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Biological and Landscape Diversity Conservation as a Systemic Tool of Sustainable Development in the Context of European Environmental Policy

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The relevance of this study lies in the need to preserve biodiversity and enhance the effectiveness of environmental policy in the context of unprecedented climate change and continually changing anthropogenic pressures. The purpose of the study was to conduct a well-founded comparative analysis of the current state of biodiversity and protected areas, covering Ukraine, Azerbaijan, as well as the countries of the European Union, in particular Germany and France. To achieve this goal, an interdisciplinary approach was employed: a combination of statistical analysis, economic and mathematical modelling, correlation and regression analysis, as well as the use of forecasting tools to determine current development scenarios. It was found that in Ukraine, the area of the protected area fund remains significantly lower than average European standards, while in France and Germany, this indicator consistently exceeded 19% of the total area of the country. Obviously, targeted financing of nature conservation initiatives is a decisive factor that significantly stimulates the

expansion of protected areas, but uncontrolled urbanisation and high industrial loads have a clearly expressed negative correlation with the nature of the protected areas. Forecast models, calculated for the period 2025–2030, indicate an excessively complete, almost stagnant, increase in protected areas in both Ukraine and Azerbaijan, which is an alarming signal that clearly increases the current acceleration of the pace of fund expansion and deep integration of European strategies into the domestic nature conservation policy. The practical value of the study is explained by the fact that the recommendations and multi-criteria assessments provide an opportunity to increase the efficiency of management of existing protected areas, ensure the systematic development of a cellular ecological network, and contribute to the formation of a qualitatively new level of environmental awareness among a wide range of the population.

Keywords: nature conservation, ecosystem services, nature reserves, climate challenges, European integration, environmental management, economic and mathematical modelling, scenario analysis.

Introduction

Biological and landscape diversity conservation is a strategic challenge and a fundamental condition for achieving sustainable development goals. Biodiversity determines ecological balance, forms the basis of agricultural sector productivity, ensures the resilience of ecosystems to climate change, and creates opportunities for the development of tourism, recreation, and preservation of cultural heritage. Landscape diversity, in turn, is a material and spiritual resource that reflects the harmony of the interaction of nature and society, creates a living environment and determines the ecological quality of territories (Bhatia et al., 2023, Ma et al., 2021). That is why modern European environmental policy considers the protection and restoration of biodiversity as a systemic tool that combines environmental protection measures with economic development and social stability.

The relevance of the study is determined by global environmental changes, including the reduction of species populations, land degradation, urbanization pressure, and climate change. As a result, there is a gradual loss of unique natural complexes in Europe and adjacent regions, which negatively affects both natural ecosystems and the well-being of society, economic security and the quality of life of the population. In view of these challenges, the European Union (EU) in strategic documents, in particular the European Green Deal and the Biodiversity Strategy for 2030, emphasizes the need for an integrated nature protection policy. It provides for the development of the Natura 2000 network, the implementation of nature-based solutions, and strengthening international cooperation (Hogan et al., 2021; Fischer et al., 2021).

It is important to note that the problem of biological and landscape diversity conservation goes beyond the European context. Similar environmental challenges are observed in the Eastern Partnership countries, in particular in Azerbaijan: a decrease in populations of rare species, soil degradation, depletion of water resources. Therefore, there is a need to find common approaches to nature protection, harmonization of legislation, and integration with European environmental standards (Herrero-Jáuregui and Concepción, 2023).

Despite the difficult socio-economic situation and military challenges, Ukraine is gradually moving in this direction: it is implementing the principles of the European Ecological Network, expanding the nature reserve fund and adapting the national environmental policy to the requirements of the Association Agreement with the EU. The experience of individual countries of Central and Eastern Europe, which have gone from national programmes to European environmental strategies, can become an effective model for forming a biodiversity management system in the region.

The aim of the study is to assess the state of biodiversity and the protected areas in Ukraine, Azerbaijan, and some EU countries, as well as to develop recommendations for increasing the resilience of ecosystems and harmonizing national policy with European standards.

Research objectives:

1 Analyse the dynamics of the hectarage of the protected areas and the ecological network in Ukraine, Azerbaijan, Germany, and France for 2010–2024.

2 Assess the volume and effectiveness of measures for forest restoration, species reintroduction and ecosystem monitoring in four countries.

3 Identify the relationship between socio-economic factors and the state of the protected areas using correlation and multivariate regression analysis.
4 Predict the dynamics of the hectarage of the protected areas for 2025–2030 and assess the prospects for the development of the ecological network.

The academic novelty of the issue under research is the treatment of biological and landscape diversity not only as an object of protection, but also as a sustainable development tool that integrates environmental, social, and economic priorities.

The scientific novelty and original contribution of this work are expressed through the use of an integrated approach. That is, biological and landscape diversity are considered not just as an object that requires protection, but also as a full-fledged, effective tool for sustainable development, which successfully integrates critically important environmental, social and economic priorities. In addition, an equally important component is a quantitative assessment of how constantly changing socio-economic factors affect the current state of the nature reserve fund, to which is added a meticulous forecast of the further development of the ecological network, which covers both the territory of Ukraine and Azerbaijan, while a detailed comparative analysis is necessarily carried out against the background of the experience of the EU countries.

