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ЗМІСТ

М. М. Бур'янчук, А. М. Білоус
Форма стовбура сосни звичайної в деревостанах Українського Полісся 8
А. П. Вакал, Ю. І. Литвиненко
Раритетне фіторізноманіття басейну річки Івотка в межах території Сумської області 21
А. А. Дзиба, К. Є. Савельєв
Важливість та ефективність культурних екосистемних послуг парків міста Києва під час війни в Україні 38
В. М. Малюга, О. В. Соваков, С. М. Дударець
Сучасний стан полезахисних лісових смуг Лівобережного Лісостепу України 53
Г. Пей, О. Ю. Горбачова, Ю. В. Цапко, С. М. Мазурчук, Б. В. Денисюк
Оцінка стійкості клейового з'єднання столярного виробу до атмосферних коливань 67
С. Пісова, О. В. Токарєва, С. Є. Сендонін
Досвід збереження вікових дерев у м. Відні, Австрія 83
П. П. Яворовський, Р. В. Гуржій, І. М. Кульбанська, Г. О. Бойко, Ю. І. Андрусяк
Вплив способів зимового зберігання жолудів на розвиток та ростові процеси дуба звичайного 96

CONTENTS

M. Burianchuk, A. Bilous
The shape of the trunk of Scots pine in the stands of the Ukrainian Polissia 8
A. Vakal, Y. Lytvynenko
Rare phyto-diversity of the Ivotka river basin within the territory of Sumy region 21
A. Dzyba, K. Saveliev
Importance and effectiveness of cultural ecosystem services of parks in Kyiv during the war in Ukraine 38
V. Maliuha, O. Sovakov, S. Dudarets
The current state of windbreaks in the Left Bank Forest-Steppe of Ukraine 53
G. Pei, O. Horbachova, Yu. Tsapko, S. Mazurchuk, B. Denysiuk
Assessment of the durability of the adhesive bond in a carpentry product to atmospheric fluctuations 67
S. Píšová, O. Tokarieva, S. Sendonin
The experience of preserving ancient trees in Vienna, Austria 83
P. Yavorovskyi, R. Hurzhii, I. Kulbanska, A. Boyko, Yu. Andrusiak
Influence of winter storage methods of acorns on the development and growth processes of common oak 96

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The shape of the trunk of Scots pine in the stands of the Ukrainian Polissia

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Abstract. Due to the transition of Ukraine in 2019 to new regulatory documents on standardisation regarding the classification of round timber by quality classes, it became necessary to develop standards for evaluating volumes in accordance with the new requirements. The purpose of the study was to develop a mathematical model of the forming stem of Scots pine for trees of two groups of diameters. The study is based on the use of empirical material collected in different years by researchers of the Department of forest taxation and forest management of the National University of Life and Environmental Sciences of Ukraine, which is 583 model pine trees. The Kozak model was use as the basic model for modelling the forming Scots pine. A mixed effect model was calibrated to characterise the variability in the tree stem shape of Scots pine. Parameters for the role of random effects were selected based on their coefficients of variation using the bootstrap process. Data were grouped into two groups of diameters by analysing modelling residues and evaluating the quality of models based on the use of the Akaike information criterion (*AIC*). By dividing the data array into two groups of thickness degrees and developing models of the creator for each of the groups separately, a decrease in the indicator of the Akaike information criterion (*AIC*) was achieved to the level of *AIC* = 7433.02 for a group (8-28 cm) and *AIC* = 13154.67 for the group (32-76 cm), which increased the accuracy of the developed models. Enabling random effect parameters in model by A. Kozak for the developed mathematical equations allowed more accurately describing

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the variability of the tree stem of Scots pine. The obtained models give a clear and fairly accurate prediction of the determination of tree stem diameters along the entire length. The use of the developed models can serve as a basis for improving forest traction standards for estimating the volume of tree stem in the process of forestry production and predicting the yield of roundwood volumes by quality classes

Keywords: modelling; Akaike information criterion; species number; diameter groups; formation equation; shape variability

Introduction

Improvement of forest taxation regulation and reference support increases the accuracy of taxation of forest resources and ecosystem services of forest ecosystems. Modern methods of data collection and analysis and modelling can substantially improve tax standards in the context of systematic accumulation and addition of the research database (Robinson & Hamann, 2011). Modelling of the tree stem taper of the main forest-forming species of Ukraine provides initial conditions for taxing the volume of tree stem and round timber obtained from them (Bilous *et al.*, 2021b). Accurate accounting of the volume of business wood contributes to the development of a transparent wood market and fair relations between sellers and consumers of wood. Ukraine has recently adopted regulatory documents on standardization (DSTU EN 1927-2:2018..., 2018; TUU-00994207-001:2018..., 2018; TUU-00994207-003:2018..., 2018) focusing on the leading practice of the European Union countries for the classification of round timber, which led to the need to model the taper equation and update all standards for determining the stem volume in accordance with the new standards of standardization. The identification of new patterns in the taper equation and the development of forest taxation information support will contribute to rational forest management on the way to sustainable development. Improved logging standards should ensure a more accurate accounting of wood during material and monetary assessment, logging and sales of products. The development of taper equations is a rather complex process that requires investigating a large number of felled model trees in modal stands.

Investigating the profile of a tree stem allows for describing the tree stem, having a detailed description of the stem diameters along its entire length, and determining the volumes for specified segments. The study of tree stem by S. Salekin *et al.* (2021) showed that they differ in their shape from the clod part to the tip, with a neiloid shape at the bottom, cylindrical in the middle and cone-shaped at the top, and possible intermediate shape types at certain areas of the tree stem height. Simple parametric models do not take these features into account, thus T. Pukkala *et al.* (2019) to solve this problem, it is recommended to use splines to approximate taper equation, having some values of diameters along the length of the tree stem.

P. He *et al.* (2020) proposed using an additive model based on the diameter at chest level, tree stem height, height at relative marks, and diameter at these marks to examine the taper equation of Scots pine. The generalised model consists of different additive elements, each of which is estimated using a spline function, and each dependent variable can be explained for each additive element separately.

For the segmented model, R. Özçelik & O. Alkan (2020) applied a nonlinear mixed effects modelling approach. The inclusion of random effects provided a better fit for the model compared to the fixed-effects model. In this paper, the effects of residual heterogeneity of variance and residual autocorrelation were included to model the variance-covariance matrix, but the inclusion of random parameters did not completely eliminate autocorrelation of heteroscedasticity in residues, so the inclusion of the variance function and the CAR(1) model was added to the model. But still, the model of A. Kozak (2004) is more widely used in a number of modern studies (Bilous *et al.*, 2021b; Myroniuk *et al.*, 2023). The study by Z. Adamec *et al.* (2019) also used model by A. Kozak (2004), with such a selection of parameters for the model, which includes the best combination of random parameters, also allows checking and compensating for the presence of heteroscedasticity and autocorrelation of prediction errors. The development of sufficiently accurate models of the generatrix provides opportunities for further modelling of tree stem volumes depending on the ratio between the diameter and height of trees.

Thus, A. Bilous *et al.* (2022) developed mathematical models of tree stem volumes at the height-diameter ratio for the main forest-forming species of Ukraine, which can be used to estimate the volume of harvested wood, predict the structure of forests and estimate the stock of tree stem wood. In addition, in this paper, the volume equations were combined into tables that give an estimate of the volume distributions depending on the thickness class. Based on the models of generators for pine trees in the study of V.B. Bychenko *et al.* (2021), the methodological prerequisites for using a random process for modelling the distribution of the length of the business part of tree stem were described since the use of generating models in estimating volumes is a more advanced method since these models allow to predict the diameters from the butt to the top and calculate the median diameter of a certain segment and its volume. The purpose of the study was to examine the variability of tree stem shape and develop a tree stem taper equation for Scots pine.

Materials and Methods

Research material

For the study, the authors conducted fieldwork on the collection of experimental material in the test area, which was laid in 2020 in a ripe stand of Scots pine in the Horodnianske Forestry of the state enterprise "Horodnianske Forestry" in the Chernihiv region. 197 model Scots pine trees were measured on the test area. The study also uses research material collected in the area of Ukrainian Polissia in different years by researchers of the Department of forest taxation and forest management of the National University of Life and Environmental Sciences t of Ukraine (hereinafter NULES of Ukraine), which was used to develop standards in previous years (Kashpor & Strochynskii, 2013; Bilous *et al.*, 2021a). The total research database is 51 trial areas (Table 1), which includes 583 model Scots pine trees (*Pinus sylvestris L.)* (Table 2).

Table 1. General characteristics of test areas

PP code	Number of models	H, m	D, cm	Administrative region
12001	197	27.3	36.8	Chernihiv region
15516	6	31.2	38.8	Kyiv region
15520	2	25.8	29.0	Lviv
15521	3	25.6	24.0	Lviv

Table 1, Continued

PP code	Number of models	H, m	D, cm	Administrative region
15522	5	20.1	27.6	Lviv
15523	6	16.1	15.4	Lviv
15529	15	16.6	18.4	Khmelnytskyi
15534	4	33.0	38.0	Rivne
15543	9	23.8	29.9	Kyiv region
15544	6	29.1	39.3	Kyiv region
15545	12	30.5	43.4	Kyiv region
15546	10	28.7	32.6	Kyiv region
15547	1	19.0	14.7	Kyiv region
15548	8	16.9	14.8	Kyiv region
15551	8	23.5	28.7	Kyiv region
15564	7	27.2	31.6	Lviv
15565	3	37.0	63.4	Lviv
15566	4	31.1	44.0	Lviv
15570	7	18.2	19.7	Khmelnytskyi
15572	8	16.8	15.8	Khmelnytskyi
15585	4	17.6	24.4	Rivne
16888	11	20.7	26.2	Rivne
16889	11	11.7	14.9	Rivne
16892	4	30.9	47.6	Rivne
16893	9	14.2	18.7	Rivne
16896	4	16.1	17.5	Rivne
16897	11	15.9	14.0	Rivne
16898	14	16.2	18.0	Rivne
103002	14	25.2	28.2	Zhytomyr Region
103003	12	25.4	28.5	Zhytomyr Region
111006	5	20.6	22.5	Zhytomyr Region
155132	10	22.5	26.4	Zhytomyr Region
155183	6	29.5	33.3	Khmelnytskyi
155201	6	16.2	16.6	Lviv
155203	7	25.8	33.1	Rivne
155206	5	17.3	23.2	Kyiv region
155213	9	28.7	33.3	Rivne
167108	16	16.5	14.2	Zhytomyr Region
167113	11	24.5	27.4	Zhytomyr Region
167133	8	23.4	30.4	Zhytomyr Region
182012	12	15.7	14.7	Volyn
182061	11	14.2	12.1	Volyn
182087	7	14.4	14.3	Volyn
183050	10	24.7	26.5	Zhytomyr Region
184004	5	18.7	15.1	Kyiv region
185011	5	23.3	26.1	Khmelnytskyi
186018	8	16.9	14.2	Zhytomyr Region
186019	1	30.2	28.7	Kyiv region
188014	7	14.4	14.5	Volyn

Table 1, Continued

PP code	Number of models	H, m	D, cm	Administrative region
188015	10	13.1	12.3	Volyn
188017	9	12.3	12.1	Volyn

Note: PP – test area; H – average height, m; D – average diameter, cm
Source: compiled by the authors according to S. Kashpor & A. Strochynskii (2013), A. Bilous *et al*. (2021a)

Table 2. Distribution of model trees by thickness and height

Degrees of thickness	Height															
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
8	1	-	3	4	4	5	3	2	-	-	-	-	-	-	-	-
12	-	-	2	4	5	16	5	11	13	2	1	-	-	-	-	-
16	-	-	-	3	3	5	10	10	15	6	5	7	4	1	1	-
20	-	-	-	-	2	1	1	3	7	5	4	5	4	2	3	2
24	-	-	-	-	-	-	2	2	1	7	4	1	4	6	4	8
28	-	-	-	-	-	-	-	-	-	1	1	2	-	3	3	10
32	-	-	-	-	-	-	-	-	-	-	1	1	1	1	3	5
36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3
40	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**1**	**0**	**5**	**11**	**14**	**27**	**21**	**28**	**36**	**21**	**16**	**16**	**13**	**14**	**15**	**29**
Degrees of thickness	**Height**															
	24	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
24	7	3	2	1	-	-	-	-	-	-	-	-	-	-	-	-
28	7	13	11	12	5	-	1	-	-	-	-	-	-	-	-	-
32	8	9	12	20	4	9	4	-	-	-	-	-	-	-	-	-
36	5	7	11	13	12	6	3	4	-	-	-	-	-	-	-	-
40	2	8	6	9	13	8	4	6	1	-	-	-	-	-	-	-
44	-	1	2	6	7	7	9	3	2	-	-	1	-	-	-	-
48	-	-	-	-	1	7	2	1	5	1	-	-	-	-	-	-
52	-	-	1	-	2	-	2	-	-	2	1	-	-	-	-	-
56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-

Table 2, Continued

Degrees of thickness	Height															
	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Total	**31**	**41**	**46**	**61**	**44**	**37**	**25**	**14**	**9**	**4**	**1**	**1**	**0**	**0**	**2**	**0**

Source: compiled by the authors according to S. Kashpor & A. Strochynskii (2013), A. Bilous *et al*. (2021a)

A number of measurements were made to determine the taper equation on each model tree, including the establishment of the following parameters: stem diameter at a height of 1.3 m ($d_{1.3}$, cm), diameter at the middle of Sections 2 m long (i.e. 1, 3, 5 M, etc.), bark thickness, total stem height (*h,* m). The data were determined using forest taxation instruments in compliance with the established measurement accuracy for each indicator. The characteristics of the general research material are shown in Table 3, where *Mean* – average value; *Min* – minimum value; *Max* – maximum value; σ – standard deviation; ν,% – coefficient of variation; *d* – diameter at a height of 1.3 m; *h* – stem height; V_{ob} – tree stem volume in the bark; f_{ob} – species number in the bark; *q1, q2, q3* – form coefficients.

