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ASSESSMENT OF THE CURRENT ECOLOGICAL STATE OF FOREST SHELTERBELT ECOSYSTEMS IN THE RIGHT-BANK FOREST-STEPPE

Pankova S.O. *– Doctor of Philosophy in Agronomy,*
Assistant at the Department of Forestry and Landscape Gardening,
Institute of Agro-Technologies and Environmental Management
of Vinnytsia National Agrarian University
Kutsenko M.I. *– Assistant at the Department of Forestry and Landscape Gardening,*
Institute of Agro-Technologies and Environmental Management
of Vinnytsia National Agrarian University

This article is dedicated to a detailed analysis of the species composition of tree species used in forest shelterbelts of the Right-Bank Forest-Steppe zone of Ukraine. The study focuses on their agroforestry significance, biological characteristics, adaptive capabilities to adverse climatic factors, as well as their role in preserving and improving agroecosystems. Forest shelterbelts play a crucial role in shaping a sustainable agricultural landscape, protecting farmlands from erosion processes, regulating the microclimate, and contributing to soil moisture retention.

The study analyzes the primary and secondary composition of tree species that form the structure of forest shelterbelts. Special attention is paid to the bioecological characteristics of trees, their viability, and resistance to stress factors such as drought, wind, frost, and anthropogenic impact. The adaptation mechanisms of plants to changing environmental conditions have been examined, allowing for an assessment of their effectiveness in performing protective functions.

Additionally, the article explores the ecological aspects of forest shelterbelt functioning, including their impact on regional biodiversity, soil quality improvement, and prevention of soil depletion and degradation. The phytomeliorative properties of tree plantations, which contribute to landscape stabilization, increased agricultural land productivity, and long-term ecological balance, have been analyzed.

The research results can be used to develop effective strategies for the conservation and restoration of forest shelterbelts in the Forest-Steppe zone of Ukraine. The proposed approaches aim to optimize the use of tree species in protective plantations, enhancing their effectiveness as natural barriers against adverse climatic conditions and promoting the development of sustainable agroecosystems. Thus, this work makes a significant contribution to the formation of scientifically based recommendations for improving the condition of forest shelterbelts and increasing their ecological and economic value.

Key words: *protective forest plantations, indication, ecosystem, forest, trees, vegetation, cultivation, ecological processes, agrolandscape, agrocenosis, biodiversity, agriculture, phytomass, leaves, cuttings.*

Панькова С.О., Куценко М.І. Оцінка сучасного екологічного стану екосистем лісосмуг Правобережного Лісостепу

Стаття присвячена детальному аналізу видового складу деревних порід, що використовуються в лісосмугах Правобережної Лісостепової зони України. У дослідженні акцентовано увагу на їхньому агролісомеліоративному значенні, біологічних характеристиках, адаптаційних можливостях до несприятливих кліматичних факторів, а також на їхній ролі у збереженні та покращенні агроекосистем. Лісосмуги відіграють важливу роль у формуванні сталого агроландшафту, захищаючи сільськогосподарські угіддя від ерозійних процесів, регулюючи мікроклімат і сприяючи збереженню ґрунтової вологи.

У межах роботи проведено аналіз первинного та вторинного складу деревних порід, що входять до структури лісосмуг. Особливу увагу приділено біоекологічним характеристикам дерев, їхній життєздатності та стійкості до таких стресових факторів, як посуха, вітер, заморозки та антропогенний вплив. Вивчено механізми адаптації рослин до *змінних екологічних умов, що дозволяє оцінити їхню ефективність у виконанні захисних функцій.*

Окрім цього, стаття розглядає екологічні аспекти функціонування лісосмуг, включаючи їхній вплив на біорізноманіття регіону, покращення якості ґрунтів, запобігання їхньому виснаженню та деградації. Проаналізовано фітомеліоративні властивості деревних насаджень, які сприяють стабілізації ландшафтів, підвищенню продуктивності сільськогосподарських земель і забезпеченню довготривалої екологічної рівноваги.

Результати дослідження можуть бути використані для розробки ефективних стратегій збереження та відновлення лісосмуг у Лісостеповій зоні України. Запропоновані підходи спрямовані на оптимізацію використання деревних порід у захисних насадженнях, що дозволить підвищити їхню ефективність як природних бар'єрів від несприятливих кліматичних умов і сприятиме розвитку стійких агроекосистем. Таким чином, ця робота робить вагомий внесок у формування науково обґрунтованих рекомендацій щодо поліпшення стану лісосмуг та підвищення їхньої екологічної та господарської цінності.

