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State and ameliorative properties of old original oak stands

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Abstract. The ameliorative properties of forest stands are essential for developing effective measures for environmental protection and sustainable use of forest resources. The purpose of the study was to assess the current condition and performance of erosion control properties of old

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oak stands of natural origin. The method of assessing the condition of old oak plantations using an integral indicator that takes into account biometric, ameliorative and health characteristics of stands, as well as agrochemical indicators of the soil has been tested. Field work was carried out on four experimental plots, where 794 age-old trees were enumerated. Comprehensive studies included determination of biometric indicators, analysis of root systems, detection of the content of available forms of nitrogen, mobile phosphorus, mobile potassium in soil. Soil hardness was measured with a durometer and soil water permeability using steel cylinders. High values of integral indicators were obtained in the experimental areas, which range from 11.9 to 19.7%. They guarantee the effective performance of erosion control properties by native old-growth forests. It has been researched that the proposed integral indicator of forest stand condition not only allows for assessing their current state but also demonstrates the effective control of erosion and ecological functions of the stand. It was established that essential requirement is to convert the absolute values of various indicators into relative values, with mandatory consideration of their positive or negative impacts on the forest stands themselves. It was found that an integral condition indicator can be used for erosion control plantations of any age range. The results can be used to develop biodiversity conservation programs and establish effective strategies for managing forest resources

Keywords: index of the integral condition of the stand; water permeability; hardness; erosion control properties; biometric indicators

Introduction

Forests play a crucial role in preserving biodiversity, which forms the basis of ecological stability in forest ecosystems. They provide a unique habitat for numerous plant and animal species, including rare and endangered ones. Studying the ameliorative properties of forests allows for the development of effective management and utilization strategies aimed at preserving their natural potential and improving the quality of forest environments. This approach helps achieve a balance among ecological, social, and economic aspects of forestry, crucial for sustainable development and ensuring future generations' access to natural resources.

The relevance of the scientific research topic stems from the necessity to assess the comprehensive indicator of the condition of naturally occurring ancient oak forests. This evaluation is crucial for understanding ecosystem health, biodiversity conservation, and sustainable forest management practices.

Old original oak stands are critically important for maintaining biodiversity as they provide habitats for numerous species of plants, animals, and microorganisms. Oak forests play a significant role in reducing carbon emissions, which is a key factor in combating climate change. According to G. Piovesan *et al.* (2022) they also hold economic value due to their high-quality timber and cultural significance as part of natural heritage, underscoring the need for their conservation and study.

Old forests are important ecosystems because they have both root systems and canopy, which makes it possible to fix a large amount of atmospheric CO₂, produce oxygen, and create a unique microclimate and living conditions, unlike young and monocultured forests. Intensive logging is causing rapid adverse impacts on ecosystems and climate. Mature forests persist in absorbing carbon and fixing nitrogen. Old trees control the underground

conditions necessary for tree regeneration, old-growth forests create a microclimate that slows down global warming and is an essential habitat for many endangered species. P. Chmielarz *et al.* (2023) researched old trees produce phytochemicals with many biomedical properties. They note that existing old trees are very important for biodiversity, as they also preserve elements of cultural heritage before industrial times.

In many ecosystems worldwide, large old trees are found as isolated individuals or small, scattered groups, qualifying them as small natural features. Despite their spatial limitations, these solitary or small groups of old trees play vital ecological roles, such as carbon storage and providing wildlife habitats. Protecting and managing these large old trees as small natural features is crucial for preserving these roles and often necessitates targeted, small-scale conservation strategies. These strategies may include prohibiting the felling of trees above a certain size, installing microfences to prevent grazing threats, and creating buffer zones of other vegetation to shield them from fire and chemical exposure. Studies on the growth and condition of ancient oaks are actively ongoing. According C. Cannon *et al.* (2022), ancient trees are unique forest assets that take centuries to develop. These old-growth trees significantly influence generation time and population fitness, transcending centennial ecological cycles. Consequently, they are crucial for the forest's long-term ability to adapt to changing climate conditions and provide invaluable data on ecological history and individual longevity. Given that they cannot be replaced by reconstruction or regeneration for many centuries, their protection is essential to preserving their irreplaceable diversity.

In scientific research of J. Zawadka (2020) it was noted environmental factors affecting the

condition and growth of old oaks and other trees are of exceptional importance; trends in growth and age of common oak along the amplitude gradient; hundred-year climate changes, as well as the impact of negative biotic, biotic and anthropogenic factors on old oak plantations; structural diversity of oak plantations in the green zone of forest parks and the protection of tree natural monuments in European countries. Most often, appraisers focus on biometric assessment studies, foresters on forestry, land amelioration on agroforestry, and soil scientists on obtaining indicators that characterize soil properties. It is not easy to combine various indicators, especially when they have different dimensions (Fawzy *et al.*, 2020).

