

UDC 630.1.630.5

DOI: 10.31548/forest/1.2024.72

The influence of agroforestry on the formation of the structure of forest ecosystems

Iryna Myskovets*

PhD in Geographical Sciences, Associate Professor
Lutsk National Technical University
43018, 75 Lvivska Str., Lutsk, Ukraine
<https://orcid.org/0000-0001-9248-4919>

Yurii Shymchuk

Assistant
Lutsk National Technical University
43018, 75 Lvivska Str., Lutsk, Ukraine
<https://orcid.org/0000-0002-4130-046X>

Rysbek Nurgaziev

Doctor of Veterinary Sciences, Professor
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Srt., Bishkek, Kyrgyz Republic
<https://orcid.org/0000-0003-1376-6921>

Uranbek Shergaziev

Doctor of Agricultural Sciences, Professor
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Srt., Bishkek, Kyrgyz Republic
<https://orcid.org/0000-0002-4203-4060>

Musakun Akhmatbekov

Doctor of Agricultural Sciences, Professor
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Srt., Bishkek, Kyrgyz Republic
<https://orcid.org/0000-0003-1075-3551>

Suggested Citation:

Myskovets, I., Shymchuk, Yu., Nurgaziev, R., Shergaziev, U., & Akhmatbekov, M. (2024). The influence of agroforestry on the formation of the structure of forest ecosystems. *Ukrainian Journal of Forest and Wood Science*, 14(4), 72-88. doi: 10.31548/forest/1.2024.72.

*Corresponding author



Abstract. The functional load of forests necessitates the activation of meliorative measures to optimize the functioning of agrolandscape complexes. These measures contribute to improving the environmental situation and advancing towards sustainable functioning of forest ecosystems. Therefore, the study of the structural and species formation of forest ecosystems is of significant scientific interest. The aim of the article was to analyse the impact of agroforestry measures on the process of forming the structure of forest ecosystems through a comprehensive examination of interrelationships. The research utilized general scientific methods, including specification, deduction, systemic analysis, synthesis, and abstraction, as well as formalization. During the study, vectors of organizing optimized systems of protective forest plantations were analysed, and environmental protection priorities for the development of agroforestry ecosystems were substantiated. Basic principles of managing the agroforestry complex based on sustainable land use were identified, including a comprehensive approach, ecologization of the process, and continuous monitoring. The study revealed current ecological consequences of irrational melioration for forest plantations, such as increased erosion processes and land resource degradation. Risks and challenges requiring preventive solutions were identified. It was proven that increasing the share of agroforestry plantations would allow optimizing the environmental situation in Ukraine, promoting the regeneration of the natural resource base, restoring landscapes, and minimizing land resource degradation processes. The article proposed key measures to optimize the environmental situation at the local level of forest ecosystems, as well as preventive measures to prevent destructive impacts, including the improvement of legal support and the implementation of strict measures of responsibility for irrational resource use. The value of the conclusions lies in their practical application for monitoring the state and the process of forming the structure of forest ecosystems under the influence of agroforestry measures. They also contribute to the effective development of preventive and regenerative protective measures and the formation of balanced forest ecosystems

Keywords: protective plantations; erosion processes; monitoring; zoning; potential risks; assortment of woody plants

Introduction

The actualization of environmental issues in the functioning of modern agrolandscapes is primarily attributed to the irrational use of land, which does not ensure adherence to optimal ecological parameters for territory functioning. Protective forest plantations (PFPs) are positioned as a fundamental component of agroforestry ecosystems and, therefore, require proper attention to the identification and implementation of landscape-ecological principles in their formation. The system of measures for forest melioration in agrolandscape complexes should ensure the optimization of

the regional environmental situation while simultaneously guaranteeing the development towards sustainable agricultural functioning. It can be argued that the agroforestry complex operating in Ukraine is identified as insufficiently effective. According to official data, soil erosion phenomena lead to significant annual losses amounting to 9 billion UAH (Furdychko & Tymochko, 2020).

The issues of agroforestry and its correlation with the structural features of forest plantations have become the subject of scientific research by several Ukrainian scientists. Some

experts argue that forestry should be identified as part of a large multifunctional system of comprehensive natural resource use and reproduction, requiring the application of a principle of comprehensive research (Skliar *et al.*, 2019). For instance, the position of I. Koval (2023) convincingly illustrates the inefficiency of organizing forestry management, leading to the irrational use of natural and economic resources, lack of investments, and loss of development prospects. At the same time, S.M. Abu Dib (2022) advocates for the need to update an innovative position for adjusting the species composition of forest ecosystems based on the principles of sustainable resource use, landscape preservation, and mitigation of destructive consequences of excessive anthropogenic pressure.

Recent works by researchers S. Amons & O. Krasnyak (2023) emphasize that systems of special protective forest plantations have a significantly more positive impact on the ecological condition in agroecosystems compared to individually formed forest belts. H.I. Kravchuk & A.I. Hutsol (2019) consider the conceptual principles of optimizing PFP systems in agrolandscape complexes, focusing on increasing the quantitative and qualitative indicators of protective forest cover on agricultural territories, which will significantly enhance the ecological functionality of PFPs.

Ukrainian scientists O.A. Bida *et al.* (2022) argue for the urgent need for institutional changes and adaptation of the existing regulatory framework to current sustainable development requirements. According to these scientists, implementing such conceptual prerequisites will ensure the optimization of forest ecosystem areas based on a functional-zonal principle and become an ecological foundation for further sustainable development of agrolandscapes. Researchers O. Savchuk & A. Liubchych (2019) highlight aspects of

compliance between the application of the resource potential of forest plantations and their extended regeneration. They see the introduction of an integrated forest management system as a priority. According to them, it is necessary to designate protected areas of a known area where ecological processes can occur naturally without being restricted by anthropogenic factors. At the same time, scientists propose transforming the forestry sector, prioritizing the satisfaction of the needs of the natural environment in areas related to agrolandscapes.

