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A NEW STRATEGIC APPROACH USED FOR THE REGENERATION OF SOIL FERTILITY, IN ORDER TO IMPROVE THE PRODUCTIVITY IN ECOLOGICAL SYSTEMS

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Abstract

The constant pressure to increase food, fiber, and fuel production in order to meet the increasing global demand and prevent malnutrition has put significant pressure on soil resources. Minimal attention to soil protection and conservation, inadequately aggressive management, as well as climate change have resulted in abandoned, degraded, and the expansion of agricultural marginal areas with major agricultural limitations. Agricultural production on degrading land necessitates increasing amounts of chemicals such as fertilizers and pesticides with a negative long-term effect. In recent years, many activities have been proposed to improve soil characteristics starting with the change of cultivation methods, grazing, mulching, composting, soil conservation, green manuring, soil remineralization, however no clear strategies are known to integrate all these measures in a unitary way. which helps farmers to restore degraded soils, while obtaining high yields in organic farming. To reverse these trends, fundamental adjustments in productive systems are required, including the implementation of sustainable natural resource management. Our study proposes a strategy that successfully integrates several soil regeneration techniques, as well as design new planning that allow farmers to benefit from the services offered by agroecosystems.

Key words: *soil regeneration, strategies for organic farming, healthy ecosystems.*

INTRODUCTION

Agro-systems that are not sustainable and resilient are deteriorating the environment by reducing soil productive capacity, degreasing biodiversity, and causing damage to water availability and quality. Food production is currently one of the most pressing global concerns, posing numerous challenges that require a multidisciplinary investigation into climate change, agricultural production limitations caused by soil and water resource degradation, as well as into social issues such as food security, and social justice in the provision and distribution of food.

Soil is composed of organic matter, minerals, living organisms, air and liquids all together supporting plants grow. Soil fertility is one of the most important factors that influence grains yields and the crop quality. Nowadays, soil degradation is a global phenomenon caused by natural land erosion, human activities and climate change. In Europe large fields from Spain, Portugal, Italy, Greece, Bulgaria and Romania are in process to desertification. (European Court of Auditors, 2018). Conventional Agriculture, based on synthetic fertilizers, monocultures and excess of tillage increase the speed of soil degradation (Lal, 1993; Mircea C., 2020). The impact strongly influences the soil biology, land health, plants health, as well as animals and human health. Soil biology is the key to an agricultural ecosystem that influence the physical properties and in the same time is an instrument of natural bioremediation and biocontrol (Shah, 2016; Nenciu F., 2022). Nature manages its own soil fertility without external inputs, but relay on microbial activity to recycle nutrients and slowly release them, in available forms, to the plant roots (Osman, 2012; Nenciu F., 2021). The use of chemical fertilizers improves soil chemistry, in the short term, but negatively affects the structure and soil biology. A mechanical aeration improves soil physics, but also creates better conditions for soil biology, and helps plants to better absorb nutrients. Soil structure depends on the balance between calcium, magnesium and sodium. Calcium is opening the soil, makes it more friable, while magnesium and sodium close it, creating hardness that restricts, water, air and roots penetration, prone to erosion. Carbon is also a very important element for soil structure and soil fertility. Carbon and nitrogen are the basic elements that provide food source for soil life. Soil biology refers to life in soil, bacteria, fungi and larger critters that break down dead matter, release nutrients and create soil organic matter.

Following intensive agricultural practices, many soils contain less than 5% soil organic matter, and have an important negative impact for plants grow (Osman, 2012). Natural soil regeneration takes place over long periods of time, usually 100 years (Petit, 2004), however farmers working with nature can rebuild soil fertility in few years.

Healthy plants thrive in fertile soil that contain humic substances like humin, humic acid and fulvic acid. Plants are less subject of stress, have high yields, high quality, full of nutrients. To increase soil organic matter recommend-dation is in changing the methods used in Conventional Agriculture to methods and principals used in Regenerative Agriculture (Nenciu F., 2022).

The present paper aims to briefly describe a regenerative technology used in Romania for a corn crop and quantifying the results obtained for a period of 6 years.

