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The impact of herbaceous plants on biodiversity and stability of pine plantations in Western Polissia

Abstract. In the field of ecology, more and more attention is paid to the analysis of the interaction of herbaceous plants with the structure of ecosystems, including forests. The aim of the study was to determine the impact of herbaceous plants on the biodiversity and stability of pine plantations in Western Polissia of Ukraine. To achieve this goal, in 2010-2023, the State Enterprise "Research Farm "Horodetske" assessed the diversity of herbaceous plant species, measured their number and cover, evaluated soil physical properties and biometric parameters of pine trees, and assessed how changes in the pine plantation ecosystem caused by herbaceous plants can affect carbon sequestration and oxygen productivity. The study found that herbaceous species among pine plantations in Western Polissia perform important ecological functions that contribute to the conservation and restoration of ecosystems. The presence of these plants enriches the soil with organic matter and helps maintain the structural and functional stability of ecosystems. The study showed that herbaceous plants contribute to the restoration of pine plantations by providing protection and support for young trees, and have a positive impact on their biometric parameters, increasing the total phytomass. Herbaceous plants also improve soil physical properties, such as pH, humus content, aggregate water resistance and water permeability, which can contribute to soil structural stability and the health of pine stands. In addition, the presence of herbaceous plants contributes to more efficient carbon sequestration and oxygen production, which is important for the balance of the air environment in the ecosystem. The results obtained are of great importance for environmental management and conservation of natural resources in the Western Polissia region, as they provide scientific basis for developing strategies for the conservation and restoration of forest ecosystems, taking into account the role of herbaceous plants in their functioning

Keywords: forest stand; phytomass; soil; carbon sequestration; oxygen production; forest communities

INTRODUCTION

Herbaceous plants play a significant role in shaping biodiversity and ensuring the stability of ecosystems, including pine plantations. They affect various aspects of forest communities, providing optimal conditions for the development and existence of not only the plants

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themselves, but also the living organisms that interact with them. The ability of herbaceous species to compete, adapt and interact with other ecosystem components makes them key players in maintaining biodiversity and preserving ecological stability.

The research of scientists aimed at studying the impact of herbaceous plants on the biodiversity and stability of pine plantations reflects a wide range of approaches and methods. For example, P. Gautam *et al.* (2021) examine the relationship between herbaceous species and pine trees at different stages of their life cycle, from sowing to the development of mature stands. The author has found that the presence of herbaceous species stimulates the formation of a favourable microenvironment for the growth and development of young pines, providing them with protection from competing plants. In addition, herbaceous species contribute to the formation of biological cover under the trees, which helps to preserve moisture and nutrients in the soil, and protects the roots of the pine from overheating and drying out. Other scientists, such as L. Gustafsson *et al.* (2020) and M. Mpanda *et al.* (2021), analyse the impact of herbaceous plants on the soil environment, water regime and forest community environment. The authors' research focuses on the role of herbaceous species in the formation of soil cover and its impact on the structure and functioning of ecosystems. Scientists have found that herbaceous plants affect carbon metabolism and nutrient availability for plants, and reduce soil erosion. In addition, there is an interaction between herbaceous plants and soil biota, such as microbes and fungi, which can affect the health and development of pine plantations.

A number of authors have focused on the impact of herbaceous plants on biodiversity due to their role in maintaining species and ecological functions in forest ecosystems. Therefore, it is strategically important, in conformity with Z. Hastings *et al.* (2022), it is therefore strategically important to study the impact of herbaceous plants on biodiversity by assessing their ability to create conditions for the life and development of various animal and plant species. The authors, in particular, Z. Zhao *et al.* (2021) and Y. Long *et al.* (2022), emphasize the need to consider the effectiveness of herbaceous cover restoration measures for the conservation of biodiversity and stability of forest ecosystems, in particular, after human intervention, such as logging or land use change. It is worth noting the ecosystem services provided by herbaceous plants, such as water filtration, climate regulation and maintenance of soil fertility. In this context, the study by M. Mamuye *et al.* (2022) notes the importance of grass cover for maintaining ecosystem functions and ensuring human well-being. After all, grass cover is an important source of food and shelter for many species of animals, from insects to large herbivores and carnivores. It can also be important for humans as a source of food, raw materials for the production of medicines and cosmetics, and for ecotourism and recreation.