During the study of the state and improvement of eroded soils V. Maliuha *et al.* (2021) tested the coefficient of soil improvement as an average integral indicator that takes into account individual elements of soil properties. According to a similar methodological approach, it was proposed to use an integral indicator of the condition of forest plantations, taking into account biometric, ameliorative, health features of forest plantations and soil properties. To obtain an integral indicator of the condition of forest plantations, calculations are performed in advance, which ensure the reduction of all various indicators with their absolute values to relative values in comparison with the selected control.

The purpose of the study was to comprehensively assess the current condition and performance of erosion control properties of old-age oak stands of natural origin.

Materials and Methods

Comprehensive studies of age-old oak stand of natural origin were carried out on the territory of the "Koshyk" tract of the Educational and Experimental Forestry of the Bila Tserkva

National Agrarian University. The area of the massif was 7.5 hectares, on which 4 trial plots (TP) were selected (Fig. 1). Field research was conducted during September-December 2022. The study of old oak plantations of natural origin, the LIDAR surveying was used, which allows you to quickly obtain detailed and spatial

information about the short-term dynamics of “windows” in the canopy of old oak plantations. This technology offers a valuable means of studying patterns of forest loss and understanding the dynamics of forest ecosystems at a narrower scale than previously possible using traditional methods (Vepakomma *et al.*, 2008).

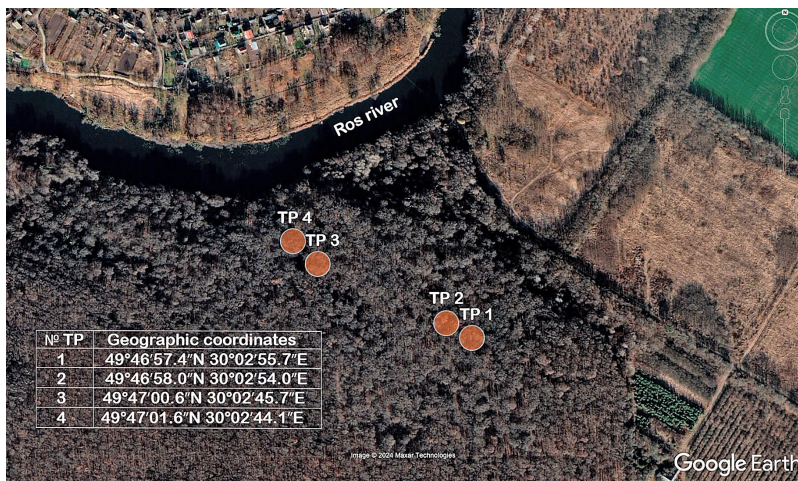


Figure 1. Location of trial plots on the territory of the “Koshyk” tract

Source: Google Earth

Based on the method of applying an integral indicator, which takes into account biometric, amelioration and health characteristics of stands, as well as agrochemical indicators of the soil. The following indicators were considered in the study: biometrics – height of trees, m; diameter, cm; stock, m³/ha; the basal area – m²/ha, etc.; amelioration – root surface area, cm²; soil hardness, kg/cm²; soil compaction density, g/cm³ and its water permeability, mm/min; forestry, characterizing health condition – the number of affected trees, pcs. and health condition index; agrochemistry – the content of available forms of nitrogen, mobile phosphorus, mobile potassium, mg/kg, humus, %, etc. (Khryk, 2024).

All trees were numbered in all trial plots, and a list of trees by diameter was made (Fig. 2a). At each trial plot, the heights of 12-15 trees were measured with an altimeter-eclimometer RM-5 (Finland), followed by construction of graphs of height curves. One model tree was selected based on the average height and diameter within each trial plot. Next to each model tree, at a distance of 3 m, samples of the root-containing layer of the soil were taken using a soil sampler (Fig. 2b). Test samples of soil cores were taken in mutually perpendicular directions from the middle tree of an old oak tree at depths of 0-10, 10-20, 20-30, 30-40, and 40-50 cm (Fig. 2b). A total of 67 samples were selected.