The hypothesis of the study is that the level of effectiveness of environmental protection policy and the sustainability of ecosystems directly depend on the scale of the nature reserve fund. An important factor is also the implementation of nature-oriented solutions and the harmonization of national practices with European standards.

Literature review

Existing ecological science and environmental practice emphasise the critical issue of preserving biological and landscape diversity, which is the basis of biosphere stability and sustainable development (Ombashi and Løvschal, 2022). Research shows that biodiversity plays the role of a kind of «cybernetic memory» of global ecosystems, ensuring their resilience and ability to adapt in response to change (Vakulyk, 2022; Rudyshyn, 2021). This idea is supported by empirical observations of large natural complexes in countries such as Canada (65% of preserved areas), Russia (41%), Australia (33%), Brazil (28%), China (20%) and Algeria (64%). These territories form a kind of «islands of stability», which serve as a potential basis for global ecological security.

Landscape strategy planning discusses the balance between cultural and natural landscapes. Rudyshyn (2023) suggests an optimal ratio of 62% cultural and 38% natural areas. However, reality often deviates from this model because of social, economic, and climatic factors. This requires adapting theoretical approaches to the conditions of specific regions.

Another area of research emphasises the threat of resource depletion for the natural self-renewal of the biosphere. In response, experts propose measures aimed at integrating human activity into natural cycles, limiting excessive use of resources and developing a culture of environmental responsibility (Špulerová et al., 2023; Terpay, 2021).

However, this approach partially underestimates the potential of natural ecosystems for self-regulation, especially where there is low human impact. The concept of the noosphere by V. Vernadsky, as described by Loreau et al. (2021), is considered an effective tool for adapting noospherogenesis to current environmental conditions. It allows the integration of academic knowledge with natural resource management and policy development (Chumachenko et al., 2022; Abbasov et al., 2023).

Analysis of national experiences shows that success in biodiversity conservation depends primarily on the scale of nature reserves and the level of integration of nature conservation solutions into the state development strategy (Fair et al., 2020). For example, the area of protected areas in Ukraine is only 7%, which is much less than the average European indicators. Meanwhile, Azerbaijan is actively expanding its nature reserves and working on the restoration of forest areas (Vakulyk, 2022; Rudyshyn, 2021). Therefore, there is an importance of harmonising theoretical models with state policy and the need to assess the effectiveness of implemented measures.

Thus, the literature review highlights two key approaches to understanding biodiversity conservation: 1) ensuring biological balance through the protection of natural areas; 2) integration of human activity into

natural processes. The above approaches complement each other, forming a methodological basis for analysing the dynamics of protected areas, assessing the impact of anthropogenic pressure, and predicting the development of the ecological network. All this is directly related to the main research hypothesis.

Methods

Research design

The research is based on an interdisciplinary approach that integrates environmental, legal, economic, and social aspects of sustainable development. The chosen design combines qualitative and quantitative methods, which provides a comprehensive assessment of the state of biological and landscape diversity, identification of trends in its transformation, and assessment of the effectiveness of political and management mechanisms in the field of environmental protection.

The methodology is based on a systems approach, according to which biodiversity and landscapes are considered as components of an open socio-ecological and economic system, interconnected with other areas of social development. In this context, attention is focused on global challenges: climate change, loss of ecosystem services and increasing anthropogenic pressure, which determines the need to harmonize national policy with the EU standards and strategic guidelines.

Research procedure

The research was conducted in several successive stages. *The first stage* involved a theoretical and methodological analysis of academic literature, as well as a study of international and national regulatory and legal documents regulating environmental and agricultural policy in Ukraine, Azerbaijan, and the EU countries. The next step was the collection of an information base for the study, which included statistical materials from international organizations such as Food and Agriculture Organization (FAO), Eurostat, Organisation for Economic Co-operation and Development (OECD), and the World Bank, as well as data from national statistical services. *At the second stage*, the collected information was systematized and subjected to quantitative and qualitative analysis in order to identify the main patterns and trends. *The third stage* involved the application of economic and mathematical methods to model the impact of key socio-economic factors on the state and dynamics of the preservation of biological and landscape diversity. *The fourth stage* was a comparative analysis of Ukraine, Azerbaijan, and the EU countries in the context of European environmental policy. *The final stage* was the provision of practical recommendations for improving mechanisms for protecting biological and landscape diversity in connection with European environmental strategies and sustainable development principles.

Research sample

The research sample was based on statistics for 2010–2024, which ensured representativeness and made it possible to trace the dynamics of changes in the long run. The main sources were official data from national statistical agencies in the field of environmental protection and natural resource management of Ukraine, Azerbaijan, Germany, and France, as well as international databases of FAO, Eurostat, and the World Bank, which allowed integrating national characteristics into a broader European and global context. In addition to quantitative indicators, the sample included programme and strategic documents, in particular the European Green Deal, the EU Biodiversity Strategy for 2030, the Concept of Environmental Policy of Ukraine, and the Strategy of Environmental Security and Adaptation to Climate Change of Azerbaijan. This approach made it possible to comprehensively assess the relationship between economic development and environmental security in different countries, compare their results and outline the directions of integration in the field of sustainable development.