MATERIALS AND METHODS

The concept Regenerative Organic Agriculture was first adopted by Rodale Institute from USA. The idea starts from using the farm internal resources to increase soil fertility and yields, avoiding chemical inputs.

Starting 2017 Regenerative Agriculture is certified under the name Regenerative Organic Agriculture (ROC).

Regenerative agriculture main goal is to regenerate the soil fertility, due to soil health that can sustain healthy plants. To solve this issue Regenerative Agriculture, have 5 main principals and materials like instruments, amendments and biological solutions.

Methods like soil protection, minimum tillage, living roots and biodiversity are accepted by all farmers and scientific workers inside Regenerative Agriculture.

The last principals, but not the least, integrated animals, is used in present in few farms, but trend is coming back in more and more farms.

Soil disturbance. Minimization or tillage going to elimination is one of the most important principals to achieve the main goal. Tillage in excess, synthetic inputs application disrupts physical soil structure and fungi hyphae and provide oxygen to soil microbes to star break down soil organic matter. Tillage to improve soil aeration, break hardpan, open pores for water flow and drill the seeds is allowed as long as soil structure is not affected.

Topsoil is always an issue of erosion. To protect the topsoil, in a cereal growing crops the principals of Regenerative Agriculture recommend using cover crops. This method reduce erosion, maintains moisture, keep temperature constant, increase microorganism population. Providing a natural shield, soil is protected from erosion caused by wind, heavy rains, while providing foods and habitat for macro and microorganisms. Soil food web starts to be active. Soil food web create tunnels and decompose organic matter in a form that plants can absorb nutrients.

In Regenerative Agriculture biodiversity has an important role in soil regeneration. Monoculture is a human practice, nature always for diversity plants and animals. Biodiversity is critical for ecosystem stability, productivity and nutrients plants absorption.

Living roots. Living roots keep the engine running during the whole agricultural year. During the photosynthesis process plants eliminate exudates through the roots. Carbohydrates inside exudates is food for bacteria and fungi. Fungi and bacteria, basement for soil food web, in return provides water and food to plants. Living roots continue growing into early winter and break biology dormancy in the spring. Plants exudates feeding soil biology keep the soil population at a high rate. This incredible soil food web creates porous soil that retains and provide water and nutrients to plants.

Integrated animals. Grazing animals helps farmers in improving soil fertility, nutrients recycle through animal manure. Applying all principals increase natural biodiversity, soil fertility while controlling weeds. It is an exact copy of nature cycle. Holistic Agriculture methods based on integrated livestock restored millions of hectares, especially in Africa. Plants and animals have a symbiotic relation and

improve ecosystem helping each other in recycle nutrients.
Growing plants inside this technology need specific implements and machineries completed by organic, mineral and biological fertilizers. No herbicides, insecticides or pesticides are allowed to be applied.
Nowadays, the main issue in soil regeneration is soil compaction. Soil compaction reduced rainfall water infiltration, increase evaporation and water runoff and reduce microbial population activity. Mould board plough, used in Conventional Agriculture, results in hardpan, being one of the most disturbance tillage used in agriculture that destroy soil structure and soil food web (Alvaro-Fuentes, 2008). Mould board ploughs aerate the soil, but soil from 25-30 cm deep is overturned and loose moisture. Intensive conventional tillage and several crossings due to compaction. In draught condition with less moisture and fungi hyphae disrupt, by intensive tillage, plants will not thrive. To solve the situation, research workers develop, in the last decades, specific implements and machineries. A special subsoil (Figure 1) is cutting and aerating the soil, break the hardpan but not rising the soil (Figure 2) and that do not result in hardpan. Deep subsoils and minimum tillage do not compact soil, but create favorable condition for root plants to grow (Bennie, 1986).