Most Ukrainian scientists agree on the priority of issues related to protecting agrolandscapes from pollution and degradation, the need to preserve biodiversity, and the formation of an ecological basis for forestry. Despite the significant contributions of researchers to the field of scientific research in this study, there is a limitation in exploring the possibilities of restructuring the structure of forest plantations within agroforestry complexes. The purpose of this research is a detailed analysis of the vectors of mutual influence between the agroforestry system and the structural formation of forest ecosystems, with the identification of priority directions for regenerative and preventive measures.

Materials and Methods

During this scientific research, a combination of general scientific methods was applied. The theoretical foundation was laid by contemporary relevant scientific works, sectoral Ukrainian and foreign literary sources, publications in specialized journals, monographs, materials from scientific conferences, regulatory documents, statistical information, and practical results related to optimizing the agroforestry system.

The scientific methodological basis of the study was built on the principles of comprehensive and systematic approaches to the analysis

of agroforestry measures and their systems as multi-vector formations in the functioning of forest and agrolandscape ecosystems. This approach allowed for the identification of conceptual principles within a comprehensive methodology for researching the optimization of forest plantations within agrolandscape complexes, based on landscape-ecological differentiation. The abstraction method was employed in the research process to identify basic categorical concepts and form a concept of the integrated process of the agroforestry system as a structurally consequential set of relationships. The abstract-logical method was applied to individualize the conceptual apparatus in the research field, form theoretical generalizations, and draw conclusions. Additionally, the method of transitioning from abstract to concrete was utilized, sequentially implementing general theoretical information on the impact of agroforestry measures on the formation of forest ecosystems structure into specific vector analysis of activities in the investigated field in Ukraine.

Synthesis and system analysis methods were involved in the research process to extract the essence of the functionality of the study object, identify priority strategic directions for optimizing agroforestry in Ukraine, primarily in terms of its impact on the formation of forest ecosystems. Furthermore, through analytical processing of information arrays, the research identified characteristic features of mutual influence among components of the agroforestry system, highlighting priority indicators of mutual influence and prospective development directions for improving the existing situation. The effectiveness assessment of the agroforestry measures system aimed at stabilizing ecosystems was realized using the method of system analysis.

The specification method was employed during the research to document the significance and effectiveness of the management-

functional system for local agroforestry complexes. Using the specification method, the assortment of tree and shrub species for protective forest plantations based on landscape-typological criteria was justified, along with outlining optimal conditions and effective solutions for the preservation and regeneration of agrolandscapes and forest plantations, while simultaneously mitigating risks to the natural environment through preventive measures.

The comparison method was used to identify the specifics of the development of agroforestry systems in Ukraine based on indicators of quantitative and qualitative dynamics. The inductive method was applied for effective predictive analysis of characteristic features of the agroforestry system's functioning in Ukraine. The deductive method was utilized to record practical proposals for improving the national management system for agro-amelioration and afforestation.

To document priority directions for prospective optimization of the national agroforestry system in accordance with the principles of sustainable natural resource use, the formalization method was applied. Moreover, through the functionality of this method, the significance of anthropogenic impact for the effective functioning and stability of agrolandscapes was emphasized. The study established the limits of transformative processes in the agroforestry system, forming conclusions for future practical implementation in the scientific-practical transformation system for managing agroforestry complexes. Throughout the research, the provisions of the Convention on Biological Diversity (1992) were adhered to.

Results

The most influential structural element of the phytomeliorative system is identified as the engineering-protective vector of activity, focusing on the formation of specific plantations

aimed at protecting landscapes from erosion processes. Agroforestry, primarily, involves the creation of protective forest plantations, most commonly represented in the form of field protection forest strips (FPFS) and their systems (Mishenin *et al.*, 2021a). The main conceptual direction of agroforestry measures is the optimization of conditions for the development of agricultural crops to increase their productivity. It is worth noting that the system of forming protective forest plantations significantly affects the structure of forest ecosystems.

The interdependence of indicators of age and species structure of the forest ecosystem and agroforestry measures is primarily actualized by inefficient land use and non-compliance with optimal landscape functional parameters. The primary practical function of linear-type PFPs should be the formation of an ecological framework for the agrolandscape (Abu Dib, 2022). However, as of today, their quantitative and qualitative condition does not meet minimum requirements that could ensure proper functionality. In Ukraine, there is an unbalanced ratio of agricultural land to forests, deterioration of the functional state of PFPs, minimization of their area, and weakening of protective and meliorative functions. An important problem is the inefficiency of the construction of protective plantations, significantly reducing their agromeliorative functionality.

Overall, the destruction of the protective function of agrolandscapes through PFPs in Ukraine, as well as the improper structural-functional state of forest ecosystems, is due to a significant slowdown in the process of creating new plantations and worsening their forestry condition, disrupting their structure. Intensive erosion phenomena and prolonged droughts, caused by climate change, are not compensated by existing systems of linear protective forest plantations, which protect only

30% of agrolandscapes (Kravchuk & Hutsol, 2019). The situation is complicated by the elimination of agroforestry services, the minimization of stimulating innovative innovations, and the lack of proper legal support and strict responsibility for irrational land use. Protective forest plantations form the ecological basis for the effective functioning of agrolandscapes, but their shortage and inadequate qualitative condition do not meet current needs.

The optimal structure of PFPs by species components significantly influences the indicators of agroforestry efficiency in different regions of Ukraine. Conversely, meliorative measures significantly affect the formation of the structure of forest ecosystems (Abu Dib, 2022; Savchuk & Liubchych, 2019). Optimal placement of PFPs within agroforestry ecosystems, correct composition of tree species structure, identification of destruction factors, involvement of innovative technological and managerial solutions can synergistically provide the highest ecological effect of agroforestry, including the process of forming the structure of forest ecosystems.

Protective forest plantations, essentially cultural biocoenoses, are characterized by uniform spatial distribution. Regarding vertical structure, four main layers are distinguished (crown, shrub, herbaceous, and ground layers) (State Agency of Forest..., 2020; Amons & Krasnyak, 2023). FPFS, in this context, perform water protection, soil protection, and climate-regulating functions. Today, these protective forests differ in age, structure, and species composition. In Ukraine, among the species structure, red oak (*Quercus rubra*), American ash (*Fraxinus americana* L.), small-leaved lime (*Tilia cordata* Mill.), field maple (*Acer campestre* L.), green ash (*Fraxinus lanceolata* Borkh.), and black locust (*Robinia pseudoacacia* L.) are most commonly found (Fig. 1).