Research methods

The research employed a combination of general scientific, statistical, comparative, econometric, and geoinformation approaches. The methods of analysis, synthesis, induction, deduction, and generalization ensured the formation of a holistic conceptual basis for the study. *Statistical analysis* was used to assess the dynamics of changes in biological and landscape diversity, determine the scale of ecosystem degradation, and also assess the level of funding for environmental protection programmes. Time series, averages, coefficients of variation, and other descriptive statistical indicators were used to quantify trends and assess the effectiveness of existing measures.

The comparative analysis was carried out to identify similarities and differences in the approaches of Ukraine, Azerbaijan, and EU countries (Germany and France) to the environmental policy implementation. The analysis included a comparison of reserve indicators, financing of nature protection, legislative framework, and structural mechanisms for natural resource management. Geographic information systems (GIS) were used for spatial analysis of landscape diversity and identification of changes in the territorial structure of ecosystems. Digital maps, satellite images and remote sensing were used to model spatial patterns, zone ecologically important areas, and assess anthropogenic impact on natural landscapes. Correlation and regression analysis was used to identify relationships between socio-economic factors (investments in environmental protection measures, level of urbanization, demographic indicators) and the state of the environment (biodiversity indicators, areas of degraded areas, level of reserve).

Scenario modelling was used to predict potential trajectories of environmental policy development in the face of increasing climate and anthropogenic challenges. Alternative scenarios were developed based on variable demographic, economic, and natural parameters, which made it possible to assess the likely consequences of political decisions and choose optimal environmental management strategies.

The method of *economic and mathematical modelling* was the key tool for quantitative assessment, which made it possible to determine the nature and strength of the impact of the main socio-economic factors on the state of biological and landscape diversity. The analysis took into account the level of funding for environmental protection programmes, land use intensity, the scale of urbanization, the volume of industrial load, and indicators of ecosystem degradation. A multifactor regression model was used for this purpose to quantitatively assess the contribution of each factor to changes in the state of biodiversity. The model was defined as:

$$NRF = \beta 0 + \beta 1 \cdot Funding + \beta 2 \cdot Lands + \\ + \beta 3 \cdot Urbanization + \beta 4 \cdot Industry + \beta 5 \cdot \\ \cdot Degradation + \varepsilon \quad (1)$$

where β0 – model constant, β1...β5 – coefficients of influence of the corresponding factors, and ε – random error reflecting the influence of unaccounted variables.

Econometric analysis of time series was also used to trace long-term trends and predict potential scenarios for the development of environmental policy and the state of ecosystems under increased anthropogenic and climatic pressure.

Variable selection approach and statistical limitations

To build a multivariate regression model, we approached the selection of variables based on two key pillars: first, their proven theoretical significance, and second, their impact on the state of the nature reserve fund. Among the most significant ones that were directly included in the analysis, it is worth highlighting the following indicators: the amount of funding for environmental initiatives, the actual intensity of land use, the general level of urbanization of the region, the scale of industrial load, as well as indicators reflecting the degree of ecosystem degradation.

At the same time, one of the strict selection criteria was the need to have reliable and comparable time series of data for all countries studied, covering the period from 2010 to 2024, as well as a real opportunity to quantitatively assess their interdependence with the target indicators of protected areas.

It should be recognized that any model that tries to cover such complex ecological processes inevitably faces a number of potential statistical obstacles. The main limitations that may affect the results of this study are the danger of multicollinearity between individual variables and the influence of external factors, such as sudden and rapid climate shocks or large-scale socio-economic crises, which are physically impossible to fully account for within the available data.

Instruments

The study used comprehensive software for statistical, spatial, and econometric analysis. Statistical analysis, as well as correlation and regression analysis was performed using R (version 4.3.2) with the tidyverse, forecast, and lmtest packages. Large-scale data processing and scenario modelling were performed in Python (version 3.12) using the pandas, numpy, matplotlib, seaborn, statsmodels, and scikit-learn libraries. Spatial analysis and geoinformation modelling of landscape diversity were implemented in QGIS (version 3.38) and ArcGIS (version 10.9) for assessing anthropogenic

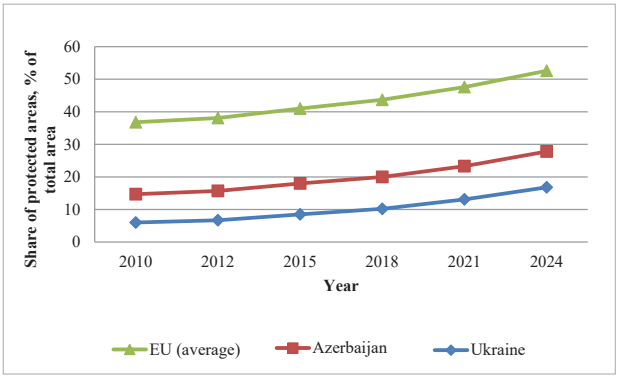
impact and creating thematic maps. Primary data processing and tabulation were performed in Microsoft Excel (version 2021), which ensured data integration into statistical and spatial models. The use of these tools made it possible to comprehensively assess the state of biological and landscape diversity, track the dynamics of ecosystem changes, and predict the effectiveness of political and management decisions in the field of environmental protection.