Table 3. Descriptive statistics of Scots pine research data

Indicator	*d*	*h*	*Vob, m³*	*fob*	*q1*	*q2*	*q3*
Mean	30.6	24.3	1.05	0.473	0.851	0.699	0.460
Min	6.60	7.9	0.01	0.284	0.628	0.474	0.235
Max	74.3	38.4	7.03	0.656	1.00	0.944	0.910
σ	11.4	5.8	0.850	0.047	0.055	0.058	0.065
ν, %	37.3	23.8	80.8	9.9	6.5	8.3	14.2

Source: compiled by the authors according to S. Kashpor & A. Strochynskii (2013), A. Bilous *et al*. (2021a)

Calculation of the tree stem volume in the bark (V_{ob}), the species number in the cortex (f_{ob}), and coefficients of the form (*q1, q2, q3*) were conducted using the PERT programme, which was developed by researchers of the Department of forest taxation and forest management of NULES of Ukraine. The programme analyses the data of list taxation of model trees with measurement by sections of constant length and gives an exhaustive tax description of trees.

Developing a taper equation model

Model of A. Kozak (2004) was used as the basis for the study, because it provides a reliable and more accurate estimate of the determination of diameters along the entire length of the tree stem, as indicated in previous studies (Li & Weiskittel, 2010):

$$d_i = a_{0*}\, d^{a_1} * h^{a_2} * \\ *X_i^{(b_1*z_i^4+b_2[1/\exp(D/H)]+b_3*X_i{}^{0,1}+b_4*\frac{1}{D}+b_5*H^{Q_i}+b_6*X_i)}, \quad (1)$$

where d_i – diameter outside barkat height h_i (cm), D – diameter at breast height 1.30 m (cm), h – height from ground level (m), H – total tree height above ground level (m), a_0-a_1 and b_1-b_6 – parameters of the equation. In the formula

$X_i = \frac{h-h_i}{h-1{,}3/H^{(1/3)}}$, $Q_i = 1 - z_i^{1/3}$, $z_i = \frac{h_i}{h}$.

The package was use to set the mathematical parameters of the model equation *nlme*

in the R (R Core Team, 2018) programming language because it allows a more reliable examination of the shape of a tree stem. A two-level model with mixed effects was also evaluated, which considers the presence of stem differences, which can be both on certain parts of the tree stem and on different tree stem in similar parts (Myroniuk *et al.*, 2023).

The bootstrap method was used to set the equation parameters. This method is a non-parametric re-sampling method, in which a large number of parameters of the same size are repeatedly selected with the replacement of one original sample. Initially, 1000 bootstrap parameters and their coefficients of variation were obtained by fitting a fixed-effect model using a nonlinear least squares function (*nlme*). For this purpose, a sample of data was used, followed by calculating estimates of their average value, standard deviation, and coefficients of variation for each parameter.

The obtained average values of parameters for all samples were used as initial values for the function *nlme* (Table 4). Candidates for the role of random effect parameters were selected for the values of the equation parameters that were most substantial (based on statistics of calculated values) at the p-value level of 0.05 in more than 95% of the initial value samples.

Table 4. Values of the initial parameters of the equation of model of A. Kozak based on 100 bootstrap ratings

Indicators	Coefficients of the equation								
	a_0	a_1	a_2	b_1	b_2	b_3	b_4	b_4	b_6
Mean	0.91235	0.95776	0.07403	0.42935	-0.07030	0.37595	-0.04130	-0.00192	0.05410
ν,%	1.45	0.95	18.2	2.29	61.88	3.13	409.13	75.9	36.0
SD	0.00329	0.00952	0.01346	0.00984	0.04350	0.01180	0.16899	0.00146	0.01946

Source: compiled by the authors

From the above data, it is decided that the values selected for the parameters used for the random effect role are a_2 and b_6, since the values b_2, b_4 and b_5 have a significance of less than 95% at the level of 0.05.

Using the initial parameters, the equation parameters were set for the entire data array. Using the Akaike information criterion (*AIC*), the error of extra-selective prediction and, consequently, the relative quality of the developed model was estimated, since it evaluates both the over-learning of the model and its under-learning with risk. For the entire data array, it was established that the criterion value is quite high and has the value *AIC* = 21092.16, therefore, the remainder of the simulation distributions was then estimated. The obtained analysis of residuals allows choosing the best model, but it should solve a number of issues (Nikitin & Shvidenko, 1978), in particular: confirmation of the normality of the distribution of residuals; the constancy of variance and its independence from values; adequacy of the model on all segments of the intervals of change of the dependent variable or the possibility of its improvement by adding nonlinear parameters.

Results and Discussion

Analysing the distribution of simulation residuals for the entire data array (Fig. 1) it was established that there is some overestimation of the residuals, as a result of which a decision was made to divide the experimental database into groups of diameters and develop a model for each of these groups.

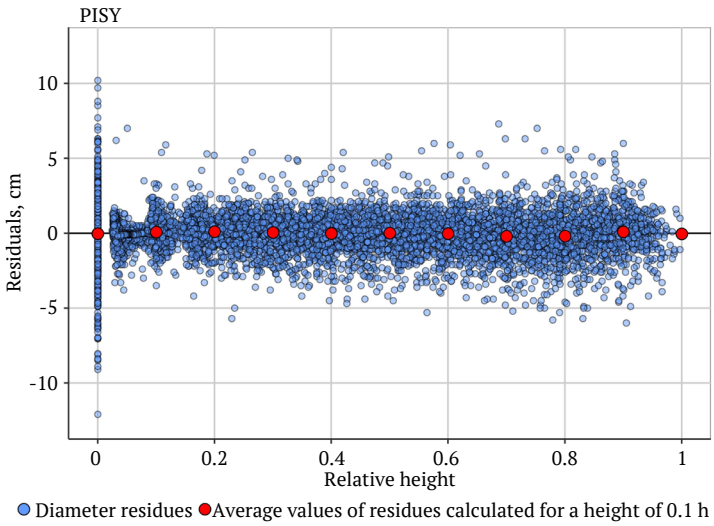

Figure 1. Distribution of residuals for the experimental data set of relative heights of model trees
Source: compiled by the author

Initially, the data array was grouped within the following thickness degrees: 8-20 cm, 24-28 cm, 32-40 cm, 44-56 cm, and 60-76 cm. For each array, the model parameters were set according to the method described above and the simulation residuals were calculated. Having obtained the values of the residuals for the established groups, it was decided to finally divide the data array into 2 groups according to the thickness degrees – 8-28 cm and 32-76 cm. The choice of such grouping consists in the fact that in fact there is no substantial difference within the data array (8-20 cm) – (24-28 cm) and in the array (34-40 cm) – (44-56 cm) – (60-76 cm), as evidenced by the graphical interpretation of the residuals in Figures 2(A) and 2(B).

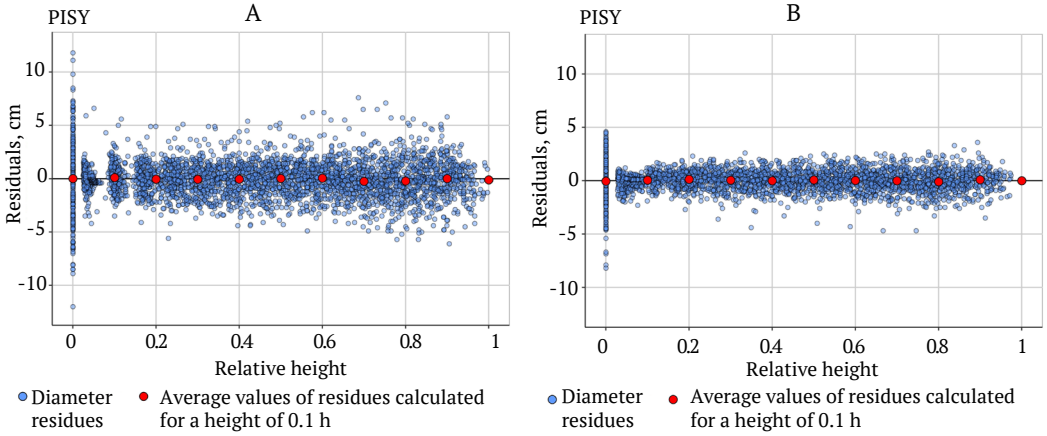

Figure 2. Distribution of residues by diameter groups
Notes: A – (8-28 cm); B – (32-76 cm)
Source: compiled by the author

In both cases, there is a certain tendency to slightly increase the residues from the butt to the top, and in the first group, this is less substantial. Notably, when using random parameters a_2 and b_6, a slightly different method of grouping variables was adopted. In the paper of V. Myroniuk *et al.* (2023) when using parameters with a random effect, grouping took place on the principle of "trial area/model tree", in turn, in this study, it was decided to group only by model trees. The error correlation structure in the model was also used using a first-order autoregressive correlation structure for a group of model trees.

Due to the division of the entire research database into two groups, a decrease in the distribution of the Akaike information criterion was achieved *(AIC)* to the level *AIC* = 7433.02 for a group (8-28 cm) and *AIC* = 13154.67 for the group (32-76 cm) and the standard error for the residuals SE = 0.154 and SE = 0.082, respectively. For both groups, the equation parameters were obtained and the standard errors of each of the parameters were calculated (Table 5).

Table 5. Calculated parameters and their standard errors of the mixed effect generating equation

Coefficient	Values of coefficients for the diameter group			
	20-28 cm		32-40 cm	
	Value	***SE***	***Value***	***SE***
a_0	1.00048	0.02353	0.8679	0.06418
a_1	0.99920	0.01099	1.03442	0.01722
a_2	0.00232	0.01418	0.00315	0.02680
b_1	0.39502	0.00806	0.47792	0.00881
b_2	-0.36305	0.04281	-0.26415	0.07992
b_3	0.50456	0.01448	0.44119	0.01880
b_4	0.11721	0.14173	-1.13157	0.91466
b_5	0.00109	0.00092	-0.00214	0.00080
b_6	-0.00387	0.01329	0.10289	0.01856

Source: compiled by the authors

Using the obtained parameter values, the tree stem profiles for both data sets were adapted (Fig. 3). When constructing the taper equation, the value of the diameter at chest level and the height of the tree stem is taken as the average value for the sample. For the first data array, this indicator is d = 20 cm and h = 19 m, for the second data array d = 39 cm and h = 28 m. Based on the obtained parameter values for the model (Table 5), it was established that pine has a slight deviation in the forecast of tree stem diameters in the bark relative to the average trend of stem narrowing. Comparing the tree stem profiles, a higher variability of stem for larger trees is evident. In addition, a characteristic feature is a smooth reduction in the diameter of the tree stem to the top of the tree. Using either of the two models in the entire database sample is inappropriate, as the simulation results are distorted. Therefore, for example, using a model developed for a group (32-76 cm) on thinner trees, the evaluation results in the lower part of the tree stem are underestimated and, accordingly, overestimated in the apical part.