Figure 2. Field and chamber work

Note: a) numbered age-old oak on the trial plot; b) sampling of soil cores using a drill; c) measurement of water absorption time by the soil; d) hardness tester; e) use of a cutting ring to determine the density of the soil composition; f) determination of the volume of conductive roots by the xylometric method; g) measurement of the weight of active roots

Source: developed by the authors

In parallel, the roots of the common oak were selected from the obtained cores and divided into fractions: physiologically active roots (with a diameter of < 2 mm) and conducting roots (with a diameter of > 2 mm). Their volume was determined by the xylometric method by measuring the displaced water during immersion of the roots in a wet state in water (Fig. 2f). The mass of raw and dry roots was determined using electronic scales with an accuracy of 0.01 g (Fig. 2g). Root diameters were determined using a micrometer, which made it possible to establish the average value of the index of each fraction. For each fraction, the surface areas of the root samples were calculated according to formula (1):

$$S = 4 \cdot \frac{V}{D}, \quad (1)$$

where, S is the lateral surface of the roots, cm^2 ; V – root volume of this fraction, cm^3 ; D – the

average diameter of the fraction, cm. Using a soil sampling device with a diameter of 10 cm, soil cores were taken from experimental plots in 5-fold repetition to obtain mixed soil samples from each 10-cm layer to a depth of 50 cm of the active root-containing horizon. Mixed soil samples for laboratory analyses weighing 1 kg were formed (Pawluk *et al.*, 2023). Soil hardness was measured by I. Golubev's hardness tester in 20 repetitions with subsequent statistical data processing (Fig. 2d). A total of 80 soil hardness measurements were made.

The time of water absorption by the soil was measured using steel cylinders with a diameter of 80 mm and a height of 100 mm by burying the cylinder halfway into the soil and filling the upper part (50 mm) with water. The stopwatch determined the absorption time of a 50 mm layer of water, which corresponds to torrential rainfall. The number of measurements is

10 times. A total of 40 measurements of water permeability of the soil were made.

Water permeability is calculated by the ratio of the amount of absorbed water to the time of its absorption (Fig. 2c). The compaction density of the soil was determined using a cutting ring with a diameter of 50 mm and a height of 30 mm. The selection of soil samples was carried out both from the surface and from depths of 10-50 cm using a soil sampler. The soil from the cutting ring was transferred to an aluminum box for drying in a cabinet to constant weight. The assembly density (volumetric mass) was determined by dividing the weight of dry soil

by the volume of the cutting ring (Fig. 2e). The content of nutrients was obtained by laboratory tests of soil samples in the certified laboratory of the Bila Tserkva National Agrarian University. Nutrient stocks of available forms of nitrogen ($N - NO_3 + N - NH_4$), mobile phosphorus (P_2O_5), mobile potassium (K_2O) were determined. The stock is calculated by the product of their content (mg/kg) by the density of the assembly and by the thickness of the soil layer of 50 cm. Researchers V. Khryk *et al.* (2024) developed a scale for assessing the state of forest stands (Table 1), which was used to determine the integral condition of the studied stands.

Table 1. Scale for assessing the condition of forest stands

Serial number	Integral indicator	Value, %	Stand condition
1	very high	0-20	safe
2	high	21-40	attenuated
3	average	41-60	weak
4	low	61-80	very weak
5	critical	81-100	threatening

Source: developed by the authors based on V. Khryk *et al.* (2024)

The experimental studies conducted on plants comply with international standards Convention on Biological Diversity (1992). According to a visual inspection of all stands, the stand on TP 4 was determined to have with the weakest health conditions (Resolution of the Cabinet of Ministers of Ukraine No. 756, 2016) and adopted by the authors of this study and was accepted as the basic (control) – for a comparative assessment of the integral condition of the investigated age-old stands on trial plots 1-3.

Results and Discussion

The concept of plantation condition has many aspects. Plantations are constantly in flux: on the one hand, their condition depends on forest conditions, and on the other hand, they are capable of creating new conditions that will be

most favourable for growth and development. The condition of forest plantations can be assessed from different positions. With the help of silvicultural and biometric indicators, it is possible to assess the condition of plantations, taking into account their qualitative (class of rating) and quantitative (stand stock) productivity. There are indicators that allow establishing the health condition of plantations. For example, a tree stand has achieved high productivity, but under certain conditions has lost its biological stability due to the manifestation of the action of forest pests or pathogens. For this, there is already an indicator of the health condition index (Resolution of..., 2016).

The condition of manifestation of ameliorative properties of old oak stands was determined by a number of soil characteristics,

including compaction density, hardness, water permeability, etc. Forests have numerous ecological functions: energy, water regulation, water absorption, soil protection, siltation, soil creation, restoration, recreation, sanitary and hygienic, aesthetic, climate regulation, ecological stabilization, etc. Their effective ability to perform many functions is closely related to the condition of the plantations.

Forestry and biometric characteristics of age-old oak forest plantations of natural origin are presented in Table 2. They are pure in composition, aged from 200 to 214 years. Trial plot 1 is distinguished by the average diameter, the rest do not have a reliably significant difference. The average heights are within the II class of rating, which characterizes it as a fairly high quality indicator of the productivity of old stands.