Results and Discussion

Quantitative indicators were used to assess the state of biodiversity. The area of the NRF (Nature Reserve Fund), the share of territories preserved in a natural state, as well as the ecosystem degradation level were among the key ones. Such parameters were used to determine how effectively a country or region supports ecological stability and what measures need to be implemented to increase it. In 2023, the hectarage of the protected areas of Ukraine was about 7% of the territory, which is significantly lower than the average European indicator (18–20%) and emphasizes the need to strengthen environmental protection policy and implement European practices.

This indicator was higher in Azerbaijan – about 11%, which indicates progress in the development of the national nature protection system, but remains below average European standards (*Fig. 1*).

Fig. 1. *Dynamics of the share of terrestrial protected areas, 2010–2024*



Source: Source: developed by the authors based on Eurostat (n.d.), State Statistical Committee of the Republic of Azerbaijan (n. d.), Ukrstat (n. d.).

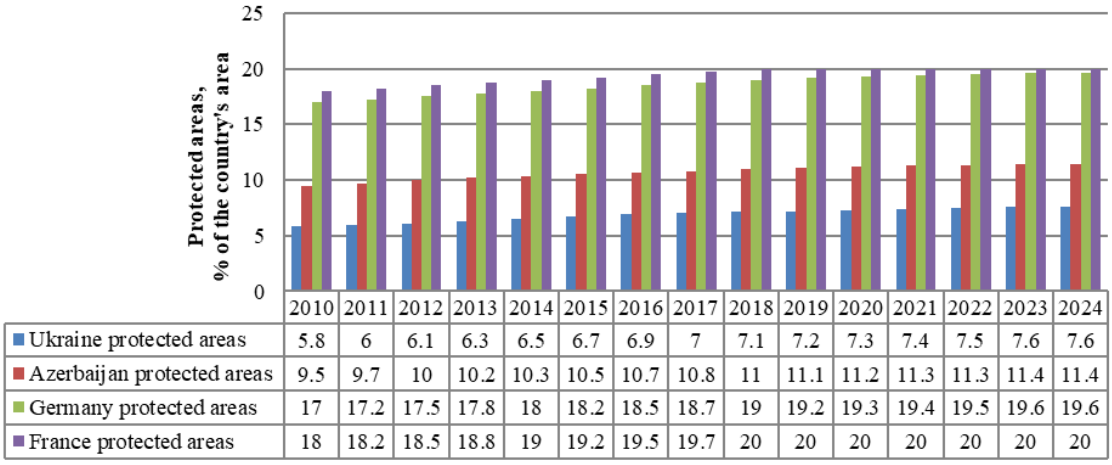
Analysis of the dynamics of the hectarage of the protected areas in Ukraine, Azerbaijan, Germany, and France for 2010–2024 revealed a steady growth trend, while the pace and levels of development differ between countries. In Ukraine, the share of the NRF in 2010 was 5.8%, and by 2024 it gradually increased to 7.6%. This indicates a gradual but stable increase in protected areas. Azerbaijan demonstrates a slightly higher level – from 9.5% in 2010 to 11.4% in 2024, maintaining stable annual growth. Germany and France demonstrate significantly higher indicators of the NRF: in Germany the area increased from 17% to 19.6%, and in France – from 18% to 20%, with stable growth in France since 2018, which indicates an optimal level of protection and effective management of natural areas (*Fig. 2*).

The data show that Ukraine, despite the lower absolute level of NRF, demonstrates consistent progress, while Western European countries have already achieved high and stable development of the nature reserve network.

The above general indicators enable moving on to a more detailed analysis of specific tools and mechanisms through which nature conservation is implemented. In Ukraine and Azerbaijan, the principles of balanced territorial planning have already been partially implemented through the development of national parks, biosphere reserves, and agro-landscape zones. For example, in 2024, the total area of national parks in Ukraine was about 900 thousand hectares, and biosphere reserves – 1100 thousand hectares. Despite the creation of an ecological network, its coverage remains relatively low and is estimated at approximately 7% of the country's territory.

In Azerbaijan, similar measures allowed increasing the area of national parks to 1200 thousand hectares, and biosphere reserves – to 1400 thousand hectares, which provided a slightly higher indicator of the ecological network – about 11%. Therefore, it is possible to outline active work on the integration of national environmental policy into European standards, although there is a gap with EU countries, where the coverage of protected areas is much higher. In particular, in Germany, the area of national parks reaches 3000 thousand hectares, biosphere reserves – 4500 thousand hectares, and the ecological network covers about 19% of the territory. In France, national parks occupy 3500 thousand hectares, biosphere reserves – 5000 thousand hectares, and the ecological network covers 20% of the territory (*Table 1*).

Fig. 2. *Dynamics of the hectarage of the protected areas and the ecological network*



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Ukraine protected areas	5.8	6	6.1	6.3	6.5	6.7	6.9	7	7.1	7.2	7.3	7.4	7.5	7.6	7.6
Azerbaijan protected areas	9.5	9.7	10	10.2	10.3	10.5	10.7	10.8	11	11.1	11.2	11.3	11.3	11.4	11.4
Germany protected areas	17	17.2	17.5	17.8	18	18.2	18.5	18.7	19	19.2	19.3	19.4	19.5	19.6	19.6
France protected areas	18	18.2	18.5	18.8	19	19.2	19.5	19.7	20	20	20	20	20	20	20

Source: developed by the authors based on EC (n.d.), MEPNR (n.d.), State Committee on Ecology and Natural Resources of the Republic of Azerbaijan (n. d.).

