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ECONOMIC VIEW ON REGENERATIVE AGRICULTURE IN CONDITION OF THE SLOVAK REPUBLIC

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Regenerative agriculture is an approach that aims to improve soil health and fertility, as well as protect water resources and biodiversity. Healthier soils are able to sequester more carbon from the atmosphere, are more resilient to the impacts of climate change, have better water retention capacity and can increase agricultural productivity, which helps to increase profits and also improve food security. The aim is to protect and enhance biodiversity above and below ground. Plant growth can be supported by more diversified crops, including cover crops or intercrops, while supporting better life for insects, soil organisms, birds and other animals. The aim of the paper is to characterize regenerative agriculture, to define the differences between conventional and regenerative agriculture and to point out situation of this system of agriculture in Slovakia. Evaluation and resolution of differences will be from economic point of view. Many researchers prevail that lower yields are achieved with regenerative agriculture. In the first years of the transition from conventional to regenerative agriculture, lower yields are achieved as the soil gradually transforms (especially its humus part). After five years, however, it can be observed that even in regenerative agriculture, comparable yields are achieved. Regenerative agriculture, on the other hand, achieves much lower costs, as some machine operations are not performed (e.g. plowing). The article shows that in regenerative agricultural production can farmers achieved positive economic results in Slovakia.

Keywords: *regenerative agriculture, conventional agriculture, economy*

INTRODUCTION

Current global agriculture produces enough food for more than 10 billion people. On the other hand, it must be noted that up to 30% of food is thrown away. It is therefore necessary to have a professional discussion and also science about production, food waste, degradation of natural resources, pollution of the environment and production of surpluses. The goal of regenerative agriculture is to address the concept of "more with less agricultural inputs and produce more with fewer inputs: smaller land area, less chemical input, less water consumption, less greenhouse gas emissions.", less risk of land degradation and less use of energy inputs. The main idea is: soil protection, minimizing natural resources, eliminating food waste, stopping environmental pollution (Rattan, 2020).

High-yield farming raises other concerns because expressed per unit area it can generate high levels of externalities such as greenhouse gas emissions and nutrient losses (Balmford, Amano, Bartlett et al. 2018).

As a result of erosion, chemical soil pollution, desertification or increasing extremes of weather, farmers are at risk of losing the yields of cultivated crops, which they can prevent by more gentle farming methods. One of them is the so-called regenerative agriculture (Langmaier, 2022).

The applied principles are also derived from it. These include the continuous maintenance of a green cover of vegetation, the consistent application of no-till technologies and possibly also the so-called intercropping, which is based on the cultivation of 2 crops at the same time. He described the use of nitrogen fertilizers and pesticides as controversial, which he considers necessary especially with fungicides, which have a direct negative effect on mycorrhizal fungi. Gabe Brown is a man who has been involved in regenerative agriculture for decades. He defined regenerative agriculture as

It is the renewal of the systems of production and agriculture. Its goal is to regenerate the soil, increase biodiversity, improve the circulation of minerals, carbon and water. According to him, the basic pillars of regenerative agriculture are:

- minimal interventions in the soil, no-tillage or minimal tillage
- diverse main crops, improved crop rotation
- involvement of catch crops and cover crops
- managed animal grazing
- building soil organic matter

• support of biodiversity (Caja, 2021).

Regenerative agriculture as an agricultural system is defined as a mix of several separate systems. By McGuire (2018) it is a mix of: conservation agriculture + holistic grazing + enhanced biodiversity + (organic farming) = regenerative agriculture.

Regenerative agriculture offers a holistic approach and a return to natural mechanisms supported by current scientific knowledge about the soil with the use of modern technologies with aim of agricultural profitability (Khangura, et al., 2023).

Regenerative agriculture brings a whole range of benefits for the soil, the landscape, the agricultural sector and society as a whole (Rhodes, 2017).

