REGENERATIVE AGRICULTURE – SUSTAINABLE SOLUTION FOR RESTORING AGRICULTURAL ECOSYSTEMS AND SEQUESTERING CARBON IN THE SOIL

Popa Roxana - Gabriela, *Constantin Brâncuşi University from Tg Jiu, ROMANIA*

ABSTRACT: Regenerative agriculture proposes a profound paradigm shift in the management of agricultural ecosystems, which goes beyond conventional and ecological approaches and offers a wide range of adaptable practices with a positive impact on soil, biodiversity and long-term productivity, which are not treated as agricultural techniques, but as means of restoring the relationship between man and nature. The aim of the paper is to highlight the potential of regenerative agriculture as a viable solution for a sustainable agriculture in Romania. The work has the following specific objectives: the presentation of the theoretical foundations regarding regenerative agricultural principles; identification of practices and use in regenerative agricultural systems; comparing the results of this model with those of conventional agriculture and organic agriculture; the expansion of regenerative agriculture in the national context.

KEY WORDS: agriculture, regenerative, sustainability, fertility, carbon

1. INTRODUCTION

The general context of contemporary agriculture is based on the fact that modern agriculture is facing a deep crisis, manifested by the degradation of soils, the loss of biodiversity, the decrease of the natural fertility of the land, the excessive consumption of chemical inputs and the significant contribution to climate change. According to the Food and Agriculture Organization of the United Nations (FAO), more than 33% of the world's soils are moderately to severely degraded, affecting their ability to support long-term agricultural production. In Romania, the effects of the intensification of conventional agriculture are visible through the depletion of organic matter in the soil, extensive monocultures, massive losses of biodiversity, excessive use of chemical fertilizers and pesticides. Climate change brings extreme weather events (drought, floods, hail) and puts additional pressure on farmers and agricultural ecosystems. In this context, there is a need for a transition to a sustainable agricultural model, that regenerates soils, supports biodiversity and reduces dependence on external inputs. Thus, regenerative agriculture appears, a holistic approach, inspired by the functioning of natural ecosystems.

Regenerative agriculture (Figure 1) is a:

- agricultural system, which aims to produce food and restore and improve the quality of the soil, biodiversity and natural ecosystems, being a sustainable alternative to intensive, industrial agriculture
- set of agroecological principles and farming practices that can be adapted locally and aims to maintain and actively restore natural resources (especially soil) and agricultural ecosystems (biological diversity, crop rotation, permanent ground cover, minimal or no tillage, composting, livestock integration and holistic pasture management) and is not a

certified standard (such as organic or organic farming)

- holistic system of agriculture and land management that uses ecological principles to improve soil health, increase biodiversity, improve water cycles, and increase agricultural resilience (as defined by the Regenerative Agriculture Initiative, California State University)
- agricultural model that emphasizes natural biological processes and closed cycles of nutrients, being supported globally by the initiatives: European Green Deal, Farm to Fork Strategy, recent reforms of the Common Agricultural Policy (CAP), which emphasize climate neutrality, biodiversity and soil health.

Figure 1. Regenerative agriculture

The central element in regenerative agriculture is the soil, which is not a simple support for plants, but a living ecosystem, full of microorganisms (bacteria, fungi, nematodes, protozoa), with essential roles in the nutrient cycle. By restoring soil life, nutrients become more available to plants, soil structure improves, water retention capacity increases and the need for external fertilization is reduced.

Carbon is an indicator of soil fertility, as a healthy soil contains a significant percentage of organic carbon, which comes from roots, plant debris and microbiological processes. Regenerative agriculture helps capture atmospheric carbon through photosynthesis, deposit carbon in the soil as stable organic matter, and increase fertility without chemical inputs. According to estimates, regenerative practices can sequester 1–3 t CO_2/ha/year, thus contributing to combating climate change.

The benefits of regenerative agriculture for the environment and society are as follows:

- increases soil fertility and long-term life
- reduces greenhouse gas emissions
- improves water and air quality
- contributes to food security
- supports rural communities through sustainable practices

Examples of regenerative agriculture in Romania:

- *Sol si Suflet* Farm, from Vlădeni, Dâmbovița - the first self-sustainable regenerative farm (model) in Romania, funded by Kaufland, covers 6 ha and includes a mixed system of biointensively grown vegetables (10.000m²) + trees, arable crops (10.000m²) + holistically managed pasture (5.000m²) + a protected space (2.500m²); the practices used to promote soil fertility and carbon sequestration are: holistic management, permaculture, agroforestry systems, biointensive crops, cover crops, no till/minimum till, mulching, crop rotation, biofertilizers, compost, integration of animals, stimulation of soil microbiology; collect rainwater and use your own compost (Figure 2.)

