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Agrolandscapes and their role in ensuring environmental safety

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Abstract. The purpose of the study was to analyse in depth the role of agrolandscapes in ensuring environmental safety and to investigate their impact on the environment, with a special emphasis on aspects of biodiversity, soil protection, and water management. The study covered a wide range of activities, including the collection and systematisation of scientific materials, a comparative analysis of different management approaches, and the development of a theoretical model of environmental safety that allows assessing the effectiveness of existing practices. The main results of the study indicated that agrolandscapes characterised by a high level of integration of

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natural elements and agricultural components can provide a significantly higher level of biodiversity compared to less integrated counterparts. In particular, forest and forest-steppe agrolandscapes have proven to be the most effective in conserving species, which is critical for maintaining ecological balance. However, steppe and dry steppe landscapes require urgent and comprehensive measures to improve the state of biodiversity, as their ecological sustainability is under threat. Thus, the results of the study emphasised the need to introduce innovative approaches to agrolandscape management that can contribute to the conservation of natural resources and improve environmental safety. The developed theoretical model revealed that the most sustainable agrolandscapes are those where natural ecosystems are harmoniously combined with agricultural land. The results confirmed the hypothesis that effective management of agrolandscapes contributes to improving environmental safety and reducing negative environmental impacts, in particular, by controlling erosion and managing water resources. The conclusions emphasised the need to implement agroforestry, support environmental approaches in policies and a system of monitoring the state of agrolandscapes for the sustainable development of agricultural regions, which would facilitate adaptation to the challenges of climate change

Keywords: ecological safety; biosafety; life safety; agrolandscapes; soil cultivation; fertilisers

INTRODUCTION

Ensuring environmental safety has become a priority in the context of global environmental challenges such as climate change, land degradation, loss of biodiversity, and increasing anthropogenic pressure on natural resources. In the context of intensive agricultural use of land, maintaining the ecological stability of agrolandscapes has become critical. Agrolandscapes that combine elements of natural ecosystems with agricultural activities have played a key role in maintaining environmental stability. They had the potential to contribute to the conservation of biodiversity, protect soils from erosion, and ensure the rational use of water resources. However, improperly organised management of agrolandscapes could worsen the state of ecosystems, reduce their sustainability, and create risks to environmental safety.

The relevance of this study was determined by the need to determine how different types of agrolandscapes, such as arable land, pastures, orchards, vineyards, etc., affect key components of environmental safety. The purpose of the study was to assess the impact of agrolandscapes on the environment and analyse how their use can contribute or, conversely, negatively affect the conservation of biodiversity, soil quality, water resources, and the overall state of ecosystems. This study is an important step in the development of strategies for sustainable management of agricultural territories, which would ensure a balance between the production of agricultural products and the preservation of environmental safety.

There are a number of problems in the field of agrolandscapes that have already attracted the attention of researchers. For example, R. Plokhikh *et al*. (2023) investigated the impact of various agrolandscapes on environmental sustainability and found that an integrated approach to managing such landscapes can significantly improve their ecosystem functions. Analyses performed by D.D. Burra *et al*. (2021) pointed out a strong link between restoring ecological balance in African agrolandscapes and improving public health. This demonstrates the importance of agrolandscapes for the conservation of biodiversity and for the social and economic aspects of life. Restoring ecosystems can lead to improved access to clean water, increased agricultural productivity, and the overall well-being of the population (Floqi *et al*., 2009). Thus, effective management of agrolandscapes is critical to ensuring sustainable development and improving the quality of life in communities. However, there are gaps in understanding the relationships between different types of agrolandscapes and their impact on biodiversity conservation, soil and water protection. I. Myskovets *et al*. (2024) investigated the impact of agroforestry on the structure of forest ecosystems, but did not sufficiently consider the elements of integrating agronomic and environmental practices. The importance of water management was emphasised by L. Kuzmych (2024), who stated that effective soil and water management practices are critical to ensuring food security. The study by M.A. Altieri *et al*. (2024) emphasised the need to develop a strategy for designing sustainable agroecosystems, but did not cover all aspects related to environmental safety. In addition, Z. Mustafayev *et al*. (2024) improved the methodology for assessing the agricultural resource potential of agrolandscapes, but insufficient attention was paid to specific ecological and economic indicators that are necessary to ensure their effectiveness.

Despite numerous studies, the complex relationships between different types of agrolandscapes and their impact on biodiversity conservation, soil and water resources protection remained poorly understood. Existing approaches often focused only on individual aspects, without considering the interaction between environmental safety components. This created the need to develop more holistic models for managing agrolandscapes, which would simultaneously increase productivity and ensure environmental sustainability. This study examined the impact of various types of

agrolandscapes on environmental safety, in particular, their role in biodiversity conservation, soil protection, and efficient use of water resources. The main goal of the study was to determine the best approaches to managing agrolandscapes that would contribute to ensuring environmental safety and minimise the risks of degradation. The study also tested the hypothesis that an integrated approach to managing agrolandscapes, considering their type and specific impact on environmental resources, would contribute to improving ecosystem functions and the sustainability of natural processes. The study offers recommendations for implementing integrated management practices that would ensure a balance between agricultural productivity and environmental safety.