Table 2. Forestry and biometric characteristics of stands according to the data of trial plots

TP number	Stand composition	Age, years	Number of trees, pcs.		Average		Plot area, ha	Class of rating	Stock, m ³ /ha	Total stock, m ³
			per plot	per/ha	Diameter, cm	Height, m				
1	10Qr	214	321	107	67.8±0.75	29.3±3.1	3.0	II	510	1530
2	10Qr	204	236	107	64.7±0.75	29.1±2.6	2.2	II	465	1023
3	10Qr	200	135	104	63.5±1.06	28.9±3.0	1.3	II	451	586
4	10Qr	204	102	102	64.6±1.41	29.2±2.5	1.0	II	429	429

Note: Qr – common oak (*Quercus robur* L.)

Source: developed by the authors

The area of the trial plots is from 1.0 to 3.0 ha, respectively, and the number of trees is from 102 to 321 pcs., although if you bring the data to an area of 1 ha, the difference in the number of trees on the plots turns out to be insignificant from 107 to 102 trees. Quantitative productivity, which is represented by the stock of trunk wood, is in the range from 429 to 510 m³/ha, which, taking into account the different area of trial plots, provides a total stock of wood from 429 to 1530 m³. From the considered forest biometric indicators, for further comparison of the obtained data, it is advisable to take into account the diameter and stock of

plantations, since the rest of the indicators do not have a significant difference.

The following indicators were chosen to evaluate the erosion control properties of the stands: hardness, water permeability of the soil and the study of root systems. It is the selected indicators that most accurately characterize the indicated properties, which depend on the possibility of transferring surface runoff to ground runoff, in order to avoid the possible manifestation of erosion processes as much as possible. With low soil hardness, sufficient water permeability and the spread of root systems, maximum absorption of water by the soil

can be ensured, that is, surface (often destructive) runoff can be transferred to safe internal soil runoff. Statistics for determination of soil hardness and assessment of the significance of the difference between the average values of

indicators are presented in the Table 3 and 4. The maximum hardness of the soil detected during the control TP 4 is 15.2 kg/cm². The rest of the obtained hardness indicators on TP 1-3 do not have significant differences.

Table 3. Soil hardness statistics

TP number	Statistics					
	N	M	m	σ	v	p
1	20	9.9	0.567	2.53	25.57	5.72
2	20	11.8	0.663	2.97	25.14	5.62
3	20	10.6	0.266	1.19	11.29	2.52
4 (Control)	20	15.2	0.571	2.55	16.74	3.74

Note: N – the number of measurements; M – the average value; m – the error of the average value; σ – mean square deviation; v – coefficient of variation; p – accuracy of research

Source: developed by the authors

Table 4. Evaluation of the significance of the difference between the average values of soil hardness indicators

The difference between the average values on the trial plots	Number of degrees of freedom	Student's criterion $t_{0.05}$	The difference between the average values on the trial plots	Number of degrees of freedom	Student's criterion $t_{0.05}$
1-2	36	2.18	2-3	36	1.68
1-3	36	1.12	2-4 (C)*	36	3.88
1-4 (C)*	36	6.60	3-4 (C)*	36	7.31

Note: * – the difference is significant; C – control

Source: developed by the authors

Therefore, a significant difference in hardness indicators was obtained for all plots compared to the control. A high soil hardness of more than 30 kg/cm² not only slows down the absorption of rainwater as much as possible, but also often prevents the development of root systems. An important indicator is the water

permeability of the soil, and for its determination, the absorption time of a 50 mm layer of water from steel cylinders, which corresponds to the level of an atmospheric downpour, was initially taken into account. The statistics of the absorption time of 50 mm of water are given in the Table 5.

Table 5. Statistics of indicators of absorption time of 50 mm of water

TP number	Statistics					
	N	M	m	σ	v	p
1	10	2.94	0.575	1.82	61.78	19.54
2	10	6.58	1.234	3.90	59.32	18.76
3	10	5.50	0.629	1.99	36.19	11.44
4 (C)	10	10.10	0.706	2.23	22.13	6.99

Note: N – the number of measurements; M – the average value; m – the error of the average value; σ – mean square deviation; v – coefficient of variation; p – accuracy of research

Source: developed by the authors

The obtained results of statistical processing of field research data show that the absorption time of a 50 mm layer of water ranges from 2.94 to 10.10 minutes (TP 1-4). At the same time, no significant difference was found between the indicated indicators at TP 2 and 3. An estimate of the significance of the difference between the average values of the absorption time of a 50 mm layer of water is

given in the Table 6. A significant difference in water absorption indicators was obtained between TP 1 and TP 2 and 3, as well as compared to the control. Indicators of soil hardness and the time taken to absorb a 50 mm layer of water revealed a direct relationship. A higher hardness index of 15.2 kg/cm² corresponds to a longer time for absorbing water from a steel cylinder – 10.1 minutes.

