - loaded trailer; 4 - waiting trailer.

During the positioning time of the next trailer of one train or other vehicle, the buffer trailer absorbs the crushed mass in its own free volume and thus there is no need to stop the crushing machine. The buffer trailer is used as an intermediate in technological schemes for harvesting different crops.

CONCLUSIONS

Based on the above, the following conclusions can be drawn:

1. Three technologies for the transport from the field of residual plant biomass of Rosa

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damascene Mill to air-dried state and converted into energy splinters are substantiated;
2. Depending on the location and size of the planted areas, it is appropriate to use one or another technology;
3. Due to the low volumetric density of energy chips, it is necessary to complete specialized vehicles for the transport of containers with gantry cranes with a trailer in order to achieve maximum use of the traction qualities of the machine;
4. With the use of an intermediate unit - buffer trailer with conveyor there is no need to stop the crushing machine when moving the trailers in one composition or when positioning another composition.

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