As a result, this study has helped to develop recommendations for farmers, agronomists and policy makers to implement sustainable agrolandscape management practices. The established links between different types of agrolandscapes and environmental safety contributed to a better understanding of ecosystem functions, which allowed the authors to develop more effective strategies for ensuring sustainable agricultural development in the face of modern environmental challenges.

MATERIALS AND METHODS

This study was conducted from June to September 2024 and was based on an analysis of scientific literature and theoretical approaches describing the interaction of agrolandscapes with the natural environment. The study covered several stages: collection and systematisation of scientific materials, comparative analysis of approaches to managing agrolandscapes, development of theoretical models of environmental safety and identification of gaps in scientific literature. The study used comparative analysis to investigate approaches to managing agrolandscapes in various climatic conditions, in particular, in steppe, forest, and dry steppe regions. The analysis focused on key factors affecting environmental safety: controlling erosion processes and soil degradation, maintaining water balance and regulating water flows, and promoting the conservation of native plant and animal species. This approach helped to determine the best ways to manage landscapes for each natural and climatic zone, ensuring long-term environmental safety.

The study systematised data on key ecosystem services provided by agrolandscapes. Special attention was paid to three aspects: biodiversity conservation, erosion control and soil protection, and water resources management. Biodiversity conservation has been studied through the combination of agricultural land with natural ecosystems, which contributes to the restoration of ecological balance. In terms of soil protection, the role of forest belts and agroforestry, which reduce erosion processes and increase soil fertility, was analysed. Water management has been studied through agrotechnical measures aimed at reducing the risks of flooding and droughts, in particular, by introducing water-retaining elements in landscapes. Such approaches contribute to environmental stability and increase the adaptability of agricultural systems to climate change. Based on the conducted comparative analysis and generalisation of data, a theoretical model was developed that reflected the relationship between the components of agrolandscapes and their impact on environmental safety. The model considered such variables as the type of agrolandscape (forest, forest-steppe, steppe, dry steppe), the level of integration of natural and agricultural elements, and ecosystem services that ensure the stability and balance of the landscape. This helped to assess how the interaction of these components contributes to biodiversity conservation, erosion control, increased soil fertility, and effective water management. The model demonstrated that agrolandscapes with a high level of integration of natural and anthropogenic elements are more resistant to environmental challenges and better perform the functions of environmental protection.

The study also involved regulatory documents governing the use of agrolandscapes to ensure environmental safety, in particular: Law of Ukraine No. 2775-IX "On Environmental Protection" (1991), Law of Ukraine No. 2973-IX "On Amendments to Certain Legislative Acts of Ukraine on the State System of Environmental Monitoring, Information on the State of the Environment (Environmental Information) and Information Support for Environmental Management" (2023, March). The study followed the standards of Convention on Biological Diversity (CBD) (1992) and Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973, March). An integrated approach was used, which included an analysis of ecosystem services of agrolandscapes and an assessment of their impact on biodiversity conservation, soil protection and water resources management. This provided a comprehensive understanding of the role of agrolandscapes in enhancing environmental security and helped to identify the best methods of integrating natural and agricultural elements for the long-term sustainability of agricultural systems.

RESULTS

The study showed that agrolandscapes have a significant impact on the environmental safety of regions. This is conditioned by their ability to maintain biodiversity, maintain soil fertility, and manage water resources. Different types of agrolandscapes, such as forest, forest-steppe, steppe, and dry steppe, show different levels of ecological sustainability depending on the integration of natural and anthropogenic elements.

Forest agrolandscapes are among the most biodiversity-rich ecosystems, which are of great importance for preserving natural resources and maintaining ecological balance (Yanitskyi, 2024). They provide numerous ecosystem services, including habitat for many

species of flora and fauna, especially rare and endangered ones, making them important for preserving biological diversity. The presence of diverse microenvironments in forests, such as wetlands, oak groves, and coniferous forests, contributes to the development of ecological niches, which increases overall species diversity. Forests also play a critical role in climate regulation, because they absorb carbon dioxide, reducing the greenhouse effect and helping to reduce global warming. They affect the local climate by providing shade, lowering temperatures, and regulating humidity. Tree roots retain moisture in the soil, which prevents erosion and improves water quality, supporting the health of ecosystems. These functions of forests are important for the natural environment and for human well-being, as they provide clean water, air, and resources for life.

Forest-steppe agrolandscapes that combine elements of forests and steppes create unique and favourable conditions for the existence of a greater variety of flora and fauna species. These agrolandscapes support a much larger number of species than their purely steppe or forest counterparts, due to the presence of various ecological niches and resources. They provide optimal conditions for the existence of pollinators such as bees, which play a critical role in the pollination processes of plants, which, in turn, is indispensable for the successful development of agriculture. Forest-steppe agrolandscapes show higher adaptability to climate change. This is conditioned by the diversity of vegetation that can withstand different climatic conditions, and the availability of more available resources, such as water and nutrients. Because of this, forest steppes can be more resilient to extreme weather events, making them important for food security and biodiversity conservation in the face of global climate change.