Table 6. Evaluation of the significance of the difference between the average values of the indicators of the time of absorption of 50 mm of water

The difference between the average values on the trial plots	Number of degrees of freedom	Student's criterion $t_{0.05}$	The difference between the average values on the trial plots	Number of degrees of freedom	Student's criterion $t_{0.05}$
1-2*	16	2.67	2-3	16	0.78
1-3*	16	3.00	2-4 (C)*	16	2.48
1-4 (C)*	16	7.87	3-4 (C)*	16	4.87

Note: * – the difference is significant; C – control

Source: developed by the authors

In terms of erosion control, it is important to take into account the peculiarities of the development of root systems, which, in addition to keeping plants in the soil, supplying them with

nutrients and water, contribute to the formation of water-resistant aggregate structures and reliably counteract the manifestation of erosion processes (washing and erosion) of the soil, Table 7.

Table 7. Ratio of roots in monoliths 50 cm deep

TP number	Mass of dry roots, g			Volume of displaced water, ml		
	conductive	active	ratio	conductive	active	ratio
1	10.48	0.80	13.1 : 1	25.4	1.3	19.5 : 1
2	8.20	0.70	11.7 : 1	10.5	0.8	13.1 : 1
3	9.60	0.75	12.8 : 1	17.4	1.1	15.8 : 1
4	9.39	0.89	10.6 : 1	17.3	1.4	12.4 : 1

Source: developed by the authors

The largest mass of roots and, accordingly, the volume of water displaced by it from the xylometer falls on TP 1. It turned out that the ratio of the mass of roots and the volume of displaced water is characteristic of all trial plots in favour of the conductive one, which provides mainly the transport function. At the same time, it contributes to the transfer of surface runoff

into the soil due to the spread of roots into deep soil horizons. The most important role of active roots is that, thanks to its own surface area, it ensures direct contact with the soil in supplying plants with water and nutrients from the bulk solution, contributes to the improvement of the soil structure and its water permeability. The surface area of the roots is given in the Table 8.

Table 8. Root surface area

TP number	The average diameter of the roots, cm		The volume of displaced water, ml			Root surface area, cm ²		
	conductive	active	conductive	active	total	conductive	active	ratio
1	0.73	0.03	25.4	1.3	26.7	139.2	173.3	1 : 1.24
2	0.52	0.03	10.5	0.8	11.2	80.8	106.7	1 : 1.32
3	0.65	0.03	17.4	1.1	18.5	107.1	146.7	1 : 1.37
4	0.67	0.03	17.3	1.4	18.9	103.3	186.7	1 : 1.81

Source: developed by the authors

Despite the fact that the ratio of the mass of the roots and the volume of displaced water was in favour of the conductive one, the ratio between the active and conductive roots in the monoliths was in favour of the active one based on the determined surface area of direct contact with the soil. Therefore, the surface area of active roots was used in further research to assess the condition of plantations by an integral indicator.

In addition to the study of the ameliorative erosion control properties of the plantations,

the determination of nutrient stocks in the soil was carried out using the example of the content of agrochemical indicators: available forms of nitrogen, mobile phosphorus and potassium. Taking into account the different absolute values of all experimental indicators, to obtain an integral indicator of the condition of stands, conversions were made to their relative values. For this purpose, TP 4 was chosen as a control. A comparison of stocks of agrochemical indicators that provide plants with food is given in the Table 9.

Table 9. Comparison of nutrient stocks in a 50 cm soil layer

TP number	Available forms of nitrogen (N-NO ₃ +N-NH ₄), mg/kg		Mobile phosphorus (P ₂ O ₅), mg/kg		Mobile potassium (K ₂ O), mg/kg	
1	613.4	+11.3%	3086.7	+33.0%	4379.3	+3.5%
2	651.2	+18.2%	3475.5	+49.7%	3749.4	-11.3%
3	707.9	+28.5%	2881.1	+24.1%	4350.6	+2.9%
4 (C)	551.0	-	2321.2	-	4229.2	-

Note: C – control

Source: developed by the authors

During the comparison of agrochemical indicators that ensure the supply of nutrients, such as available forms of nitrogen and mobile phosphorus and potassium, a decrease in the indicator of mobile potassium at TP 2 (-11.3%) was established. Indicators

of the health state of stands are also taken into account, in particular, the presence of transverse cancer of common oak, the total percentage of affected trees and the index of the health condition of plantations, which is given in Table 10.

