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REVIEW ARTICLE

Increasing soils fertility as a factor in the sustainability of agriculture and resilience to climate change

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Abstract

This article emphasizes the vital role of soil health in promoting sustainable agricultural production and ecosystem functionality. By focusing on agricultural practices that enhance key physical and chemical soil properties, it aims to mitigate environmental impact, particularly on climate change, while advancing the Sustainable Development Goals. The discussion underscores the significance of nurturing healthy soil to ensure food security and ecological balance, highlighting the interconnectedness of soil health with agricultural sustainability. Through strategic soil management practices, this research advocates for a holistic approach to agriculture that fosters resilience, productivity, and environmental stewardship. Ultimately, the findings presented in this article offer valuable insights into fostering healthy soils as a cornerstone for sustainable agriculture and ecosystem health.

Keywords: Soil tillage, Crop rotation, Organic farming, Biofertilizers, Sustainable Development Goals

Introduction

In order to understand the impact of soil health on climate change and agricultural sustainability, it is necessary to understand the term itself. So, this terminology is used by many scientists, and each interprets it in a slightly different way. For instance, a team of authors from the United States and Germany define this concept as follows: «Soil health is the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans, and connects agricultural and soil science to policy, stakeholder needs and sustainable supply-chain management» (Lehmann et al., 2020).

In this definition, the meaning of soil health is presented quite broadly. The authors cover all possible areas related to soil, but do not give a specific definition that would really indicate to a person involved in agriculture or other activities what signs can be used to determine that the soil is truly healthy.

At the same time, (Kibblewhite et al., 2008) divide this value depending on several factors. They talk about integrated and restorative concepts and describe each of them in detail. Thus, if we talk about the restorative concept, it is more based on the physical, chemical and biological properties of the soil. That is, soil health is assessed primarily by its suitability for growing crops. As for the integrated concept, it is broader and perhaps somewhat similar to the one proposed by Lehmann et al., 2020. It states that soil health is more than just its properties, but a combination of factors and soil components that interact with each other. In their own understanding, the authors say that healthy soil is, first and foremost, the soil that is capable of producing agricultural products.

However, it is quite difficult to combine the concepts of soil health and agricultural sustainability because of the world's population. There are currently seven billion people on Earth, and one of their main needs, in addition to fresh water, is food. Sustainable agriculture primarily involves the use of more environmentally friendly methods of growing crops, i.e. reducing the use of mineral fertilizers and plant protection products. The goals of such a policy are clear, as the planet needs to be preserved and passed on to our descendants in at least the same condition as we have now. Many human actions have already led to certain irreversible processes, such as loss of biodiversity, deterioration of soil properties, in particular, reduction of humus and nutrients, desertification of certain areas, etc. (Cardoso et al., 2013). However, the population of people does not stand still, but rather grows every day. This requires the use of certain "assistants" to help provide the necessary amount of food to prevent hunger (Tahat et al., 2020).

However, it is necessary to understand how to conduct agricultural activities to ensure their sustainability and at the same time maintain soil health. Thus, the review article (Velten et al., 2015) cites a rather good definition of this term: «Sustainable agriculture is an "integrated system of plant and animal production practices having a site specific application that will, over the long term: (a) satisfy human food and fiber needs; (b) enhance environmental quality; (c) make efficient use of non-renewable resources and on-farm resources and integrate appropriate natural biological cycles and controls; (d) sustain the economic viability of farm operations; and (e) enhance the quality of life for farmers and society as a whole» U.S. Farm Bill (1990).

Although it does not directly state that it is necessary to move away from the use of chemicals, if we analyze this definition, we can understand this from the phrase "enhance environmental quality." That is why the combination of the concepts of "soil health" and "sustainable agriculture" is quite appropriate. Sustainable agriculture involves improving soil performance, which will lead to its health. Accordingly, scientists have picked up on this topic and have begun to actively research the impact of certain agricultural practices on soil sustainability and health (Tab. 1).