This study uses the model of generating of A. Kozak (2004) as a basis for modelling the forming Scots pine. This is the second study of the formation equation with a variable indicator for characterising the taper equation of tree species in Ukraine. A similar study was done in Ukraine (Myroniuk *et al.*, 2023), but

it provides a general model of the generatrix for each tree species without dividing it into groups of diameters. The analysis showed that the developed models provide a clearer and more accurate prediction regarding the determination of tree stem diameters along the entire length of the stem for different groups of diameters.

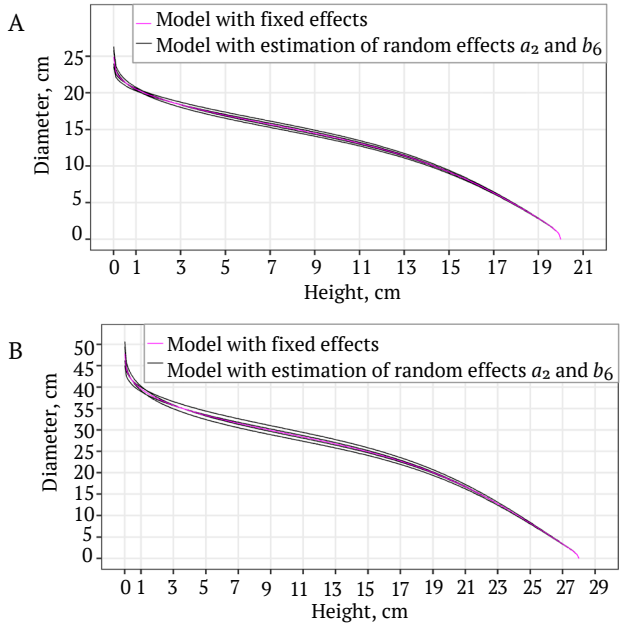

Figure 3. Variation in the tree stem shape based on the interquartile range of a random effect estimated from the selected parameters

Notes: A – (8-28 cm); B – (32-76 cm)
Source: compiled by the author

For the study, methodological approaches to modelling were applied almost identical to those of V. Myroniuk *et al*. (2023). In particular, a mixed-effect modelling approach was used, which gives better results compared to conventional least squares regression in terms of accessing a hierarchical data structure that includes repeated measurements. Since the research data has a hierarchical structure, ignoring autocorrelation in the simulation could lead to a violation of statistical data, such as hypothesis testing and confidence intervals. A method similar to the one in the study by R. Li & A.R. Weiskittel (2010) was used to solve this problem, which includes the specification of the autoregressive error structure and random effects. Since the measurement data is collect at unequal heights along the tree stem, the inclusion of the correlation structure (corCAR1) solved the problem of data heterogeneity and independence (Zuur, 2009). Two random effect parameters (Arias-Rodil *et al.*, 2015) were also included in the mixed effects model. Random effect parameters were evaluate based on selection based on the principle of greater variability in different the tree stem profiles. An approach based on the principle of repeated sampling in the initial loading of 1000 initial parameters from the initial data set and model restructuring for each sample is used to solve this problem (Myroniuk *et al.*, 2023). Thus, the two most variable parameters in the model were selected

and used as a random effect. Low values of the Akaike information criterion confirmed the feasibility of using random effect parameters (*AIC*) for developed models.

Mathematical models of the Scots pine stem developed, based on the equation of A. Kozak (2004) also showed good results for a number of species in different bioclimatic zones. Thus, A. Rojo *et al.* (2005) used 31 equations of the generating tree stem, of which the model of A. Kozak (2004) showed the lowest root-mean-square error, which was 4.5% less relative to other equations. R. Li & A.R. Weiskittel (2010) used 13 models of different types to estimate the taper equation of balsamic spruce, red spruce, and white pine. During the study, model of A. Kozak (2004) showed the best results for red spruce and white pine with an average absolute offset of 0.538 and 1.156, and an average percentage offset of 5.039% and 5.713%, respectively.

The accumulated research data and the obtained patterns of stem shape can be use in the future to prepare models of the dependence of the diameters of round forest materials in the upper section and in the middle of logs.

Conclusions

This study presents the results of modelling the taper equation of Scots pine in stands of Ukrainian Polissia for two groups of thickness degrees – 8-28 cm and 32-76 cm. Using model of A. Kozak as the base for modelling with the inclusion of random effect parameters. Random parameters of the mathematical model were set and their errors were calculated using the bootstrap method. When developing models for different groups of diameters, the Akaike information criterion (*AIC*) was evaluated to assess the quality and accuracy of the model. Due to the division of the data array into groups by diameter, a decrease in its indicator was achieved, which in turn increased the accuracy of the obtained models. The use of random effect parameters allowed more accurate characterisation of the shape features of pine tree stem. Based on the established parameters of the model, the variation in the tree stem shape for two groups of diameters was estimated based on the interquartile range of the random effect. The resulting models provide a clear and fairly accurate prediction of tree stem diameters over its entire length.

The created models can serve as an applied basis for improving forest removal standards for assessing the volume of forest products, in particular, in accordance with the rules and best practices of forest management in European countries. The prospect of further research is modelling the coincidence of round timber of Scots pine based on the developed mathematical models for two groups of diameters and the development of standards for assessing the yield of round timber by quality classes.

Conflict of Interest

None.

Acknowledgements

None.

References

[1] Adamec, Z., Adolt, R., Drápela, K., & Závodský, J. (2019). Evaluation of different calibration approaches for merchantable volume predictions of Norway spruce using nonlinear mixed effects model. *Forests*, 10(12), article number 1104. doi: 10.3390/f10121104.

[2] Arias-Rodil, M., Castedo-Dorado, F., Cámara-Obregón, A., & Diéguez-Aranda, U. (2015). Fitting and calibrating a multilevel mixed-effects stem taper model for maritime pine in NW Spain. *PLOS ONE*, 10(12), article number e0143521. doi: 10.1371/journal.pone.0143521.

[3] Bilous, A., Kashpor, S., Myroniuk, V., Svynchuk, V., & Lesnik, O. (2021a). *Forest inventory handbook*. Kyiv: Vinichenko Publishing House.

[4] Bilous, A., Myroniuk, V., Svynchuk, V., Kashpor, S., & Lesnik, O. (2022). Stem volume by height classes of immature, mature and overmature stands of the main forest-forming species of Ukraine. *Ukrainian Journal of Forest and Wood Science*, 13(3), 7-12. doi: 10.31548/forest.13(3).2022.7-12.

[5] Bilous, A., Myroniuk, V., Svynchuk, V., Soshenskyi, O., Lesnik, O., & Kovbasa, Y. (2021b). Semi-empirical estimation of log taper using stem profile equations. *Journal of Forest Science*, 67(7), 318-327. doi: 10.17221/209/2020-JFS.

[6] Bychenko, V.B., Myroniuk, V.V., Lakyda, P.I., & Burianchuk, M.M. (2021). Modeling structure of Scots pine stems volume by grade categories using stochastic process. *Ukrainian Journal of Forest and Wood Science*, 12(3), 6-20. doi: 10.31548/forest2021.03.001.

[7] DSTU EN 1927-2:2018. (2018). *"Round coniferous timber. Classification by quality. Part 2. Pine"*. Kyiv: Derzhspozhyvstandart Ukrainy.

[8] He, P., Xin, S., & Jiang, L.-C. (2020). Research on stem taper equation of Scots pine based on generalized additive model. *Journal of Beijing Forestry University*, 42, 1-8. doi: 10.12171/j.1000−1522.20200094.

[9] Kashpor, S., & Strochynskii, A. (2013). *Forest inventory handbook*. Kyiv: Vinichenko Publishing House.

[10] Kozak, A. (2004). My last words on taper equations. *The Forestry Chronicle*, 80(4), 507-515. doi: 10.5558/tfc80507-4.

[11] Li, R., & Weiskittel, A.R. (2010). Comparison of model forms for estimating stem taper and volume in the primary conifer species of the North American Acadian Region. *Annals of Forest Science*, 67(3), article number 302. doi: 10.1051/forest/2009109.

[12] Myroniuk, V., Bilous, A., Lakyda, P., Lesnik, O., Burianchuk, M., Svynchuk, V., Bychenko, V., Tyshchenko, O., Zadorozhniuk, R., Soshenskyi, O., Matushevych, L., Diachuk, P., Bala, O., Smolin, V., Yaroshchuk, M., Hrytsenko, O., & Matsala, M. (2023). Taper equations for eight major forest tree species in flat land Ukraine. *Forestry: An International Journal of Forest Research*, 2023, article number cpac052. doi: 10.1093/forestry/cpac052.

[13] Nikitin, K., & Shvidenko, A. (1978). *Methods and techniques for processing forestry information*. moscow: Forestry Industry.

[14] Özçelik, R., & Alkan, O. (2020). Fitting and calibrating a mixed-effects segmented taper model for Brutian pine. *CERNE*, 26, 464-473. doi: 10.1590/01047760202026032737.

[15] Pukkala, T., Hanssen, K., & Andreassen, K. (2019). Stem taper and bark functions for Norway spruce in Norway. *Silva Fennica*, 53, article number 10187. https://doi.org/10.14214/sf.10187.

[16] R Core Team. (2018). Retrieved from https://www.r-project.org/.

[17] Robinson, A.P., & Hamann, J.D. (2011). *Forest analytics with R: An introduction*. Berlin: Springer.

[18] Rojo, A., Perales, X., Sánchez-Rodríguez, F., Álvarez-González, J.G., & von Gadow, K. (2005). Stem taper functions for maritime pine (*Pinus pinaster* Ait.) in Galicia (Northwestern Spain). *European Journal of Forest Research*, 124(3), 177-186. doi: 10.1007/s10342-005-0066-6.

[19] Salekin, S., Catalán, C.H., Boczniewicz, D., Phiri, D., Morgenroth, J., Meason, D.F., & Mason, E.G. (2021). Global tree taper modelling: A review of applications, methods, functions, and their parameters. *Forests*, 12(7), article number 913. https://www.mdpi.com/1999-4907/12/7/913

[20] TUU-00994207-001:2018. (2018). *"Timber of round coniferous and deciduous species. Classification rules"*. Kyiv: Derzhspozhyvstandart Ukrainy.

[21] TUU-00994207-003:2018. (2018). *"Timber of round coniferous and deciduous species. Classification rules"*. Kyiv: Derzhspozhyvstandart Ukrainy.

[22] Zuur, A.F. (2009). *Mixed effects models and extensions in ecology with R*. Berlin: Springer.

Форма стовбура сосни звичайної в деревостанах Українського Полісся

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Анотація. У зв'язку з переходом України в 2019 році на нові нормативні документи зі стандартизації щодо класифікації круглих лісоматеріалів за класами якості постала необхідність в розробці нормативів оцінювання об'ємів відповідно до нових вимог. Метою статті було розроблення математичної моделі твірної стовбура сосни звичайної для дерев двох груп діаметрів. Робота базується на використанні емпіричного матеріалу, зібраного в різні роки науковцями кафедри таксації лісу та лісового менеджменту Національного університету біоресурсів і природокористування України, який становить 583 модельних дерева сосни звичайної. Як базову для моделювання твірної сосни звичайної було використано модель Козака. Для характеристики мінливості форми стовбурів сосни звичайної проведено калібрування моделі змішаного ефекту. Параметри на роль випадково ефекту відбиралися на основі їх коефіцієнтів варіації за допомогою процесу початкового завантаження (метод bootstrap). Групування даних на дві групи діаметрів проводилося за рахунок аналізу залишків моделювання та оцінювання якості моделей здійснювалось на основі використання інформаційного критерію Акаіке (*AIC*). За рахунок поділу масиву даних на дві групи ступенів товщини і розроблення моделей твірної для кожної з груп окремо досягнуто зниження показника інформаційного критерію Акаіке (*AIC*) до рівня *AIC* = 7433,02 для групи (8-28 см) та *AIC* = 13154,67 для групи (32-76 см), що підвищило точність розроблених моделей. Включення параметрів випадкового ефекту в модель А. Козак для розроблених математичних рівнянь дозволило більш точно описати мінливість деревного стовбура сосни звичайної. Отримані моделі дають чітке і достатньо точне передбачення визначення діаметрів стовбура по всій довжині. Використання розроблених моделей може бути базисом для удосконалення лісотаксаційних нормативів для оцінювання об'ємів стовбурів дерев у процесі лісогосподарського виробництва та прогнозування виходу об'ємів круглих лісоматеріалів за класами якості

Ключові слова: моделювання; інформаційний критерій Акаіке; видове число; групи діаметрів; рівняння твірної; мінливість форми

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Rare phyto-diversity of the Ivotka river basin within the territory of Sumy region