Steppe agrolandscapes, despite their high productivity, show increased vulnerability to erosion processes and ecosystem degradation. These territories can provide significant yields of agricultural crops due to optimal conditions for plant growth. However, overexploitation of land caused by intensive agriculture can lead to severe depletion of natural resources such as soil and water (Gavkalova *et al.*, 2024). Without proper management and implementation of sustainable agronomic practices, steppe landscapes face numerous problems, in particular, erosion. Vegetation cover, which performs an important function of soil retention, can be destroyed due to irrational use of land, which leads to further deterioration of soil quality and a decrease in their fertility. Although these agrolandscapes have some adaptation to arid conditions, constant climate changes, including rising temperatures and changes in precipitation patterns, endanger their stability and productivity. Therefore, it is important to take steps to preserve these valuable ecosystems by implementing sustainable development strategies that will help preserve their fertility and environmental value.

Dry steppe agrolandscapes, for their part, face serious challenges related to water scarcity, which is one of the key problems for the sustainable development of agriculture in these regions. Water scarcity not only limits the diversity of species, but also significantly affects the overall productivity of agricultural systems, which can lead to reduced yields and economic losses for farmers. Adaptive strategies are required to preserve biodiversity in these challenging environments, such as introducing water-retaining elements, which may include irrigation systems, the use of mulch, and the choice of crops that require less water. Although these agrolandscapes may contain adapted plant and animal species, their abundance and diversity are usually limited, making them vulnerable to climate change and other environmental stresses. Therefore, it is important to develop and implement comprehensive natural resource management programmes that will contribute to the conservation of biodiversity and increase the resilience of agrolandscapes to water scarcity. The main results related to the impact of agrolandscapes on biodiversity are presented in Table 1, which demonstrates species diversity, conservation levels, and key ecosystem services for each type of agrolandscape. This provides a comprehensive view of their contribution to environmental sustainability and importance for the conservation of natural resources.

***Table 1**. Impact of different types of agrolandscapes on biodiversity*

Type of agrolandscape	Number of plant species	Number of animal species	Species conservation level	Basic ecosystem services	Management features
Forest	200+	100+	85%	Biodiversity support, air purification, water storage	Forest conservation, agroforestry
Forest-steppe	150+	80+	75%	Promotion of diversity, control of erosion	Integration of natural elements
Steppe	100+	50+	50%	High performance but low stability	Measures to reduce erosion
Dry steppe	80+	30+	40%	Adaptation to dry conditions, limited diversity	Water resources management

***Source:** created by the authors based on T. S. Priyadarshana et al. (2024)*

In general, agrolandscapes with a high level of integration of natural elements provide significantly higher levels of biodiversity than their less integrated counterparts. Forest and forest-steppe agrolandscapes show the greatest efficiency in species conservation, while steppe and dry steppe landscapes require urgent measures to improve the state of biodiversity. These data highlight the need for active management of agrolandscapes to maintain environmental sustainability. Agrolandscapes play an important role in providing a range of ecosystem services that contribute to maintaining ecological balance and sustainable agricultural development. One of the key ecosystem services is soil conservation and erosion control, which is crucial for long-term farming. Data analysis shows that agrolandscapes that integrate natural elements such as forest belts and watersheds show significant advantages in controlling erosion.

Firstly, the use of forest belts in agrolandscapes is an effective method for reducing the rate of wind and water erosion. Forest belts located along the fields serve as natural barriers that hold the soil in place, preventing it from leaching out. This approach not only preserves soil fertility, but also contributes to the preservation of biodiversity, because it creates conditions for the existence of various plant and animal species. Secondly, agroforestry is an important tool for integrating trees and shrubs into agricultural land. It improves the structure of the soil and increases its fertility, and helps to retain moisture. Studies show that in the regions where these methods are used, there is a significant reduction in erosion processes, which makes agricultural systems more resistant to climate change. In addition, contour treatment is another effective method that helps reduce surface water runoff. This method consists of cultivating the soil along the contours of the field, which allows retaining moisture in the soil and reduces the loss of fertility. This is especially important in areas with heavy rainfall, where the risk of erosion is high. It is also important to introduce water-retaining elements, such as terracing and irrigation systems. These methods help to control the water balance in agrolandscapes, preventing both flooding and droughts. Effective water management contributes to the sustainable development of agricultural systems by improving their productivity and reducing the risks associated with climate change (Table 2).

***Table 2**. Basic methods of soil conservation and erosion control in agrolandscapes*

Method	Description	Advantages
Forest belts	Planting of trees along the fields	Reduction of wind and water erosion
Agroforestry	Integration of forest elements into agricultural systems	Improve fertility and moisture retention
Contour processing	Tillage along field contours	Reduction of water runoff, maintenance of fertility
Water-retaining elements	Use of terraces and irrigation systems	Water balance control, erosion prevention

***Source:** created by the authors*

In general, agrolandscapes that actively implement these methods demonstrate significant advantages in controlling erosion and preserving soils. Systematisation of ecosystem services of agrolandscapes shows that the integration of natural elements not only improves agricultural productivity, but also contributes to the preservation of the environment. Active management of agrolandscapes should include these approaches to ensure long-term stability and resilience to climate change and anthropogenic impacts. Water management is a critical aspect of agrolandscapes, as it affects agricultural productivity, ecosystem conservation, and overall environmental sustainability. In the face of climate change and the increasing frequency of extreme weather events, such as droughts and floods, effective water management is becoming particularly relevant.