Regenerative agriculture is based on a modern combination of known procedures, but the term itself began to be used only in the 1980s by the American non-profit organization Rodale Institute. Its founder, Robert Rodale, is the author of a number of publications on regenerative practice, and the experiments conducted under the auspices of the institute continue to enrich the public to this day. Regenerative agriculture primarily focuses on improving the quality or restoring the properties of degraded soils (Rodale, 2023).

Soil organisms create many substances that are also beneficial for human health. These substances move from microbes, through fungi and mycorrhiza to plants. Their content in field crops from regenerative agriculture is higher than in crops from conventional agriculture (Bongiorno, Postma, Bünemann, Brussaard, de Goede, Mäder, Thuerig, 2019).

Regenerative agriculture is an approach that aims to improve soil health and fertility, as well as protect water resources and biodiversity. Healthier soils are able to sequester more carbon from the atmosphere, are more resilient to the impacts of climate change, have better water retention capacity and can increase agricultural productivity, which helps to increase profits and also improve food security. The aim is to protect and enhance biodiversity above and below ground. Plant growth can be supported by more diversified crops, including cover crops or intercrops, while supporting better life for insects, soil organisms, birds and other animals (White, 2020).

Many authors from different countries have agreed that regenerative agriculture is good for soil health and has other environmental benefits as well. No-till technology minimizes the occurrence of soil erosion and also promotes the absorption of water into the soil. Catch crops and cover crops are also very beneficial, they also support the soil from drying out and increase soil quality. Crop rotation can lead to a reduction in pesticides. Likewise, this system of agriculture is also beneficial for livestock grazing associated with frequent movement of livestock, which can increase vegetation production and also protect water resources (Ranganathan, Waite, Searchinger and Zionts, 2020).

In the USA, in the project, farmers devised an agricultural system that consists of several procedures, the output of which is the achievement of profit based on ecosystem services. Regenerative agricultural entities are against the current system of food production, which is based on profit maximization at the expense of farmers. The basic elements of a given farming system include:

Promoting soil conservation through soil biology, soil humus and biodiversity. A system based on reduced costs of insecticides and fertilizers.

The main priority was increasing the share of the organic component of the soil as production volumes. Regenerative farms sold their products according to a different pricing policy and different distribution channels (LaCanne and Lundgren, 2018).

The literature is extensive and still growing.

The aim of the paper is to characterize regenerative agriculture, to define the differences between conventional and regenerative agriculture and to point out situation of this system of agriculture in Slovakia.

RESEARCH METHODS

For the elaboration of the article, mainly foreign sources as well as domestic ones were used. Among these sources were mainly:

- professional literature and articles,
- Internet sources,
- laws and regulations, and
- statistical data.

The article was prepared based on the necessary methods:

- The method of analysis is one of the basic methods. It represents the analysis of data that are part of the current state of regenerative agriculture in Slovakia and in the world. This method was used in the first part of the article where we analyzed regenerative agriculture.
- The method of synthesis is actually about summarizing the information, so called linking into units.
- Comparison method The essence of this method lies in comparison. It was used to compare individual data over a given period of time.
- The inference method was used to summarise the results of individual forecasts and analyses. We have generalised individual information on regenerative agricultural production in Slovakia and worldwide.
- The meta-analysis method was used to systematically synthesise or merge the findings of single, independent studies about regenerative agriculture (Míka 2006).

The present article focuses on regenerative agriculture in the Slovak Republic. The article is divided into three parts. The first part focuses on the theoretical knowledge gained about regenerative agriculture. The article pointed out the basic differences between conventional and regenerative land management. The data were obtained mainly from book publications and internet articles.

In the second part, statistical data on regenerative agriculture in Slovakia are compiled. We have compared the development over time, also of individual sectors. We have taken into account the number of subjects, agricultural production as well as land use in Slovakia. The data in this section were used from the official databases of the Statistical Office, Eurostat and FiBL.