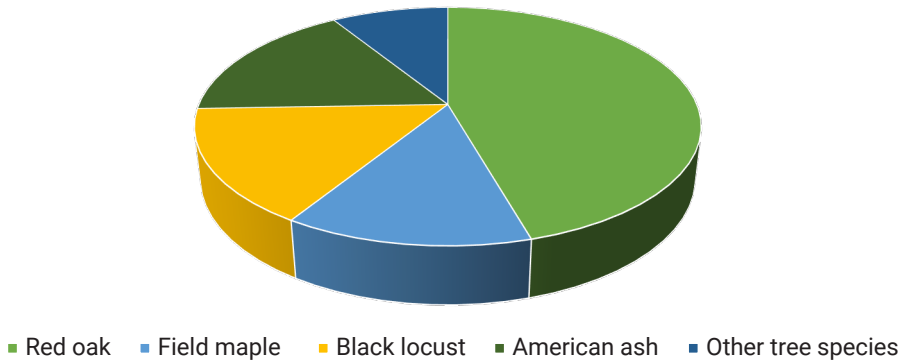


Figure 1. The structure of protective forest plantations within the agricultural landscapes of Ukraine

Source: compiled by the authors based on State Agency of Forest Resources of Ukraine (2020)

Overall, in Ukraine, the indicator of protective afforestation coverage averages 1.4%, while the optimal level is 4-5% (Kravchuk & Hutsol, 2019). Thus, it can be seen that the area of protective forest plantations needs to be increased by at least three times to optimize the agro-landscape protection system. However, currently, there is a reverse trend in Ukraine, causing significant concern among scientists. The priority functionality in the system of PFPs is determined by the structure of the plantation, which is a combination of parameters such as species composition, canopy structure, and width. Dense and open basic constructions are usually distinguished, with intermediate constructions between them. The analysis of the taxonomic characteristics of forest plantations within agro-forest-meliorative complexes, representative of the territory of Ukraine, convincingly positions species such as common oak, weeping birch, common ash, and poplar as priorities. They are recommended as the main species in PFPs, ensuring effective protection of agro-landscapes (Abu Dib, 2022). It is evident that an optimized PFPs system should guarantee the formation of a stable agro-forest landscape, stabilization of local and regional ecological

conditions, and the provision of optimal conditions for the functioning of agro-landscapes.

The moisture-regulating properties of protective forest plantations are determined by a combination of aspects such as the comprehensive interaction of all forest elements, the functionality of the forest litter, optimal soil structure, conditions for vertical water drainage, snowdrift prolongation, and protection against soil freezing. Anti-erosion forest plantations have specific functionality that mitigates erosion processes, regenerates the condition of erosion-affected soils, and ensures the balance of landscapes. It is important to note that the forest litter has significant water conservation and soil-protective value. It protects the soil from erosion, excessive compaction, and drying while acting as a filter. The litter allows excess moisture to pass through, promotes the transfer of surface run-off to groundwater, optimizes the physical structure of the soil, and contributes to the intensive biological cycling of substances in the forest plantation (Bida *et al.*, 2022). The water conservation properties of the forest litter are crucial for the sustainable functioning of agro-forest-meliorative complexes, leading to specific requirements for the

structure of protective plantations. It should ensure the formation of litter with improved qualities, including significant thickness and looseness, as well as a high calcium content. Shrubby species, as well as linden, ash, pine, oak, and birch, meet these requirements (Furdychko & Tymochko, 2020; Abu Dib, 2022). Moreover, they have maximum water-holding capacity.

As an optimum, the model of the optimal structure of PFPs should be positioned considering the functionality of their structure, with a focus on prioritizing species optimization directions. On arable slopes, it is appropriate to apply the functionality of protective and wind-regulating forest strips. It is evident that in the development of fringe and protective forest plantations, their most effective design solutions should be implemented, considering the natural features of regional ecosystems. For instance, open forest belts are advisable in regions with dust storms, and windbreaks are suitable for locations with cold and snowy winters. It is worth noting that FPFS (Forest Protective and Functional Systems), depending on the concept of agro-forest-melioration system, are formed in a pure or mixed form. Typically, they include one main species with slow growth rates. To enhance the protective functions of FPFS, a fast-growing species is introduced into the inter-forest row. On chestnut soils and southern chernozems, it is advisable to introduce up to 35% of low-growing shrubs in a rotational pattern with tree species (Schwarz *et al.*, 2021; Amons & Krasnyak, 2023). FPFS on irrigated lands are usually formed with an open structure in combination with windbreaks.

Anti-erosion plantations with the most optimal composition are positioned as mixed plantations with a combination of tree species and shrubs. Functional features determine their optimal structure. The implementation of effective PFPs systems is also influenced by natural-climatic features and landscape char-

acteristics. Additionally, the process is affected by the possibilities of agronomy in providing favourable development conditions. During the practical implementation of agro-meliorative measures, these requirements are often overlooked, leading to the destruction of meliorative characteristics and a decrease in the efficiency of PFPs (Savchuk & Liubchych, 2019; Pantera *et al.*, 2021). However, research indicates a significant ecologically stabilizing effect of agro-forest-meliorative plantations. The fundamental goal of optimizing the species structure of PFPs is to maximize the utilization of natural potential, considering the type of forest plant conditions. This potential can be effectively manifested only in conditions favourable for a particular species. In addition, determining factors for choosing the optimal structure of PFPs include their species diversity, the selection of effective main and accompanying species, their purpose, territorial location, and mixing.

The formation of PFPs in terms of their species categories currently cannot guarantee the prospective optimal balance between protective forests and plantations. The intensification of agro-forest landscapes for production purposes has significantly reorganized land resources, intensifying processes of deforestation and erosive destruction. Under these circumstances, the significance of PFPs with different purposes as a priority stabilizing factor in agro-forest ecosystems is highlighted. The experience of developed countries regarding the successful implementation of modern agro-meliorative systems underscores the need to revitalize protective forest plantations as a fundamental structural unit of contemporary agro-landscapes. For instance, the Sloping Agricultural Land Technology (SALT) method is successfully used to combat soil erosion and enhance crop yields (Zinngrebe *et al.*, 2020). In this approach, both protective tree-shrub plantations and vegetables/legumes are planted

in contour lines across slopes. This way, trees prevent erosion processes, and their leaves and organic matter enrich the soil.