The introduction of water-retaining elements, such as terracing, can significantly improve water management. Terraces that are formed on slopes help to slow down water runoff, which prevents erosion and improves soil moisture absorption. This is especially important in regions with dry climates, where moisture retention is crucial for successful crop cultivation. Irrigation systems provide control over the water regime in the fields. Modern irrigation technologies, such as drip irrigation, can optimise water use, reducing the risk of exceeding the irrigation rate. This increases water efficiency by reducing water costs and minimising the risk of flooding. Monitoring of water resources is important. The use of modern technologies, such as remote sensing and data management systems, allows agricultural producers to obtain accurate information about the state of soils and humidity levels. This allows making informed decisions about irrigation and the use of water resources, contributing to the preservation of their quality and quantity (Table 3).

***Table 3**. Basic methods of water resources management in agrolandscapes*

Method	Description	Advantages
Water-retaining elements	Terraces that slow down water runoff	Prevention of erosion, preservation of soil moisture

Table 3. Continued

Method	Description	Advantages
Irrigation systems	Technologies that provide irrigation control	Optimisation of water use, reduction of costs
Monitoring of water resources	Use of technologies for humidity analysis	Timely decision-making, improved water management

Source: *created by the authors*

Water management in agrolandscapes is a key factor affecting their sustainability and productivity. The introduction of innovative methods, such as water-retaining elements, irrigation systems, and monitoring, ensures not only the conservation of water resources, but also increases the adaptability of agricultural systems to climate change. This highlights the importance of active water management to achieve sustainable development in the agricultural sector. Agrolandscapes vary depending on the geographical location, climatic conditions, and methods of farming. These factors have a significant impact on their productivity, sustainability, and ability to provide ecosystem services. In this context, it is important to analyse different types of agrolandscapes, such as forest, forest-steppe, steppe, and dry steppe, to understand their advantages and disadvantages in the context of environmental safety.

Forest agrolandscapes are characterised by the presence of a significant area of forests that are integrated with agricultural land. They provide high biodiversity due to the availability of natural habitats for rare plant and animal species. Forest agrolandscapes effectively control erosion, due to forest coverings that prevent soil leaching. Forest-steppe agrolandscapes combine elements of forests and steppes, creating favourable conditions for a variety of species. They provide a moderate balance between agricultural productivity and biodiversity conservation. This type of agrolandscape is particularly effective for growing crops that require a diverse environment.

Steppe agrolandscapes are characterised by high productivity, but they have an increased vulnerability to soil erosion and degradation. The main problems faced by steppe agrolandscapes are soil depletion due to intensive agriculture and climate change. To improve their condition, it is necessary to introduce special measures, such as agroforestry. Dry steppe agrolandscapes are affected by water deficiency, which requires specific management strategies. This type of agrolandscape requires special attention to the conservation of water resources and the introduction of technologies that will help retain moisture in the soil. Biodiversity conservation in such conditions can be achieved by integrating agricultural land with natural ecosystems.

Table 4*. Comparison of the main types of agrolandscapes*

Type of agrolandscape	Main features	Advantages	Disadvantages
Forest	High biodiversity, availability of forests	Erosion control, conservation of rare species	Requires significant territories for conservation
Forest-steppe	Combination of forests and steppes	Variety of species, good performance	Possible conflicts between agriculture and nature conservation
Steppe	High performance, vulnerability to degradation	High yield, ease of cultivation	Prone to erosion, requires soil improvement
Dry steppe	Water deficiency, need for specific measures (irrigation)	Potential for agronomic innovation	Risks of resource depletion, need for conservation measures

Source: *created by the authors*

Comparison of different types of agrolandscapes highlights the importance of adapting management strategies to the specific conditions of each type. Effective management of agrolandscapes contributes to increasing agricultural productivity and ensures environmental sustainability, which is critical in the current conditions of climate change and increasing anthropogenic loads. Understanding the characteristics and benefits of each type of agrolandscape allows for more effective implementation of strategies for preserving biodiversity and ensuring environmental safety.

Agrolandscapes play a critical role in ensuring environmental safety, in particular, through the maintenance of biodiversity, soil conservation, and effective water resources management. The results of the study confirm the need to preserve and develop forest and forest-steppe agrolandscapes, and implement measures to improve the state of steppe and dry steppe regions. These actions will help to ensure the resilience of agricultural systems to environmental challenges and climate change. Agrolandscapes play an important role in providing a comprehensive set of ecosystem services that are critical to maintaining not only the natural environment, but also socio-economic systems (Dovgal *et al.*, 2024). Data analysis has confirmed that the main ecosystem services of agrolandscapes can be divided into several key categories.

The combination of agricultural land with natural ecosystems contributes to the maintenance of ecological balance and the conservation of local species. This is especially noticeable in forest-steppe regions, where natural landscapes complement agriculture. For example, the presence of forest belts, shrubs, and protected areas provides habitat for rare animal and plant species. These elements create conditions for the migration of species, their restoration and preservation of genetic diversity. Studies have shown that agrolandscapes with high levels of biodiversity are more resistant to environmental changes, such as climate change, due to natural mechanisms of population regulation. Agrolandscapes also play an important role in controlling erosion processes and protecting soils. The use of forest belts that function as barriers to wind and rain has proven effective in reducing the rate of erosion. Agroforestry methods, such as planting trees and shrubs, are actively used in steppe regions to improve soil fertility. These methods not only prevent erosion, but also help retain moisture in the soil, which is crucial for agricultural production. Studies have shown that the regions where these measures are implemented have more stable agricultural systems with increased productivity.