A similar opinion is also expressed by V. Lavnyy *et al.* (2022), who argue that one of the possible impacts of herbaceous plants on biodiversity is their role in creating microclimate conditions that support a diversity of living organisms. Grass cover can create favourable conditions for various species of insects, small mammals, and birds, which in turn supports biodiversity. In addition, herbaceous cover can affect the stability of pine stands by competing for resources such as light, water, and nutrients. Some species of herbaceous plants can maintain soil stability by maintaining soil fertility, which contributes to the healthy development of pine plantations. Investigating the impact of herbaceous plants on the biodiversity and sustainability of pine plantations in Western Polissia is of great importance due to the uniqueness of this region in terms of natural diversity and forest ecosystems. Western Polissia, which is located within Ukraine, Belarus, and Poland, is known for its abundance of natural greenery, including pine forests and rich herbaceous vegetation. Here, the unique combination of biodiversity and forest ecosystems creates favourable conditions for research on the relationship between grassland and pine plantations (Valeriano *et al.*, 2021; Kimeichuk & Kaidyk, 2022).

In general, the lack of research on the impact of herbaceous plants on the biodiversity and stability of pine plantations indicates the complexity of this problem and the need for

further research to understand and conserve forest ecosystems. The emphasis on this is important not only from the point of view of scientific knowledge, but also from a practical perspective, as it can play a critical role in solving problems of conservation and management of forest resources. The aim of the study is to investigate the impact of herbaceous plants on the biodiversity and sustainability of pine plantations in the Western Polissia region of Ukraine, in particular, to understand their role in the ecosystem and interaction with other environmental components. To achieve the stated goal, the following objectives were set: to assess the species composition of herbaceous cover in pine plantations, to study their impact on soil physical parameters and biometric parameters of pines.

MATERIALS AND METHODS

The research was conducted in 2010-2023 on the territory of Horodetske village council of Volodymyrets district, Rivne region, at the state enterprise "Research Farm "Horodetske", which belongs to the Institute of Agriculture of Western Polissia of the National Academy of Agrarian Sciences of Ukraine and is subordinated to the Ministry of Economic Development, Trade, and Agriculture of Ukraine. Its area is 106.3 ha. This area is located in the Ukrainian Polissia zone and the Western Polissia Forestry District. Most of the tree plantations at the enterprise grow in fresh subsoil conditions. Coniferous plantations occupy about 65% of the total area, and broadleaved plantations – about 35% (Fig. 1).

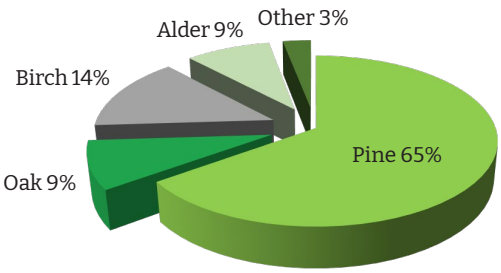

Figure 1. Share of tree species in Western Polissia
Source: compiled by the author

The study was based on the location of experimental plots in pine plantations with varying degrees of herbaceous plants: a control plot (30-45% herbaceous vegetation cover) and an experimental plot (50-75% herbaceous vegetation cover) of 0.25 ha each with a number of pine trees that should be at least 150 pcs.

The data on the diversity of plant species and their percentage was collected by recording all plant species found in the selected plots. The classical method of comparative forest ecology was used, with details on the forestry and taxation area. Soil pH was measured using a pH meter MT-300 – 2388-00005 (Chemtest, Ukraine). The humus content of the soil was assessed in the laboratory using the Turin method to a depth of 0-30 cm. The soil density was determined by the pycnometric method. The content of water-resistant aggregates in the soil was determined by the sieving method, in which the soil is sieved through a sieve with known mesh sizes, and then the content of large aggregates that did not pass through the sieve is measured. The water permeability of the soil was determined by the Nesterov method. The impact of herbaceous plants on the survival rate of pine plantations was determined by counting. The forestry-taxation method was used to determine the biometric parameters of the forest stand, in particular, equation (1) was used to determine the phytomass of the Scots pine crown:

$$P_{crown} = 8.379 + 0.087 * P_{boot}, \quad (1)$$

where P_{crown} – crown phytomass, kg; P_{boot} – boot phytomass, kg.