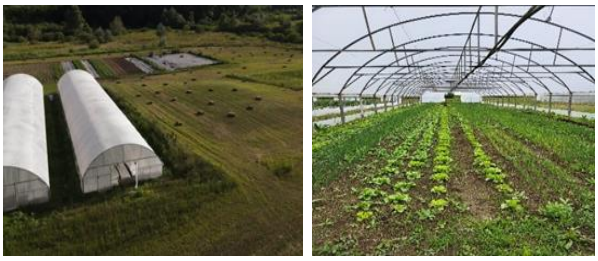

Figure 2. *Sol si Suflet* Farm, from Vlădeni, Dâmbovița - the first self-sustainable regenerative farm (model) in Romania

- the program *O șansă pentru familia ta,* from the town of Zimnicea, Teleorman is a socio-economic initiative run by Danone Romania, the ONG Open Fields and Ecosysteme Fund, involving over 220 small farmers (family-scale agriculture), who apply regenerative practices on 1.000 ha (crop rotation, deep scarification 60-70cm, minimum tillage and the creation of mobile oases

for animal welfare); the project includes the planting of 31.000 saplings (poplar, walnut, acacia) to increase biodiversity and reduce erosion; Danone invested 7 million euros in this program, supporting rural entrepreneurship, quality milk production and the 30 % reduction of the carbon footprint; is a pilot farm integrating holistic grazing and crop rotation to reduce carbon footprint (Figure 3).

Figure 3. The program *O șansă pentru familia ta,* from the town of Zimnicea, Teleorman- a socio-economic initiative run by Danone Romania

- Black Angus Farm from Mureș is a modern cattle breeding farm, which adopts regenerative agriculture through plant diversification (pastures with over 100 plant species/m²), the estimated carbon sequestration rate being 2,5–4,5 t C/ha/year, thanks to the activity of mycorrhizae and glomalin produced by fungi (key elements for soil health and structure) (Figure 4)

Figure 4. Black Angus Farm from Mureș - a modern cattle breeding farm

- the GreenFields Academy program, launched by Bayer Romania in collaboration with Amazag, aims at education, offers courses, training, workshops and visits to regenerative and conservation farms; more than 80 farmers participate and practices such as minimum tillage, plant mulches, agroforestry and carbon sequestration are promoted (Figure 5.)

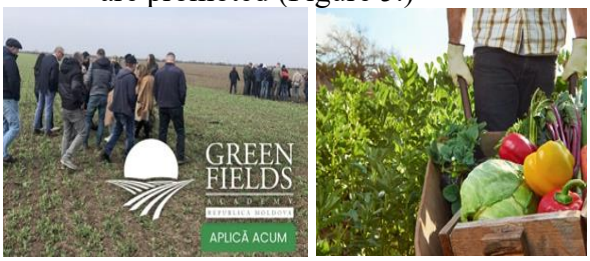

Figure 5. The GreenFields Academy program

2. MATERIAL AND METHOD

The methodological approach includes:

- documentary analysis (review of specialized literature, scientific articles, official reports FAO, IPCC, European Commission, specialized websites and national sources)
- case study (documenting the activity of farms based on the model of regenerative agriculture, based on official sources, public reports and available interviews)
- comparative analysis (the contrast between the performances of regenerative agriculture and those of conventional agriculture, in terms of soil, yield, ecological and economic impact)
- SWOT analysis (assessing the strengths, weaknesses, opportunities and threats of such an agricultural model in Romania)

The fundamental practices or principles on which regenerative agriculture is built are adapted according to the local context and the specifics of the farm:

1. Cover crops - the permanent covering of the soil, with plants that cover the soil between the main crops (they prevent water evaporation and soil erosion, fix nitrogen in the soil, attract beneficial insects, improve biodiversity, provide organic matter for the soil through decomposition, prevent the development of weeds); examples: legumes (peas, clover, fodder beans), perennial grasses (rye, oats), cruciferous plants (mustard, canola).

2. Minimizing or eliminating tillage (no-till, minimum-till) – reducing or eliminating

traditional tillage (preserves the natural structure of the soil and microbial life, maintains the layer of organic matter on the surface, reduces compaction, water evaporation and erosion, protects microorganisms and mycorrhizal networks, reduces fuel consumption and machinery wear); special no-till seeders are used or plant residues are incorporated on the surface with light tools (light disc harrow, shallow cultivator).

3. Integrating animals into the agricultural ecosystem and rotational grazing - animals (cows, sheep, goats, birds) have a role in the nutrient cycle, which fertilizes the soil through natural manure, mobilizes nutrients through controlled grazing, stimulates the regeneration of pastures and ensures diversity in income (milk, meat, eggs).

4. Composting, biofertilization, mulching - soil quality is restored by increasing the content of organic matter and humus and by microbiologically activating the soil and reducing chemical inputs; compost is a high-quality natural fertilizer, formed from organic materials (plant residues, dung, household waste) and fermented under controlled conditions; mulching is the application of a layer of plant material to the soil surface (straw, leaves, sawdust, crop residues), which nourishes the soil, maintains moisture, reduces weed development, regulates soil temperature and improves its structure over time.