In the United States, there is an effective combination of trees and shrubs with agricultural crops and livestock on the same land plot. This method improves soil fertility, prevents erosion, and promotes biodiversity (Schwarz *et al.*, 2021). There is an urgent need to establish comprehensive protective forest systems for agro-landscapes of various scales, including through the integration of individual PFPs and areas earmarked for future afforestation. The concept of enhancing the functionality of protective plantations of different purposes should be based on a landscape-ecological approach,

ensuring the formation of a stable agro-forest landscape. Such an approach will stabilize the environmental situation, regenerate regional resource potential, create optimal conditions for the development of agro-landscape complexes, and contribute to the balanced functioning of forestry in the agrosphere, enhancing the effectiveness of the biospheric functionality of forest ecosystems. An algorithm for the effective planting of trees to fulfil protective functions can be proposed, consisting of five qualitative stages of development for massive anti-erosion forest plantations (Table 1). The phased nature of the formation scheme ensures the effectiveness of the regeneration of the ecological balance in areas affected by erosion processes.

Table 1. Stages of ecological regeneration of agrolandscapes using protective forest plantations

Stage number	Period, years	Qualitative changes in the landscape
I	1-7	The gradual influence of artificially created protective forest plantations on ecological parameters, the reduction of the manifestation of erosion processes, the beginning closure of plantations.
II	8-14	Closure of the canopy, formation of a protective layer of forest litter, minimization of erosion, activation of biological soil processes, succession of living above-ground cover.
III	15-30	Intensive differentiation of trees, formation of tree stands and other components of the protective plantation (undergrowth, undergrowth, living topsoil), optimization of soil properties, establishment of a small cycle of substances, complete cessation of the development of erosion processes.
IV	31-55	Formation of sustainable forest ecosystems, regeneration of lost soil properties, intensification of soil formation processes, formation of the ability of protective forest plantations to natural recovery and anti-erosion impact on adjacent territories.
V	after 55	Restoring the ecological balance of eroded territories, increasing the area of their optimization impact on the landscape.

Source: compiled by the authors based on O.I. Furdychko & I.I. Tymochko (2020), A. Pantera *et al.* (2021), S.M. Abu Dib (2022)

Forest species in agro-forestry systems (main, accompanying, shrub) are identified based on the characteristics of forest conditions and soil-climatic features (Ladychenko *et al.*, 2022). Typically, the structure is formed by one main species, with a mandatory proportion of accompanying species. To enhance protective

efficiency and biological resilience, the introduction of shrub species, often fruit-bearing, is considered appropriate for Steppe and Southern Forest-Steppe forest plantations. The common oak is identified as the primary main species for forest belts in Polissia, Chernozem Steppe, and Forest-Steppe, being a tall and long-lived

species (Abu Dib, 2022; Savchuk & Liubchych, 2019). It is established that the extreme rows of protective plantations should include accompanying fruit-bearing species, such as common pear, cherry, white mulberry, wild apple, and walnut. In Polissia and Forest-Steppe, pendulous birch is introduced in the extreme rows, while in the middle rows, common pine is considered appropriate. However, the formation of pure pine plantations is considered inefficient.

In Steppe conditions, honey locust is suitable as a fast-growing species on chernozem soils, while for the Southern Steppe, small-leaved elm and white acacia are the priority species. Poplar plantations are formed in both pure and mixed forms, alternating with accompanying fruit-bearing species in Forest-Steppe and Polissia, while in Steppe, a combination with shrub species is preferred (Kravchuk & Hutsol, 2019; Amons & Krasnyak, 2023). The optimization of the structure of forest plantations with agro-meliorative functional orientation requires the mandatory consideration of soil conditions. It is advisable to prefer species that, based on years of experience, demonstrate maximum local resistance and longevity (such as sharp-fruited ash, Japanese sophora, feathered elm) (Kravchuk & Hutsol, 2019; Koval, 2023). On stony soils, coniferous species should be included in the structural-species composition of plantations. On irrigated lands, it is appropriate to form forest plantations, involving species like walnut and various types of poplar. On saline soils, tree species such as Crimean pine, narrow-leaved olive, Tatar honeysuckle, and Canadian redbud should be introduced (Mishenin *et al.*, 2021b).

The process of forming an optimal structure for forest ecosystems within agro-meliorative complexes involves maximizing the share of protective forest plantations in all natural zones of Ukraine, optimizing the species composition of PFPs, implementing

agro-meliorative measures and protective afforestation, applying monitoring of PFPs based on geoinformation technologies. Such a conceptual approach allows the regeneration of the environmental potential and increases the resilience of forest-meliorative ecosystems, optimize the placement of protective forest plantations, increase the yield of agricultural crops, and ensure the additional absorption of greenhouse gases.

Discussion

The features of the relationship between the agroforestry meliorative system and the structure of forest ecosystems have long been a subject of broad scientific interest among modern researchers. Many scientists focus on the general aspects of the impact of agro-melioration on forest plantations within agroecosystems, as well as on the ecological and economic consequences of irrational forest meliorative measures or their absence. Each of them has made a significant contribution to understanding the relationships between soil and phytocenosis or laid the foundations for sustainable agrolandscape use through agroforestry methods. For instance, S. Fahad *et al.* (2022) argue that protective forest plantations are the basis for soil protection against erosion processes, positioning themselves as the foundation of forest melioration. S. Jiang *et al.* (2022) and F.M. Santos *et al.* (2021) emphasize the undeniable impact of PFPs on increasing crop productivity, optimizing temperature and water regimes, and preventing soil degradation. Scientists see an additional positive effect in reducing wind speed, protecting against excessive drying and blowing away of the top fertile soil layer.

Analysis of current scientific research summarizes that areas with existing PFP systems in agricultural landscapes create significantly more favourable ecological conditions for the sustainable functioning of agrolandscapes.