Phytomass of a stand was defined as the phytomass of all trees in the stand per unit area. The volume of carbon sequestration was determined by measuring the amount of carbon absorbed from the external environment over a certain period. The oxygen productivity of the plantations was estimated using formula (2):

$$K = S * NPP * 1000, \quad (2)$$

where K – oxygen productivity, NPP – net primary production (in grams of carbon per square metre per year, determined using a CO_2 analyser (PCE-CMM 5, Germany), S – area of reforestation (in ha).

Correlation and regression analysis was used to determine the relationship between the presence of herbaceous plants and the amount of carbon sequestration and oxygen production of pine plantations. The obtained research results were processed for their reliability using the multivariate method of analysis of variance MANOVA. Microsoft Excel software and the Statistica 10 software package were used for this purpose. To identify differences between the results, the Student's t-test was used with a significance level of $P \leq 0.05$.

RESULTS

The Ukrainian Polissia is a unique ecosystem region with rich vegetation adapted to humid conditions and diverse forest communities. In the western Polissia region of Ukraine, it is possible to find a variety of herbaceous plant species that reproduce in the region's conditions. As Polissia is characterized by high humidity and diverse forest communities, specific species of herbaceous plants can be found here. Some of them include: mosses and lichens that grow on trees, stones and soil, marsh plants such as *Sheuchzeria*, *Carex limosa*, *Menyanthes trifoliata*, *Calla palustris*, *Peucedanum palustre*, *Lysimachia vulgaris*, *Calamagrostis canescens*, as well as forest herbaceous plants such as *Fern*, *Veronica*, *Corydalis*, *Oxalis*, *Poa pratensis*, *Lolium pratense*, *Agrostis capillaris*.

When studying changes in topsoil vegetation, the main indicators are species composition and number of plants per unit area, projective cover, abundance, biomass, and average height. Particular attention is paid to the analysis of changes in the quantitative ratios of species, ecological groups, and plant life forms. The ratio of different ecological groups of herbaceous plants in the cover can be an indicator of the stage of degradation. Recreational impacts, regardless of the type of forest, contribute to the simplification of the structure and gradual destruction of the forest cover. In the later stages of degradation, when the undergrowth is thinned out, the soil becomes littered, its surface covered with layers of leaves, branches, rotten woody material, and other organic residues. This leads to the formation of a thick topsoil, which can prevent the penetration of water and air into the deeper soil layers, and impede seed germination and the development of the root system of plants. This process can contribute to the degradation of the forest environment, as it delays the regeneration of tree species and the development of vegetation, and therefore the conditions for tree species regeneration are deteriorating.

Grassy vegetation minimizes degradation and has a multifunctional impact on reforestation processes. Under certain conditions, it promotes the growth of young tree seedlings, protecting them from frost and overheating, and enriching the soil with nutrients. A diverse community of herbaceous plants can provide a number of benefits for forest restoration. For example, some herbaceous plants can improve soil structure and increase its water-holding capacity, creating a more favourable environment for tree seedlings. In addition, herbaceous plants can provide shade and protection from extreme temperatures, reducing the risk of frost damage and overheating to young tree seedlings. It is also important to note that herbaceous plants can contribute to the nutrient cycle in the soil, releasing essential nutrients through decomposition and improving soil fertility.

Prior to the study, we analysed the species composition of herbaceous plants in pine plantations at each site. Analysing the data obtained, about 20 species of herbaceous plants are found in the control and experimental plots, but the number of individuals of each species is different (Table 1).

Table 1. Diversity of herbaceous plants in pine plantations

No.	Type of herb plant	Number of specimens in the study area, pcs.	
		Control plot	Experimental plot
1	*Dactylis glomerata*	45	80
2	*Anthoxanthum*	30	56
3	*Poa pratensis*	20	39
4	*Lolium pratense*	35	76
5	*Agrostis capillaris*	50	60

Table 1, Continued

No.	Type of herb plant	Number of specimens in the study area, pcs.	
		Control plot	Experimental plot
6	*Thymus serpyllum* (Breckland thyme)	18	37
7	*Helichrysum arenarium*	12	29
8	*Sedum acre*	25	35
9	*Artemisia vulgaris*	22	28
10	*Calamagrostis epigejos*	15	20
11	*Veronica officinalis*	20	41
12	*Festuca ovina*	25	64
13	*Calluna vulgaris*	30	59
14	*Carex brizoides*	36	67
15	*Pteridium aquilinium*	28	74
16	*Viola odorata*	24	76
17	*Stellaria holostea*	37	58
18	*Galeopsis tetrahit*	43	73
19	*Lactuca sativa*	47	79
20	*Bidens frondosa*	29	68
21	*Calamagrostis arundinacea*	33	81