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Abstract. The search and study of the distribution conditions of rare plants are important for their protection from extinction and the conservation of biodiversity. This activity becomes even more relevant due to the acceleration of climate change due to anthropogenic impact on biocenoses, in the formation of which plants play a substantial role, creating grass cover of meadows, floodplains, and undergrowth. The purpose of this study was to collect and analyse information on protected plant species and communities in the Ivotka river basin in the Sumy region and study the conditions of their distribution. In the course of the study, field examinations were conducted to search for rare plants and describe the places of their localisation using the route diagnostic method and desk studies to identify the found material. The result of the study was the finding of 28 rare species of vascular plants in the Ivotka river basin within the Sumy region, among which 2 are listed in Resolution No. 6 of the Berne Convention and the Red Book of Ukraine, 10 – in the Red Book of Ukraine, 16 – in the list of plant species that are not listed in the Red Book of Ukraine, but are rare or endangered in the territory of the Sumy region. These plants can be classified as especially valuable for conservation that require protection and balanced use of both these species and the biocenosis complex in their distribution territory. It is not enough to change the protected status of the plant species itself or the territory of their localisation to preserve and protect rare plants. Systematic implementation of responsible forest and land use

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practices is essential to preserve existing biodiversity. The results obtained help to establish the protected status for rare plants, develop measures for their protection and use, and determine the need to implement a system of responsible forest and land use for Biodiversity Conservation

Keywords: Left-Bank Polissia; rare species of higher plants; flora protection; Red Book of Ukraine; responsible forest and land use

Introduction

One of the main tasks facing humanity is the preservation of biological diversity, as one of the key factors that ensures the stability and stability of not only the biosphere but also the global climate (Kovalenko, 2021). The depletion of biological diversity occurs both under the anthropogenic impact of global climate change and as a result of human activities to destroy species or the natural environment of their distribution directly, or to worsen their condition due to fragmentation, degradation, overexploitation, exposure to invasive species and pollution. Under the influence of these factors, the following processes occur: a decrease in the vitality of individual plants, a decrease in the population size, and fragmentation of the population into individual loci until its complete disappearance (Kovalenko *et al.*, 2022). The most vulnerable species are the first to respond to this. The same impact was experienced by the territory of the Ivotka river basin within the Sumy region, where this study was conducted to search for rare vascular plant species over a fairly large area (1310 m^2) of Left-Bank Polissia of Ukraine.

Special search for rare plant species in the river Ivotka basin within the Sumy region began only at the beginning of the 21st century as part of national programmes for environmental protection. This activity, aimed at ensuring the protection of rare and endangered species, is relevant in view of their losses over the past decades as a result of the anthropogenic destruction of their dwellings. Reclamation works that were conducted in the 60s of the 20th century along the entire floodplain of the Ivotka river basin, ploughing of floodplains led to the disappearance of some species of rare plants, especially those that are biosubjectally tied to floodplain meadows and swamps of the river valley.

Firstly, it is necessary to streamline knowledge about living organisms, their species, and coenoses in specific regions to prevent the impoverishment and destruction of biodiversity (Vakal *et al.*, 2003; Kovalenko, 2021). Examinations in the river basins of the Left-Bank Forest-Steppe of Ukraine were almost never conducted (Bondar *et al.*, 2017). In addition, even the third edition of the "Red Book of Ukraine" in 2009, according to researchers V.V. Budzak & Ya.P. Didukh (2020), contains fragmentary information about the growth sites of rare vascular plants.

For a long time, the study of plants and vegetation cover concerned plant anatomy and morphology, taxonomy, phytocenology, and phytogeography. Such trends dominated the world of science. Only at the end of the 20th century did populations begin to be considered as real forms of existence of plant species and cenotic relationships were examined – typical and local, which ensure the stability of the species in general and individual individuals. According to I.P. Lohvynenko *et al.* (2019), monitoring populations, especially rare plants, allows tracking processes that occur at the level of plant species, in plant communities, and in the biosphere in general.

The in-depth study of forest and meadow ecosystems is currently a highly researched subject related to global warming and climate aridification. These processes are chain-based and begin in forest ecosystems with changes in the formation of the grass and shrub tier and meadow ecosystems adjacent to forests and reservoirs, which is also typical for Polissia. This is highlighted by researchers such as O.O. Chusova *et al.* (2022) and I. Kovalenko *et al*. (2022).

Understanding of the importance of biodiversity conservation, especially in forest systems, is increasingly reflected in international instruments and national strategic programmes. Most countries that have submitted materials to the State of Europe's Forests (2021) report, the Ministerial Conference on forest conservation in Europe, provide support, conservation, and improvement of forest biodiversity. Back in 1992, the European Union adopted Council Directive 92/43/EEC (1992), which provides for the protection of not only representatives of fauna and flora but also their places of residence.

Furthermore, the Forest Stewardship Council (FSC) (n.d.) back in 1999 proposed the concept of "High Conservation Value" (HCV) to identify special value for the conservation of species, biocenoses, ecosystems that need protection and balanced use. HCV conservation is becoming increasingly a requirement for timber companies when obtaining a certificate. Such work on identifying plant and animal species from the positions of their dwellings is conducted in many countries.

Y.O. Kremenetska *et al.* (2022) noted that at the national level in Ukraine, obstacles to the implementation of the HCV system as the basis for responsible forest and land use are the lack of localised information on the availability of values for conservation in forests; imperfect legal regulation in the field of forestry, in particular, the lack of approved national criteria for identifying forests with special values and conflict with existing land use planning. The most difficult obstacle was the identification of HCV ecosystems and habitats, which is the basis of all further actions to protect and preserve biodiversity, and finally, to form forest and land use policies and implement them.

The purpose of this study was to collect and analyse information about plant species and their groups that need protection in the Ivotka river basin in the Sumy region and investigate the conditions of their distribution.

Materials and Methods

In this study on rare plant species in the Ivotka river basin within the Sumy region, one of the most important approaches was population-based. The main research methods are empirical, namely observation, analytical, cartographic, and statistical. Empirical, statistical, and cartographic methods were mainly used in the course of field expeditions to identify rare plant species and their localisations in the river basin.

Analytical methods were used mainly in desk studies to identify identified plant communities, and their belonging to protected rare plant species of various statuses – from international, national, to regional. The study was conducted through field and desk research.

Field examinations in the course of field studies were conducted during 2001 and 2020-2021 using the route diagnostic method. Routes were laid across the entire territory of the river Ivotka basin within the Sumy region from west to east and from north to south, along and across its valleys and valleys of its tributaries to examine all biotopes characteristic of this area.

The studies were conducted according to the following parameters: the total number of protected species in areas of a certain type of distribution environment, determining the area of protected species distribution sites and their

location, the number of sites where each of the protected species is present, and, if possible, the parameters of the average number of plants of the protected species per site within the habitat or projective cover. The study followed the international principles set out in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973).

In desk studies of the cenotic affiliation of the identified plant species and communities, the method of geobotanic descriptions was applied (Yakubenko *et al.*, 2020), for which the ecological and phytocenotic classification of the vegetation of Ukraine was used (Prokudin, 1987; Shelyag-Sosonko, 1991). The following methods were used to identify protected plant species: Resolution No. 6 of Convention on the Conservation of European Wildlife and Natural Habitats Standing Committee (1998), Red Book of Ukraine (Didukh, 2009a), Green Book of Ukraine (Didukh, 2009b).

Scientific sources containing information about the flora were also used to identify the plant communities of the Ivotka river basin and adjacent territories of Novhorod-Siversky Polissia (Vakal *et al.*, 2003; Chornous, 2006; Boychenko *et al.*, 2019). This allowed identifying a number of located plant communities as those that are not included in the Red Book of Ukraine, but are rare or endangered in the Sumy region.

When investigating the cenotic affiliation of the found plant species and groups, and their identification with protected plant species of different rarity status, or with those species that are threatened with extinction but are not included in the lists of protected species, an analytical comparison method was used. The applied approaches contribute to creating the basis for further research and conservation of biocenoses and ecosystems of Eastern Polissia, and for forming a policy of responsible forest and land use.

Results

The Ivotka River begins within the Central Russian Upland, at an altitude of about 220 m, near the village of Podliesnyie Novosiolki in the South-East of the Bryansk region, flows into the river Desna between the villages of Korotchenkove and Obrazhiivka. The total length of the river is 93 km. Area of the Ivotka river basin within the Sumy region is 1310 km^2 (Yatsyk, 1991).

In the system of physical and geographical zoning of Ukraine, the territory of the river belongs to the Shostka (Prydesniansky) and Yampolsky physical-geographical regions of the Novhorod-Siversky Polissia region of the mixed forest zone of Ukraine (Popov *et al.*, 1968). This zone is characterised by Polissia landscapes, which are determined by the valley types of terrain of the rivers Desna and Ivotka and morainic-outwash plains created by glacial accumulation.

In the geobotanical zoning system, the territory of the river Ivotka is located within the Chernihiv-Novhorod-Siversky geobotanic district, Shostkinsky district, for which the typical and dominant groups of natural vegetation are pine, oak-pine and lime-oak-pine forests, floodplain meadows, eutrophic swamps (Andrienko *et al.*, 1977).

The wide floodplain of the river Ivotka is characterised by meadow and swamp vegetation, which is now degraded from excessive anthropogenic impact (draining land reclamation, overgrazing, ploughing, large recreational load, etc.). Substantial areas are represented by agrophytocenoses on the site of erected forests.

Forest vegetation of the Ivotka river basin is mainly represented by groupings of the *Pinus sylvestris* formation. Pine forests are mostly represented by associations of *Pinetum calamagrostidosum (epigeioris), Pinetum pholytrichosum, Pinetum festucosum (rubrae), Pinetum pteridiosum (aquilini), Pinetum (pterldioso-hylocomiosum)*. Oak-pine forests are dominated by

formations of *Querceto-Pinetum coryloso (avellanae)-stellariosum (holosteae), Querceto-Pinetum pteridioso-calamagrostidosum (epigei), Querceto-Pinetum (pteridiosuim (aquilini))*, and in lime-oak-pine trees – *Tilieto-Querceto-Pinetum vacciniosum (myrtilli)*.

Spruce forests are mostly of artificial origin and consist mainly of associations of *Piceetum oxalidoso (acetosellae)* and *Piceetum athyriosum (filix-feminae)*. There are *Betuleto-Pinetum sphanosum* associations in small areas, and in floodplains of rivers – *Saliceta albae, Alneta glutinosae, Populeta tremulae.* Shrubby vegetation of the floodplain of the river Ivotka mainly consists of *Saliceta cinereae, Saliceta triandrae*.

According to the classification, floodplain meadows of the river Ivotka belong to the formations of true, settled, swampy, and soddy meadows(Afanasyev *et al.*, 1956; Sipailova, 1976). Among their vegetation, the following formations predominate – *Agrostideta stoloniferae, Alopecureta pratensis, Anthoxantheta odorati, Calamagrostideta epigeioris, Cynosureta cristati, Festuceta pratensis, festuceta rubrae, Phleeta pratensis, and Poeta pratensis.*

To a large extent, the meadow lands of the reserve are used as pastures. In some areas with excessive pasture load (Ivot, Antonivka villages), there is a high level of degradation of meadows. Eutrophic swamps in the Ivotka river basin on the territory of the Sumy region is represented mainly by groups of formations of *Alneta glutinosae, Betuleta pendulae, Phragmiteta australis, Equiseteto (palustris)-hypneta, Glycerieta maximae, Cariceta fcutiformis.*

The type of aquatic vegetation in this area is represented by air-water and aquatic classes of plant formations. The most common formations of air-water vegetation are *Phragmiteta australis, Glycerieta maximae, Typheta latifoliae, Shoeoplecteta lacustris, Sagitarieta sagitofoliae, Sparganieta erecti.*Among the aquatic vegetation, the most widespread groupings are the formations of *Nuphareta luteae, Nymphaeeta albae, Nymphoideta peltatae, Rotamogetoneta pectinati, Myriophylleta spicati, Elodeeta canadensis, Ceratophylleta demersi, Utricularieta vulgaris, Lemneta minoris, Spirodeleta polyrhizae.*

The main result of this study was original information about rare, sparsely distributed, and endangered plant species collected during field research in the Ivotka river basin within the Sumy region. Notably, the plant world of this part of Polissia is insufficiently examined, and the relatively small number of special scientific papers, which are quite fragmentary in nature. Therefore, a comprehensive collection and initial analysis of empirical information about the flora of each part of Polissia is an important basis for further research and conservation of both individual vegetation species, coenoses, and ecosystems in general.