Figure 1. John Deere Subsoil SR 1203

Figure 2. Image of field after a subsoil pass

To keep living roots alive all year long Regenerative Agriculture is using a large biodiversity of cover crops like rye, oats, vetch, mustard, radish, etc. These plants keep the soil covered until spring. In spring, before flowering cover crop is mow and row crops are seeded. Cover crops will be decomposed slowly and provide nutrients to row crop. Research workers from Rodale Institute, developed a roller crimper (Figures 3 and 4), used to drives over cover crops, mows the plants down and cutting them every 7 inches. Cover crops protect the soil from erosion, keep the moisture and temperature constant and suppress weeds. Fungi and bacteria decompose the cover crops and provide plants with nutrients. Long term benefits include minimization compaction, soil structure improvement. To avoid compaction, attach on the rear tractor a no-till drill. No-till drill (Figures 5 and 6) are used for a long period of time in No-Till technology. No-Till technology is part of Regenerative Agriculture, but is not a must because a deep subsoil to break the hardpan is sometimes necessary.

Figure 3. Tractor with roller grimper and no-till drill- in progress-

Figure 4. Roller grimper mounted in front of the tractor-in progress-

Figure 5. John Deere 7000 planter lateral equipped with granular and liquid fertilizer- lateral view

Figure 6. John Deere 7000 planter 4 rows in progress- rear view

In order to keep living roots alive all year long, Regenerative Agriculture is using a large biodiversity of cover crops like rye, oats, vetch, mustard, radish, etc. These plants keep the soil covered until spring. In spring, before flowering cover crop is mow and row crops are seeded. Cover crops will be decomposed slowly keep the soil temperature and moisture constant while providing nutrients to row crop. A large pallet of cover crop is used to attract a large number of microorganisms.

Microorganisms like bacteria and fungi are the basement for restoring soil food web. An active soil food web is improving soil fertility, crate healthy plants due to animal and human health.
Regenerative agriculture is based on fertilizers like organic fertilizers, amendments and biofertilizers applied on soil or on leaf that increase plant immunity due to pests and diseases resistant. Synthetic inputs suppress soil biology that create compaction and decrease soil fertility. Organic fertilizers like compost, manure, vermicompost

RESULTS AND DISCUSSIONS

Management inside Conservative Agriculture is focus on quantity. Conservative Agriculture methods include monoculture, synthetic inputs, bare soil, excess of tillage, due to soil degraded, unhealthy plants, animals and humans. All these methods have a negative impact on soil properties, compaction, crusted, hardpan, excess of synthetic inputs leaching in ground water, rivers and lakes, beneficial fungi and bacteria are suppressed (Hirt, 2020).
Inside INMA, few years ago, started a new strategy in developing new tillage implements and drilling machinery that are doing more operation on one pass to reduce fuel consumption, soil compaction and increase soil fertility (Bularda, 2020). The goal of this new strategy is to grow healthy plants and regenerate degraded soils.
To achieve the goal first change is in management. Growing healthy plants with high immune system will increase the quantity. Healthy plants create healthy soil and increase yields. Regenerative Organic Agriculture is based on increasing photosynthesis process which is the engine that never should be stopped. Regenerative Agriculture management is focus on balance nutrients and soil biology. Increasing photosynthetic process results in a larger quantity of exudate that increase the microorganism population and rebuild soil food web (Ingham, 2014).
Firs step was to do a logical scheme based on Regenerative Agriculture principals and our local farm renewable materials (Figure 7).
In red is the decision center. In yellow measurement for hardpan, soil and sap analysis. Information, from soil analysis and plant sap are processed and a decision is taken to fertilize with the needed minerals and biological solution. In green the growing crops during one year. Cover crop is growing as a main crop to get a maximum mulch and nutrients for main crop. In blue are the mechanical operation to achieve the goal. Subsoil is used only when hardpan is present. In grey are minerals and organic fertilizers for soil and leaf.