RESEARCH RESULTS AND DISCUSSION

Regenerative agriculture seeks to use a comprehensive, holistic approach that to some extent integrates the goals of all the above practices. However, the main goal of regenerative agriculture, which can be placed at the head of all other sub-goals, is one, namely: the regeneration of natural soil fertility by increasing the content of organic matter (carbon) and restoring life in the soil (micro- and macro-organisms).

In terms of its approaches, regenerative agriculture is probably the closest to a sustainable way of farming, however, the fundamental difference between sustainable and regenerative agriculture is that sustainable agriculture tries to ensure that the current state does not deteriorate further and thus preserves the productivity (and other, non-productive functions) of agriculture and for future generations. On the other hand, regenerative agriculture realizes that intensive agricultural management has led and leads to the degradation of agricultural land (erosion, decrease in organic carbon content in the soil, compaction, reduction of water retention, etc.) and comes up with active procedures for improving the condition (regeneration) of soils. The fundamental difference compared to all previous methods of agricultural management is that regenerative agriculture does not try to overcome or compete with natural processes, but rather uses these processes to the greatest extent possible in order to create an environment in the soil that will be able to adequately and supply plants and other organisms with water, nutrients and energy in a balanced way. (Klem, 23)

In principle, therefore, regenerative agriculture must be built on two basic pillars.

a) Permanent vegetation cover without a period of black fallow (bare processed soil), ensuring the continuous production of root exudates and their gradual binding to mineral particles of the soil (clay and dust).

b) Minimal disturbance of the soil by cultivation, which leads to the destruction of soil aggregates and, overall, to the acceleration of the decomposition of organic carbon in the soil.

Due to the proven importance of mycorrhizal fungi for stabilizing soil aggregates, and thus for the physical protection of organic carbon from decomposition, as well as the importance of the entire complex of microorganisms (soil microbiome) together with meso- and macrofauna in the transformation of dead plant biomass into substances stably bound in the soil, it is possible add a third pillar to these two pillars, and these are measures leading to the support of soil edaphone, which include, in addition to the already mentioned permanent vegetation cover and limitation of tillage, the diversity of cultivated plants and the reduction of the use of synthetic pesticides and fertilizers.

It is clear that the role of soil edaphone and the mechanisms by which it participates in the stabilization and long-term storage of carbon in the soil have yet to be clarified, for example using isotopic labeling of carbon and nitrogen, however, the results so far clearly demonstrate its key role in these processes, while essential attention would should probably have been dedicated to mycorrhizal fungi and their support (Stepanek, 2023).

The system of regenerative agriculture should therefore include the following elements, which must always be applied in a complex and whose efficiency when used separately is often very low (positive effects in the form of long-term storage of organic carbon in the soil and restoration of life in the soil only occur through their synergistic action) .

Ensuring permanent vegetation cover by growing species-rich intercrops. Intercrops must be sown immediately after harvesting the previous crop in a no-till way (in the mulch of post-harvest residues). In the case of a delayed harvest of the main crop, for example in higher locations or for crops with a late harvest, the sowing of an intermediate crop a few weeks before harvest using pneumatic spreaders or by air can be very effective. Green bridging can also be provided by auxiliary crops sown together with the main crop, particularly small and annual clovers that create a continuous vegetation cover already at the time of harvest (a system also referred to as relay intercropping).

No-till sowing of the main crop and intercrop into the mulch of post-harvest residues (crop) or green plants (intercrop). Only in the case of maize and low soil temperature or with higher rainfall, strip tillage can be used as an alternative, which then ensures faster heating or aeration of the soil.

Ensure the diversity of plants on the plot not only in time (seeding sequence) but also in space. This is a very important condition for the development of arbuscular mycorrhiza, which is supported by the joint cultivation of several species and especially by the presence of plants from the leguminous family (legumes). This can be achieved either by growing species-rich intercrop mixtures, by growing two crops together (so-called intercropping), such as winter wheat with winter peas, spring cereals with broad beans, etc., or by growing auxiliary plants together with the main crop (e.g. white clover, clover, Alexandrian clover).

