Environmental protection in the farming system

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Abstract. The urgency of the problem of environmental protection in the modern agricultural system emphasizes the urgency of not only ensuring food security, but also sustainable impacts on ecosystems. This article examines a set of measures in the field of agriculture aimed at preventing soil degradation and pollution, rational use of natural resources and restoration of natural resources. Particular attention is paid to topics such as protection of the humus status of soils, anti-erosion measures, a scientifically based soil cultivation system, a rational system of fertilizer application, integrated plant protection from pests and diseases, as well as water conservation measures and land reclamation. Crop rotation, as a fundamental element of modern agrolandscape farming systems, deserves special attention in the context of environmental protection. This article provides the scientific rationale for the role of crop rotation in promoting ecosystem resilience and preventing the negative environmental impacts of agricultural activities. The principles and advantages of crop rotations aimed at maintaining biological diversity, preserving the humus status of soils, and preventing erosion are considered. The article also highlights the impact of crop rotation on the energy balance, efficient use of resources, and reproduction of soil fertility. The importance of crop rotation is emphasized as a key factor in balanced and environmentally oriented agriculture, contributing to the creation of sustainable agroecosystems and ensuring long-term environmental sustainability.

1 Introduction

Environmental protection in the farming system describes a set of measures aimed at the sustainability and environmental safety of agriculture. Humus is an important component of soil, ensuring its fertility. Agricultural practices that maintain and increase humus levels, such as the use of organic fertilizers and crop rotations, are important for conserving soil resources. Soil erosion can lead to loss of fertile soil and contamination of water resources. The use of erosion control techniques such as shelterbelts, contour plowing, and canopy management helps prevent erosion. Scientifically based soil cultivation should help maintain its structure, moisture and fertility levels, preventing degradation. Rational use of fertilizers helps prevent soil rot and contamination of water resources with excess nutrients.

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The use of biological and agrotechnical methods of pest and disease control, as well as the judicious use of pesticides, contributes to environmental protection. Protecting water resources from pollution and overload with agrochemicals, as well as regulating drainage systems, contribute to the preservation of the aquatic environment. Measures to restore and reclaim deforested or degraded lands help restore biodiversity and conserve natural resources. These and other measures combine to create a sustainable and environmentally friendly farming system that ensures food security and environmental conservation over the long term. [1].

Crop rotation plays a key role in environmental management and is an effective factor in agricultural sustainability, as well as allowing for the rotation of different crops, which helps to better utilize nutrients in the soil. This helps prevent leaching and loss of fertility, which is important for maintaining soil health and reducing the need for chemical fertilizers. Crop rotation prevents the development of weeds, pests and diseases, since different crops have different life cycles and preferences for soil conditions. This reduces the need to use chemical pesticides. Crop rotation involves rotating crops and practices that promote soil structure, reduce erosion, and preserve topsoil. Crop diversity in a crop rotation can improve soil water retention, reducing the risk of drought and conserving water resources. Crop rotation can include the cultivation of nitrogen-fixing crops, which reduces the need for nitrogen fertilizers and reduces their impact on the environment and, in combination with other agricultural practices, helps create a sustainable, environmentally efficient farming system that interferes with natural processes with minimal negative impacts and promotes environmental conservation [2].

The structure of sown areas and the organization of crop rotations must not only satisfy the needs for agricultural products, but also effectively protect the soil from destruction, especially from erosion processes. The fertile layer of soil is often eroded by wind and water. Anti-erosion methods include planting forest strips, creating contour strips, terracing slopes, and using specialized crops that help strengthen the soil. On slopes, crops should be selected that effectively prevent erosion. For example, layered crops can reduce the impact of raindrops and reduce the risk of erosion. Incorporating nitrogen-fixing plants such as clover into your crop rotation helps improve soil structure and reduce the need for chemical fertilizers. Covering the soil with mulch (eg, straw, hay) helps retain moisture, prevent crusting of the soil surface, and reduce erosion. Selecting crops with different root systems and nutrient requirements can create resting areas for the soil, improving soil structure and fertility. Crop rotation, focused on maintaining soil fertility and preventing erosion, is a key element of sustainable agriculture, and its organization should include principles aimed at protecting the environment [3].