Table 1. *Dynamics of development of protected areas and ecological networks*

Country	Area of national parks (thousand hectares)	Area of biosphere reserves (thousand hectares)	Econet-work (%)
Ukraine	900	1100	7
Azerbaijan	1200	1400	11
Germany	3000	4500	19
France	3500	5000	20

Source: developed by the authors based on Eurostat (n.d.), State Statistical Committee of the Republic of Azerbaijan (n. d.), Ukrstat (n. d.).

The presented data indicate that the basic principles of forming balanced landscapes and ecological networks in Ukraine and Azerbaijan are being implemented, but there is significant room for improving the effectiveness of environmental protection activities and approaching European standards. Achieving higher ecological network indicators requires not only expanding the areas of nature reserves, but also developing monitoring mechanisms, supporting biodiversity, and integrating environmental protection measures into socio-economic strategies. Particular attention should be paid to the implementation of comprehensive measures to preserve biodiversity, similar to the practices of EU countries under the Natura 2000 system, which unites protected areas to maintain the species composition of flora and fauna and ensure the integrity of ecosystems.

Ukraine and Azerbaijan are gradually integrating similar practices through international programs, in particular with the support of the United Nations Development Programme (UNDP), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), as well as within the framework of bilateral projects with EU countries.

It is worth noting that about 250 thousand hectares of forest areas were restored in Ukraine, 15 species were reintroduced, and monitoring covered 50 sites during 2010–2024. In Azerbaijan, the volume of work was somewhat larger: 300 thousand hectares of forest were restored, 20 reintroductions were carried out, and monitoring covered 60 sites. In Germany, 400 thousand hectares of forest were restored, 25 reintroductions were carried out, and 80 sites were monitored, while in France the corresponding figures are 450 thousand hectares, 30 reintroductions, and 90 monitoring sites (*Table 2*).

Effective management of natural resources and conservation of biodiversity affects not only environmental stability, but also the economic and social sustainability of the state. Biodiversity conservation directly contributes to economic stability by supporting key sectors such as agriculture, tourism, and forestry. Healthy

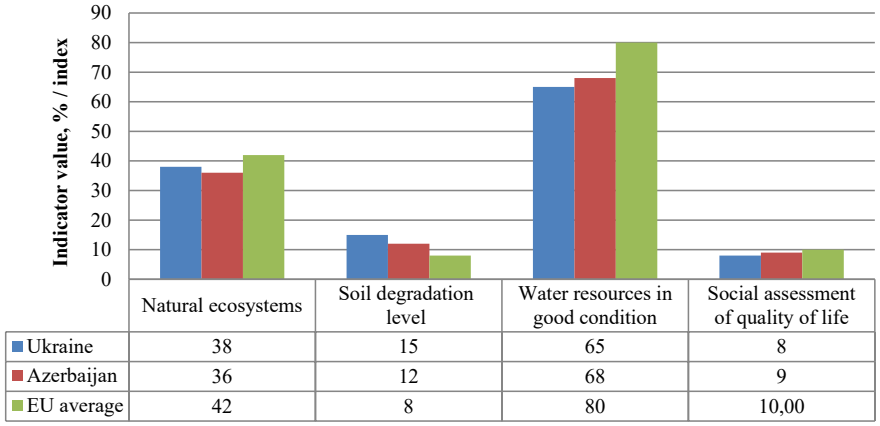
ecosystems provide soil fertility, water supply and resources for recreational activities, which creates additional economic value and increases the competitiveness of national economies. Ecological sustainability is ensured by reducing soil degradation, conserving water resources and adapting to climate change, which reduces the risks of natural disasters and losses in agriculture. Social sustainability is implemented by improving the quality of life of the population, developing educational programmes ton environmental literacy, preserving cultural values and forming responsible environmental behaviour of citizens (*Fig. 3*).

Table 2. Main types of biodiversity conservation measures (2010–2024)

Country	Forest restoration (thousand hectares)	Species reintroduction	Ecosystem monitoring
Ukraine	250	15	50
Azerbaijan	300	20	60
Germany	400	25	80
France	450	30	90

Source: developed by the authors based on EC (n.d.), MEPNR (n.d.), State Committee on Ecology and Natural Resources of the Republic of Azerbaijan (n. d.).

Fig. 3. *The relationship between biodiversity protection and sustainable development indicators*



Source: developed by the authors EC (n.d.), MEPNR (n.d.), State Committee on Ecology and Natural Resources of the Republic of Azerbaijan (n. d.).

Given the above results on the dynamics of the hectarage of the protected areas and the main biodiversity conservation activities, the next step is to quantitatively assess the relationship between socio-economic factors and the state of protected areas. Such an analysis determines which economic and management factors have the greatest impact on the effectiveness of biodiversity conservation and where there is potential for improving the effectiveness of environmental policy. For this purpose, a correlation analysis of the main variables characterizing the socio-economic development of countries and the hectarage of the protected areas was conducted. The results (*Table 3*) demonstrate a clear interdependence between socio-economic factors and the state of the protected areas in four countries.