Source: compiled by the author

The herbaceous plants in pine plantations have a variety of effects on the soil. They ensure soil conservation by retaining topsoil and preventing erosion. They also contribute to the formation of organic fertilizer, improving fertility and carbon storage in the soil. The roots of herbaceous plants improve water absorption and drainage, which helps to improve soil structure and provide access to water for other plants, including pine trees. In addition, they help to increase biodiversity in the soil, creating a favourable environment for a variety of microorganisms and insects.

When analysing the impact of herbaceous plants on the physical properties of the soil, it should be noted that the experimental plot showed an increase in the pH level towards the neutral medium compared to the control plot, which may be due to an increase in the content of organic matter in the soil due to the growth of herbaceous plants. According to the results of the study, the humus content in the soil on the experimental plot was 21% higher than on the control plot, which indicates a positive impact of herbaceous plants on the processes of organic matter decomposition and humus formation. The experimental plot also showed a significant decrease in soil density compared to the control plot. This improvement in soil bulk may be due to an increase in the number of herbaceous plants that loosen the soil with their roots, which saves the soil environment from over-compaction. The study also found that the content of water-resistant aggregates in the soil on the experimental site was 16.8% higher than on the control site. This may indicate an increase in soil stability and its ability to withstand the damaging effects of water and erosion. In addition, the experimental plot showed a 21.5% increase in soil permeability compared to the control plot, which may be the result of a decrease in soil density and an increase in the amount of water-resistant aggregates (Table 2).

Table 2. Impact of herbaceous plants on soil physical properties

Indicator	Control plot	Experimental plot
Acidity, pH	5.5	6
Humus content, %.	3.3	4
Soil density, g/cm^3	1.2	1.44
Content of water-resistant aggregates in the soil, %.	26.8	31.3
Soil permeability, mm/h	65	79

Source: compiled by the author

In summary, the presence of more herbaceous plants in the experimental plot affected the physical properties of the soil, including an increase in pH, humus content, water-resistant aggregates, and water permeability. These changes suggest that the presence of herbaceous plants may improve soil structure and stability, which would consequently affect pine plantations.

As a result of the study, it was found that the presence of herbaceous plants has a significant positive impact on the processes of pine plantations restoration. Thus, on average, the growth of trees in the experimental plot increases by 20% compared to the control conditions. This allows us to conclude that herbaceous plants contribute to the creation of optimal conditions for the growth of pine trees. In addition, the percentage of survival of new seedlings reaches 60-82%, which indicates that herbaceous plants provide protection and support for young pine trees. Herbaceous plants in pine forests can have a positive impact by reducing competition between trees and contributing to their health by improving water absorption and soil fertility. This is achieved through a variety of biogeochemical processes, such as the influence of foliage and litter layers on the availability of nutrients in the soil. This positive impact of herbaceous plants in pine forests can improve forest stand biometrics, contribute to biodiversity and ecosystem maintenance. The expansion of herbaceous species can contribute to the formation of more resilient and diverse forest communities, while providing additional nutrition and protection for pine trees.

The study determined the impact of herbaceous plants on the biometric parameters of trees in the plots. Firstly, it was found that the average height of the pine boot in the experimental group is less than in the control group – 10 m vs. 11.5 m, respectively. The total phytomass in the experimental group is higher than in the control group – 93.7 thousand tonnes versus 88.6 thousand tonnes, respectively. The average phytomass of the boot and crown per 1 tree in the experimental group was also higher than in the control group – 168.8 kg vs. 252.7 kg, respectively (Fig. 2).