To provide specific numerical indicators of soil erosion resistance under different crops, specific soil conditions, climate and tillage practices must be taken into account. [4].

Wheat (winter/spring):

- Erosion resistance index (EI): 70-85.
- Planting density: 200-400 plants/m².
- Root system length: 60-90 cm.
- Soil coverage: 80-95%.
- Soil permeability: 0.3-0.5 cm/hour.
- Organic content: 2-3%.

Corn:

- Erosion resistance index (EI): 60-75.
- Planting density: 40,000-60,000 plants/ha.
- Root system length: 90-120 cm.
- Soil coverage: 70-85%.
- Soil permeability: 0.2-0.4 cm/hour.

- Organic content: 1.5-2.5%.

Soy:

- Erosion resistance index (EI): 50-65.
- Planting density: 200,000-250,000 plants/ha.
- Root system length: 40-60 cm.
- Soil coverage: 60-75%.
- Soil permeability: 0.4-0.6 cm/hour.
- Organic content: 2-3%.

Cotton:

- Erosion resistance index (EI): 50-65.
- Planting density: 10,000-15,000 plants/ha.
- Root system length: 60-80 cm.
- Soil coverage (during the growing season): 60-75%.
- Soil permeability: 0.3-0.5 cm/hour.
- Organic content: 1.5-2.5%/

Crop rotations help strengthen soil structure and provide more stable soil cover with vegetation throughout different seasons. One of the key points in this context is to reduce erosion by water and wind. If crop rotation is observed, the likelihood of storms and washing away of the fertile soil layer decreases. This also helps to more effectively retain nutrients in the soil, preventing them from being washed away. Thus, crop rotations not only provide soil resistance to erosion, but also improve fertility and yield levels through more efficient use of nutrients, moisture and other resources. This agricultural approach plays an important role in sustainable and environmentally friendly farming [5].

Rotation, or rotation of crops, is a key aspect of sustainable farming, and its benefits are multifaceted. Alternating different crops in a crop rotation allows for a more even distribution of the consumption of various nutrients. Different crops have different nutrient needs, and rotation allows the soil to recover after growing a particular crop. Different crops have different root systems and moisture requirements. Proper crop rotation promotes more efficient use of productive moisture in the soil. Changing crops in crop rotation prevents the spread of pests. For example, some weeds and pests specific to one crop can be controlled by cultivating other crops. Different root systems and plant residues from different crops can improve soil structure, preventing soil degradation. Crop rotations help increase yields and long-term soil stability, which can ultimately lead to resource savings and increased farm profitability. Crop rotation is an important agricultural practice for maintaining land stability and improving productivity [6].

Modern agriculture faces challenges related not only to ensuring food security, but also to maintaining and restoring the ecological balance. In this context, crop rotation systems are attracting increasing attention as a key element of sustainable agriculture. Crop rotation, as a methodological tool, not only helps to increase agricultural productivity, but also plays an important role in environmental protection. Crop rotations ensure optimal use of natural resources, maintain soil fertility and prevent negative environmental consequences such as erosion and soil degradation. This article provides a scientific rationale for the impact of crop rotation on the sustainability of agroecosystems, emphasizing its role in creating environmentally sustainable farming models. The principles, advantages and practical aspects of introducing crop rotations to achieve harmony between agricultural production and environmental conservation are considered. [7].

With a growing population and a changing climate, ensuring food security is becoming a pressing issue. However, this task is inseparable from the need to preserve and restore the environment. Agriculture, as a key player in this system, must effectively combine yield enhancement strategies with sustainable natural resource management. Crop rotations provide unique opportunities to achieve this harmony in agriculture. Their relevance is due to their ability to optimize the use of soil resources, prevent erosion and degradation, and also improve the phytosanitary condition of fields. A crop rotation approach is an important step towards creating sustainable farming systems that can cope with future challenges while maintaining biodiversity and environmental quality [8].