Table 10. Comparison of indicators by health condition

TP number	Transverse cancer of common oak, %		Number of affected trees, %		Health condition index	
1	33.0	+5.7	46.4	+17.0	1.96	+24.0%
2	38.7	-10.6	44.9	+19.7	1.49	+42.2%

Table 10, Continued

TP number	Transverse cancer of common oak, %		Number of affected trees, %		Health condition index	
3	25.5	+27.1	48.5	+13.2	2.48	+3.9%
4 (C)	35.0	-	55.9	-	2.58	-

Note: C – control

Source: developed by the authors

During the calculations, the (+) or (-) obtained relative value of the indicator with the state of the plantation must be taken into account. That is, how will the impact of this indicator on the condition of the plantation be manifested – positively or negatively? The peculiarity of the comparison of indicators of the health condition is that negative values are given to those of them that worsen the condition. Thus, during the calculation of the indicator of transverse cancer compared to the control, an increase in the indicator on TP 2 by 10.6%, a decrease on TP 1 by - 5.7% and on TP 3 by - 27.1%, but for the stand this decrease is a positive phenomenon, and growth is negative, so the signs are reversed. The number of affected trees and indices of health condition are lower than the

control, but instead of minuses, pluses are given, since the reduction of the indicated indicators according to the calculation turns out to be a positive phenomenon for stands.

Among the ameliorative indicators, the following indicators were selected: surface area of active roots, hardness and water permeability of the soil. In part, the role of active roots has been considered earlier, it is worth noting that it takes the most active part in improving the properties of the soil, both physical (loosening, strengthening of waterproofing capacity, resistance to washing and erosion, etc.), and chemical – it contributes to soil formation due to the processes of mineralization and humification of organic matter. Comparison with the control of ameliorative indicators is given in the Table 11.

Table 11. Comparison of ameliorative indicators

TP number	Surface area of active roots, cm ²		Soil hardness, kg/cm ²		Absorption time of 50 mm of water, min.	
1	173.3	-7.2%	9.9	+34.9%	2.94	+70.9%
2	106.7	-42.8%	11.8	+22.4%	6.58	+34.9%
3	146.7	-21.4%	10.6	+30.3%	5.50	+45.5%
4 (C)	186.7	-	15.2	-	10.10	-

Note: C – control

Source: developed by the authors

The comparison of ameliorative indicators also warrants clarification. While the decrease in the surface area of active roots compared to the control is evident, further explanation is needed for the soil hardness and the absorption time of 50 mm of water. A decrease in the value of the soil hardness indicator for plantations

is a positive thing. Under such conditions, root systems develop better and atmospheric precipitation is better absorbed by the soil. Absorption time decreased, this is also a positive phenomenon because more moisture is absorbed in a shorter period of time (50:2.94 = 17.0 mm/min, and 50:10.1 = 5.0 mm/min), which corresponds

to the water permeability indicator. Absorption time and hardness are directly related, while hardness and water permeability indicators have an inversely proportional relationship. They provide an opportunity for the optimal spread of root systems due to a certain hardness and moisture of the soil, which is related to water permeability. Both indicators affect soil erosion processes. For example, with significant hardness, the development of root systems becomes impossible, which worsens their binding effect and reduces the water-absorbing role to a minimum, and as a result, concentrated surface runoff leads to soil washing and erosion.

Two of the biometric indicators were chosen to obtain an integral condition indicator –

the average diameter and the stock (Table 12). A total of 11 indicators were selected during complex studies to establish an integral condition indicator, the comparison of which is shown in the Tables 9-12. The integral indicator of the condition of stands is the average value of the algebraic sum of all relative compared indicators, eleven of which are considered in this study.

Most often, certain aspects of the plantations are studied and analysed, taking into account certain indicators that are obtained using separate methods and have their own absolute values. To assess such multidimensionality as natural forest stands, in particular age, a generalized integrating indicator is needed.

Table 12. Comparison of biometric indicators

TP number	Diameter of an average tree, cm		Stock of the stand, m ³ /ha	
1	67.8	+4.9%	510	+18.9%
2	64.7	+0.2%	465	+8.4%
3	63.5	-1.7%	451	+5.1%
4 (C)	64.6	-	429	-

Note: C – control

Source: developed by the authors

As for the biometric characteristics, it is possible to notice a non-significant difference between the indicators of the average diameters of TP 2 and 3 with the control. The diameter of the average tree on TP 2 exceeds the control by 0.2%,

and on TP 3 it is smaller by 1.7%, which was discussed earlier during the comparison of statistics. The stock of trees in all areas is higher than the control. The calculation of the integral indicator of the condition of the stands is given in the Table 13.