Modern researchers, led by S. Chen *et al.* (2022), highlight the crucial importance of the optimal species structure of PFPs for the performance indicators of the agroforestry melioration system. These research results align with conclusions in the context of updating the algorithm for effective structuring of forest ecosystems within agroforest landscape complexes. The main idea of these findings is further developed in the works of F. Montagnini & S. del Fierro (2022) and Y. Zinngrebe *et al.* (2020), who suggest that for the optimization of FPFS in Ukraine, a profound reconstruction and regeneration of protective forest plantations are necessary. According to researchers, this work should be carried out based on scientifically grounded recommendations within special state programs, including those outlined in the “Concept of Agroforestry Development in Ukraine” (2013). Scientists forecast that priority directions in scientific and practical work in this area should include restoring the protective functions of forest strips, ecological balance, and stimulating the productivity of agrolandscapes.

Z. Marais *et al.* (2022) in their research draw special attention to the need for improving the management system for agroforestry melioration development, their accounting, and control, which would, to some extent, stabilize existing negative natural processes in agrolandscapes. This fact is developed in the scientific works of D. Octavia *et al.* (2022), emphasizing the multiple increase in the risks of destructive consequences of prolonged anthropogenic influences and highlighting the need for effective protection of agrolandscapes. A comprehensive approach to the functioning of agroforestry meliorative complexes involves indicating aspects of the local ecological situation. The basis of intensive ecological impact by PFPs should consist of main long-lived tree species at the land use boundaries and in

large crop rotations. Simultaneously, the precondition for the effectiveness of optimization measures is the updating of the regulatory framework and legal field in the field of agroforestry melioration (Prakhovnik *et al.*, 2022). This issue is developed in the works of modern scientists M. Santos *et al.* (2022) and S. Sorge *et al.* (2022). Researchers emphasize that with effective management regulation of the increase in PFP areas and the fundamental conceptual provisions of agroforestry melioration, significant ecological and economic effects can be achieved. The conclusions of scientists need to be supplemented in terms of differentiating the above-mentioned effect, as, according to the current research, it can manifest directly, such as increasing crop yield or protecting land from erosion, as well as indirectly, in terms of preserving biological diversity and optimizing the local and regional ecological situation.

Comparing the results of this study with M.T. Sri Budiastuti *et al.* (2021), the common conclusion is that the primary causes of the destruction of protective plantations are identified as their unsatisfactory sanitary condition, uncontrolled growth processes, and irrational structural and species composition. However, the main precondition for the degradation of the agroforestry melioration system is the legal vulnerability of FPFS (Puzrina *et al.*, 2022). This thesis is consistent with the works of scientists J. Xiao & K. Xiong (2022), who argue that, mostly, official information regarding the real qualitative and quantitative state of FPFS does not correspond to reality today. The absence of sanitary and care logging is a separate problem that has intensified during wartime. This is emphasized by several researchers, including G.C. de Mendonça *et al.* (2022). Correlating the statements of scientists with the results of this study, it can be highlighted that due to the disruption of the structure, protective forest plantations become overgrown, weed-infested, and filled

with unwanted shrubby vegetation, losing their water-regulating and ventilating properties.

The pressing issue is the need to create unified synergized systems of protective forest plantations for various natural-ecological conditions, studied during the research, and also discussed in the works of D.A. Martin *et al.* (2020) and V. Rolo *et al.* (2023). Scientists advocate for fundamental changes in the legal regulation of stabilizing components of agroecosystems by achieving their optimal ratio, sustainable functioning, and increased productivity. Despite the identical results of this study to the conclusions of other researchers, it is essential to emphasize the significance of the relationships between the state of individual forest ecosystems and the agrolandscape complex as a whole. The concept of optimizing the structure of forest ecosystems affected by agroforestry melioration measures should be based on landscape management principles involving agroforestry methods, following the principles of balanced sustainable development (Abaikyzy *et al.*, 2020). Similarly, scientists A. Nuddin *et al.* (2019) draw attention to the need for timely monitoring of the agroforestry melioration system. It is challenging to disagree with the researchers' conclusions, considering the risks of indirect impacts that often go unnoticed but are equally significant due to their continuous, multifaceted, and large-scale nature. The main direction of optimization in the studied area, according to scientists, should be the creation of a unified database of forest-taxon characteristics of agroforestry plantations. For effective inventory and monitoring of agroforestry plantations, the application of unmanned aerial vehicles, geoinformation technologies, and online cartographic services is considered prospective (Fedoniuk & Skydan, 2023).

O.P. Tkachuk & N.G. Viter (2022) in their scientific research correlate with the findings of this study regarding the need to form PFPs in

an optimal volume, creating opportunities for optimizing Ukraine's national ecological network, regenerating natural ecosystems and agrolandscapes, ensuring favourable conditions for increased productivity and agricultural ecologicalization, as well as actively influencing regional climatic characteristics. Despite the numerous publications dedicated to agroforestry melioration, there is a need for detailed research on its impact on the structure of forest ecosystems within a unified landscape complex. Despite the active position of leading scientists in the field of agroforestry melioration, the overall state of the industry in Ukraine is undergoing gradual destruction, and protective forest strips suffer from uncontrolled logging (Reshetilov, 2022). Therefore, the topicalization of the issues of protective forest cultivation and the popularization of the studied topics in the scientific community are deemed necessary.

The aim of future scientific research in this direction should be to identify strategic priorities for the formation and integration of practical measures to optimize the structure of agroforestry protective plantations. In the functional aspect of further research, it is considered appropriate to apply landscape-ecological principles as the basis for the concept of forming a sustainable agroforestry landscape. This concept should ensure the maximum efficiency of rational placement and optimal ratio of PFPs in agrolandscape complexes, compliance with their regulatory parameters, and a rational structural-species configuration.

Conclusions

The process of implementing the principles of sustainable land use and the development of agroecosystems involves optimizing the structure of protective plantations through the application of innovative approaches to agroforestry melioration algorithms. During the conducted research, the vector nature of

interdependencies between the agroforestry melioration system and the structure of related forest ecosystems was clarified. The peculiarities of the destruction of the agroforestry melioration system in Ukraine were identified. It was established that the optimization system of measures based on scientific grounds for the formation of sustainable agroforestry meliorative complexes in Ukraine is currently not functioning properly. The study identified the urgent need for the development of optimization measures for the formation of a stable genetic forest component of agroecosystems based on landscape-ecological differentiation.