Ключові слова: *захисні лісові насадження, індикація, екосистема, ліс, дерева, рослинність, вирощування, екологічні процеси, агроландшафт, агроценоз, біорізноманіття, землеробство, фітомаса, листя, вирубки.*

Relevance of the research topic. Forest shelterbelts are a crucial component of agroforestry systems, aimed at protecting arable land from wind erosion, improving soil moisture retention, and enhancing the stability of agroecosystems. The effectiveness of shelterbelts largely depends on the biological properties of the tree species used for their establishment [1, c. 180].

Problem statement. Scientific principles for the placement of forest shelterbelts generally involve creating them in two mutually perpendicular directions: longitudinal – forming the main shelterbelts, which are positioned across the prevailing wind direction of a given area, and transverse – consisting of auxiliary shelterbelts placed perpendicular to the main ones [1, c. 190-193].

Research methodology. In the conditions of the Right-Bank Forest-Steppe zone, particularly in the Vinnytsia district of Vinnytsia region, westerly winds prevail in summer and easterly winds in winter. The main shelterbelts in the surveyed area were located from south to north, i.e., perpendicular to the prevailing winds. The auxiliary shelterbelts were laid from east to west, across the main ones.According to their construction, shelterbelts are divided into dense, semi-permeable (openwork), and permeable types. In the surveyed area, dense shelterbelts dominated among the main ones, accounting for 57% of all analyzed main shelterbelts [2, c. 86].

Research results. Openwork shelterbelts constituted 29%, and permeable ones only 14%. Among the auxiliary shelterbelts, openwork and permeable shelterbelts each made up 50%, while no dense auxiliary shelterbelts were observed (Table 1).

Table 1

Biometric Indicators of Shelterbelt Distribution in the Right-Bank Forest-Steppe Zone, 2021–2023 (M±m)

Indicator	Shelterbelt Type	Main	Auxiliary
Number of shelterbelts surveyed	70 (64%)	40 (36%)	
Orientation	North–South	–	East–West
Construction	Openwork – 29%	Openwork – 50%	
	Permeable – 14%	Permeable – 50%	
	Dense – 57%	Dense – 0%	

Dense shelterbelts that dominated the study area had wind-permeability openings no more than 10% of the total cross-sectional area [2, c. 88]. These shelterbelts were typically multi-row, created from dense-crown tree species with tall and thick undergrowth forming a continuous forest edge. Wind barely penetrates such belts, providing a calm leeward zone (Table 2).

Table 2

Characteristics of Shelterbelt Structures

Characteristic	Unit	Dense	Openwork	Permeable
Wind-permeable gaps (% of cross-section)	%	5–10%	15–35%	60–70% (in trunk zone)
Number of rows	pcs	More than 7	5–7	3–5
Number of vertical tiers	pcs	3	3	1
Species diversity	–	Dense-crown trees, thick undergrowth	Mixed-growth trees, sparse undergrowth	Trees with open crowns

Openwork shelterbelts have 15–45% wind-permeable spaces, allowing wind to pass through while reducing its speed. Permeable shelterbelts have about 10% gaps in crown profiles and up to 60% in trunk zones, and are considered the most effective in improving soil and crop conditions, whereas dense shelterbelts are considered least effective.

Our observations showed that only 14% of main shelterbelts and 50% of auxiliary shelterbelts were permeable in design. These shelterbelts demonstrated the highest agroecological effectiveness and contributed the most to crop yield increases. Conversely, 57% of main shelterbelts were dense, with the lowest positive effect on crop productivity [3, c. 120].

The placement distance between shelterbelts must also be scientifically justified for optimal environmental and agricultural impact. Recommended spacing between main shelterbelts should not exceed 2000 m, and auxiliary shelterbelts – not more than 600 m apart within the same field.

Actual lengths ranged from 300–1100 m for main shelterbelts and 1000–2800 m for auxiliary shelterbelts. The most common average shelterbelt length was about 1000 m, corresponding to the field's dimension [3, c. 120].

The recommended shelterbelt width ranges from 7.5 to 15 m, depending on the number of rows. Actual observed widths of main shelterbelts varied from 8 to 26 m, with 14 m being most common (30%). Auxiliary belts varied from 8–10 m, with 9 m being most frequent (50%).

Notably, 42% of main shelterbelts exceeded the recommended width, possibly due to tree growth and lack of thinning. However, such broader shelterbelts may serve as natural biodiversity reserves.

Shelterbelt heights ranged from 13 to 18 m. The most frequent heights were 13 m, 15 m, and 17 m (29% each). Auxiliary shelterbelts ranged from 15 to 18 m, with 15 m being most common (50%).

The number of rows in main shelterbelts ranged from 3 to 8, with 4-row shelterbelts dominating (30%). Auxiliary shelterbelts had 2, 3, or 5 rows, with 5-row belts dominating (50%).