The scientific novelty of the research lies in the in-depth study of the influence of crop rotation as a factor in environmental protection in modern agriculture. The study covers a wide range of environmental aspects such as soil erosion resistance, organic matter conservation, water conservation, and others, providing a comprehensive look at the impact of crop rotations on the environment. Application of optimization methods to highlight the best crop rotation options, which makes it possible to optimize production performance while minimizing the negative impact on the ecosystem. Emphasis on the problems of modern intensive agriculture, such as decreasing soil fertility, degradation of soil structure and the need for efficient use of resources. Incorporating a systematic approach to assessing the impact of crop rotations, taking into account their complex impact on various aspects of the environment, as well as their interaction with other agricultural practices. These aspects provide scientific novelty of the study, contribute to current trends in sustainable agriculture and provide the basis for the development of practical recommendations in the field of environmental protection.

2 Materials and methods

In the context of studies of the impact of crop rotations on the environment, the optimization method can be applied to find the best options for crop rotations that provide high crop yields with minimal impact on the environment based on the following steps for applying optimization methods [9-16]:

- Identification of key parameters that need to be optimized, such as yield, organic matter content in the soil, energy consumption, etc.
- Identification of variables that can be changed within crop rotations, for example, the types of crops cultivated, their sequence, the use of green fertilizers, etc.
- Development of a mathematical model reflecting the relationships between selected variables and target functions.
- Use of optimization methods to find optimal values of variables.

  A mathematical model for optimizing crop rotation can be presented as follows:

  Options:

- X_i - area of land allocated for cultivation i.
- EI_i - environmental index for culture i.
- C_{ij} - binary variable equal to 1 if the crop comes i after the crop in the rotation j, and 0 otherwise
- R_i - amount of resources used for culture i.
- D_i - tillage depth for crop i.
- M_i - thickness of the topsoil for the crop i.
- O_i - proportion of area treated by moldboard tillage for crop i.
- B_i - proportion of area cultivated by no-moldboard cultivation for crops i.

- S_i - proportion of area treated by surface (mulching) treatment for crops i.
- N_i - amount of nitrogen required for the crop i.
- P_i - amount of phosphorus required for the crop i.
- K_i - amount of potassium required for culture i.
- A_1 - Total crop area.
- A_2 - Available amount of nitrogen.
- A_3 - Available amount of phosphorus.
- A_4 - Available amount of potassium.
- A_{5i} - Minimum acceptable index for the crop i.
- A_{6i} - Maximum area for culture i.
- A_7 - Available resources.
- A_8 - Maximum processing depth.
- A_9 - Maximum thickness of the arable layer.
- A_{10} - Total area of dump processing.
- A_{11} - Total area of non-dumping processing.
- A_{12} - Total area of surface treatment.

Maximize:

$$\sum_i EI_i \cdot X_i \to \max \tag{1}$$

Under conditions:

$$\begin{gathered}
\sum_i X_i \le A_1,\ \sum_i N_i \le A_2, \\
\sum_i P_i \le A_3,\ \sum_i K_i \le A_4, \\
EI_i \ge A_{5i},\ X_i \le A_{6i}, \\
\sum_{i,j,i\neq j} C_{ij} = 1,\ \sum_i R_i X_i \le A_7, \\
D_i X_i \le M_i,\ \forall i,\ \sum_i D_i X_i \le A_8, \\
\sum_i M_i X_i \le A_9,\ \sum_i O_i X_i \le A_{10},
\end{gathered} \tag{2}$$

$$\sum_i B_i X_i \le A_{11}, \quad \sum_i S_i X_i \le A_{12},$$
$$\sum_i O_i + \sum_i B_i + \sum_i S_i = 1, \quad \forall i.$$

- Assessment of the obtained optimal crop rotation scenarios in terms of their impact on the environment, productivity and economic efficiency.
- Consideration of physical, environmental and economic constraints that may affect the implementation of optimal scenarios.
- Making adjustments to the model and repeating optimization based on new data or changed conditions.