Effective water management is another important ecosystem service provided by agrolandscapes (Shuka *et al.*, 2011). Agrotechnical measures, such as the introduction of water-retaining elements (for example, terracing, contour treatment), help to reduce the risk of flooding and droughts. These measures contribute to a more balanced water regime in agrolandscapes, which is especially important in the context of climate change. The use of such methods can increase the efficiency of water use, conserving resources and ensuring stable irrigation of crops. According to the study, agrolandscapes where these agronomic practices are actively implemented show better resistance to climate stress.

In general, agrolandscapes that integrate natural elements with agricultural practices provide a wide range of ecosystem services that promote biodiversity conservation, erosion control, and effective water management. These services not only improve the environmental sustainability of agrolandscapes, but also contribute to the sustainable development of the agricultural sector, increasing its adaptability to climate change and anthropogenic impacts. Therefore, active management of agrolandscapes is necessary to ensure their efficiency and long-term stability. Based on the analysis, a theoretical model of environmental safety of agrolandscapes (Fig. 1) was developed, which reflects the complex relationships between various components of agricultural landscapes and their impact on the environmental sustainability of the environment. This model is an important tool for evaluating and planning agricultural production, considering environmental factors.

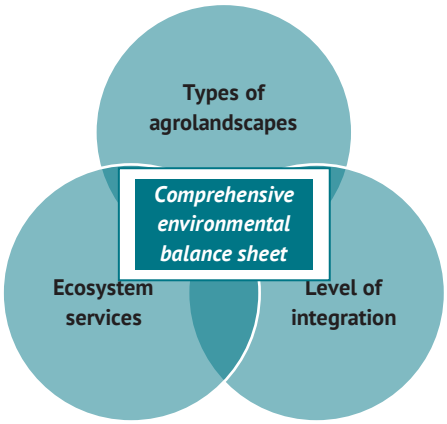

Figure 1. *Theoretical model of environmental safety of agrolandscapes*
Source: *created by the authors*

The model considers several key variables. Firstly, the type of agrolandscapes: forest, forest-steppe, steppe, and dry steppe agrolandscapes have their own specific ecological characteristics that affect their ability to provide ecosystem services and adapt to climate change. Secondly, the level of integration of natural and agricultural elements is an important aspect. High integration indicates an effective combination of agriculture with natural ecosystems, which allows maintaining biodiversity, maintaining soil fertility, and ensuring sustainable water resources management. The model also considers the main ecosystem services that are critical for environmental safety. This is the conservation of biodiversity, which supports the functioning of ecosystems and ensures the sustainability of agrolandscapes, soil protection, which includes reducing erosion and maintaining fertility, and regulating water flows, which is important in the context of climate change.

The developed model demonstrated that agrolandscapes with a high level of integration of natural and agricultural elements are the most stable. This is conditioned by the increased adaptability of such agricultural systems to climate change, which reduces the risks associated with droughts and floods. In addition, such integration helps to reduce the negative impact of anthropogenic factors, such as soil and water pollution, and also contributes to the restoration of natural resources. This model of environmental safety is an important tool for assessing the sustainability of agrolandscapes and determining optimal management strategies. It is aimed at improving environmental sustainability, preserving biodiversity and efficient use of natural resources. This, in turn, contributes to the achievement of sustainable development of the agricultural sector in the context of modern environmental challenges.

Based on the results of the study, a number of recommendations were developed aimed at improving the environmental safety of agrolandscapes and

sustainable development of agriculture. The first important recommendation is to optimise the management of agrolandscapes by introducing agroforestry and restoring natural ecosystems in agricultural regions. This includes the use of forest belts, trees and shrubs to improve environmental conditions. For example, creating forest belts will help to protect against wind erosion and improve the microclimate. The restoration of natural reservoirs and wetlands can serve as hotbeds of biodiversity, and the use of cover crops will increase soil fertility and preserve moisture. These measures will not only improve environmental conditions, but also increase agricultural productivity.

The second recommendation is to develop holistic policies that support agricultural enterprises implementing ecological approaches to soil and water management. An important aspect of such policies is to provide financial support to farmers who are switching to organic farming or implementing innovative water conservation technologies. This may include subsidies, grants, or tax breaks that will encourage farmers to adopt sustainable practices. Educational programmes and trainings for farmers will significantly increase their awareness of environmental practices. Such programmes can cover topics related to the management of natural resources, biodiversity, and the latest technologies in agriculture. This would allow farmers to gain new knowledge and exchange experience with colleagues, which will contribute to the overall development of the agricultural sector. The introduction of regulations that promote biodiversity conservation and the rational use of natural resources will be an important step in supporting environmental initiatives. Such regulations may include requirements for farming that consider environmental aspects, and mechanisms for monitoring their compliance, which will contribute to the responsible environmental behaviour among farmers and ensure sustainable development of rural areas.