Table 1. Impact of agricultural practices on improving soil health

Agricultural practices	Impact on soil health	References
Crop rotation	Scientists have made significant progress in this area. In particular, most researchers study the impact of monoculture and crop rotation on certain soil health parameters. In particular, it was found that soybean cultivation in a crop rotation, where the crop returns to the same field in the third year after corn and winter wheat, is the most beneficial. Soybean yields are the highest and soil health indicators, including carbon content, have increased significantly. In another study, the same authors found that winter wheat monoculture improved soil health compared to 2 year and 3 year crop rotations.	(Agomoh et al., 2020, 2021)
Mini- or no-till	Many studies have shown that the use of such types of tillage significantly improves soil health, especially if these practices are used in combination with cover crops. In addition, no-till allows you to destroy the tiller sole. Speaking of soil health indicators, no-till cultivation helps to increase carbon content, aggregate stability and reduce erosion.	(Nunes et al., 2018; Reicosky, 2020)
Organic farming	A set of measures to reduce the negative impact of intensive farming on soil health indicators. In particular, when comparing the impact of conventional and organic farming on soil health indicators, it was found that organic farming improves soil bio-physical and chemical indicators.	(Sihl et al., 2017)
Cover crops	It is an extremely important agricultural practice that helps to preserve moisture in crops, reduce soil temperature and erosion. However, not all crops can be sown as cover crops. In particular, it is best to use grasses and grass mixtures. We should also not forget about broadleaf species, which are an excellent organic fertilizer after the main crop is harvested and allow for the accumulation of more carbon and nitrogen. In addition, the use of cover crops can increase the activity of soil biota.	(Koudahe et al., 2022)
Strip-till	A compromise agricultural technique that combines the advantages of no-till and the use of cover crops, but still uses strip tillage. In particular, when comparing the impact of this method of tillage	(Jaskulska et al., 2020; Datsko &

with conventional and minimal tillage, it was found that the use of strip-till increased the number of worms and microorganisms. Also, compared to other types of tillage, the content of mobile forms of nitrogen, phosphorus and potassium increased. Zakharchenko, 2022)

Biofertilizers or bioinoculants The use of such preparations allows for the introduction of beneficial microflora into the soil or seeds, which will increase the microbiological activity of the soil compared to the native microflora. (Iqbal et al., 2023)

As can be seen from the table, all of the tools that help improve soil health are sustainable, meaning they have minimal impact on the environment, are energy efficient, and improve the physical and chemical properties of the soil. This makes it possible to obtain higher yields, which also satisfies one of the Sustainable Development Goals - "Zero hunger". In fact, the problem of hunger in the world is quite serious. In more developed countries, it is hardly felt, but in many African countries, the risk of hunger is quite high. Therefore, the Global Hunger Index (GHI) was created. This is an indicator designed to track the level of hunger and measure it over time (Wiesmann, 2006). Fig 1 shows the ranking of countries by the number of people suffering from hunger.

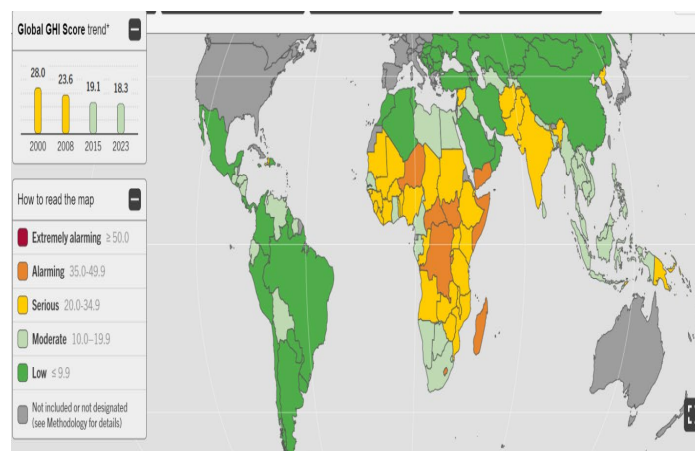


Figure 1. Map by GHI ranking (Global hunger index, 2024)

The map clearly shows that the countries at greatest risk of hunger are those in Africa and some Asian countries. Although the chart in this figure shows that the trend in the number of hungry people is indeed falling, comparing the data from 2000 and 2023, it is clear that the percentage of hungry people has fallen by almost 10%, which is significant progress and indicates that humanity is moving in the right direction. The most obvious reason for this situation is that the very concept of health in African soils is missing. In particular, African soils have a low organic matter content, which limits their fertility and ability to retain moisture. In turn, this leads to low microbiological activity, which prevents the accumulation of organic matter (Swanepoel et al., 2016; Zakharchenko et al., 2024). Another problem is erosion, whether by water or by fission, which is found in many parts of Africa, especially in arid and semi-arid zones (Chapman et al., 2021). Also, many soils in Africa are poor in macronutrients such as nitrogen, phosphorus, and potassium, which means that fertilizers are needed to maintain agricultural productivity (Hengl et al., 2021). There are also problems with soil salinity and acidity. That is why it is worth using the principles of sustainable agricultural production to prevent such problems in other countries.

Agriculture has a significant impact on climate change. Particular attention should be paid to soil cultivation. No-till is still the best method to reduce greenhouse gas emissions, and we should not forget about such relatively new products as nitrification inhibitors, which also reduce N₂O emissions (Bhattacharyya et al., 2022). This is if we talk about the cultivation itself, but it is performed by agricultural machines and it is a lot of operations, which also leads to greenhouse gas emissions directly from these agricultural machines.

Conclusions

Therefore, it is worth saying that these three concepts mentioned in the essay are interconnected and cannot exist without the other. That is, there can be no soil health without maintaining it and applying sustainable agriculture practices. At the same time, sustainable agriculture helps to reduce the negative impact on the climate.

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