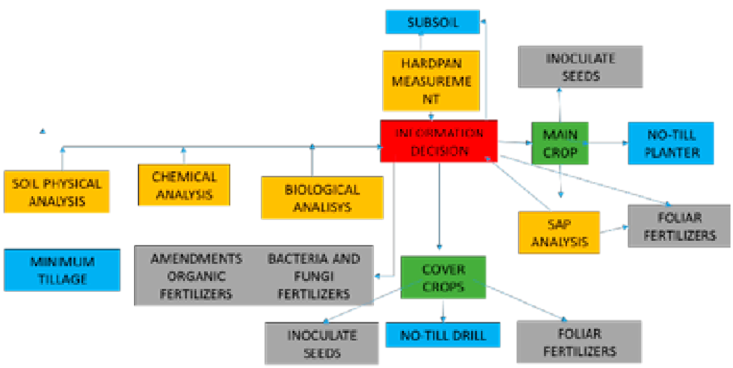

Figure 7. Regenerative Agriculture Technology

We developed a subsoil equipment (Figure 8) that is cutting the soil, breaking the hardpan and inoculate the soil with microorganisms and enzymes at one pass. Inoculation solution contain aerobic bacteria and fungi to decompose organic waste. Our expectation is that microorganism population increase, crate pores and tunnels and soil layers will not create hardpan again. Organic wastes decompose by microorganisms, and create long term nutrients for plants. Compared with a mould board plough, the new type of subsoil reduces the fuel consumption, break hardpan, aerates the soil and do not overturn the furrow. On the contrary, a mould board plough overturns the furrow, create hardpan, disrupt fungi hyphae. Soil chemical analysis was performed to determine humus, pH, organic carbon, N, P, K, as seen in Table 1.

Table 1. Centralizing table of soil characteristics, before the implementation of Regenerative Agriculture technology

No. crt.	Samples	Tests performed					
		pH	Corg.	Humus	N	PAL	KAL
			%	%	%	mg/L	mg/L
1	P1	6.43	1.84	3.17	0.118	45	302
2	P2	6.42	1.28	2.20	0.101	32	244
3	P3	5.02	1.26	2.17	0.108	63	244
4	P4	6.33	1.13	1.94	0.120	38	232
5	P5	6.06	1.28	2.20	0.117	31	228
6	P6	5.65	1.23	2.12	0.107	33	206
7	P7	6.03	1.30	2.24	0.126	35	226
8	P8	6.41	1.70	2.18	0.100	35	216
9	P9	5.95	1.15	1.98	0.104	59	262
10	P10	7.64	1.66	2.86	0.129	101	356

Based on soil analysis, decision was to apply 200 calcium carbonate, 100 soft rock phosphate and organic fertilizers to be applied in rows when planting. Amendments are applying every spring and summer in small quantities that are not affected microorganisms and not leaching.

Biological analysis done visual, no worms, or tunnels was notice. Soil was sprayed with microorganisms to restore soil food web. Expectation is to restore soil food web in 2-3 years, then production will increase significantly.

Figure 8. Activities associated with the integration of the vegetal mass in the soil, in order to increase the fertilization

A combination of cover crops has been selected to increase biodiversity, control weeds, pests, diseases, erosion and improve soil fertility. We selected rye, oats, vetch, mustard, phacelia and Daikon radish seeds to accomplish these tasks. Seeds were previously inoculated with nitrogen fixing bacteria and phosphorus solubilizing bacteria. Cover crops are growing as a normal crop and fertilize with foliar applications (Figure 9). Minerals from foliar application will not be remove because in spring when plants start to bloom cover crop will be cut and left on soil as a mulch. We expect to control weeds, soil temperature and moisture. In time cover crop is decomposed by microorganisms and provide nutrients to main crop.

Maize is the main crop that will be seeded in this spring. Maize seeds will be inoculated with arbuscular mycorrhizae that will create a symbiotic relation between maize and mycorrhizae fungi. During the photosynthetic process maize eliminate exudates through the roots. Carbohydrates, part of exudates, represents food for fungi and in return fungi provide nutrients to plants.

To maize seeding have been used a No-Till Planter. A No-Till Planter (Figure 10) was designed and manufacture in our institute few years ago. In a conventional technology the fuel consumption for plowing, disking and planting is 48.35 l/ha while the new planter consumption is 30.6 liters/ha. It was using a Romanian tractor 65Cp equipped with mould board plough PPM, disk harrow GDU 3.4 and planter SPC 6 compared with new No-Till Planter SDB6.

Maize seeds will be inoculated with arbuscular mycorrhizae, this will create a symbiotic relation between plant and fungi they will feed each other.