5. Rotary and regenerative grazing - holistic grazing or holistic land management or planning agricultural activities according to the natural interdependencies between soil, water, plants, animals and people; is a method of managing livestock on pasture by rapidly, regularly and planned moving herds to stimulate plant growth, improve soil and sequester carbon.

6. Biological diversity - crop rotation, polyculture and animal integration; favors the stability of the agricultural ecosystem and the natural control of pests

7. Agroforestry and permaculture – is based on the integration of trees in agricultural land or pastures, creating a complex system that combines agriculture with forestry (mixed orchards; crops between rows of trees (walnuts + vegetables); protective forest strips); protects the soil from wind and erosion, regulates the microclimate, provides habitat for beneficial insects and birds, generates additional products (fruits, wood, mushrooms).

8. Crop rotation - alternating crops on the same plot from one season to another and avoiding monoculture; prevents the accumulation of pests and diseases, optimizes the use of nutrients, improves soil fertility, favors soil structure; examples: peas (fixes nitrogen), corn (uses a lot of nitrogen), rye (cover crop), cabbage (late harvest crop)

9.Water management - water is a critical resource in agriculture, and regenerative agriculture promotes the capture and storage of rainwater (ponds, gutters), reduction of runoff through soil and terraced land, efficient irrigation (drip, localized watering), use of recycled gray water, naturally treated; a farm may include an irrigation pond and a biological rainwater filtration system.

In order to highlight the ecological, economic and social benefits of regenerative agriculture, as well as the advantages, limitations and challenges of regenerative agriculture, a comparative analysis of the main agricultural systems (conventional, ecological and regenerative) was carried out based on several criteria.

3. RESULTS AND DISCUSSION

Following the comparative analysis of the differences between conventional, ecological and regenerative agriculture, the fundamental differences, the impact on the environment, productivity and long-term sustainability, for the three agricultural systems are presented (Table 1).

Table 1. Differences between conventional, organic and regenerative agriculture

The analyzed criterion	Conventional agriculture	Ecological agriculture	Regenerative agriculture
fertility and soil impact	based on chemical inputs depletion and erosion	natural, but passive maintenance conservation, but not regeneration	active recovery of organic matter increase in ferility
soil works	intense (plug, disk)	sometimes moderate	minimal or non existent (no-till)
biodiversity	reduced dominant monocultures	moderate favors biodiversity	high polycultures, rotations complex and diverse systems
carbon sequestration	low high emissions	neutral or limited	high CO2 capture by organic matter
external inputs	large fertilizers, pesticides, disel	reduced but expensive fertilizers, natural pesticides	minimal internal farm cycles natural fertilizers and internal processes
the role of animals	rarely integrated	possible, but limited	central (grazing, fertilization)
the main objective	maximizing production high productivity in the short term	minimal ecological impact	restoring the agricultural ecosystem
production costs	large (chemical inputs, energy) dependent on chemical inputs and price fluctuations, which makes it vulnerable	medium to large	lower in the long run
resilience to climate change	low	average	high (healthy soil, biodiversity)

The advantages of regenerative agriculture compared to other agricultural systems are:

- ecological (soil sustainability, by continuously and actively improving its properties and restoring fertility, reducing erosion and water loss, reducing the carbon footprint and capturing it, by stimulating photosynthesis and accumulating organic matter in the soil, which contributes to reducing emissions and combating climate change, increasing biodiversity)
- economic (sustainability, durability, stability, by reducing dependence on expensive inputs, increased resilience in the face of drought and extreme phenomena, the possibility of selling regenerative products at premium prices)
- social (supports the revitalization and development of rural communities by creating jobs, promoting ecological education, supporting small farmers for the production of healthy food, consumer awareness, revitalization of rural communities)

The limitations and challenges of regenerative agriculture compared to other agricultural systems are:

- implementation and education (requires a high level of knowledge and careful management, which can be an obstacle for traditional farmers; need for training programs and institutional support)
- time to results (beneficial changes in soil and ecosystems can take several years, and farmers need to be patient and consistent, which can discourage rapid adoption of these practices)
- policies and financing (the lack of clear policies and financial support mechanisms in Romania limits the expansion of regenerative agriculture, even if the benefits are obvious)

CONCLUSIONS

1. Regenerative agriculture represents a solution to the challenges of modern agriculture, offering a sustainable model from an ecological, economic and social point of view.
2. Regenerative agriculture is not a rigid set of techniques, but a flexible system that applies ecological principles according to the local context.
3. The case studies and analyzed practices demonstrate that this approach can also be applied in Romania, contributing to the restoration of degraded soils, water conservation, combating climate change through carbon sequestration, promoting biodiversity, integrating animals, increasing the quality of agricultural products and sustainable development of the rural environment.
4. Large-scale adoption of regenerative agriculture requires an effort between farmers, researchers, authorities and consumers, through support policies, education and the promotion of sustainable products.
5. Due to its characteristics, regenerative agriculture is a promising solution for a

sustainable future in Romania and globally.

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