From scientific recommendations, shelterbelts should have 3–6 rows. All studied belts met or exceeded this minimum. Additional rows may enhance ecological benefits.

The dominant tree species in main shelterbelts were Common Maple (63%) and Common Ash (37%). In auxiliary shelterbelts, species included Common Ash (40%), Oak, Maple, and Hornbeam (each 20%). Common maple (Acer platanoides) has significant agroforestry and land reclamation value. This species is included in the assortment of tree species for state protective forest belts due to its shade tolerance and frost resistance [5, c. 64].

Common ash (Fraxinus excelsior) has long been considered the primary species for protective and phytomeliorative shelterbelt planting. However, it is not resistant to air pollution and is often affected by atmospheric contaminants, pests, and diseases. Under current climate change conditions, especially with increasing drought, common ash can become weakened and dry out, leading to the degradation or even death of the shelterbelt, where it serves as a primary forest-forming species. Additionally, common ash requires bare soil for intensive growth and development and is strongly suppressed by the presence of herbaceous ground cover.

Common oak (Quercus robur) is recommended for use in forest reclamation plantations within shelterbelts due to its longevity, large biometric dimensions, and powerful crown. However, it is a light-demanding species, sensitive to soil conditions, and is frequently damaged by numerous pests [5, c. 63].

Common hornbeam (Carpinus betulus) is used in shelterbelt forestry as a secondary species, especially for afforestation of ravines and gullies. It is shade-tolerant and undemanding but susceptible to certain diseases.

The secondary species in the main shelterbelts included common ash, common oak, and white willow (Salix alba). In most main shelterbelts where common maple was the primary species, common ash served as the secondary species – this combination was observed in 67% of all studied main shelterbelts. Other secondary species, such as oak and white willow, occurred equally in 16–17% of the shelterbelts.

The effectiveness of the environmental protection functions of forest shelterbelts largely depends on their ecological condition, which can be affected by various factors such as the intensification of agricultural practices on adjacent farmland, climatic and weather changes, natural disasters, the spread of pests and tree diseases, industrial and vehicular air pollution, domestic littering with solid waste, unauthorized tree cutting, as well as accidental or deliberate anthropogenic damage [6, c. 63].

In the auxiliary shelterbelts, the secondary species were silver birch (Betula pendula) and common maple, each recorded in 25% of the auxiliary belts. Notably, 50% of all auxiliary shelterbelts did not contain any secondary species and were formed by a single dominant species – either common ash or common maple.

White willow is a moisture-loving tree species but also demonstrates frost resistance and light-demanding characteristics. Although it does not provide full-scale shelterbelt protection, it can be a valuable secondary species in low-lying landscape elements. Silver birch also has limited shelterbelt value but is frost-resistant and light-demanding.

The herbaceous, shrub, and underbrush cover within forest shelterbelts can be trampled by domestic or wild animals or due to anthropogenic factors such as unauthorized logging, recreational activities, or the collection of medicinal plants, fruits, and berries. However, any trampling of the shelterbelt cover disrupts its stability and reduces its effectiveness in performing protective functions. In the studied main forest shelterbelts, an average of 4.3% of the herbaceous cover was trampled, with a range of 2.0–9.0%, while in auxiliary shelterbelts this figure was 2.3% lower – at 2.0%.

Trees in forest shelterbelts were cut down due to drying, damage caused by pests, disease infection, breakage, as well as due to unauthorized logging. The higher proportion of felled trees in the main forest shelterbelts is explained by their greater density compared to auxiliary shelterbelts, resulting from a larger number of tree rows and shorter spacing between trees within the rows, which intensifies competition among trees for survival [7, c. 86].

A potential hazard within forest shelterbelts is the risk of fire outbreaks. The likelihood of spontaneous combustion is increased by the presence of dry grass, shrubs, underbrush, cut tree branches, and flammable household waste. The greater the amount of these components in the shelterbelts, the higher the probability of fire occurrence.

Analysis showed that in the studied main forest shelterbelts, the fire hazard level was 16.4%, with a range of 7.0–30.0%**,** depending on the specific shelterbelt. In auxiliary forest shelterbelts, the fire hazard was 4.1% lower, amounting to 12.3%**,** with a range of 7.0–20.0%.

Main shelterbelts also experience greater exhaustion due to their significantly higher environmental protection functions compared to auxiliary ones. Additionally, because of the denser tree arrangement and a greater number of rows in the main shelterbelts, it is easier to conceal and hide felled trees there than in auxiliary shelterbelts during unauthorized logging activities [7, c. 91].

According to all the studied ecological stability parameters, the main forest shelterbelts were inferior to the auxiliary ones. In particular, they were characterized by a higher proportion of felled, dry, and dying trees, trampled vegetation, greater fire hazard, and significant littering with solid household waste. At the same time, an analysis of the ecological conditions of the placement of main and auxiliary shelterbelts did not reveal any significant differences.