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Figure 9. In first plan soil is tillage with new subsoil breaking the hardpan and inoculate microorganisms, in second plan soil was plowed with a mould board plough

Figure 10. Establishment cover crops using no-till planting technology

A sap analyze will be done before and after foliar applications. Based on sap analyze and crop stage of growing a different mixture solution will be applied. A sap analyze is similar with a blood sap. The parameters values are measure in hours; decision is taken immediately.
Main crop will be fertilized foliar with vermicompost solution in which minerals will be added. In Institute we developed a vermicomposting system to produce vermicompost in a continuous flow. Vegetal waste like leaf, chopped branches and manure are transported, separated and feeding the continuous flow vermicompostor (Figure 11). The vermicompost obtained is used, as solid, in our green houses to fertilize the soil, 200 grams on a tomato seedling when planting. A small quantity, 2 kilo per hectares is used to manufacture vermicompost liquid solution for foliar applications. We develop a bioreactor (Figure 12) to manufacture a liquid vermicompost solution. A foliar vermicompost solution contain clean water, vermicompost, biostimulants for plants, biostimulants for microorgansms and minerals.
Bacteria and fungi are the basement for soil food web. When web food store is restored, foliar fertilization is less needed. First year expenditure is similar with Conventional Agriculture, but in second year they are at 75% and starting third year at 50% while soil fertility is improved and yields increases. Our expectation is to regenerate the tested soil in 2-3 years.

Figure 11. Vermicompost production using innovative equipment, developed by INMA Bucharest

In terms of cost reductions, the most important improvements take place in the crop establishment and maintenance works.
Regarding the costs of establishing crops, they can be reduced compared to conventional technology by eliminating the plowing and disking processes. Instead of these works, a scarify equipment will be used in the first year (and probably in the second year, only if the hardpan strengthens again), then the high level of loosening will no longer require mechanical activities.
The loosening occurs due to the inoculated microorganisms, the cover crops and due to the minimal processing technique.
In terms of maintenance works, no synthetic fertilizers, insecticides or herbicides are being used, which would also lead to a decrease in soil fertilization. Vermicompost amendments (which are much cheaper than chemical fertilizers) are used when needed. The technology uses only foliar fertilizers, and their costs will decrease over time (the reduction only for this component being 30-40%), and with the evolution of technology over time the required amount decreases. The costs of hoeing (neither mechanical nor chemical) are also reducing the total cost. Regenerative technology, however, has additional costs for establishing cover crops and their mechanical processing.
The total reduction has an increasingly importance over time, as can be seen in Figure 12.
Although regenerative agriculture could lead to small decreases in production in the first two years, the income is higher than that in conventional agriculture by up to 80% (after 3-6 years).
Figure 13 shows the increase in the total amount of humus in the soil during the

analyzed period, as well as the improvement in the amount of maize obtained per hectare.

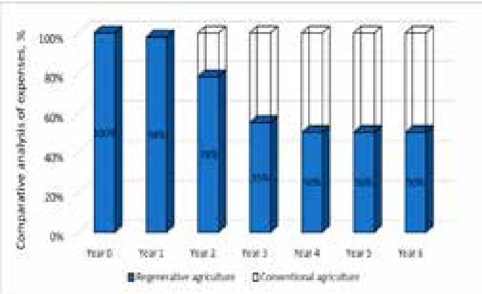

Figure 12. Comparative analysis of expenditures made in conventional versus regenerative agriculture

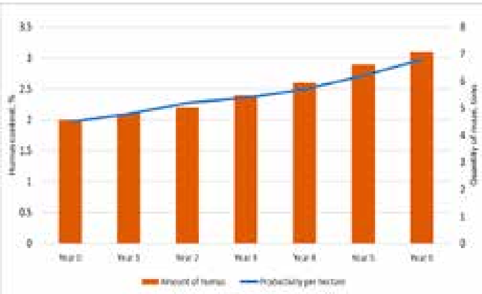

Figure 13. Increasing the total amount of humus and productivity per hectare in 6 years from the establishment of the technology

CONCLUSIONS

The regenerative technology used has shown to be effective in reducing the costs of setting up and managing maze crops. Even if in the first two years the expenses are similar or even higher than those associated with traditional agriculture, in longer periods of time the costs decrease significantly.