Table 13. Calculation of the integral indicator of the condition the stands

TP number	N	P ₂ O ₅	K ₂ O	Toc	Ta	Ihc	S	T	Wa	D	Stock	Iic
1	11.3	33.0	3.5	5.7	17.0	24.0	-7.2%	34.9	70.9	4.9	18.9	19.7
2	18.2	49.7	-11.3	-10.6	19.7	42.2	-42.8%	22.4	34.9	0.2	8.4	11.9
3	28.5	24.1	2.9	27.1	13.2	3.9	-21.4%	30.3	45.5	-1.7	5.1	14.3

Note: N – available forms of nitrogen; P₂O₅ – mobile phosphorus; K₂O – mobile potassium; Toc – transverse oak cancer; Ta – the number of affected trees; Ihc – health condition index; S – surface area of active roots; Hs – soil hardness; Wa – absorption time of 50 mm of water; D – average diameter; Iic – integral indicator of condition

Source: compiled by the authors

Therefore, an analysis of eleven indicators was carried out, which made it possible to obtain a synthesizing result of the assessment of the condition of aged oak stands of natural origin. Another approval of the integral indicator of the state of plantations took place. Under the conditions of comparison of the assessed plantations of TP 1, 2, 3 with the control of TP 4, the integral indicators of the conditions were as follows: the result – 19.7% has TP 1, and further in descending order – 14.3% of TP 3 and – 11.9% at TP 2.

The number of indicators can be significant, which makes it possible to take into account their cumulative effect on the final result in more detail. It is especially important to use such a methodical approach to evaluate a large number of objects that will require comparative evaluation.

An old age tree is one that holds biological, cultural, or aesthetic significance due to its notable age, size, or condition. C. Leuschner & H. Ellenberg (2017) proved such trees are of great interest as they serve as living witnesses to the past and relics of former landscapes. These grand old age trees are among the most iconic life forms on Earth and play a crucial role in various terrestrial ecosystems. M. Gilhen-Baker *et al.* (2022) examined those large old trees have an active impact on ecosystem conservation, productivity and climate improvement.

A. Kushnir & I. Vakulyk (2018) described that big old age trees are an important part of shared cultural heritage, providing people with aesthetic, symbolic, religious and historical markers. Bringing their many ecological, oceanic, therapeutic and socio-cultural benefits to the fore and learning to appreciate old trees holistically can contribute to halting the global decline of old growth forests.

D. Lindenmayer & W. Laurance (2017) and D. Lindenmayer (2017) analysed the state of old

oak stands during research on the influence of climate on vegetation change in the eastern regions of the USA. Large old trees play an important ecological role in the hydrological regime, nutrient cycling, etc. Age-old plantations affect the spatial and temporal distribution and number of individuals of one species and populations of many other plant and animal species. Researchers A. Larionova & A. Klestch (2019) suggested that important parameters of old-growth trees, such as height, life span, and excessive sparsity, which provide competitive advantages in an undisturbed environment, can make such trees highly vulnerable to a number of anthropogenic impacts.

Centuries-old trees suffer from droughts, fires, pests and pathogens, as well as from logging, land clearing, landscape fragmentation and climate change. P. Zarzyński & A. Grzywacz (2019) researched that addressing the above threats is challenging because they often interact and manifest differently in different ecosystems, requiring targeted responses to specific species or ecosystems. According F. Indresputra *et al.* (2023), new management actions are often needed to protect the existing large old trees and to ensure the recruitment of new cohorts of such trees. In agro-industrial and urban areas, there is a need to conserve and preserve individual specimens of centuries-old trees. Landscape-level approaches will be needed, such as protecting sites where large old trees are most likely to occur. A. Arif *et al.* (2024) noted the trees demonstrate significant potential for land reclamation due to their ability to thrive in high salinity conditions. Their adaptability not only aids in soil stabilization but also improves the overall ecological health of degraded areas.

However, this raises problems related to the likely redistribution of trees depending on climate change, as old trees may exist at this time in places unsuitable for the development

of new communities of the same species. Researchers P. Adamič *et al.* (2023) studied suitable future ecological domains for a species may exist in new places where it has never been encountered before. Future distribution and conservation of large old trees may require conflicting responses, including assisted migration via seeds or seedlings to new locations. K. Kimic (2021) studied the global decline in the number of large old trees and their importance to ecosystems, which may be relevant to the assessment of the condition of old-growth oak stands.

According to I. Vakuluk & O. Balalaieva (2018), the effectiveness of such approaches is limited by the ecological characteristics of large old trees (e.g., the presence of hollows) dependent on other species, such as termites, fungi, and bacteria.

Morphological indicators of old trees according to N. Sukri *et al.* (2023) vary greatly on a species-to-species basis, creating significant challenges in identifying large old trees and requiring an ecosystem-specific and identification method that is rarely readily transferable to other species or ecosystems. Such variability is also manifested in the marked interspecific relationships of the main characteristics of old-growth trees, including the root system, crown habit, degree of development of the bark microenvironment, and prevalence of gaps.