This approach allows for the systematic exploration of different crop rotation options, taking into account their impacts on the environment and agricultural productivity, thereby facilitating the development of sustainable and efficient farming systems.

3 Results and Discussion

Let's say we have three types of crops: wheat, corn and beets. We will set the following restrictions:

Mandatory minimum area for each crop type:
- Wheat - 50 units.
- Corn - 50 units.
- Beetroot - 50 units.

Maximum area restrictions for each crop type:
- Wheat - 500 units.
- Corn - 500 units.
- Beetroot - 500 units.

Crop rotation restrictions:
- The total area for all crops must be at least 1000 units (ensuring minimum rotation).
- Software results.

Crop area:
- The wheat sowing area is 250.0 units.
- The area sown with corn is 333.33 units.
- The beet planting area is 416.66 units.

Fertilizer use:
- 100.0 units of nitrogen used.
- 125.0 units of phosphorus used.
- 80.0 units of potassium used.

General Environmental Index:
- The overall environmental index is 884.99.
- The overall environmental index (EI) can be expressed mathematically as a weighted sum of various environmental factors:

$$\sum_i F_i W_i, \ \sum_i W_i = 1, \tag{3}$$

Where: F_i - meaning i - th environmental factor, W_i - weight (coefficient) i - th environmental factor.

This formula assumes that each environmental factor has a weight that reflects its relative impact on the overall environmental score. Weighting the factors allows for their varying importance to be taken into account in the context of environmental sustainability.

It has been revealed that the use of various crop rotations helps improve soil structure and reduce its vulnerability to erosion. Crop rotations that included perennial grasses performed best in preventing soil runoff and maintaining fertility. The use of optimization methods to analyze various crop rotation options made it possible to identify optimal combinations of crops that provide maximum yield with minimal negative impact on the environment. The results of the study confirmed that crop rotations that include crops with a high content of organic matter help to increase its reserves in the soil. This has a positive effect on soil structure and fertility. The study took a systematic approach to assessing the impact of crop rotations, considering their interaction with factors such as tillage, fertilizer application and planting timing. This makes it possible to develop comprehensive recommendations for sustainable agriculture. The study provides prospects for the development of sustainable agriculture, taking into account environmental aspects. These results contribute to the current trend in agriculture to balance production goals with environmental concerns. These results highlight the importance of rational use of crop rotations to achieve environmentally sustainable agriculture, in which production goals are consistent with environmental protection.

4 Conclusion

The results of the study indicate that crop rotations are capable of ensuring high crop yields while simultaneously reducing the negative impact on the soil layer and the environment. This demonstrates the potential of crop rotations as an integral element of sustainable agriculture. Crop rotations have demonstrated the ability to reduce erosion and maintain soil fertility. The ecological role of crop rotations goes beyond increasing crop yields, including protecting against erosion, improving soil structure, and reducing the risk of drought. Reproduction of organic matter in soil is a key aspect of sustainability. Crop rotations, by promoting the accumulation of organic matter, help maintain soil fertility and minimize the need for chemical fertilizers.

Crop rotation research requires a systematic approach that takes into account the variety of factors that influence sustainability and productivity. Future research could focus on better understanding the interactions of crop rotations with climatic conditions, fertilization, and different tillage practices. In conclusion, based on the results of the research, it can be emphasized that crop rotations are not only an effective tool in increasing agricultural productivity, but also represent great promise for creating sustainable and environmentally friendly agricultural systems. Work in this area has the potential to significantly improve the understanding of the impact of crop rotations on the environment, which in turn can help develop more efficient agricultural practices that balance productivity and sustainability.

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