The result of the analysis of field research materials and their identification using databases of international and national conservation documents for the conservation of wildlife and biodiversity was information about the finds in the Ivotka river basin within the territory of the Sumy region of populations of 28 rare vascular plant species, among which 2 are listed in Resolution No. 6 of the Berne Convention and the Red Book of Ukraine, 10 – in the Red Book of Ukraine, 16 – in the list of plant species that are not listed in the Red Book of Ukraine but are rare or endangered in the territory of the Sumy region.

Among the plants included in Resolution No. 6 two species were identified at the Berne Convention – *Nymphoides peltata* (S. G. Gmel.) and *Pulsatilla patens* (Mill.). Among the plants included in the Red Book of Ukraine, 10 species were identified – *Lycopodium annotinum* (A. Haines)*, Iris sibirica* (L.)*, Lilium martagon* (L.), *Dactylorhiza fuschsii* (Druce, Soó)*, Dactylorhiza incarnata* (L.), *Epipactis helleborine* (L.), *Goodyera repens* (L.)*, Neottia nidus-avis* (L.),

Platanthera bifolia (L.)*, Platanthera chlorantha* (Custer and Rchb.). Among the plants that are not listed in the Red Book of Ukraine but are rare or endangered in the Sumy Region, 16 species were identified – *Lycopodium clavatum* (L.), *Matteussia struthiopteris* (L.), *Juniperus communis* (L.), *Nymphaea alba* (L.), *N. candida* (J. Presl), *Aquilegia vulgaris* (L.), *Drosera rotundifollia* (L.), *Gentiana pneumonanthe* (L.), *Antennaria dioica* (L.), *Parnassia palustris* (L.), *Dianthus pseudosquarrosus* (Novak) Kleopow, *Arctostaphylos uva-ursi* (L.), *Psephellus sumensis* (Kalen.), *Pyrethrum corymbosum* (L.), *Digitalis grandiflora* (Mill.), *Calla palustris* (L.). In the Ivotka river basin, plant groups listed in the Green Book of Ukraine were also found, namely – *Nuphareta luteae, Nymphaeeta albae, Nymphaeeta candidae, Nymphoideta peltatae.*

Their conservation status characteristics: the species are listed in Resolution No. 6 of the Berne Convention (Boychenko *et al.*, 2019), the Red Book of Ukraine (Didukh, 2009a), and species that are rare or endangered in the Sumy region (Andrienko & Peregrym, 2012). Plant species included in Resolution No. 6 of the Berne Convention, – *Nymphoides peltata* (S. G. Gmel.) and *Pulsatilla patens* (Mill.).

Nymphoides peltata (S.G. Gmel.) in Ukraine, occur in the estuaries and floodplains of the lower reaches of the Danube, Dnipro, Southern Bug, Dniester rivers, in Transcarpathia, Zhytomyr, and Chernihiv Polissia, in the Forest-Steppe (Boychenko *et al.*, 2019). The total population area is about 0.5 ha with a density of up to 200 generative plant specimens per 100 m^2.

Pulsatilla patens (Mill.) in Ukraine is distributed in Polissia, Forest-Steppe, and Northern Steppe (Boychenko *et al.*, 2019). In the area of the field studies, it is scattered throughout the territory on sod-podzolic, in middle-aged and old pine, pine-oak soils. In the course of field studies of the Ivotka river basin on the territory of the Sumy Region, 10 plant species included in the Red Book of Ukraine were identified. The results are presented in Table 1.

Table 1. Plant species included in the Red Book of Ukraine found in the Ivotka river basin

No.	Species name	Localisation in Ukraine	Characteristics of the environment of loci of the species	Area of loci found	Places where the species was found in the Ivotka river basin
1.	*Lycopodium annotinum* (L.)	Carpathians, Roztochia, Volyn Upland, Polissia, Forest-Steppe (occasionally)	1. Wet pine forest on the hog terrace of the Ivotka river. 2) Old spruce forest. 3) Associations of *Pinetum-Querceto coryloso (avellanae)-caricosum (pilosae)* on a plot with low terrain. 4) Old pine forest. 5) Old pine-oak forest.	1. 0.01 ha with a projective coating of 30%. 2. 0.1 ha with a projective coating of 50-60%. 3. 0.05 ha. 4. 0.01 ha with a projective coverage of about 20%. 5. 0.1 ha with a projective coating of up to 100%.	1. Tract "Radkiv Bir" Myronivsky Forestry, sq. 15. 2. Prudyshchanske Forestry, sq. 106. 3. Kremlianske Forestry, sq. 62. 4. Tract "Forest Plot" of the Kremliansky Forestry, sq. 96. 5. Protected area "Pidivotsko-Chuikivska dacha" Chuikivsky Forestry, sq. 32.
2.	*Iris sibirica* (L.)	Transcarpathia, Prykarpattia, Roztochia, Polissia, less often – Forest-Steppe, occasionally – the northern part of the Steppe Zone, and the Crimea	Meadow vegetation of the floodplain of the river Ivotka	Up to 0.2 ha in the floodplain of the river Ivotka	1 km south of the village Chuikivka

Table 1, Continued

No.	Species name	Localisation in Ukraine	Characteristics of the environment of loci of the species	Area of loci found	Places where the species was found in the Ivotka river basin.
3.	*Lilium martagon* (L.)	Carpathians, Transcarpathia, pre-Carpathia, Roztochia, Opillia, Polissia, in the Forest-Steppe	Old su-boron of the *Querceto-Pinetum pteridioso-calamagrostidosum* (*epigei*) *association*	0.05 ha, 4 generative age specimens	Protected area "Prudyshchanska dacha" Prudyshchansky Forestry, sq. 62
4.	*Dactylorhiza fuschsii* (Druce and Soó)	Carpathians, pre-Carpathia, Roztochia, Opillia, Polissia, northern part of the Forest-Steppe, Steppe	Soddy meadow with a predominance of *Deschfmpsia caespitosa (L.) Beauv., Carex nigra (L.) Reichard.*	0.01 ha, up to 20 specimens	East of the village Derazhnia
5.	*Dactylorhiza incarnata* (L.)	Carpathians, Forest Zone, Forest-Steppe, mountains of Crimea, occasionally Steppe	1. Wet meadows among shrubs of *Caricetum (nigrae) agrostidosum (caninae)* association. 2.Wet and swampy meadows.	1. 0.1 ha, 30 specimens of generative age. 2. 0.2 ha, location density up to 20 generative age specimens per 100 m^2.	1. floodplain of the river Kosychykha near the village Derazhnia. 2. Hydrological reserve of local importance "Doroshivsky".
6.	*Epipactis helleborine* (L.)	Carpathians, Forest, Forest-Steppe, Steppe zones (in the forests of large river valleys)	1. Old pine-oak forest. 2. medium-age wet su-boron.	1. 6 plants of generative age. 2.28 instances in multiple locations.	1. Protected area "Prudyshchanska dacha" Prudyshchansky Forestry, sq. 62. 2. Sveske Forestry, sq. 58.
7.	*Goodyera repens* (L.)	Carpathians, Roztochia, Polissia, Podillia, mountains of Crimea	Old spruce forest in the association of *Piceetum oxalidoso (acetosellae)*	0.05 ha, 200 specimens	Prudyshchanske Forestry, sq. 106
8.	*Neottia nidus-avis* (L.)	Carpathians, Transcarpathia, Polissia, Forest-Steppe, northern Steppe, mountains of Crimea	1. Pine-oak Forest. 2. Association *Querceto-Pinetum coryloso (avellanae)-caricosum (pilosae).*	1.0.01 ha, 28 plants of generative age. 2. 5 specimens.	1. Protected area "Prudyshchanska dacha" of the Prudyshchansky Forestry district, sq. 62. 2. Sveske Forestry, sq. 58.
9.	*Platanthera bifolia* (L.)	Carpathians, Roztochia, Opillia, Polissia, northern Forest-Steppe, occasionally Steppe	Old pine-oak forest	0.1 ha, 12 specimens of generative age	Protected area "Prudyshchanska dacha" of Prudyshchansky Forestry, sq. 62
10.	*Platanthera chlorantha* (Custer and Rchb.)	Carpathians, Roztochia, Opillia, Polissia, Forest-Steppe, occasionally – Steppe	Oak-pine forest	18 specimens	Landscape reserve of local importance "Prudyshchansky" of the Prudyshchansky Forestry, sq. 65

Source: compiled by the authors

In the course of field study in the Ivotka river basin 16 plant species that are not listed in the Red Book of Ukraine were also identified but are rare or endangered in the Sumy region (Andrienko & Peregrym, 2012). The results are presented in Table 2.

Table 2. Rare plants or those that are threatened with extinction on the territory of the Sumy region, not included in the Red Book of Ukraine, found in the Ivotka river basin

No.	Species name	Localisation in Ukraine	Characteristics of the environment of loci of the species	Area of loci found	Places where the species was found in the Ivotka river basin
1.	*Lycopodium clavatum* (L.)	Carpathians, Polissia, northern Forest-Steppe	1. Sparse grass stand *Molinia caerules* (L.) Moench. and *Lysimachia vulgaris* L. among cultures *Pinus sylvestris* L. and *Betula pendula* Roth. 2. Pine forest. 3. *Pinetum polytrichosum association.* 4. Pine-Oak forest in hollow depressions. 5. Pine forest. 6.Old Pine forest on low terrain areas.	1. 0.05 ha with a projective coating of up to 30%. 2. 0.02 ha with a projective coating of 5-10%. 3. 0.01 ha with a projective coating of up to 70%. 4. 0.01 ha, small curtains. 5. 0.1 ha, scattered, small spots with an average projective coverage of 40%. 6. 0.05 ha.	1. Tract "Radkiv Bir" Myronivsky Forestry, sq. 15. 2. Myronivske Forestry, sq. 81. 3. protected area "forest plot" of the Kremlianske Forestry district, sq. 96. 4. Protected area "Pidivotsko-Chuikivska dacha" Chuikovsky Forestry, sq. 32. 5. Forest tract "Sveska dacha" of the Svesky Forestry district, sq. 14. 6. protected area "Kremlianska dacha" of the Kremlianske Forestry, sq. 40-42.
2.	*Matteussia struthiopteris* (L.)	Carpathians, Polissia, Forest-Steppe	Grassy snyt vegetation in a wet oak forest	0.05 ha, 30 specimens	Ostriv Tract
3.	*Juniperus communis* (L.)	Carpathians, Polissia, Crimea, occasionally Steppe	Pine forest	0.1 ha	Kremlianske Forestry, sq. 116
4.	*Nymphaea alba* (L.)	Occasionally throughout Ukraine	Starytsia, sometimes the riverbed of Ivotka river and its tributaries	Multiple plots up to 0.05 ha	
5.	*Nymphaea candida* (J. Presl)	In lakes and floodplain reservoirs in broad-leaved forest and Forest-Steppe zones	Staritsa, riverbeds	Sporadically throughout the territory	The entire pool river Ivotka
6.	*Aquilegia vulgaris* (L.)	Forest-Steppe, Polissia	Medieval meadows, the edge of the forest	0.05 ha, 8 specimens	Protected area "Prudyshchanska dacha" of Prudyshchansky Forestry, sq. 62
7.	*Drosera rotundifollia* (L.)	Carpathians, Polissia, northern part of the Forest-Steppe	1. Sphagnum swamp surrounded by pine forest. 2. Mesotrophic forest swamp.	1. 0.01 ha. 2. 27 specimens.	1. Chuikivske Forestry, sq 38. 2. Kremlianske Forestry, sq. 42.
8.	*Gentiana pneumonanthe* (L.)	Most of the territory of Ukraine, except Crimea	Wet meadows in the floodplain of tributaries of river Ivotka	2.0 ha, 34 specimens	Near the village of Derazhnia