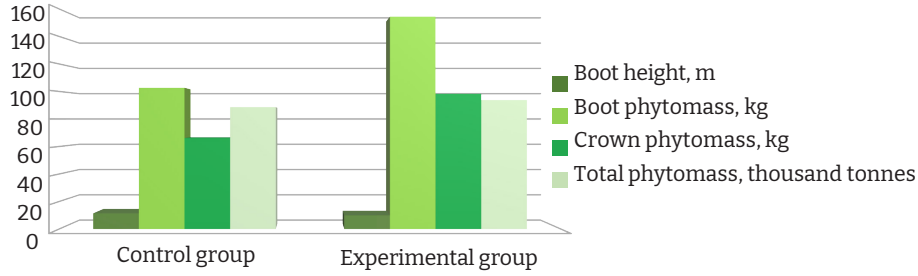

Figure 2. Average biometric parameters of the forest stand

Source: compiled by the author

Thus, from the data obtained, it can be argued that the growth of herbaceous plants affects the biometric parameters of pine trees, in particular, their height decreases, but the total phytomass of the plantation increases. Carbon sequestration and oxygen production are indicators of the biological activity of an ecosystem. They indicate the ability of plants and other organisms to carry out photosynthesis, the process by which green plants use sunlight, carbon dioxide and water to produce organic compounds, such as glucose, and release oxygen into the atmosphere.

It is worth noting that the amount of carbon sequestration and oxygen production differ significantly between the control and experimental plots. Thus, in the control plot, the volume of carbon sequestration is 64.6 thousand tonnes, while in the experimental plot, the volume of carbon sequestration is much higher and amounts to 214.3 thousand tonnes. This may be due to an increase in the number of herbaceous plants that are able to effectively absorb carbon during photosynthesis. On the control site, the volume of oxygen production is 139.2 thousand tonnes, while on the experimental site there is

a significant increase in the volume of oxygen production, which is 361.5 thousand tonnes, which is an indicator of the positive impact of the presence of herbaceous plants on the photosynthesis process, which leads to an increase in oxygen production. In order to verify the reliability of the results obtained, a correlation and regression analysis was conducted. This highly effective statistical method is used to identify relationships between different variables. In this study, correlation and regression analysis was used to determine the correlation between the presence of herbaceous plants and the amount of carbon sequestration and oxygen production by pine forests. This analytical approach allows us to determine whether there is a relationship between the two, and if so, what it might be. The correlation component measures the strength and direction of the relationship between two variables. If a relationship is found, the regression component is used to model the relationship and predict one variable based on the other. In this case, the analysis will allow us to understand how the presence of herbaceous plants affects carbon sequestration and oxygen production in pine forests. According to the correlation and regression analysis, the reliability value for carbon sequestration and oxygen production was R=1, which means that the model accurately describes the available data (Fig. 3).

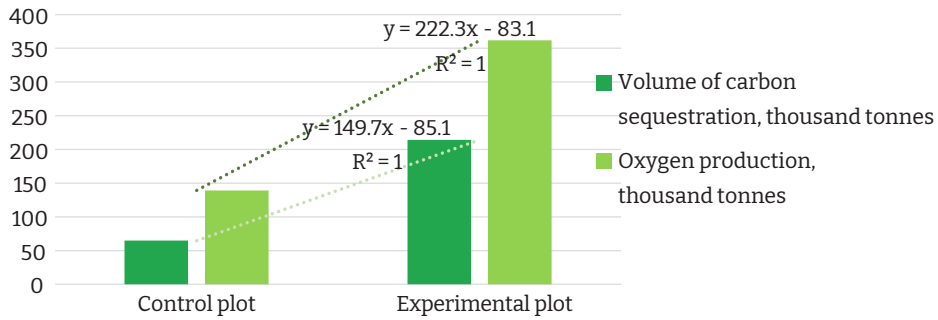

Figure 3. Correlation and regression dependence of the presence of herbaceous plants with the volume of carbon sequestration, thousand tonnes, and the volume of oxygen production, thousand tonnes of pine plantations

Source: compiled by the author

Thus, herbaceous plants, due to their sufficient leaf surface, are able to efficiently collect sunlight for photosynthesis, which contributes to more intensive carbon uptake and oxygen production. A greater number of such plants in the experimental plot can lead to an increase in photosynthesis, which in turn affects the carbon and oxygen balance in the ecosystem. This can be important for the ecosystem, as the balance between carbon and oxygen is critical for life on Earth. Oxygen produced during photosynthesis is essential for the respiration of most living organisms, while carbon sequestration helps to reduce the concentration of greenhouse gases in the atmosphere and contributes to the fight against global warming. Thus, increasing the number of herbaceous plants can have a positive impact on environmental sustainability and biodiversity conservation.

The study revealed a significant species diversity of herbaceous species in the studied pine plantations. It was found that herbaceous plants have a significant impact on the stability of pine plantations. They contribute to the preservation of soil cover, improve its physical properties, and reduce the risk of erosion. Studies have shown that herbaceous plants influence the natural regeneration of pine plantations. They help to increase the productivity and diversity of the new generation of trees. To summarize, the results of the study confirm the importance of herbaceous plants in the conservation of biodiversity and stability of pine plantations in the Western Polissia region.