In particular, the main forest shelterbelts are located on four types of soils, three of which are highly fertile chernozems of different varieties, while only 14.3% of the main shelterbelts are situated on less fertile dark gray podzolized soils. All the studied auxiliary shelterbelts are located on chernozem soils. Additionally, 14.3% of the main forest shelterbelts are located on slightly eroded soils with a slope angle of 3°, whereas all auxiliary shelterbelts are situated on non-eroded flat soils. These auxiliary factors partially contribute to the higher percentage of decline observed in the main shelterbelts compared to the auxiliary ones [5, c. 72–74].

Therefore, common maple and common ash, which were the primary tree species used during the establishment of the studied shelterbelts, were once considered essential and optimal for this purpose. However, today they are subject to various stressors – especially common ash, which is highly vulnerable to pests, diseases, air pollution, and increasing drought – posing a significant concern for the sustainability of shelterbelts in the near future.

Isolated tree species in main shelterbelts included small-leaved linden (Tilia cordata), black locust (Robinia pseudoacacia), common hornbeam, walnut (Juglans regia), and wild cherry (Prunus avium). In auxiliary shelterbelts, wild cherry and wild pear (Pyrus communis subsp. pyraster) were observed. However, the small number of trees from these species does not significantly affect the overall condition or agroecological functions of the shelterbelts.

Common hornbeam (Carpinus betulus) is used as a supplementary species for afforestation of ravines and gullies. It is shade-tolerant and undemanding but susceptible to diseases. In the studied shelterbelts, common ash, common oak, and white willow (Salix alba) were recorded as secondary species. In most shelterbelts where common maple was the primary species, common ash was the secondary species (67% of main shelterbelts). Other secondary species such as oak and willow each accounted for 16–17% of the belts [6, c. 64].

Dry trees in forest shelterbelts generally do not fulfill their environmental protection functions, as they have completely or almost completely lost their foliage. They often serve as breeding grounds for diseases and pests, which can spread from the dry trees to healthy ones. However, trees may also dry out due to the impact of unfavorable climatic and weather conditions. In such cases, they do not necessarily contribute to the spread of drying processes to other trees. Nevertheless, regardless of the cause of drying, such trees should be removed.

In auxiliary shelterbelts, silver birch (Betula pendula) and common maple were the most frequent secondary species (25% each). Notably, 50% of auxiliary shelterbelts had no secondary species and consisted solely of either common ashor common maple.

White willow is moisture-loving but also frost- and light-tolerant. Although it has limited shelterbelt value, it can be useful in low-lying terrain as a secondary species. Silver birch is similarly limited in protective value but exhibits frost resistance and light tolerance [7, c. 89].

Our observations have shown that only 14% of all studied main forest shelterbelts and 50% of all studied auxiliary shelterbelts are permeable in their design. These shelterbelts demonstrate the highest effectiveness in terms of positive agroecological impact on adjacent agroecosystems of agricultural crops and contribute to the greatest increase in crop yields. As much as 57% of all studied main shelterbelts are dense in structure and are the least effective in terms of their positive influence on crop yield improvement.

Common maple and common ash, once considered essential shelterbelt species, are now increasingly stressed under current ecological conditions. In particular, common ash is vulnerable to disease, pests, air pollution, and drought, which poses a threat to the long-term viability of shelterbelts.

Minor species in main shelterbelts included small-leaved linden (Tilia cordata), black locust (Robinia pseudoacacia), hornbeam, walnut (Juglans regia), and wild cherry (Prunus avium). In auxiliary belts, wild cherry and wild pear (Pyrus pyraster) were observed. Due to their limited abundance, these species have minimal impact on the overall ecological function of shelterbelts [8, c. 59].

Shrub Species and Their Role. Common shrubs in main shelterbelts were box elder (Acer negundo), Tatarian honeysuckle (Lonicera tatarica), and common hazel (Corylus avellana). In auxiliary belts, common hazel and rowan (Sorbus aucuparia) were prevalent.

Box elder is an aggressive invasive species, frost- and drought-resistant, tolerant of air pollution, and often forms dense thickets. Common hazel is a shade-tolerant phytomeliorative species with wind-protective properties. Rowan is valued for its frost resistance and shade tolerance.

Conclusions and prospects for further research. The selection of appropriate tree species is critical for the ecological effectiveness and durability of forest shelterbelts. Although common maple and common ash were historically dominant and effective, their sustainability is now questionable under changing environmental conditions. The use of diverse species, including adaptable shrubs and trees, can enhance shelterbelt resilience and agroecological benefits.

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