Table 2, Continued

9.	*Antennaria dioica* (L.)	Scattered almost all over Ukraine	*Pinus sylvestris* culture with sparse stands of trees, among grassy vegetation	0.3 ha, single specimens	Tract "Radkiv Bir" Myronivske Forestry, sq. 28
10.	*Ragpasia rlustris* (L.)	Polissia, Forest-Steppe (occasionally)	Wet meadows around a grassy swamp in a *Alopecureta (pratensis) deschampsiosum (cespitosae)* formation	0.1 ha, 20 specimens	Doroshivsky hydrological reserve
11.	*Diantus pseudosquarros* (Novak) Kleopow	Polissia, northern Forest-Steppe	Clearing in a pine forest with sparse grass	0.01 ha, single specimens	Kremlianske Forestry, sq. 42
12.	*Arctostahylos uva-ursi* (L.)	Polissia	*Pinus sylvestris* Culture	0.3 ha, small sparse curtains, sometimes single bushes	Landscape reserve of local importance "Prudyshchansky", near the village of Prudyshche
13.	*Psephellus sumensis* (Kalen.)	Polissia, Forest-Steppe, Steppe (occasionally)	Culture *Pinus sylvestris,* boron sands	Not localised, occurs throughout the territory	Landscape reserve of local importance "Prudyshchansky" of the Prudyshchansky Forestry of the Svesky State Forestry Enterprise
14.	Pyrethrum corymbosum (L.)	The entire territory of Ukraine	Forests, shrubs, dry meadows	Not localised, occurs throughout the territory	Landscape reserve of local importance "Prudyshchansky" of the Prudyshchansky Forestry of the Svesky State Forestry Enterprise
15.	*Digitalis grandiflora* (Mill.)	Carpathians, Right Bank of Ukraine, Left Bank (occasionally)	Deciduous and mixed forests, clearings, shrubs	Not localised, occurs throughout the territory, single instances	Landscape reserve of local importance "Prudyshchansky" of the Prudyshchansky Forestry of the Svesky State Forestry Enterprise
16.	*Calla palustris* (L.)	Polissia	Swamps, swampy riverbanks	Sporadically, in small curtains or groups	Landscape reserve of local importance "Prudyshchansky" of the Prudyshchansky Forestry of the Svesky State Forestry Enterprise

Source: compiled by the authors

In the course of this study, the place of growth in part of the Novhorod-Siversky Polissia in the Sumy region *Psephellus sumensis* (Kalen.), *Pyrethrum corymbosum* (L.), *Digitalis grandiflora* (Mill.), *Calla palustris* (L.) on the territory of the landscape reserve of local importance "Prudyshchansky" of the Prudyshchansky Forestry of the Svesky State Forestry Enterprise was also confirmed. In the Ivotka river basin, *Nuphar lutea* (Smith)*, Nymphaea alba (L.), Nymphaea candida* (J. Presl)*, Nymphoides peltata* (S.G. Gmel) plant groups, listed

in the Green Book of Ukraine were identified (Didukh, 2009B).

Finds of rare plants and places of their localisation on the territory of the Ivotka river basin within the Sumy region will allow further spatial monitoring of populations, conducting information and explanatory work on their conservation and measures to ensure their protection regimes.

Discussion

The intensification of research on the phyto-diversity of the Left-Bank Polissia over the past three decades has been in the trend of global scientific research and international and national management decisions on measures to preserve biodiversity. These studies can be divided into three groups – those that relate to strategic issues of biodiversity conservation, the study of phyto-diversity in river basins or other unique territories, the study of individual species of rare plants or species that were the basis of the forests of Polissia and phytosystems with rare herbaceous plants.

All researchers pay attention to the main factor that is a threat to biodiversity, namely the thoughtless and irresponsible practice of human activity, which destroys its habitat. This practice concerns the irresponsible treatment of forest, land, water, plant, and animal resources. Anthropogenic impact on the environment has reached such a level that it has become a key factor in global climate change. Many researchers highlight the connection between these processes.

For example, R.T. Corlett (2020) explicitly states that the anthropocene was marked by crises related to climate change and biodiversity loss, and shows the link between biodiversity and ensuring climate sustainability. Thus, wild plants are used by people as food, medicine, and genetic resources, as wood, feed for pets, etc. However, their functions, such as regulating water supply and absorbing carbon, already depend on the entire community, and not on individual species. Therefore, for the protection of biodiversity, it is proposed to apply an ecosystem approach, in which the priorities should be to improve the plant cadastre with a focus on geographical areas and groups that are insufficiently examined, expand the reserve system, prevent overexploitation, manage invasive species, and preserve endangered species *ex situ*, ecosystem restoration, climate change control.

One of the main threats to humanity is the deterioration of the health of the global ecosystem, according to K. Kougioumoutzis *et al.* (2020). At risk of extinction are primarily endemic species that suffer from habitat loss and fragmented populations, as they have smaller geographical ranges and ecological niches. The author argues that the conservation of as many species/communities as possible should form the basis of a "climatically reasonable" strategy, which should be based on identifying relatively climatically stable regions with a large number of species of high conservation value with high endemic and genetic diversity. This could be a way to quickly raise global temperatures.

A. Raven & M. Wackernagel (2020) state that biodiversity conservation is achieved by limiting excessive human demand, focusing on areas where the greatest diversity is concentrated, and taking inventory of species diversity. Preservation *in situ*, preserving ecosystems and biodiversity in their natural habitats through biotechnology, is the most appropriate conservation approach for the conservation of species, including endemic species, as it preserves the original genetic and geographical centres of biodiversity. It includes not only the conservation of plant genetic resources but also their management (sustainable use) (Coelho *et al.*, 2020).

Researchers A. Di Sacco *et al.* (2021), pointing to the interconnectedness of biodiversity

and climate change, suggests ten rules for forest ecosystem restoration: protect the existing forest, engage all stakeholders, strive to maximise biodiversity restoration, select areas for restoration, use natural restoration whenever possible, select species to maximise biodiversity, use sustainable plant material, plan infrastructure, capacity and seed supply, learn in practice, and ensure the economic sustainability of the project.

H. Albrecht *et al.* (2016), S. Pironon *et al.* (2020) proposed to combine to preservation of biodiversity with the preservation of agro-diversity. E. Dinerstein *et al.* (2020), describing the Global Safe Network for saving life on Earth, emphasise that the crises of biodiversity loss and climate change have generally been considered separately, the key solution to the two most pressing challenges of our time are the same: to preserve enough nature and in the right places.

Many researchers in Ukraine emphasise the relevance of botanical inventory of plants and determination of their conservation status, inventory of phyto-diversity throughout Ukraine, determination of localisation of plant populations, especially rare ones, creation of protected areas of rare plant locations to prevent further fragmentation of their populations to maximise the restoration of their integrity in the future (Budzak & Didukh, 2020; Kremenetska *et al.*, 2022; Chusova *et al.*, 2022).

In particular, the biosphere role of forests is indicated by I.M. Kovalenko (2021), T.V. Marukha (2022), highlighting their part in regulating the accumulation of greenhouse gases in the atmosphere, the hydrological cycle, and air purification. The researchers draw attention to the fact that forest catchments provide more than 75% of the available fresh water in the world – the most important resource of all life on the planet. In Ukraine, the largest woodlands have been preserved in the Carpathians and Polissia, but they are destroyed by continuous logging, resulting in the fragmentation or even destruction of local ecosystems. It is proposed to take measures to abandon continuous logging, mono-specie artificial afforestation, and afforestation with mixed tree species to preserve the forests of Polissia, which are vital not only for Ukraine, with their rich biodiversity, (Bondar *et al.*, 2017; Kovalenko, 2021) inherent in this area, the transition to the principles and methods of sustainable forestry.

The importance of locating, identifying, and preserving integral (intact) forest landscapes for the restoration of a human-friendly biosphere is emphasised by Y.O. Kremenetska *et al.* (2022). The role of meadows in ecosystem resilience to global climate change is highlighted by O.O. Chusova *et al.* (2022), in particular, on thermoregulation, soil formation, and erosion control. In addition, meadows, especially dry ones, are home to many local endemics.

Other researchers, J. Bengtsson *et al.* (2019) consider grasslands to be one of the world's major ecosystems, covering about one-third of the Earth's surface. Grasslands are not only locally important for maintaining biodiversity and food production, but they also affect environmental processes in the landscape (e.g. pollination), regionally (e.g. water regulation, recreation), and globally (e.g. climate regulation). Grasslands remain undervalued in ecosystem services compared to, for example, forests. They were largely ignored in global political discussions, although more attention was paid to them at the regional level.

A number of researchers conducted search and identification work on rare plants in river basins or in a specially defined search area. Thus, V. Skliar *et al.* (2022) conducted a study of the Phyto-diversity of the Syrovatka river basin in the Sumy region for the purpose of using natural resources for the development of ecotourism. In the course of the study, about 50 plant species belonging to the international

rank of protection were found and identified. This study, as presented in this study, is aimed at the inventory of plant species that are found in the river basins of the Sumy region.

Long-term monitoring can provide important data for managers to prioritise management actions, namely resource status and benchmarks for comparison with other modified or protected environments, early warning of abnormal conditions in selected resources, helping to develop mitigation measures, the dynamic nature of natural systems and trends in selected indicators of these systems (Perles *et al.*, 2022).

Rare plant species on the territory of the Volyn Upland (Right-Bank Polissia of Ukraine) were searched and examined by a group of researchers I.P. Lohvynenko *et al.* (2019). In addition to searching for and identifying rare plants of the Volyn Upland, they made a comparative analysis of the populations they examined with populations from other areas. Population regression was identified to be a general trend for rare species due to the negative impact of anthropogenic factors. Approaches to the inventory and conservation of phyto-diversity on the territory of territorial communities, as a factor of their sustainable development, are considered in a study by A. Kostyshin (2019). The studies of a number of researchers are devoted to the specific features of the state of populations of species that are important for forest formation or individual rare plant species.

In Particular, I.M. Kovalenko *et al.* (2022) investigated the processes of replacing the species composition of Polissia forests from boreal to nemoral, drawing attention to the greater resilience of non-moral species in the context of global warming, which increases their competitiveness in the forest environment and leads to the displacement of boreal species. In addition, changes in temperature conditions lead to the fact that the flowering of boreal species does not coincide with the life cycles of pollinating insects, which leads to a decrease in the populations of both species. The role of grassy and shrubby forest cover also attracted the attention of researchers. They note that the composition of the soil cover depends not only on the species contribution of trees but the composition of the grass and shrub cover is dominant in the formation of the species diversity of the forest.

Common oak (*Quercus robur*) is one of the main, and often the main forest-forming species in the Ukrainian Polissia. The features of self-healing of oak forests in the Left-Bank Polissia are considered in the study by V. Skliar *et al.* (2019). Self-restoration of oak forests in Polissia is considered by them as a way to restore forest phyto-diversity. It can also become one of the methods of sustainable forestry.

Rare species of forest orchids are examined in the studies of J. Roleček (2021) and O.P. Chornous (2022). The study by J. Roleček (2021) is mainly devoted to the description of the species of *Ophrys insectifera* (L.) *(Orchidaceae)* and found places of its location, while the paper of O.P. Chornous (2022) is based on multi-year observation of *Epipactis helleborine* (L.) *(Orchidaceae)* populations in different parts of the Left-Bank Polissia, including in the Ivotka river basin. The author examined the influence of various factors, in particular, anthropogenic, on the state and resilience of populations *Epipactis helleborine (Orchidaceae)* (L.). In addition, he concluded that the optimal types of forest trees for *Epipactis helleborine* (L.) *(Orchidaceae)* populations, there are old ones – *Quercus robur* (L.)*, Tilia cordata* (Mill.)*, Acer platanoides* (L.).

The study by I. Zubtsova *et al.* (2019) is devoted to the examination of the conditions that are most favourable for the existence and distribution of populations *Hypericum perforatum* (L.) *(Hypericaceae)* and *Saponaria officinalis* (L.) *(Caryophyllaceae)* in Polissia. Expanding

healthy populations of these medicinal plants would allow them to be used more widely in medicine. Notably, all the studies mentioned in the discussion, and studies of earlier periods, are a contribution to unfilled niches of scientific information on the biodiversity of the Ukrainian Polissia and do not contradict, but complement each other.

Conclusions

The presented study concerned the identification of rare plants and the description of their loci in the Ivotka river basin within the Sumy region. Rare plants are now an integral part of the ecosystems of Polissia, which were formed for thousands of years. In case of violation of the hydrological regime of ecosystems, fragmentation of forests due to deforestation, excessive ploughing of land and destruction of ecosystems themselves under the anthropogenic influence, the most vulnerable were plants whose survival depends to a greater extent not only on the amount of moisture or air temperature but also on the composition of established cenoses. They passed into the category of rarities.

Detected in the process of the study, a rare component of the flora of the vegetation of the Ivotka river basin within the territory of the Sumy region includes 2 species that are included in Resolution No. 6 of the Berne Convention, 12 species listed in the Red Book of Ukraine and 16 plant species that are not listed in the Red Book of Ukraine, but are rare or endangered in the Sumy region. Analysis of the state of protection of rare species showed that out of 28 rare plant species found in the research area, 12 species grow outside the territory of the objects of the nature reserve fund, which indicates the need to create new objects of the nature reserve fund.