Overall, the significant number of indicators allows for a more detailed consideration of their cumulative effect on the final result, which is important when evaluating a large number of objects for comparative analysis. Old trees are not only biologically, culturally, and aesthetically significant, but also play a critical role in various ecosystems by providing hydrological regimes, nutrient cycling, and numerous ecosystem processes. This underscores the need for their protection and adaptation to climate change to maintain ecological stability.

Conclusions

The analysis and comparison of taxation indicators shows that the leading position is occupied by TP 1, where the stock of stem wood is 510 m³/ha or 18.9% higher than the control. The average diameter is 67.8 cm, which is 4.9% higher than the control. The large difference in stock is caused by the difference in diameters and the number of trees. Analysing the nutrient reserves, found that TP 3 has advantages in terms of available nitrogen forms, which is 28.5% more than the control. In terms of mobile phosphorus reserves, TP 2 has the best position, which is 49.7% higher than the control. There is no big difference in mobile potash reserves, but TP 1 is 3.5%.

The study of the health condition showed the best results in TP 3, where the presence of cross cancer is 27.1% less than in the control. The smallest number of affected trees was found in TP 2 (by 19.7%). The health condition index of 1.49, which is typical for healthy plantations, corresponds to the conditions of TP 2. The analysis of reclamation indicators shows that the best results in terms of the surface area of active roots were obtained in the control. This is due to the presence of the largest amount of undergrowth and undergrowth in this area. In terms of soil hardness, the best result was found in TP 1 – 9.9 kg/cm², which differs by 34.9% compared to the control. The time of absorption of 50 mm of water layer was also the best in TP 1 (70.9% faster compared to the control).

On the basis of the results of the comprehensive assessment of the condition and performance of the properties of the aged oak stands of natural origin of the Educational Farm of the Bila Tserkva National Agrarian University, it can be concluded that very high values of integral indicators, which do not exceed 20%, have been obtained. They guarantee a general safe condition in the performance of erosion control

properties by studied forest stands. Under the conditions of comparison of the assessed plantations of TP 1, 2, 3 with the control of TP 4, the integral indicators of the conditions were as follows: the result – 19.7% has TP 1, and further in descending order – 14.3% of TP 3 and – 11.9% at TP 2.

Therefore, the proposed integral indicator of the condition of plantations provides the possibility of applying a comprehensive approach to their assessment, taking into account the manifestation of various ecological properties by forest stands. It is crucial to convert various indicators from absolute values to relative values, taking into account whether

they have positive or negative effects on the forest stands. The methodology for assessing the integral indicator of plantation condition requires comprehensive testing. The need for the most complete assessment of the condition of plantations as a multifaceted research object remains, which indicates its relevance. Its refinement and revision may not be ruled out, but this will be proved by further testing.

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Conflict of Interest

None.

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Стан і меліоративні властивості вікових корінних дубових насаджень

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Анотація. Меліоративні властивості лісових насаджень мають важливе значення для розробки ефективних заходів з охорони довкілля та сталого використання лісових ресурсів. Вивчення цих лісів допомагає розробити ефективні стратегії їх збереження та сталого використання. Актуальність теми дослідження визначається необхідністю апробації методики оцінки стану вікових дубових насаджень за допомогою інтегрального показника. Метою дослідження було оцінити сучасний стан та ефективність протиерозійних властивостей старих дубових насаджень природного походження. Апробовано методику оцінки стану вікових насаджень дуба за інтегральним показником, що враховує біометричні, меліоративні та санітарні характеристики насаджень, а також агрохімічні показники ґрунту. Польові роботи проводились на чотирьох дослідних ділянках, де обліковано 794 вікові дерева. Комплексні дослідження включали визначення біометричних показників, аналіз кореневої системи, визначення вмісту в ґрунті доступних форм азоту, рухомого фосфору, рухомого калію. Твердість ґрунту вимірювали за допомогою твердоміра, а водопроникність

ґрунту – за допомогою сталевих циліндрів. На дослідних ділянках отримано високі значення інтегральних показників, які коливаються від 11,9 до 19,7 %. Вони гарантують ефективні протиерозійні властивості місцевих старовікових лісів. Досліджено, що запропонований інтегральний показник стану деревостанів не тільки дозволяє оцінити їх поточний стан, але й демонструє ефективний контроль ерозійних та екологічних функцій деревостану. Встановлено, що важливою вимогою є переведення абсолютних значень різних показників у відносні, з обов'язковим врахуванням їх позитивного чи негативного впливу на самі лісові насадження. Встановлено, що інтегральний показник стану може бути використаний для протиерозійних насаджень будь-якого вікового діапазону. Результати можуть бути використані для розробки програм збереження біорізноманіття та створення ефективних стратегій управління лісовими ресурсами

Ключові слова: індекс інтегрального стану деревостану; водопроникність; твердість; протиерозійні властивості; біометричні показники