DISCUSSION

Herbaceous plants have a positive impact on the health of pine trees by improving water absorption and soil fertility. This impact can improve forest stand biometrics and contribute to biodiversity. The study shows that herbaceous plants play an important role in maintaining soil cover, improving its physical properties, and reducing the risk of erosion. They also influence the natural regeneration of pine plantations, which increases the productivity and diversity of the new generation of trees.

The analysis of the study results confirmed the importance of herbaceous plants in shaping biodiversity and ensuring the sustainability of ecosystems, including pine forests. Herbaceous species are able to compete, adapt and interact with other ecosystem components, making them key players in maintaining biodiversity and preserving ecological stability. Y. Zhang *et al.* (2022) also investigated the impact of herbaceous plants on ecosystems. According to their study, herbaceous species play a significant role in maintaining biodiversity and ecological stability, which confirms the results of our study. Comparing our results with the authors' data, we can see similar trends in the impact of herbaceous plants on ecosystems, including pine forests. This highlights the importance of considering herbaceous species in ecosystem management and conservation.

Herbaceous plants can have a positive impact on understory and young plantations by reducing competition between understory trees for light, water, and nutrients. They can help to distribute these resources more evenly, which promotes healthy growth and development of the understory. C. Beierkuhnlein *et al.* (2023) and Q. Liu *et al.* (2020) studied the impact of herbaceous plants on understory and young plantations. Their research proved that the presence of herbaceous species helps to improve the conditions for the growth of young trees in the understory, providing them with access to the necessary resources. Comparing the results of the study with the authors' data, we can see similarities in the conclusions regarding the positive impact of herbaceous plants on the healthy development of the undergrowth and young pine trees.

The roots of herbaceous plants are able to hold soil, preventing it from being washed away during rain or snowmelt. This helps to preserve the soil layer, which is important for healthy plant growth. Herbaceous plants can create additional habitats for a wide variety of microorganisms, insects, and other living things to live and grow, which helps maintain the biodiversity of the forest ecosystem. R.M. Navarro-Cerrillo *et al.* (2023) and A.A. Shah *et al.* (2022), in a study on this aspect, found that herbaceous plants affect soil retention and promote biodiversity in forest ecosystems, which confirms similar findings on the importance of herbaceous plants for soil conservation and biodiversity.

The results of the study confirmed the importance of the interaction between herbaceous species and pine trees in the forest ecosystems of Western Polissia. The study has shown that the presence of herbaceous plants helps to improve the conditions for the growth and development of pine trees, which can be of great importance for the restoration and maintenance of sustainable forest stands. Comparison of the results with previous studies in this area confirms the consistency and complementarity of the findings. For example, studies by R.A. Slesak *et al.* (2020) and M.M. Qaderi *et al.* (2019) also point to the positive impact of herbaceous plants on the health and productivity of forest ecosystems. The authors' findings demonstrate the need to conserve and maintain the diversity of herbaceous species in forest ecosystems. Appropriate management of these elements of natural complexes can help to increase the resilience of forests to external stressors and maintain their productivity.

The diversity of herbaceous species contributes to the conservation and increase of biodiversity in the ecosystem, which in turn has a positive impact on the resilience and ability of the ecosystem to adapt to changes. The results of the study coincide with the data obtained by the authors in this area. For instance, the study by Q. Lyu *et al.* (2021) also confirms the positive impact of herbaceous species on the biodiversity and stability of forest ecosystems. After all, plants provide diversity among natural resources and ecosystem services, such as soil improvement, water conservation, erosion reduction. In

addition, they contribute to greater resilience of ecosystems to environmental changes, thus helping to ensure the ecosystem's ability to adapt to environmental changes and rapid response to various stressors. The results of these studies emphasize the importance of sustainable management of herbaceous plants to ensure the sustainability and productivity of forests.

The study by C. Ramsey *et al.* (2023) indicates a significant impact of herbaceous species on the survival of pine trees in the early stages of their development. They found that the presence of certain herbaceous plant species promotes the survival and growth of pine trees in the early stages of their life. These results indicate an important interaction between herbaceous plants and trees in ecosystems, especially during the developmental stages when trees are still young and vulnerable. The presence of certain species of herbaceous plants can provide protection from weed competition, facilitate access to light and water, and provide other beneficial conditions for optimal growth of pine trees, as also noted in the present study.