The third important aspect is the need to monitor the state of agrolandscapes to respond in a timely manner to environmental challenges associated with climate change. The introduction of monitoring systems will allow identifying problems at an early stage, such as soil degradation, reduced biodiversity, and other negative consequences that may threaten ecosystems. Monitoring systems can include both stationary and mobile platforms that provide constant monitoring of changes in agrolandscapes. The use of modern technologies, such as remote sensing and geographic information systems (GIS), will help in collecting and analysing data on the state of ecosystems. These technologies provide detailed information on land use, changes in vegetation, and the impact of agricultural practices on the environment. By integrating data from different sources, agronomists and environmentalists will be able to develop more effective management strategies aimed at reducing the negative impact on nature.

Regular assessment of the impact of agricultural practices on the environment will allow adapting management strategies in accordance with the identified environmental problems. This, in turn, will contribute not only to the conservation of natural resources, but also to increasing agricultural productivity. These recommendations are aimed at ensuring an integrated approach to agrolandscape management, which will help to maintain ecological balance and ensure sustainable agricultural development in the face of climate change. It is also important to involve local communities in the monitoring process, which will help raise awareness and address environmental issues. The results obtained confirmed the hypothesis that effective management of agrolandscapes really contributes to improving environmental safety and reducing the negative impact on the environment. The study found that integrated approaches to landscape management are key to achieving sustainability in agricultural ecosystems. This, in turn, ensures the conservation of biodiversity, which is an important aspect of environmental stability.

The use of agroforestry methods, the creation of forest belts and the restoration of natural ecosystems has proved particularly effective in preventing soil erosion and maintaining their fertility. Such practices allow the conservation of natural resources, reducing the risk of degradation and reducing greenhouse gas emissions. Water management through the introduction of water-retaining elements and optimisation of irrigation systems contributes to balanced water use, which is critical in the face of climate change. Effective management of agrolandscapes improves the ecological situation and supports the socio-economic development of agricultural regions (Hartmane *et al.*, 2024). This is achieved by increasing agricultural productivity, ensuring food security and increasing farmers' incomes. Accordingly, the integration of environmental practices into agricultural production creates conditions for sustainable development, where economic progress does not occur at the expense of environmental damage.

The Law of Ukraine No. 2775-IX "On Environmental Protection" (1991) is a fundamental regulation that defines the foundations of the state's environmental policy. In the context of the study of agrolandscapes, this law focuses on ensuring environmental safety, preserving natural resources and biodiversity. It sets out the obligations of government bodies, enterprises and citizens to comply with environmental norms and standards. The law also provides for environmental pollution control mechanisms, which are particularly important in the agricultural sector, where the use of pesticides and fertilisers can negatively affect the environment. Considering the conducted research, this law emphasises the importance of integrating environmental requirements into agrolandscape management strategies, which reduces their negative impact on the environment and ensures sustainable development.

Law of Ukraine No. 2973-IX "On Amendments to Certain Legislative Acts of Ukraine on the State System of Environmental Monitoring, Information on the State of the Environment (Environmental Information) and Information Support for Environmental Management" (2023) is an important tool for implementing systematic monitoring of the ecological state in agricultural landscapes. It provides an opportunity to create an effective system for collecting, analysing and distributing environmental information, which allows detecting negative changes in the natural environment in time. This law is critical for the study of agrolandscapes, since monitoring environmental indicators, such as soil quality, water and the state of biodiversity, is crucial for the assessment of the environmental safety of agricultural systems. It supports the implementation of measures to improve the state of the environment and the efficient use of natural resources, which is consistent with the purpose of the study – optimise the management of agrolandscapes to ensure their sustainability and safety.

Both laws support the theoretical basis of the study and define practical steps that are necessary for the implementation of environmental principles in agriculture, which contributes to the establishment of environmentally friendly agrolandscapes. Thus, the results of the study indicate the importance of an integrated approach to the management of agrolandscapes, which allows preserving natural resources, supporting biodiversity and ensuring the sustainable development of agricultural regions. This highlights the need to implement state policies and programmes that support farmers in switching to environmental practices, which can lead to an improvement in the overall state of the environment.

DISCUSSION

The findings confirmed that agrolandscapes play a critical role in ensuring environmental safety. In particular, it was found that the integration of natural elements into agriculture is key to preserving biodiversity and improving the state of the environment. Forest and forest-steppe agrolandscapes have demonstrated the greatest efficiency in species conservation. The study by J. Zhao *et al.* (2024) examines the impact of various agricultural practices on biodiversity in both agricultural lands and natural environments. The authors emphasise that intensive land use, accompanied by a high level of anthropogenic pressure, significantly reduces species diversity, while environmentally oriented approaches such as agroforestry, conservation of natural areas, and integration of natural elements into agricultural landscapes can minimise the negative impact. The paper offers a detailed analysis of adaptation strategies that contribute to maintaining ecological sustainability and creating favorable conditions for rare species in agricultural systems. The findings of J. Zhao *et al.* (2024) are in harmony with the conclusions of our study, which emphasizes the critical role of preserving natural elements in agricultural landscapes to ensure ecological sustainability.