The effect must be analyzed integrated in the context of the rapid soil degradation in Romania and Europe and considering the effects of climate change on different crops.

One of the major improvements is that crop rotation is no longer required, so corn can be planted for 5-6 consecutive years without affecting production. This gives some management and prediction benefits to farmers and local authorities.

Depending on the quality of the soil (from year zero), regenerative technologies may have lower yields at first, but if farmers opt for conversion to organic products, then the financial benefit will be up to 4 times higher.

The equipment designed and executed by INMA has been shown to be effective, but for a more accurate analysis the experimental study must be extended to production farms, in order to identify the problems of farmers.

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REFERENCES

Álvaro-Fuentes J., López M.V., Cantero-Martínez C, J.L. Arrúe (2008). Tillage Effects on Soil Organic Carbon Fractions in Mediterranean Dryland Agroecosystems. *Soil Science Society of America Journal*, 72, 541-547.

Balesdent J. Chenu C. Balabane M. (2000). Relationship of soil organic matter dynamics to physical protection and tillage. *Soil and Tillage Research*, 53, 215-230.

Bennie A. T.P. Botha F.J.P. (1986). Effect of deep tillage and controlled traffic on root growth, water-use efficiency and yield of irrigated maize and wheat. *Soil and Tillage Research*, 7, 85-95.

Bougherra H., Bedini S. Flamini G., Cosci F., Belhamel K., Conti B, (2015). Pistacia lentiscus essential oil has repellent effect against three major insect pests of pasta. *Industrial Crops and Products*, 63, 249-255.

Dayakar V. Badri, Jorge M. Vivanco M. (2009). Regulation and function of root exudates. *Plant cell & Environment.*

Hirt H. (2020) How beneficial microbes in the soil, food and gut are interconnected and how agriculture can contribute to human health. *Science & Society*.

Lal R. (1993). Tillage effects on soil degradation, soil resilience, soil quality, and sustainability. *Soil and Tillage Research*. 27, 1-8.

Mircea C., Nenciu F., Vlăduț V., Voicu G., Gageanu I., Cujbescu D. (2020). Increasing the performance of cylindrical separators for cereal cleaning, by using an inner helical coil, *INMATEH - Agricultural Engineering*, vol. 62, No. 3, pp. 249-258.

Nenciu F., Paraschiv M., Kuncser R., Stan C., Cocarta D., Vladut V.N. (2022). High-Grade Chemicals and Biofuels Produced from Marginal Lands Using an Integrated Approach of Alcoholic Fermentation and Pyrolysis of Sweet Sorghum Biomass Residues. *Sustainability*. 14(1):402. https://doi.org/10.3390/su14010402

Nenciu F., Stanciulescu I., Vlad H., Gabur A., Turcu O.L., Apostol T., Vladut V.N., Cocarta D.M., Stan C. (2022). Decentralized Processing Performance of Fruit and Vegetable Waste Discarded from Retail, Using an Automated Thermophilic Composting Technology. *Sustainability*. 14(5):2835. https://doi.org/10.3390/su14052835

Nenciu F., Voicea I., Vladut V., (2021). Developing an operation strategy for a hybrid diesel-wind-photovoltaic system used to power an autonomous and remote fishing pond, Rural Development, DOI: http://doi.org/10.15544/RD.2021.020

Osman K.T. (2012). Soil Organic Matter. Soils, 89-96.

Petit R. E. (2004). Organic matter, humus, humate, humic acid, fulvic acid and humin: their importance in soil fertility and plant health. Harvestgrow.

Shah S. Prashar P. (2016). Impact of Fertilizers and Pesticides on Soil Microflora in Agriculture. Sustainable Agriculture Reviews, 331-361.

Van H.Es. (2017). A new definition of soil. Csa News, European court of auditors (2018). Combating desertification in the EU: a growing threat in need of more action. Special report 33. European Court of auditors, 2018.

Vladut V. Cujbescu D. (2020) THE effect of conservative agricultural works on soil and field plants and optimized mechanization technologies. *INMATEH - Agricultural Engineering*, 61, 35.

Yong R.N. Warkentin B.P. (2021). Soil properties and behaviour. *Developments in Geotechnical Engineering*, 5.