Limitation of soil compaction and soil structure damage by agricultural mechanization crossings at high soil moisture and ideally by using the technology of controlled crossings only in defined tracks (CTF - Controlled Traffic Farming). This is especially true for the transitional period of 3-6 years before the stabilization of the soil aggregates and thus the improved resistance of the soil to mechanical stress (Caja, 2021).

Minimising the use of pesticides and artificial fertilisers. Since the transition from conventional to regenerative farming may initially present some problems with slowed nitrogen mineralization or the spread of certain types of weeds, diseases and pests, an immediate reduction is not usually possible, but a process that takes between 3 and 6 years , when the positive effects of a greater representation of leguminous plants (increasing the nitrogen content in the soil accessible to plants) and the intercrops cultivation or intercropping on the occurrence of weeds, diseases and pests will begin to manifest. However, it is a very important part of regenerative agriculture, without which there can be no complete regeneration of life in the soil and full use of its effects.

Supporting the soil microbiome and ensuring improved availability of nutrients in the transition period by using high-quality composts (before the start of the transition period) and compost extracts (used, for example, for seed inoculation). Biochar (ideally activated by composting) can also be used at the beginning of the transition period to improve the physical properties of the soil and to store carbon in the soil for a long time, but at the moment, considering the price of biochar, this measure is economically unprofitable.

It is clear that the transition to a regenerative way of farming is not easy, and it is important to avoid a number of possible mistakes. Therefore, in the next part, we will focus on the main principles and solutions to possible problems when switching to a regenerative way of farming.

Economical view on Regenerative Agriculture

The EU does not yet work with the concept of regenerative agriculture in programs or in the Green Deal. The priority is carbon sequestration and reduction of greenhouse gas emissions. The Common Agricultural Policy focuses on carbon farming; a tool to allow farmers to join the ETS carbon allowance system.

Carbon farming as a tool to introduce ETS carbon credits for carbon sequestration agricultural practices In 2021, the European Parliament approved a regulation on climate change in the European Union. The EU Climate Regulation converts the political promise of the European Green Deal to achieve climate neutrality in the Union by 2050 into a commitment. At the same time, the new legislation gradually provides European citizens and businesses with the legal certainty and predictability they need to properly prepare for the transition to climate neutrality. Beyond 2050, the EU should strive to achieve negative emissions.

The EU's original target of a 40% reduction in greenhouse gas emissions by 2030 compared to 1990 is increased to at least 55% under the new 2021 EU climate rule. The Commission-approved draft Land Use and Forestry Regulation (LULUCF) - aimed at regulating emissions and capturing them from land use, land-use change and forestry - promotes carbon capture in the EU and a de facto increase in the 2030 emissions reduction target to 57% (Radley, Keenleyside, Frelih-Larsen et al., 2021).

The size of agricultural land in Slovakia is 2,379,101 ha. About 60% of it is arable land. Almost 20% of arable land in our country is in the category of extreme erosion, i.e. with a loss of more than 30 tons of soil per hectare per year. Only 56.01% of the area has no or weak erosion, which, however, in practice means the removal of a maximum of 4 tons of soil per hectare per year. The creation of agroforestry systems, the support of the mosaic-like use of the landscape and the introduction of regenerative and ecological agriculture are essential for these threatened or already degraded plots of land with arable land.

More and more farmers in Slovakia are using the principles of regenerative agriculture. According to our estimate, approximately 6 000 ha of land is currently used in regenerative agriculture, which represents 0.32% of the total area used (1 856 128 ha of the total agricultural area used in 2021) (Green Report, 2021).

In terms of farm structure, there are 4 large farms and several smaller farms in Slovakia.