The study confirms the opinion of Z. He *et al.* (2022), who emphasize the relationship between herbaceous plants and soil physicochemical properties. The study found that the presence of herbaceous plants can affect the physicochemical characteristics of the soil, such as pH, water holding capacity, structural properties, and others. These results indicate that the interaction between herbaceous plants and soil is an important factor in the formation and maintenance of soil quality. Herbaceous plants affect the soil not only through their root system, but also through the processes of biological decomposition of plant residues, which can change the chemical composition of the soil.

Another proof of this and confirmation of the results obtained is the opinion of M. Malashevskyi & O. Malashevska (2022), who believe that herbaceous plants play an important role in ensuring the stability of forest ecosystems. The presence of a diversity of herbaceous species can contribute to the conservation and maintenance of biodiversity, as well as have a positive impact on the physical and chemical properties of soil, which play an important role in ensuring the productivity and resilience of ecosystems. These findings highlight the importance of conserving and maintaining herbaceous plant diversity in forest ecosystems as a means to reduce soil erosion, conserve water resources and maintain the resilience of these ecosystems to external stressors.

The study found that grass cover significantly improved soil properties, including organic matter and soil structure. The results of the studies by K. Chao *et al.* (2023) and L.M. San-Emeterio *et al.* (2021) indicate that certain grass species may be more effective in improving soil organic matter and structure, which are important factors for the health and resilience of forest ecosystems. These findings highlight the need to consider herbaceous species diversity when planning and implementing forest conservation and restoration programmes, and indicate the importance of further research to understand the mechanisms of these effects and identify the most effective management strategies for forest ecosystems. Thus, the present study interacts with the results of other authors, confirming the importance of considering herbaceous plant diversity in the conservation and restoration of forest ecosystems.

The data obtained in this study emphasize the importance and interconnectedness of the various components of the ecosystem to ensure their stable functioning and conservation. The study adds to the knowledge of the impact of herbaceous species on the pine forest ecosystem, highlighting their role in conserving soil moisture and preventing soil from drying out. This demonstrates the importance of herbaceous plants in maintaining an optimal water regime for pine growth, which is reflected in their health and ecological sustainability. Such an impact not only helps to preserve forest ecosystems, but also improves conditions for their further development and increases their biodiversity (Chun *et al.*, 2020; Li *et al.*, 2021).

A study by M.T. Löbmann *et al.* (2020) also confirms that herbaceous plants can influence the health of forest ecosystems through their interactions with other environmental components. For example, they can create favourable conditions for the life and development of a variety of organisms, including soil microorganisms and insects, which in turn are important for the health of the forest environment. In addition, herbaceous plants can serve as a source

of food and shelter for various animal species, which contributes to the conservation of biodiversity and ecosystem resilience. The results of the study by H. Xie *et al.* (2021), which found that the presence of herbaceous plants in pine forests significantly affects the biometric parameters of trees, also resonate with the present study. In particular, the authors proved that the average height of pine boots may be lower in the area with the presence of herbaceous plants. However, this is compensated by an increase in the total phytomass and the average phytomass of boots and crowns per tree. This influence indicates the importance of herbaceous plants in shaping the biometric characteristics of the forest stand in pine forests.

Importantly, herbaceous plants can contribute to the reduction of CO_2 through photosynthesis, which converts CO_2 into oxygen and organic matter. However, the extent of this contribution depends on various factors such as plant species, growth rate and environmental conditions. For example, fast-growing herbaceous plants with high levels of photosynthesis can potentially absorb more CO_2 than slow-growing plants. The study also confirmed the importance of photosynthesis and its impact on the balance of carbon and oxygen in the ecosystem. An increase in the number of herbaceous plants can lead to an increase in photosynthesis, which can have a positive effect on environmental sustainability and biodiversity conservation (Belmecheri & Lavergne, 2020; Ren *et al.*, 2024).

A study of the diversity of vegetation cover at different stages of forest development conducted by Z. Ni *et al.* (2021) showed changes in the composition of herbaceous cover at different stages of pine plantations development. Thus, in the early stages of forest formation, one composition of herbaceous plants may prevail, while in later stages this composition may change due to competition and other factors. Such changes in plant composition may occur over time and reflect natural processes of forest ecosystem development, such as succession and environmental changes, or may be the result of anthropogenic impacts, such as changes in forest management or human intervention. These studies can be important for understanding vegetation dynamics in forest ecosystems and developing management strategies to conserve and maintain the biodiversity and ecological resilience of these ecosystems.