It is established that to preserve the Red Book, regionally rare and endangered species identified in the area of research, and the phytogenofond of Polissia, and implement practical measures to reproduce their resources, it is necessary to expand the territory of the hydrological reserve of local importance "Doroshivsky"; it is advisable to expand the territories of protected forest tracts and transfer them to the category of botanical nature monuments of local importance; create a "Desniansko-Ivotsky" hydrological reserve of local importance, at the confluence of the river Ivotka in river Desna.

The conducted study is a contribution both to the enrichment of an array of scientific information about the vegetation of the Left-Bank Polissia of Ukraine and to the formation of the basis for creating a system of responsible forest and land use in Polissia in the context of climate change. For Polissia, where the rich phyto-diversity is insufficiently examined and localised, search and research work is the basis for further study of the mechanisms of the existence of local cenoses, which should become the basis for creating a system of responsible forest and land use.

Conflict of Interest

None.

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None.

References

[1] Afanasyev, D.Ya., Bilyk, G.I., Bradis, E.M., & Gryn, F.O. (1956). Classification of vegetation of the Ukrainian SSR. *Ukrainian Botanical Journal*, 13(4), 63-82.

[2] Albrecht, H., Cambecèdes, J., Lang, M., & Wagner, M. (2016). Management options for the conservation of rare arable plants in Europe. *Botany Letters*, 163(4), 389-415. doi: 10.1080/23818107.2016.1237886.

[3] Andrienko, T.L., & Peregrym, M.M. (2012). *Official lists of regionally rare plants of the administrative territories of Ukraine (reference edition)*. Kyiv: Alterpress.

[4] Andrienko, T.L., Bilyk, H.I., Bradis, E.M., Holubets, M.A., Makhayeva, L.V., Rubtsov, M.I., Tkachenko, V.S., & Shelyah-Sosonko, Yu. (1977). *Geobotanical zoning of the Ukrainian SSR*. Kyiv: Naukova Dumka.

[5] Bengtsson, J., Bullock, J.M., Egoh, B., Everson, C., Everson, T., O'Connor, T., O'Farrell, P.J., Smith, H.G., & Lindborg, R. (2019). Grasslands – more important for ecosystem services than you might think. *Ecosphere*, 10(2), article number e02582. doi: 10.1002/ecs2.2582.

[6] Bondar, O., Adamenko, O., Korobkova, H., Hryn, Y., Tsytsiura, N., Zaiarna, O., Halahan, O., Chalaya, O., Pavlushenko, Ye., Stankevych, S., & Matsyura, A. (2017). Forest species diversity in river watersheds of the Left-Bank Forest-Steppe of Ukraine. *Ukrainian Journal of Ecology*, 11(3), 79-85. doi: 10.15421/201712.

[7] Boychenko, R.V., Vertel, V.V., & Karlyukova, O.Y. (2019). *Nature reserve fund of Sumy region*. Kyiv: LLC "Ukrainian Cartographic Group".

[8] Budzak, V.V., & Didukh, Ya.P. (2020). Synphytoindicative evaluation of plant habitats of the Red Book of Ukraine and habitat risk assessment under the impact of climate change. *Ukrainian Botanical Journal*, 77(6), 434-453. doi: 10.15407/ukrbotj77.06.434.

[9] Chornous, O.P. (2006). Forest vegetation of Shostka geobotanical district (Sumy Oblast). *Ukrainian Botanical Journal*, 63(3), 401-410.

[10] Chornous, O.P. (2022). Cenopopulation of *Epipactis helleborine* (Orchidaceae) in forest ecosystems that have been anthropogenically transformed to various degrees. *Biosystems Diversity*, 30(2), 198-204. doi: 10.15421/012221.

[11] Chusova, O.O., Shyriaieva, D.V., Budzhak, V.V., Chorney, I.I., Dziuba, T.P., Iemelianova, S.M., Kucher, O.O., Moysiyenko, I.I., Tokariuk, A.I., Vasheniak, Iu.A., Vynokurov, D.S., Boyko, M.F., Khodosovtsev, O.Ye., & Kuzemko, A.A. (2022). Protected species in grassland habitats of Ukraine. *Ukrainian Botanical Journal*, 79(5), 290-307. doi: 10.15407/ukrbotj79.05.290.

[12] Coelho, N., Gonçalves, S., & Romano, A. (2020). Endemic plant species conservation: Biotechnological Approaches. *Plants*, 9(3), article number 345. doi: 10.3390/plants9030345.

[13] *Convention on International Trade in Endangered Species of Wild Fauna and Flora. (1973)*. Retrieved from https://cites.org/sites/default/files/eng/disc/CITES-Convention-EN.pdf.

[14] Corlett, R.T. (2020). Safeguarding our future by protecting biodiversity. *Plant Diversity*, 42(4), 221-228. doi: 10.1016/j.pld.2020.04.002.

[15] *Council Directive 92/43/EEC "On the Conservation of Natural Habitats and of Wild Fauna and Flora". (1992, May 1992)*. Retrieved from https://www.data.europa.eu/eli/dir/1992/43/oj.

[16] Di Sacco, A., Hardwick, K.A., Blakesley, D., Brancalion, P.H.S., Breman, E., Rebola, L.C., Chomba, S., Dixon, K., Elliott, S., Ruyonga, G., Shaw, K., Smith, P., Smith, R.J., Antonelli, A. (2021). Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. *Global Change Biology*, 27(7), 1328-1348. doi: 10.1111/gcb.15498.

[17] Didukh, Y.P. (2009a). *Red Book of Ukraine. Plant world*. Kyiv: Globalconsulting.

[18] Didukh, Y.P. (2009b). *The Green Book of Ukraine*. Kyiv: Alterpress.

[19] Dinerstein, E., Joshi, A.R., Vynne, C., Lee, A.T.L., Pharand-Deschênes, F., França, M., Fernando, S., Birch, T., Burkart, K., Asner, G.P., & Olson, D. (2020). A "Global Safety Net" to reverse biodiversity loss and stabilize Earth's climate. *Science Advances*, 6, article number eabb2824. doi: 10.1126/sciadv.abb2824.

[20] Forest Stewardship Council (n.d.). Retrieved from https://fsc.org/en.
[21] Kostyshin, A. (2019). Determination of environmental sustainability and antropogenic loading in the territory of the amalgamated community. *Management, Economic Engineering in Agriculture and Rural Development*, 19(3), 329-340.
[22] Kougioumoutzis, K., Kokkoris, I.P., Panitsa, M., Trigas, P., Strid, A., & Dimopoulos, P. (2020). Plant diversity patterns and conservation implications under climate-change scenarios in the Mediterranean: The case of Crete (Aegean, Greece). *Diversity*, 12(7), article number 270. doi: 10.3390/d12070270.
[23] Kovalenko, I.M. (2021). Forest ecosystems of the North-East of Ukraine in the context of global and regional antropogenesis. In: *Effects of pollution and climate change on the ecosystem components* (pp. 40-69). Praha: Oktan Print.
[24] Kovalenko, I.M., Butenko, S., Zhezhkun, A., Porokhniach, I., Abduraimov, O., & Klymenko, H. (2022). Trends in the transformation of plant ontogenesis under global climate warming. *Journal of Agricultural Science*, 2(33), 410-417. doi: 10.15159/jas.22.27.
[25] Kremenetska, Y.O., Holub, M.G., & Cherepovsky, M.V. (2022). Methodical approaches and identification of territories with special values for conservation (in the eastern part of the forests of the Sumy region). *Bulletin of Sumy National Agrarian University*, 44, 19-32. doi: 10.32845/agrobio.2021.2.3.
[26] Lohvynenko, I.P., Lyko, S., Trochymchuk, I.M., Portukhay, O., & Glinska, S.O. (2019). Structure of some rare flora species populations in conditions of Volhynian Upland. *Ukrainian Journal of Ecology*, 9(1), 102-114.
[27] Marukha, T.V. (2022). Ecological and typological assessment of the forest vegetation of the Starogut forest massif of the "Desnyansko-Starogutskyi" NPP. *Balanced Environmental Management*, 3, 116-122. doi: 10.33730/2310-4678.3.2022.266565.
[28] Perles, S., Fotinos, T., & Raskin, E.M. (2022). Strategies for long-term monitoring of riverscour plant communities to inform science-based management. *Natural Areas Journal*, 42(3), 177-184. doi: 10.3375/21-22.
[29] Pironon, S., Borrell, J.S., Ondo, I., Douglas, R., Phillips, C., Khoury, C.K., Kantar, M.B., Fumia, N., Soto Gomez, M., Viruel, J., Govaerts, R., Forest, F., & Antonelli, A. (2020). Toward unifying global hotspots of wild and domesticated biodiversity. *Plants*, 9(9), article number 1128. doi: 10.3390/plants9091128.
[30] Popov, V.A., Marynych, A.M., & Lanko, A.I. (1968). *Physico-geographical districting of the Ukrainian SSR*. Kyiv: Izd. Kyiv University.
[31] Prokudin, Yu.N. (1987). *Key to higher plants of Ukraine*. Kyiv: Naukova Dumka.
[32] Raven, P., & Wackernagel, M. (2020). Maintaining biodiversity will define our long-term success. Plant Diversity, 42(4), 211-220. doi: 10.1016/j.pld.2020.06.002.
[33] Resolution No. 6 of Convention on the Conservation of European Wildlife and Natural Habitats Standing Committee. (1998). *Listing the species requiring specific habitat conservation measures*. Retrieved from https://rm.coe.int/1680746afc.
[34] Roleček, J. (2021). A recent find of *Ophrys insectifera* (Orchidaceae) in Ukraine – will it survive another 100 years? *Ukrainian Botanical Journal*, 78(4), 297-302. doi: 10.15407/ukrbotj78.04.297.
[35] Shelyag-Sosonko, Yu.R. (1991). *Prodromus of Ukrainian vegetation*. Kyiv: Naukova Dumka.
[36] Sipailova, L.M. (1976). Floodplains of the Ivotka River. *Ukrainian Botanical Journal*, 33(1), 64-67.

[37] Skliar, V., Kovalenko, I., Skliar, I., & Sherstiuk., M. (2019). Vitality structure and its dynamics in the process of natural reforestation of *Quercus robur* L. *AgroLife Scientific Journal*, 8(1), 233-241.
[38] Skliar, V., Tykhonova, O., Kyrylchuk, K., Klymenko, H., Onoprienko, V., Bondarieva, L., Trotska, S., & Klimenko, Ju. (2022). Study of the phytodiversity of the Syrovatka river valley with the perspective of using its natural complexes in ecological tourism. *Bulletin of Sumy National Agrarian University*, 45, 45-51.
[39] State of Europe's Forests. (2020). Retrieved from https://foresteurope.org/wp-content/uploads/2016/08/SoEF_2020.pdf.
[40] Vakal, A.P., Vakal, K.K., & Rodinka, O.S. (2003). Vegetation of the Ivotka River Basin within the Yampil and Shostky Districts of Sumy Oblast. In: *Natural sciences: Coll. of science works* (pp. 26-37). Sumy: Sumy DPU named after A.S. Makarenko.
[41] Yakubenko, B.Ye., Popovych, S.Yu., Ustymenko, P.M., Dubyna, D.V., & Churilov, A.M. (2020). *Geobotany: Methodical aspects of research*. Kyiv: Lira-K.
[42] Yatsyk, A.V. (1991). *Small rivers of Ukraine*. Kyiv: Urozhai.
[43] Zubtsova, I., Penkovska, L., Skliar, V., & Skliar, I. (2019). Dimensional features of cenopopulations of some species of medical plants in the conditions of North-East Ukraine. *AgroLife Scientific Journal*, 8(2), 191-201.

Раритетне фіторізноманіття басейну річки Івотка в межах території Сумської області

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Анотація. Пошук і вивчення умов поширення раритетних рослин є важливими для їх захисту від зникнення та збереження біорізноманіття. Ця діяльність стає ще більш актуальною з огляду на прискорення процесу змін клімату внаслідок антропогенного впливу на біоценози, у формуванні яких суттєву роль відіграють рослини, які створюють трав'янистий покрив лук, заплав річок і підліску. Метою цього дослідження були збір і аналіз інформації про види і угруповання рослин, що підлягають охороні, в басейні річки Івотка на території Сумської області і вивчення умов їх поширення. В процесі роботи були проведені польові дослідження по пошуку раритетних рослин і опису місць їхньої локалізації з застосуванням маршрутно-діагностичного методу та камеральні дослідження з ідентифікації знайденого матеріалу.