Since 2022, a programme aimed at developing regenerative agriculture is being implemented in Slovakia under the umbrella of the European Institute of Innovation and Technology (EIT). The EU-supported EIT FOOD represents the largest and most dynamic food innovation community in the world. It aims to create links directly within the food system that stimulate new ideas and innovation. EIT Food has launched the 'Regenerative Farming Revolution' programme, which aims to educate farmers in Europe on how they can farm more sustainably. For example, they will learn more about how to improve soil health, promote biodiversity, produce more nutritious products and make their farms more profitable. EIT Food offers innovative farmers a comprehensive training programme to help them learn about and then apply the principles of regenerative agriculture on their farms.

Agricultural intensification has led to a significant decline in the health of Slovakia's landscape since EU accession, particularly through the transition to the area-based subsidy system (SAPS). Farmers have ploughed up much of the remaining landscape features in pursuit of the largest possible subsidies. A landscape without vegetation overheats and dries out easily in summer, is exposed to strong winds and soil blowing away by wind and heavy rains, which carry millions of tonnes of topsoil into watercourses every year. The decline in health is also evident in the decline in the numbers and diversity of wildlife and plants. As a result of the destruction of landscape features and widespread chemicalization, a significant number of insects, birds and other species of animals and plants have disappeared from the landscape. This trend is evident throughout Europe.

Regenerative agriculture fits well with our strategy of investing in environmentally sustainable projects. At the same time, we see considerable economic potential in it. Indeed, expensive fuel and the rising price of artificial fertilisers will force many farmers to look for economically sensible alternatives. It also depends on how the Czech legislation and authorities approach this way of farming. Regenerative farmers are often hampered by outdated legislation that restricts new agrotechnical practices.

Soil-friendly regenerative farming initially reduces farmers' yields slightly. However, lower yields are partly offset by lower costs of running machinery and less investment in fertilisers and other agricultural chemicals. In addition, farmers can participate in the 'carbon economy'. "In our operation, we expect slightly lower yields. In addition to the lower costs of running machinery and fertiliser, the Carboneg carbon reduction project, which enables companies to become carbon neutral, will compensate us for this (Caja, 2021).

Thus, the main advantages of regenerative agriculture with the elimination or minimization of tillage include lower costs and less labour, including time savings and the complete elimination of water erosion, improved soil quality, less capital intensity and even higher profitability (Travnicek, Samsonova, 2023).

Regenerative agriculture is not only about arable land, but also about pastures and permanent grassland.

If farmers used more nitrogen-fixing plants, symbiosis with mycorrhizal fungi and left part of the plant matter in the field for decomposition, they could largely cover the annual fertiliser consumption per hectare in the Slovak Republic. A switch to no-till techniques would contribute significantly to this, as regular ploughing destroys soil organisms that are able to fix atmospheric nitrogen and provide other nutrients. Specifically, symbiotic fungi provide around 10 kg N per hectare, decomposing plant matter 10-15 kg N and 1% of nitrogen-fixing plants in the crop (e.g. vetch, alfalfa) provide 3 kg N per year. Let us consider an example where, with 10% of nitrogen-fixing plants in the crop, no-till farming, and leaving the mass on the field (mulching), a natural fertilisation of 55 kg N per hectare can be achieved, while the total consumption of nitrogen mineral fertilisers in Slovakia is about 100 kg per ha.

If manure were fertilised or the proportion of some of the soil's natural components increased, agriculture could function completely without artificial fertilisers. Nature-friendly measures such as intercropping, combined with no-till techniques, would help to significantly reduce fertiliser and fuel costs in agriculture and increase profits. A system of financial compensation for carbon stored in the soil can also help farmers with economic profitability if they apply carbon farming techniques. Factoring in higher area subsidies for organic farmers, carbon storage surcharges and significantly lower operating costs, regenerative agriculture is already more profitable than conventional agriculture under current conditions, so the only barriers to its rapid development are fossil fuel subsidies and a certain social inertia. In any case, the future belongs to ecological approaches such as regenerative agriculture, while conventional agriculture is already a bygone chapter in human history. Table 1 shows the economic situation of a comparison of regenerative and conventional agriculture in a selected farm in southern Slovakia. Many opinions prevail that very low yields are achieved with regenerative agriculture. Yes, as mentioned above, in the first years of the transition from conventional to regenerative agriculture, lower yields are achieved as the soil gradually transforms (especially its humus part). After five years, however, it can be observed that even in regenerative agriculture, comparable yields are achieved (table 1)

Regenerative agriculture, on the other hand, achieves much lower costs, as some machine operations are not performed (e.g. plowing)

It can be seen from the calculations that regenerative agriculture in the conditions of the Slovak Republic achieves positive economic results.