The article by P. Batáry *et al.* (2020) provides an overview of the role of agrolandscapes in the conservation of biodiversity in agricultural areas. The authors emphasize the importance of a landscape approach to ensure environmental sustainability, which includes the integration of natural elements such as forest belts and perennial plantations into agricultural systems. The focus is on how different types of agricultural landscapes affect biodiversity, climate change resilience, and the provision of ecosystem services. The authors note that agricultural landscapes with a high level of natural integration, such as forest-steppe systems or lands with forest elements, are the most favorable for biodiversity conservation. They contribute to the formation of conditions for the existence of rare species, climate stabilization, regulation of water balance and reduction of erosion processes. The findings of P. Batáry *et al.* (2020) are consistent with the conclusions of our study, demonstrating the commonality of approaches to assessing the importance of agricultural landscapes for biodiversity conservation and environmental sustainability. Both studies emphasize the importance of integrating natural elements into agricultural systems, including the use of forest belts, perennial plantings, and other nature-based solutions that help reduce erosion, improve water quality, and maintain species diversity. Both studies also emphasize the role of biodiversity as a key factor in increasing the resilience of agricultural systems to climate change and anthropogenic impacts.

This issue was discussed in detail in by V.Š. Kremsa (2021), which emphasised the importance of sustainable resource management, which includes not only efficient land use, but also water conservation and maintenance of soil fertility. Such management is critical for ensuring long-term crop production that meets modern requirements for environmental safety and economic efficiency of the agricultural sector. The results highlight the need for active management of agrolandscapes to maintain environmental sustainability. This is consistent with the conclusions obtained by I. Soloviy *et al.* (2021), who states that integrating ecosystem services assessment into land use planning can be an effective tool for improving natural resource management. The researcher claims that the correct use of these services allows preventing negative consequences associated with anthropogenic impact. The developed model of environmental safety showed the importance of integrating natural and agricultural elements to increase the sustainability of agricultural systems. The results of the study confirmed the importance of agrolandscapes in ensuring environmental safety and their impact on biodiversity, soils, and water resources. This was confirmed by V. Belolipskyi and M. Poluliakh (2020), who analysed the ecological

efficiency of agrolandscapes, focusing on drainage systems. They pointed out that properly designed agrolandscapes can significantly reduce the risks of land degradation and increase their productivity, which is also consistent with the results of this study.

T.S. Priyadarshana *et al.* (2024) conducted a global review and meta-analysis of the impact of landscape and crop heterogeneity on biodiversity in agricultural regions. The study demonstrates that landscape and cultural diversity are key factors in biodiversity conservation, especially in the context of intensive agricultural land use. The authors emphasise that the creation of mosaic landscapes that combine natural elements such as forest strips, perennial plantations, and diverse crops significantly increases species diversity and ensures the stability of agroecosystems. An important finding is that species richness not only improves the resilience of agricultural systems to climate change, but also contributes to the provision of important ecosystem services.

The study also highlighted the importance of management practices in agriculture to reduce negative environmental impacts. For example, D. Ladychuk *et al.* (2021) pointed out the importance of determining the typicality of agrolandscapes for water supply design. This suggests that effective water management is critical to maintaining the sustainability of agrolandscapes. The results of the study emphasised that agrolandscapes with integrated natural elements play a key role in ensuring environmental safety. This is consistent with the conclusions of the study by L. Kuzmych (2024), which focused on the practices of sustainable soil and water management. The findings confirm that such practices increase the productivity of agricultural crops, preserve natural resources, and ensure environmental sustainability.

S. Tanchyk *et al.* (2024) discussed the concept of environmentally friendly agricultural systems in Ukraine, which confirms the results obtained in this study on the importance of ecological approaches to agricultural production. The introduction of such systems can become one of the key aspects of sustainable development of agricultural regions. The study by S.L. Cappelli *et al.* (2022) emphasizes the importance of plant biodiversity for sustainable agricultural development. It is noted that biodiversity contributes to increasing the productivity of agricultural systems by improving soil quality, regulating water balance, reducing erosion processes, and preserving ecosystem services. Particular attention is paid to underground processes that ensure the functionality of soil ecosystems and help maintain fertility in the long term. The study emphasizes that plant biodiversity contributes to the resilience of agricultural landscapes to climate change and anthropogenic impacts. The results of the study are consistent with the conclusions about the role of biodiversity in agricultural landscapes, which is reflected in the analysis of the impact of forest and forest-steppe systems on soil fertility and ecosystem stability. Data on the positive impact of nature-based practices, such as agroforestry and the use of perennial plants, confirm the importance of measures to reduce erosion and improve soil characteristics. The subsurface processes identified by S.L. Cappelli *et al.* (2022) are consistent with findings on the importance of water-holding elements and their role in soil moisture retention.

The role of fiscal instruments in the implementation of low-carbon agriculture, discussed by O. Butrym *et al.* (2023), is another important aspect that links economic and environmental goals. This can be useful in the context of developing policies that support agricultural enterprises that implement environmental practices. It also highlights the role of digitalisation in reducing the carbon footprint of agricultural production, which can be an important tool for optimising agrolandscapes (Butrym *et al.*, 2024). The integration of digital technologies into agricultural production can contribute to better monitoring and management of resources, which, in turn, will increase the resilience of agricultural systems to climate change. A. Silva-Caballero *et al.* (2024) pointed out the importance of agrolandscapes for the conservation of species such as the jaguar. This is consistent with the results of this study, which highlighted the role of agrolandscapes in preserving biodiversity, which is important for maintaining environmental safety.