Table 3. Correlations between socio-economic factors and NRF

Variables	Ukraine	Azerbaijan	Germany	France
Financing of environmental protection programmes	0.98	0.97	0.99	0.99
Land use intensity	–0.92	–0.90	–0.88	–0.85
Urbanization	–0.85	–0.82	–0.80	–0.78
Industrial load	–0.88	–0.86	–0.83	–0.81
Ecosystem degradation	–0.95	–0.94	–0.91	–0.90

Source: developed by the authors.

The greatest positive interdependence is noted for the financing of nature conservation programmes: this indicator ranges from 0.97 to 0.99 in all countries. At the same time, land use intensity, urbanization level and industrial load have a noticeable negative impact on the area of NRF. These negative correlations are somewhat stronger in Ukraine and Azerbaijan than in Germany and France. This reflects the greater pressure of anthropogenic processes in the countries of Eastern Europe and the Caucasus, while more effective regulatory mechanisms in the EU countries reduce the harmful effect of these factors. Ecosystem degradation is still the strongest limiting factor, especially in Ukraine and Azerbaijan, where its correlation with the hectarage of protected areas reaches of –0.94 to –0.95.

This indicator is somewhat lower in Germany and France, which indicates a more stable state of natural environments and the effectiveness of biodiversity protection activities. Overall, the obtained data confirm that supporting the financing of environmental protection programmes is critically important. Control over intensive land use, urbanization and industrial impact can significantly reduce the risks of ecosystem degradation and preserve biodiversity.

The results of the multivariate regression (*Table 4*) give grounds to assess in more detail the contribution of individual socio-economic factors to the change in the hectarage of protected areas in each of the four countries. The model constant, which ranges from 2.1 in Ukraine to 3.2 in France, reflects the baseline level of protected areas in the absence of the influence of other factors. Positive financing coefficients indicate that investments in nature conservation programmes directly increase the hectarage of protected areas, with the strongest effect observed in Germany (0.035) and France (0.034). This is consistent with the high effectiveness of environmental programmes in the EU countries. Negative β values for land use intensity, urbanization, and industry confirm that these factors constrain the development of protected areas. The most significant negative impact is exerted by industry, especially in Ukraine (–0.06) and Azerbaijan (–0.055), which indicates a high anthropogenic pressure on ecosystems in these countries. This effect is somewhat mitigated in Germany and France, which reflects effective mechanisms for regulating industrial impact and the integration of environmental protection measures into public policy.

Table 4. *Multivariate regression*

Variable	Ukraine β	Azerbaijan β	Germany β	France β
Constant β0	2.1	2.5	3.0	3.2
Financing	0.03	0.028	0.035	0.034
Land	–0.05	–0.045	–0.04	–0.038
Urbanization	–0.04	–0.038	–0.035	–0.033
Industry	–0.06	–0.055	–0.05	–0.048

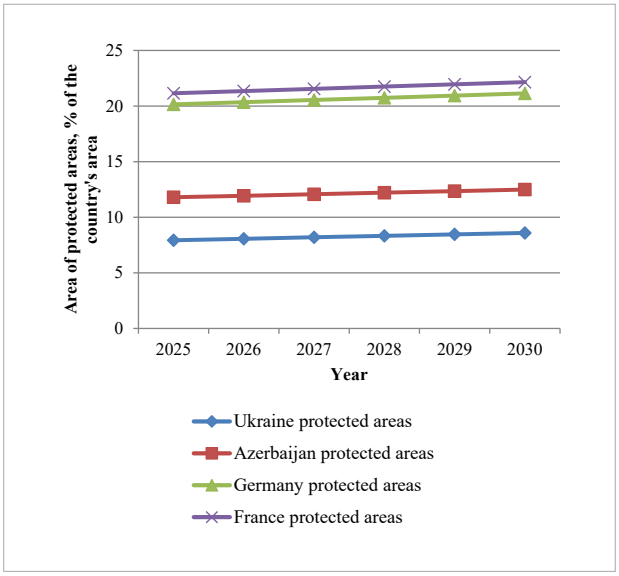
Source: developed by the authors

The obtained multifactor models and the dynamics of the protected areas for 2010–2024 were the basis for making a forecast for 2025–2030 using the linear extrapolation method (*Fig. 4*). The forecast data indicate a gradual increase in the hectarage of the protected areas in all four countries, which reflects a stable trend of strengthening environmental protection activities and the implementation of environmental programmes. The forecast for 2025–2030 predicts an increase in the protected areas in Ukraine from 7.93% to 8.59%, which indicates a gradual but slow increase in protected areas and emphasizes the need to accelerate the integration of national environmental policy with European standards. In Azerbaijan, the protected areas are predicted at 11.8–12.49%, which reflects a stable expansion of the ecological network, but the indicator remains lower than the European average.

In Germany and France, the expected growth to 21.14% and 22.15%, respectively, reflects the high effectiveness of national environmental policies and long-term experience in implementing environmental protection measures. The gradual growth in these countries demonstrates not only a steady expansion of protected areas, but also the support of already existing ecosystems through systematic monitoring and resource management.