The research successfully identified the features of the species structure of protective forest plantations in Ukraine, pinpointing the basic priority tree species for the formation of functional PFPs. The primacy of conceptual landscape-ecological principles and the principles of developing a sustainable agroforestry landscape during the optimization of the structure of protective forest plantations of various purposes were substantiated. The adaptation of regulatory and legal support and control in the researched area, as well as the implementation of an innovative modern system of environmental monitoring for the agroforestry meliorative complex, including the utilization of advanced

geoinformation system capabilities, were justified. During the research, significant efforts were synergized to demonstrate the need for vectoring the impact of agroforestry melioration on the structure of forest ecosystems in terms of stabilizing the environmental state, preserving the natural resource potential, and providing optimal conditions for increasing the productivity of agrolandscapes. Recommendations regarding the assortment of tree species for protective forest plantations under different forest-plant conditions were developed.

Based on the conclusions obtained from the research, priority directions for further scientific research on the investigated topic were developed, justifying the need to update the issues of the agroforestry melioration system in Ukraine at the national level. The necessity for a deep and detailed development of practical measures for the regeneration of forest ecosystems within agroforestry meliorative complexes, in the aspect of optimizing the structure of plantations, was highlighted.

Acknowledgements

None.

Conflict of Interest

None.

References

- [1] Abaikyzy, M., Yerkinbayeva, L.K., Aidarkhanova, K.N., Aigarinova, G.T., & Baimbetov, N.S. (2020). The formation of land conservation principles as the framework for the implementation of the concept of sustainable development of society. *Journal of Landscape Ecology (Czech Republic)*, 13(3), 23–38. [doi: 10.2478/jlecol-2020-0015](https://doi.org/10.2478/jlecol-2020-0015).
- [2] Abu Dib, S.M. (2022). [*Ecological assessment of the impact of engineered forest protection plantations on natural and anthropogenic landscapes*](#). Kyiv: Kyiv National University of Construction and Architecture.
- [3] Amons, S., & Krasnyak, O. (2023). Ecologization of agricultural production as the basis of the formation of the food security system of Ukraine. *Economy and Society*, 47. [doi: 10.32782/2524-0072/2023-47-41](https://doi.org/10.32782/2524-0072/2023-47-41).
- [4] Bida, O.A., Ores, I.I., & Honcharuk, V.V. (2022). [*Theoretical fundamentals of professional training of future forestry professionals: Strategic objectives of environmental protection*](#). *Academic Notes. Series: Pedagogical Sciences*, 200, 10–13.

- [5] Chen, S., Chen, J., Jiang, C., Yao, R.T., Xue, J., Bai, Y., Wang, H., Kiang, C., Wang, S., Zhong, Y., Liu, E., Guo, L., Lv, S., & Wang, S. (2022). Trends in research on Forest Ecosystem Services in the most recent 20 years: A bibliometric analysis. *Forests*, 13(7), article number 1087. [doi: 10.3390/f13071087](https://doi.org/10.3390/f13071087).
- [6] Convention on Biological Diversity. (1992, June). Retrieved from <https://www.cbd.int/doc/legal/cbd-en.pdf>.
- [7] de Mendonça, G.C., Costa, R.C., Parras, R., de Oliveira, L.C., Abdo, M.T., Pacheco, F.A., & Pissarra, T.C. (2022). Spatial indicator of priority areas for the implementation of agroforestry systems: An optimization strategy for agricultural landscapes restoration. *Science of the Total Environment*, 839, article number 156185. [doi: 10.1016/j.scitotenv.2022.156185](https://doi.org/10.1016/j.scitotenv.2022.156185).
- [8] Fahad, S., Chavan, S.B., Chichaghare, A.R., Uthappa, A.R., Kumar, M., Kakade, V., Pradhan, A., Jinger, D., Rawale, G., Yadav, D.K., Kumar, V., Farooq, T.H., Ali, B., Sawant, A.V., Saud, S., Chen, S., & Poczai, P. (2022). Agroforestry systems for soil health improvement and maintenance. *Sustainability*, 14(22), article number 14877. [doi: 10.3390/su142214877](https://doi.org/10.3390/su142214877).
- [9] Fedoniuk, T.P., & Skydan, O.V. (2023). Incorporating geographic information technologies into a framework for biological diversity conservation and preventing biological threats to landscapes. *Space Science and Technology*, 29(2), 10-21. [doi: 10.15407/knit2023.02.010](https://doi.org/10.15407/knit2023.02.010).
- [10] Furdychko, O.I., & Tymochko, I.I. (2020). Methodological bases of the concept creating a stable ecologically sustainable space in agrolandscapes. *Balanced Nature Using*, 2, 60-66. [doi: 10.33730/2310-4678.2.2020.208809](https://doi.org/10.33730/2310-4678.2.2020.208809).
- [11] Jiang, S., Xiong, K., & Xiao, J. (2022). Structure and stability of agroforestry ecosystems: Insights into the improvement of service supply capacity of agroforestry ecosystems under the karst rocky desertification control. *Forests*, 13(6), article number 878. [doi: 10.3390/f13060878](https://doi.org/10.3390/f13060878).
- [12] Koval, I. (2023). *Dendrochronological principles of pine and oak stands assessment in Ukraine*. Kharkiv: Machulin.
- [13] Kravchuk, H.I., & Hutsol, A.I. (2019). Analysis of the ecological state of forest ecosystems of the Eastern Podillia. *Agriculture and Forestry*, 14, 206-219. [doi: 10.37128/2707-5826-2019-3-18](https://doi.org/10.37128/2707-5826-2019-3-18).
- [14] Ladychenko, V.V., Golovko, L.O., Gulak, O.V., & Kidalov, S.O. (2022). *Environmental protection: European experience*. Kyiv: National University of Life and Environmental Sciences of Ukraine.
- [15] Marais, Z.E., Baker, T.P., Hunt, M.A., & Mendham, D. (2022). Shelterbelt species composition and age determine structure: Consequences for ecosystem services. *Agriculture, Ecosystems & Environment*, 329, article number 107884. [doi: 10.1016/j.agee.2022.107884](https://doi.org/10.1016/j.agee.2022.107884).
- [16] Martin, D.A., Osen, K., Grass, I., Hölscher, D., Tschardtke, T., Wurz, A., & Kreft, H. (2020). Land-use history determines ecosystem services and conservation value in tropical agroforestry. *Conservation Letters*, 13(5), article number e12740. [doi: 10.1111/conl.12740](https://doi.org/10.1111/conl.12740).
- [17] Mishenin, Y., Yarova, I., Zolochovskyi, V., Nazarenko, M., & Bohomolova, K. (2021a). Economic assessment of ecological and social functions of forest resources in the system of sustainable spatial forestry. *Mechanism of an Economic Regulation*, 1(91), 70-91. [doi: 10.21272/mer.2021.91.06](https://doi.org/10.21272/mer.2021.91.06).
- [18] Mishenin, Ye.V., Yarova, I.Ye., Zhylynska, O.I., & Stepanenko, I. (2021b). Forest bioeconomy in the system of sustainable spatial development: Global and regional orientations. *Visnyk of Sumy State University*, 2, 183-194. [doi: 10.21272/1817-9215.2021.2-23](https://doi.org/10.21272/1817-9215.2021.2-23).