The coordination of the findings with previous studies provides grounds for the assertion that the integration of natural and agricultural elements is an important condition for achieving sustainable development of agricultural regions. Further research may focus on implementing digital solutions in conventional agronomic practices, and monitoring the impact of technological innovations on the environmental safety of agrolandscapes. This will not only reduce the negative impact on the environment, but also ensure more efficient use of natural resources in agriculture.

CONCLUSIONS

The study confirmed the importance of agrolandscapes in ensuring environmental safety, finding that agrolandscapes with a high level of integration of natural and agricultural elements provide a significantly higher level of biodiversity than their less integrated counterparts. In particular, it was found that forest and forest-steppe agrolandscapes demonstrate the highest efficiency in species conservation, which emphasises their role in maintaining ecological balance. Quantitative indicators obtained as a result of the study indicate the need for urgent measures to improve the state of biodiversity in steppe and dry steppe agrolandscapes, which turned out to be the most vulnerable. As part of the analysis of ecosystem services, it was determined that the integration of natural ecosystems into agricultural practices can significantly reduce the

risks of soil erosion and improve water management, which, in turn, will have a positive impact on the productivity of agricultural systems. The results obtained confirm the hypothesis that effective management of agrolandscapes significantly reduces the negative impact on the environment. This is achieved, in particular, through the introduction of such innovative practices as agroforestry, which involves the integration of forest stands into agricultural systems and the creation of forest belts that serve as natural barriers. These measures not only help reduce soil erosion and improve water quality, but also ensure the adaptability of agricultural systems to climate change. Consequently, they play an important role in promoting the sustainable development of agricultural regions, which is critical in the context of global environmental challenges and the need for food security.

The recommendations resulting from the study include the active implementation of environmental approaches in support policies for agricultural enterprises, which can significantly contribute to the sustainable development of agriculture. This includes not only adapting existing programmes, but also developing new initiatives that focus on preserving natural resources and maintaining ecosystems. Another important aspect is the creation and implementation of monitoring systems for the state of agrolandscapes, which will facilitate timely detection of negative changes in the environment and take appropriate measures to neutralise them. One of the key areas of further research is the need to develop specific measures aimed at improving biodiversity in steppe and dry steppe regions. Since these areas have proven to be the least resilient to current environmental challenges, it is important to focus on studying the ecosystem processes occurring in these regions, and implementing practices that can contribute to the restoration and conservation of natural diversity. This includes not only agronomic practices, but also environmental initiatives that can be implemented at the local community level.

Limitations of the study associated with insufficient data for all agrolandscapes significantly complicate the possibility of generalising the results obtained to wider geographical areas. This can lead to underestimation or, conversely, exaggeration of the impact of agrolandscapes on environmental processes. In the future, it is important to expand the study to include additional analysis methods such as geographic information systems (GIS) and remote sensing, and to attract more regions with different climatic and environmental conditions. This would provide a more comprehensive and integrated understanding of the impact of agrolandscapes on environmental safety. As a result, such efforts will contribute to more effective adaptation of agrolandscape management practices to constantly changing conditions, ensuring the sustainability of agricultural systems and the conservation of natural resources.

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CONFLICT OF INTEREST

None.

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Агроландшафти та їх роль у забезпеченні екологічної безпеки

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Анотація. Мета дослідження полягала в глибокому аналізі ролі агроландшафтів у забезпеченні екологічної безпеки, а також у вивченні їхнього впливу на навколишнє середовище, з особливим акцентом на аспекти біорізноманіття, захисту ґрунтів і управління водними ресурсами. Дослідження охоплювало широкий спектр діяльності, включаючи збір та систематизацію наукових матеріалів, проведення порівняльного аналізу різних управлінських підходів, а також розробку теоретичної моделі екологічної безпеки, що дозволяє оцінити ефективність існуючих практик. Основні результати дослідження вказують на те, що агроландшафти, які характеризуються високим рівнем інтеграції природних елементів та сільськогосподарських компонентів, здатні забезпечувати значно вищий рівень біорізноманіття в порівнянні з менш інтегрованими аналогами. Зокрема, лісові та лісостепові агроландшафти виявилися найбільш ефективними у збереженні видів, що є критично важливим для підтримання екологічної рівноваги. Водночас, степові та сухостепові ландшафти потребують термінових і комплексних заходів для покращення стану біорізноманіття, оскільки їхня екологічна стійкість знаходиться під загрозою. Таким чином, результати дослідження підкреслюють необхідність впровадження інноваційних підходів до управління агроландшафтами, що можуть сприяти збереженню природних ресурсів та покращенню екологічної безпеки. Розроблена теоретична модель виявила, що найбільш стійкими є агроландшафти, де природні екосистеми гармонійно поєднані із сільськогосподарськими угіддями. Отримані результати підтвердили гіпотезу про те, що ефективне управління агроландшафтами сприяє підвищенню екологічної безпеки та зменшенню негативного впливу на довкілля, зокрема шляхом контролю ерозії та управління водними ресурсами. Висновки підкреслюють необхідність впровадження агролісомеліорації, підтримки екологічних підходів у політиках та системи моніторингу стану агроландшафтів для сталого розвитку аграрних регіонів, що дозволить адаптуватися до викликів зміни клімату

Ключові слова: екологічна безпека; біобезпека; безпека життєдіяльності; агроландшафти; обробіток ґрунту; удобрення