Table 1. Economical results of wheat production in different agricultural systems in Slovakia (year 2022)

Wheat production	Conventional Agriculture	Regenerative Agriculture
Costs per 1 ha in Euro	1 136,70	898,20
Yields per 1 ha in tonnes	7,55	6,61
Price per 1 tonne in Euro	214,14	214,14
Revenues per 1 hectare in Euro	1 616,76	1 415,47
Profit per 1 hectare in Euro	480,06	517,27
Profit per 1 tonne in Euro	63,58	78,25

Source: selected farm (without name) and own calculation, 2023

The economic analysis shows that when comparing the individual indicators of conventional and regenerative agriculture, the following results were recorded:

- Costs per 1 ha of agricultural land are lower in regenerative agriculture, as some operations are not carried out compared to conventional agriculture (e.g. plowing).
- Yields per hectare are lower in regenerative agriculture.
- There were no differences in prices, and therefore yields from 1 ha were lower in regenerative agriculture.
- The overall result of management - profit was lower in conventional agriculture.

CONCLUSIONS

Targeted support for regenerative agriculture currently does not exist in the Slovak Republic (status in 2023). The implementation of individual techniques of regenerative agriculture depends rather on the awareness of the farmer. In Slovakian practice, various no-till techniques, techniques of minimizing plowing and agroforestry are most often used (silvo-tillage systems – joint cultivation of trees and production of field crops on the same area or silvopastoral systems – targeted cultivation of trees on pastures). Conscious farmers are implementing the principles of holistic rangeland management. Instead of permanent grazing on the entire area, they divide the pastures into smaller units, between which

they move the cattle, so that the individual sections of the hunt "rest" for up to several months. This has a positive impact on the health of the soil and livestock and reduces the consumption of veterinary preparations.
For the exchange of experience, the concept of model farms, where practical seminars on gentle farming methods are held; so-called field days. In practice, the knowledge of good practice and methods enabling soil regeneration is quite decent, but few people do it because it is more expensive and there is a lack of motivation (badly set subsidy system). Respondents repeatedly draw attention to the risk of using glyphosate when applying intercrops.
Plowing still predominates in arable farming. However, the number of farmers who have access to no-till techniques (own machines or order no-till sowing as a service) is gradually increasing, which they use when growing all or only selected crops.
Grain, corn and sunflowers are most often grown without tillage. The main reason for no-till sowing is the effort to save costs (minimization of inputs), the need to cope with excessively wet years when it is not possible to go to the field with agricultural machinery and there is a risk that it will not be possible to complete the standard pre-sowing soil preparation. On areas at risk of erosion, the reason is also the elimination of erosion events, especially by means of strip tillage.
In connection with the tightening of the conditions for drawing agricultural subsidies, more and more farmers have experience with catch crops. They are discouraged from their wider spread in practice by the higher costs for seed and fuel, which are currently not directly compensated, and the impossibility of preparing the soil in time for the subsequent early-sown spring crops (this problem is eliminated in the case of heat-loving, later-sown spring crops). Here it makes sense to offer education in the form of field days at demonstration farms. Economic production values were measured in the conditions of Slovakia, where wheat production in regenerative and convenctional agriculture was compared in 2022. The economic results show that in the conditions of Slovakia, it is possible to achieve positive economic results also in regenerative agriculture – profit 78,25 Euro.ha^{-1} (not only in conventional – profit 63,58 Euro.ha^{-1}).

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