Having considered the current state of biodiversity protection and a comparative analysis of practices, it becomes obvious that there is a need for systematic improvement of national policy in this area. First of all, achieving European standards requires a significant expansion of the hectarage of protected areas. In Ukraine and Azerbaijan, 7% and 11% of the state territory are currently protected, respectively, which is significantly below the average European indicator of 18–20%.

Fig. 4. *Forecast of the dynamics of the hectarage of the protected areas for 2025–2030*



Source: developed by the authors.

To get closer to European practices, it is appropriate to set target indicators of 15% for Ukraine and 14% for Azerbaijan. This approach will allow creating a sufficient number of "islands of stability" to support ecosystems and preserve the genetic diversity of flora and fauna.

One of the key steps is to create a network of national and regional biodiversity monitoring centres integrated into the European data exchange system. As a result, it will be possible to monitor the state of ecosystems in real time, respond more effectively to degradation processes, and evaluate the results of natural landscape restoration programmes. Along with the expansion of the protected areas and the development of monitoring infrastructure, it is important to implement the golden proportion concept, which provides for a ratio of 62% of cultural and 38% of natural landscapes. Such a balance ensures a harmonious combination of economic activity with the protection of natural resources and contributes to the sustainable development of territories.

International cooperation is another effective mechanism for increasing the effectiveness of environmental protection measures. Programmes for the restoration of species, the reintroduction of flora and fauna, and the restoration of degraded landscapes, implemented with the participation of the EU, allow for the exchange of knowledge, technologies and methods for assessing the state of ecosystems.

An equally important aspect is educational activities and the establishment of an ecological culture among the population. Educational programmes, public initiatives, and information campaigns contribute to raising public awareness of the value of biodiversity and the need for its conservation, forming a socially responsible attitude towards the environment (*Table 5*).

So, the comprehensive implementation of the proposed measures will allow Ukraine and Azerbaijan to approach European standards for biodiversity conservation, ensure the sustainability of ecosystems, and create the prerequisites for a harmonious combination

Table 5. *Proposals for improving biodiversity conservation policy*

Direction of improvement	Ukraine	Azerbaijan	Expected effect
Expansion of the hectarage of the protected areas	15% of the territory	14% of the territory	Increase in "islands of stability", support of genetic diversity
Network of national and regional monitoring centres	Establishment of 5 national centres + regional branches	Establishment of 4 national centres + regional branches	Monitoring the state of ecosystems, assessing the effectiveness of measures
Balanced ratio of cultural and natural landscapes	62% / 38%	62% / 38%	Harmonization of economic activity and nature protection
International cooperation with the EU	Participation in species and landscape restoration programmes	Participation in species and landscape restoration programmes	Exchange of experience, technologies, increasing the effectiveness of measures
Education and educational programmes	Implementation of educational and public initiatives	Implementation of educational and public initiatives	Raising environmental awareness of the population and forming a culture of responsible nature management

Source: developed by the authors

of economic development, nature protection, and social stability.

The study clearly demonstrated that both in Ukraine and Azerbaijan, biodiversity status indicators and the level of integration of national ecological networks are significantly inferior to average European standards. As for the key contribution, it comes down to a comprehensive assessment of how socio-economic factors correlate with the status of the nature reserve fund, as well as to identifying those critical constraints that reduce the overall effectiveness of all nature conservation initiatives.

The analysis conducted irrefutably proves the importance of financing nature conservation programs, as this directly correlates with an increase in the area of protected areas. In contrast, factors such as ongoing ecosystem degradation, intensive urbanization, and significant industrial load systematically undermine the overall effectiveness of environmental protection measures. Such patterns are fully consistent with the studies of Addy and Wilkinson (2021), which emphasized the fundamental importance of the size of protected areas for ensuring the stability of both agriculture and forestry. Furthermore, they confirm the work of Atkinson et al. (2022), who established a direct link between ecosystem degradation and a significant decline in water productivity and biodiversity.

Equally important is the social dimension: Bradbury's et al. (2021) observations on the need for active public involvement in environmental initiatives and the importance of quality environmental education fully confirm this aspect of sustainable development.

It should be added that a balanced ratio of cultural and natural landscapes is one of the cornerstones of this system. Correia and Lopes (2023) argue that only an optimally adjusted proportion guarantees long-term ecosystem stability. Markl et al. (2022) emphasize the urgent need for an integrated approach to planning ecological networks, while the critical importance of public and international investments for ecosystem stabilization is confirmed by Wang et al. (2021) and Nakamura et al. (2020).

It is noteworthy that in the countries of the EU, programs function effectively due to the close integration of financial flows directly into overall sustainable development strategies (Girardin et al., 2021; Gonzalez et al., 2020). And Genung et al. (2020) and Hermoso et al. (2021), clearly confirm the detrimental impact of intensive land use and urbanization processes on the functional integrity of natural systems.

At the same time, Radulescu et al. (2025) note that effective regulatory mechanisms and thoughtful planning of ecological networks in countries such as Germany and France can significantly mitigate the impact of these destructive factors. However, according to the predictive modeling conducted by Mori et al. (2021), Ukraine, unfortunately, has a chance to achieve only 8.6% of protected areas by 2030, and this is a very clear signal that requires the immediate implementation of a truly integrated approach.