- [19] Montagnini, F., & del Fierro, S. (2022). Functions of agroforestry systems as biodiversity islands in productive landscapes. In *Biodiversity Islands: Strategies for Conservation in Human-Dominated Environments* (pp. 89-116). Cham: Springer. doi: [10.1007/978-3-030-92234-4_4](https://doi.org/10.1007/978-3-030-92234-4_4).
- [20] Nuddin, A., Arsyad, M., Putera, M.I., Nuringsih, N., & Teshome, T.T. (2019). Making the case for institutional support on designing agroforestry technology models for rehabilitating critical lands. *Forest and Society*, 3(1), 49-61. doi: [10.24259/fs.v3i1.5975](https://doi.org/10.24259/fs.v3i1.5975).
- [21] Octavia, D., Suharti, S., Murniati, Dharmawan, I.W., Nugroho, H.Y., Supriyanto, B., Rohadi, D., Njurumana, G.N., Yeny, I., Hani, A., Mindawati, N., Suratman, Adalina, Y., Prameswari, D., Wati Hadi, E.E., & Ekawati, S. (2022). Mainstreaming smart agroforestry for social forestry implementation to support sustainable development goals in Indonesia: A review. *Sustainability*, 14(15), article number 9313. doi: [10.3390/su14159313](https://doi.org/10.3390/su14159313).
- [22] Order of the Cabinet of Ministers of Ukraine No. 725-r “On Approval of the Concept of Agroforestry Development in Ukraine”. (2013, September). Retrieved from <https://zakon.rada.gov.ua/laws/show/725-2013-%D1%80#Text>.
- [23] Pantera, A., Mosquera-Losada, M.R., Herzog, F., & den Herder, M. (2021). Agroforestry and the environment. *Agroforestry Systems*, 95(5), 767-774. doi: [10.1007/s10457-021-00640-8](https://doi.org/10.1007/s10457-021-00640-8).
- [24] Prakhovnik, N., Kachynska, N., Zemlyanska, O., Kovtun, A., & Ilchuk, O. (2022). Environmental security as a guarantee of national security. *Law. Human. Environment*, 13(1), 34-42. doi: [10.31548/law2022.01.004](https://doi.org/10.31548/law2022.01.004).
- [25] Puzrina, N., Karpuk, A., Vasylyshyn, R., Melnyk, O., & Tokarieva, O. (2022). Thirty-year dynamics of the pine stand sanitary conditions of Boyarka forestry research station. *Scientific Horizons*, 25(10), 43-52. doi: [10.48077/scihor.25\(10\).2022.43-52](https://doi.org/10.48077/scihor.25(10).2022.43-52).
- [26] Reshetilov, G. (2022). Implementation of environmental policy of Ukraine in the context of circular economy. *Ukrainian Black Sea Region Agrarian Science*, 26(3), 87-96. doi: [10.56407/2313-092X/2022-26\(3\)-8](https://doi.org/10.56407/2313-092X/2022-26(3)-8).
- [27] Rolo, V., Rivest, D., Maillard, É., & Moreno, G. (2023). Agroforestry potential for adaptation to climate change: A soil-based perspective. *Soil Use and Management*, 39(3), 1006-1032. doi: [10.1111/sum.12932](https://doi.org/10.1111/sum.12932).
- [28] Santos, F.M., Terra, G., Piotto, D., & Chaer, G.M. (2021). Recovering ecosystem functions through the management of regenerating community in agroforestry and plantations with *Khaya* spp. in the Atlantic Forest, Brazil. *Forest Ecology and Management*, 482, article number 118854. doi: [10.1016/j.foreco.2020.118854](https://doi.org/10.1016/j.foreco.2020.118854).
- [29] Santos, M., Cajaiba, R.L., Bastos, R., Gonzalez, D., Petrescu Bakış, A.-L., Ferreira, D., Leote, P., Barreto da Silva, W., Cabral, J.A., Gonçalves, B., & Mosquera-Losada, M.R. (2022). Why do agroforestry systems enhance biodiversity? Evidence from habitat amount hypothesis predictions. *Frontiers in Ecology and Evolution*, 9, article number 630151. doi: [10.3389/fevo.2021.630151](https://doi.org/10.3389/fevo.2021.630151).
- [30] Savchuk, O., & Liubchych, A. (2019). Legislative framework for the development of innovative infrastructure of efficient use and protection of land under forest shelter belt plantations. *Science and Innovation*, 15(3), 5-14. doi: [10.15407/scin15.03.005](https://doi.org/10.15407/scin15.03.005).
- [31] Schwarz, J., Schnabel, F., & Bauhus, J. (2021). A conceptual framework and experimental design for analysing the relationship between biodiversity and ecosystem functioning (BEF) in agroforestry systems. *Basic and Applied Ecology*, 55, 133-151. doi: [10.1016/j.baae.2021.05.002](https://doi.org/10.1016/j.baae.2021.05.002).