CONCLUSIONS

Herbaceous species among pine plantations in Western Polissia perform several important ecological functions. They help to preserve soil and reduce erosion, as their roots hold the topsoil, preventing it from being washed away by rain and wind. In addition, herbaceous plants constantly regenerate and decompose, adding organic matter to the soil and enriching it. This creates favourable conditions for plant growth and promotes the development of various species of animals and microorganisms, which are important maintainers of forest ecosystem biodiversity. Thus, herbaceous plants play a key role in maintaining the health and stability of forest ecosystems in this region.

The study found that the presence of herbaceous plants has a significant positive impact on the regeneration of pine plantations. Herbaceous plants contribute to the creation of optimal conditions for the growth of pine plantations, providing protection and support for young trees. In addition, herbaceous plants affect the biometric parameters of pine trees on the plots, increasing the total phytomass of the plantation. In addition, herbaceous plants also have a significant impact on the physical properties of the soil, increasing pH, humus content, water-resistant aggregates, and water permeability. These changes suggest that the presence of herbaceous plants can improve soil structure and stability, which will consequently affect pine plantations.

The presence of more herbaceous plants in the experimental plot promotes photosynthesis and deepens the processes of the carbon cycle, which ensures more efficient carbon uptake and oxygen production, which can be important for the balance of carbon and oxygen in the ecosystem. Thus, these research results confirm the positive impact of herbaceous plants on pine plantations, which may be important for the sustainability and health of forest ecosystems in the Western Polissia region. The study may be limited geographically to a specific region of Western Polissia in Ukraine, and the results may be less universal for other forest ecosystems. Further research could be conducted

to investigate the specific ecological functions performed by herbaceous species in forest ecosystems. This could include investigating their impact on nutrient cycling, water regime, and soil microbial diversity.

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CONFLICT OF INTEREST

None.

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Вплив трав'янистих рослин на біорізноманіття та стабільність соснових насаджень у Західному Поліссі

Анотація. У сфері екології все більше уваги звертається на аналіз взаємодії трав'янистих рослин зі структурою екосистем, в тому числі лісових масивів. Мета дослідження полягала у визначенні впливу трав'янистих рослин на біорізноманіття та стабільність соснових насаджень у Західному Поліссі України. Для досягнення поставленої мети впродовж 2010-2023 рр. на території державного підприємства «Дослідне господарство «Городецьке» проведено оцінку різноманітності видів трав'янистих рослин, вимірювання їх кількості та вкриття, оцінку фізичних властивостей ґрунту та біометричних показників соснових дерев, а також оцінку того, як зміни в екосистемі соснових насаджень, викликані трав'янистими рослинами, можуть впливати на обсяг поглинання вуглецю та киснепродуктивність. У результаті досліджень встановлено, що трав'янисті види серед соснових насаджень у Західному Поліссі виконують важливі екологічні функції, які сприяють збереженню та відновленню екосистем. Наявність цих рослин збагачує ґрунт органічними речовинами та сприяє підтримці структурної і функціональної стабільності екосистем. Дослідження показало, що трав'янисті рослини сприяють відновленню соснових насаджень, забезпечуючи захист та підтримку для молодих дерев, а також позитивно впливають на їх біометричні показники, збільшуючи загальну фітомасу. Також, трав'янисті рослини покращують фізичні властивості ґрунту, такі як рівень pH, вміст гумусу, водостійкість агрегатів і водопроникність, що може сприяти структурній стабільності ґрунту та здоров'ю соснових насаджень. Крім того, присутність трав'янистих рослин сприяє більш ефективному поглинанню вуглецю та виробленню кисню, що важливо для балансу повітряного середовища в екосистемі. Отримані результати мають вагоме значення для екологічного управління та збереження природних ресурсів у регіоні Західного Полісся, адже вони надають наукові підстави для розробки стратегій збереження та відновлення лісових екосистем з урахуванням ролі трав'янистих рослин у їхньому функціонуванні

Ключові слова: деревостан; фітомаса; ґрунт; поглинання вуглецю; продукування кисню; лісові угруповання