According to Soininen et al. (2023), the introduction and integration of international experience, especially practices similar to the European Natura 2000 network, provides an opportunity to significantly accelerate restoration processes in ecosystems and, no less importantly, significantly optimize the use of available natural resources.

So, in summary, the original value of the research is precisely that it systematically combines a thorough quantitative analysis, high-precision predictive modeling and absolutely specific practical recommendations aimed at integrating European environmental standards directly into national policies. Such an approach allows us to clearly identify priority areas that will ensure a significant increase in the effectiveness of environmental protection activities in the future.

The results of the study confirm the initial hypothesis that the state of biodiversity and the development of eco-networks in the countries of Eastern Europe and the Caucasus lag significantly behind the average European indicators. The integration of environmental protection measures into socio-economic policies is a key factor in increasing the efficiency of natural resource management.

Correlation and predictive analysis indicates a direct relationship between the financing of environmental protection programmes, the scale of urbanization and the intensity of land use with the level of protected areas and biodiversity conservation. At the same time, the experience of Germany and France demonstrates that systematic planning of eco-networks, the integration of environmental protection measures into national strategies, and the active participation of communities ensure the sustainability and stability of natural systems.

The practical use of the results is the possibility of developing strategic recommendations to increase the efficiency of environmental protection policies in Ukraine and Azerbaijan. Such measures include expanding the hectarage of protected areas, implementing systematic biodiversity monitoring, integrating conservation measures into socio-economic development plans of regions, as well as actively involving international experience and participating in programmes similar to Natura 2000. The proposed measures will not only bring national indicators closer to average European standards, but also ensure the long-term environmental, economic, and social sustainability of the state.

Limitations

The study, despite its contribution, has a number of significant limitations. Although the use of a multivariate regression model is a valuable tool that allows for a fairly accurate assessment of the relationships between numerous socio-economic factors and the general state of the nature reserve fund, it is not able to definitively establish direct cause-and-effect relationships. In addition, the model may be extremely sensitive to the phenomena of multicollinearity and the influence of unaccounted for, hidden variables.

The statistical data set used, which covers the period from 2010 to 2024, may not reflect the latest developments that have occurred both in environmental policy and in the dynamics of the state of ecosystems themselves or in the process of integrating the latest international environmental programs. A critical limitation is also the partial and often fragmented availability of information on local monitoring, especially regarding the actual anthropogenic load, which inevitably reduces the accuracy of assessing the effectiveness of the environmental measures taken.

As for forecast scenarios, they are traditionally based on mechanical extrapolation of observed trends and only a limited, fixed set of factors, so actual results may differ from those expected. Such a divergence may be triggered by unpredictable macro-political, abrupt economic or global environmental changes, as well as by sudden climatic shocks, a series of extreme natural disasters or other unexpected crisis situations.

Recommendations

Gradual increase in the hectarage of protected areas to target values (Ukraine – 15%, Azerbaijan – 14%) with priority for areas with high biodiversity. Development of monitoring infrastructure – creation of national and regional biodiversity monitoring centres with integration into international data exchange systems. Strengthening financing of environmental protection programmes – increased investment in forest restoration, species reintroduction, control of ecosystem degradation and support for academic research.

Conclusions

The study revealed discrepancies in the dynamics of the development of the nature reserve fund between Ukraine, Azerbaijan and two key countries of the EU: Germany and France. Over the period 2010–2024, the area of protected areas in Ukraine increased only from 6.2% to 7.8%. In Azerbaijan, this figure is somewhat higher – a jump from 10.2% to 11.7%. In contrast, Germany and France demonstrate truly high efficiency of national environmental policies and systematic management of natural resources, as their indicators have long crossed the 19% and 20% marks, respectively.

Regression analysis confirmed the fundamental role of targeted financing of nature protection programs in the expansion of protected areas. At the same time, there is a completely expected negative impact of urbanisation, overly intensive land use and industrial load, which is especially noticeable in countries with economies in transition. According to the forecast, by 2025–2030, Ukraine will reach only 8.6% of the nature reserve fund, Azerbaijan – 12.5%, while Germany and France will already have more than 21%, although these results are certainly still far from the international target of 30%.

The data obtained serve as the basis for the formation of a number of practical recommendations. In particular, at the national level, it is necessary to increase funding for nature conservation programs, integrating these measures directly into state strategies for socio-economic development. It is important to introduce systematic planning of ecological networks, which will be accompanied by regular monitoring of the state of biodiversity. In addition, the introduction of «green» technologies and more rational land use should be actively stimulated. And at the regional level, a key step

will be to strengthen the involvement of local communities in nature conservation initiatives, increase the general level of environmental awareness and mandatory implementation of best international practices, in particular, the adaptation of Natura2000 network practices.

Only through the implementation of these measures will it be possible to significantly reduce the existing gap with the EU countries, increasing not only the effectiveness of preserving biological but also landscape diversity, which will ensure long-term ecological, economic and social stability. Further scientific research should focus on a careful assessment of the effectiveness of policies at the local level, as well as on studying the impact of new socio-economic and climatic factors. Undoubtedly, it is necessary to model scenarios for the development of ecological networks, taking into account unpredictable external conditions.

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