- [32] Skliar, V., Kovalenko, I., Skliar, I., & Sherstiuk, M. (2019). [Vitality structure and its dynamics in the process of natural reforestation of *Quercus robur* L.](#) *Agrolife Scientific Journal*, 8(1), 233-241.
- [33] Sorge, S., Mann, C., Schleyer, C., Loft, L., Spacek, M., Hernández-Morcillo, M., & Kluvankova, T. (2022). Understanding dynamics of forest ecosystem services governance: A socio-ecological-technical-analytical framework. *Ecosystem Services*, 55, article number 101427. [doi: 10.1016/j.ecoser.2022.101427](#).
- [34] State Agency of Forest Resources of Ukraine. (2020). *Natural structure of Ukrainian forests (infographics)*. Retrieved from <https://forest.gov.ua/news/prirodna-struktura-lisiv-ukrayini-infografika>.
- [35] Sri Budiastuti, M.T., Purnomo, D., & Setyaningrum, D. (2021). Agroforestry system as the best vegetation management to face forest degradation in Indonesia. *Reviews in Agricultural Science*, 10, 14-23. [doi: 10.7831/ras.10.0_14](#).
- [36] Tkachuk, O.P., & Viter, N.G. (2022). Ecological problems of functioning of field protective forest belts in conditions of climate change. *Scientific Reports of NULES of Ukraine*, 96(2). [doi: 10.31548/dopovidi2022.02.001](#).
- [37] Xiao, J., & Xiong, K. (2022). A review of agroforestry ecosystem services and its enlightenment on the ecosystem improvement of rocky desertification control. *Science of the Total Environment*, 852, article number 158538. [doi: 10.1016/j.scitotenv.2022.158538](#).
- [38] Zanzi, A., Andreotti, F., Vaglia, V., Alali, S., Orlando, F., & Bocchi, S. (2021). Forecasting agroforestry ecosystem services provision in urban regeneration projects: Experiences and perspectives from Milan. *Sustainability*, 13(5), article number 2434. [doi: 10.3390/su13052434](#).
- [39] Zinngrebe, Y., Borasino, E., Chiputwa, B., Dobie, P., Garcia, E., Gassner, A., Kihumuro, P., Komarudin, H., Liswanti, N., Makui, P., Plieninger, T., Winter, E., & Hauck, J. (2020). Agroforestry governance for operationalising the landscape approach: Connecting conservation and farming actors. *Sustainability Science*, 15(5), 1417-1434. [doi: 10.1007/s11625-020-00840-8](#).

Вплив агролісомеліорації на формування структури лісових екосистем

Ірина Ярославівна Мисковець

Кандидат географічних наук, доцент
Луцький національний технічний університет
43018, вул. Львівська, 75, м. Луцьк Україна
<https://orcid.org/0000-0001-9248-4919>

Юрій Петрович Шимчук

Асистент
Луцький національний технічний університет
43018, вул. Львівська, 75, м. Луцьк Україна
<https://orcid.org/0000-0002-4130-046X>

Рисбек Зарилдикович Нургазієв

Доктор ветеринарних наук, професор
Киргизький національний аграрний університет ім. К.І. Скрябіна
720005, вул. Медерова, 68, м. Бішкек, Киргизька Республіка
<https://orcid.org/0000-0003-1376-6921>

Уранбек Адійович Шергазієв

Доктор сільськогосподарських наук, професор
Киргизький національний аграрний університет ім. К.І. Скрябіна
720005, вул. Медерова, 68, м. Бішкек, Киргизька Республіка
<https://orcid.org/0000-0002-4203-4060>

Мусакун Ахматбекович Ахматбеков

Доктор сільськогосподарських наук, професор
Киргизький національний аграрний університет ім. К.І. Скрябіна
720005, вул. Медерова, 68, м. Бішкек, Киргизька Республіка
<https://orcid.org/0000-0003-1075-3551>

Анотація. Функціональне навантаження лісів зумовлює актуалізацію меліоративних заходів для оптимізації функціонування агроландшафтних комплексів. Ці заходи сприяють покращенню екологічної ситуації та розвитку в напрямку стійкого функціонування лісових екосистем. Саме тому дослідження структурно-видового формування лісових екосистем викликає суттєвий науковий інтерес. Мета статті полягала у проведенні аналізу впливу агролісомеліоративних заходів на процес формування структури лісових екосистем у сукупності взаємозв'язків. Дослідження проводилось із залученням загальних методів наукового пізнання, у тому числі, конкретизації, дедукції, системного аналізу, синтезу та абстрагування, формалізації. Під час проведення дослідження проаналізовано вектори організації оптимізованих систем захисних лісових насаджень, обґрунтовано природоохоронні пріоритети розвитку агролісових екосистем. Виокремлено базові принципи управління комплексом агролісомеліорації на засадах сталого природокористування, серед яких – комплексний підхід, екологізація процесу та постійний моніторинг. В дослідженні виявлено актуальні екологічні наслідки нераціональної меліорації для лісових насаджень, зокрема, посилення ерозійних процесів та деградацію земельних ресурсів, виокремлено ризики та виклики, котрі вимагають превентивних рішень. Доведено, що збільшення частки

агролісомеліоративних насаджень дасть змогу оптимізувати екологічну ситуацію в Україні, сприятиме регенерації природної ресурсної бази та відновленню ландшафтів, мінімізує процеси деградації земельних ресурсів. Запропоновано основні заходи з оптимізації екологічної ситуації на локальному рівні лісових екосистем, а також превентивні міри для запобігання деструктивному впливу, зокрема, вдосконалення правового забезпечення та впровадження жорстких мір відповідальності за нераціональне ресурсокористування. Цінність висновків вбачається в доцільності їх практичного використання для моніторингових досліджень стану та процесу формування структури лісових екосистем під впливом реалізації агролісомеліоративних заходів, а також задля ефективної розробки превентивних і регенераційних захисних мір та формування збалансованих лісових екосистем

Ключові слова: захисні насадження; ерозійні процеси; моніторинг; районування; потенційні ризики; асортимент деревних рослин