Результатом дослідження стали знахідки на території басейну річки Івотка в межах Сумської області 28 раритетних видів судинних рослин, серед яких 2 – занесені до Резолюції No. 6 Бернської конвенції та Червоної книги України, 10 – до Червоної книги України, 16 – до списку видів рослин, які не занесені до Червоної книги України, але є рідкісними або такими, що перебувають під загрозою зникнення на території Сумської області. Ці рослини можна віднести до категорії особливих цінностей для збереження, які потребують захисту і збалансованого використання як самих цих видів, так і комплексу біоценозу на території їх поширення. Для збереження і захисту раритетних рослин недостатньо зміни охоронюваного статусу самого виду рослин чи території його локалізації. Необхідним є системне впровадження практики відповідального лісо- і землекористування, щоб зберегти існуюче біорізноманіття. Отримані результати допомагають встановити охоронний статус для рідкісних рослин, розробити заходи з їхнього захисту та використання, а також визначити необхідність впровадження системи відповідального лісо- і землекористування для збереження біорізноманіття

Ключові слова: Лівобережне Полісся; раритетні види вищих рослин; охорона флори; Червона книга України; відповідальне лісо- і землекористування

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Importance and effectiveness of cultural ecosystem services of parks in Kyiv during the war in Ukraine

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Abstract. In Ukraine, during the full-scale Russian-Ukrainian war, rapid economic and social changes took place, the war caused a massive reduction and destruction of cities, and the environmental situation worsened due to which the cultural services of the ecosystem decreased. Such changes provide an opportunity for the remaining cities to improve the quality of the environment through urban green spaces and solve the problem of meeting the aspirations of the community. The purpose of the study was to identify the importance and effectiveness of eight cultural ecosystem services during the war for park visitors in Kyiv. The following methods were used in the study: field survey (route), analytical, systematisation, sociological, socio-psychological, statistical. The Likert psychometric scale was used to survey visitors of two parks in Kyiv to identify the importance and effectiveness of eight cultural ecosystem services provided by parks. The data were analysed using descriptive statistics. It was established that during the war, the visitors of the parks "Yunist" and "Sovky" noted the importance and effectiveness of such cultural ecosystem services as recreation, aesthetics, and nature awareness. It is determined that young people aged 16-30 and 51-60 are most in need of such services, and social relations in both Yunist and Sovky parks for all age categories are located in the reserve zone of service supply. The proven that effectiveness and

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importance of such services as cultural heritage and spiritual enrichment are the lowest for all age categories. Almost half of the visitors in the two parks provided suggestions for improving the quality of the environment, the greatest need was to increase the number of plantings and improve the improvement of territory, in the park "Sovky" respondents stated the need cultural heritage. It was established that the quality of plantings and the location of parks affected the overall satisfaction of visitors. Respondents' satisfaction with the cultural ecosystem services of Sovky park is higher than that of Yunist park. The results of the studies can be used to improve the quality of cultural ecosystem services in the Sovky and Yunist parks

Keywords: green spaces; satisfaction; recreation; aesthetics; social relations; spirituality

Introduction

Internationally, the most common markets for ecosystem services are carbon, swamp, water quality, water supply (quantity), and biodiversity markets (Soloviy, 2018). R. Pace *et al.* (2018) established that trees at the Englischer Garten in Munich in 2012 potentially removed 4 tonnes of pollutants, especially ozone and nitrogen dioxide, and 200 tonnes of carbon dioxide. According to N. Chenmin & Q. Zhengming (2020), a valuable focus is also the Xiamen Park Expo Garden (Jimei Zhongzhou island, Xinglin bay), the plantings of which contribute to the removal of carbon dioxide, oxygen release, air purification, and water resources conservation. Z. Li *et al.* (2022) argued that differentiating the impact of urbanisation levels on ecosystem service supply and demand budgets in terms of core functional-oriented areas is of great importance for formulating sustainable development strategies at the regional level. Forests and the human connection to nature have a big impact on human health. M. Hochmalová *et al.* (2021) established that through exercise and recreation in the forest, people get many benefits from forest ecosystem services that have a positive impact on their physical and mental health. Therewith, they note that the Czech Republic lacks legislative recommendations on cultural ecosystem services at the national level (M. Hochmalová *et al.*, 2021). M. Dallimer *et al.* (2014) note that green spaces have a positive impact on the mental health of park visitors. Ecosystem services are all useful resources and benefits that a person can get from nature (O. Vasyliuk & L. Ilminska, 2020). The cultural services of the ecosystem are aimed at meeting the cultural and intellectual needs of the individual, ensuring creative and spiritual development, and have a certain value.

A number of studies on ecosystem services have been conducted in Ukraine. N. Vysotska *et al.* (2021) reviewed the main benefits and challenges of ecosystem services provided by buffer forest strips. Their economic assessment was conducted for two groups of services: provision and regulation, maintenance. The content of the economic category of public welfare through the prism of ecosystem services, and approaches to their classification, assessment, and payments; the relationship between the intensity of environmental management and the vulnerability of ecosystems and their stability are examined. L.O. Shashula *et al.* (2019) conducted an economic assessment of ecosystem services for various types of land use (agricultural, forest, and swamp land) by region. It is noted that services provided by ecosystems can fall into one of four broad categories, namely, they can be providing, regulating, cultural, or

supporting. N. Havadzyn & I. Melnychuk (2020) reviewed and supplemented the classification criteria for which it is advisable to conduct an inventory of ecosystem services to further determine their economic value. O.I. Furdychko *et al.* (2019) conducted an assessment of forest ecosystem services (carbon deposition, biodiversity conservation, and climate regulation) in the test area of the Drevliansky nature reserve, using remote sensing data. The cost of ecosystem services of the regional landscape park "Znesinnia" as an object of the nature reserve area and the green zone of the urban environx

Thus, in Ukraine, studies have been conducted on the economic categorisation and evaluation of ecosystem services. Ecosystem services of green spaces in urbanised areas (providing, regulating, fragmentary cultural) were considered, however, there have been no studies on the importance and effectiveness of cultural ecosystem services, including in times of war. According to the authors, during the war, most people are stressed and need more cultural ecosystem services such as recreation, aesthetics, and social relations. D. Saadi *et al.* (2020) established that the green environment has a strong restorative effect on the psychological and physiological parameters of a person, which depends on the function, aesthetics, and quality of park plantings.

The purpose of the study is to identify what cultural ecosystem services (aesthetics, recreation, nature awareness, social relations, cultural heritage, inspiration, sense of place, spiritual or religious enrichment) park visitors need during the war and which ones are most effective.

Task: conduct a survey of visitors of different age groups of two parks in Kyiv on the importance and effectiveness of eight cultural ecosystem services (aesthetics, recreation, nature awareness, social relations, cultural heritage, inspiration, sense of place, spiritual or religious enrichment) and establish which of them are important and effective in restoring the respondents' condition during the war.

Materials and Methods

The study was conducted in Yunist and Sovky parks on weekends. The first survey was conducted in November 2022, and the second – in December 2022. During the survey, ethical standards were observed when working with people: the study was conducted in accordance with the WMA Declaration of Helsinki – ethical principles for medical research involving human subjects (2013). The first anonymous survey determined which cultural ecosystem services visitors prefer (a total of 30 respondents were interviewed in Yunist park and Sovky park). The following anonymous survey was based on previous results, considering the importance and effectiveness of cultural ecosystem services among casual park visitors. 32 respondents were interviewed again in Yunist park and 29 – in Sovky park. Respondents of different age categories took part in the survey: 16-30 years, 31-40 years, 41-50 years, 51-64 years, and 64+ years.

The questionnaire consisted of four parts. The first part was the persons` personal information. As shown in Table 1, the ratio of male and female respondents was not the same: women predominated in Yunist park and men – in Sovky park. Among the respondents, the share of elderly people over 64 years of age at 13.8% is recorded only in the park "Sovky". The main respondents to parks were middle-aged people and young people. 65.6% of respondents had a higher level of education. Classes of respondents were the largest in the field of state, corporate professions and technical personnel in Yunist park (46.9%) and in the service sector (34.5%) in Sovky park, and a certain number of pensioners and students. In two parks, visitors were local residents and only one migrant was surveyed in Sovky park, which to a certain extent indicates the diversity of people.

Table 1. Characteristics of respondents

Categories	Yunist park	Sovky park
	%	%
Gender		
Male	43.7	58.6
Female	56.3	41.4
Age, years		
16-30	50.0	41.4
31-40	18.7	31.0
41-50	12.5	6.9
51-64	18.8	6.9
64+	-	13.8
Education		
School	21.9	17.2
College	12.5	17.2
University	65.6	65.6
Monthly profit		
up to 10000	15.6	24.2
From 10000 to 20000	31.3	17.2
From 20000 to 30000	15.6	17.2
>30000	12.5	17.2
absent	25.0	24.2
Profession		
Service-oriented/ Factory workers	21.9	34.5
Government and corporate organisations professions and technical staff	46.9	27.6
Pensioners	3.1	17.2
Pupils/students	25.0	17.2
Unemployed	3.1	3.5
Place of residence		
A local resident of Kyiv	93.8	97.1
Displaced person		2.9
Passerby	6.2	

Source: compiled by the authors

The second part was the importance scale for cultural ecosystem services, using the five-point Likert scale to measure eight types of importance; 1 point – completely unimportant, 2 points – unimportant, 3 – satisfactory, 4 – important, and 5 points – very important. The third part was the satisfaction (efficiency) scale, which also used the Likert method. 1-5, respectively, extremely dissatisfied, dissatisfied, neutral, satisfied, and extremely satisfied, respectively. Visitors evaluated the importance and effectiveness (satisfaction) of eight cultural ecosystem services (aesthetics, recreation, nature awareness, social relations, cultural heritage, inspiration, sense of place, spiritual or religious enrichment) by a questionnaire on

a five-point Likert scale. The fourth part is an open question about what aspects of the park should be improved.

The importance analysis method was used. Statistical analysis was performed using IBM SPSS Statistics 29.0. Likert scale – used to assign values and get points for eight types of importance and eight performance efficiency (satisfaction) using a questionnaire. The Cronbach's alpha coefficient was used to test the reliability of the questionnaire.

Results and Discussion

Urban green spaces are the main providers of ecosystem services in cities, as the diversity of urban flora and fauna is very limited. The quality and variety of ecosystem services provided by natural plant communities and urban green spaces vary substantially and depend on human activity (Radomska, 2022).

Sovky park was established in 1976 in Sviatoshinsky district of Kyiv on the territory of the tract "Treasure forest" on an area of 30 hectares (Fig. 1) based on natural plantings of *Pinus sylvestris* L. In 2018-2019, the park was reconstructed. Alleys have been arranged and dendroflora of *Quercus robur* L., *Prunus padus* L., *Picea abies* Karst., *Prunus serrulata* Lindl., *Prunus cerasifera subsp. pissartii* (CarriŠre) Dost l has been replenished. The infrastructure was updated. There are 3 playgrounds and a 400 m^2 workout area. A 2 km long eco-route and a chess pavilion have been created (Recreation park "Sovky", 2022).

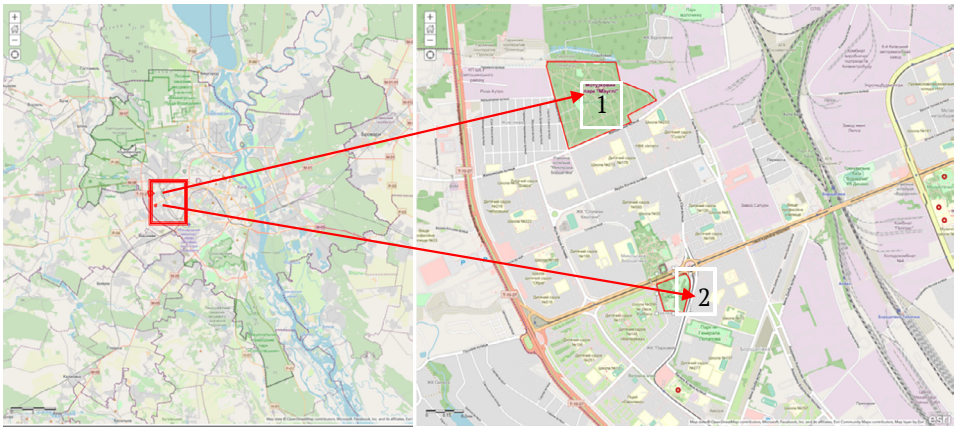

Figure 1. Recreation park "Sovky" (1), park-monument of landscape art "Yunist" (2), Kyiv
Source: OpenStreetMap (n.d.)

Yunist park (a park-monument of landscape art of local importance), created in 1979 by school students, is located on the territory of the Svyatoshinsky district of Kyiv (Fig. 1). In 2015, the park was reconstructed: alleys, kiosks were arranged, two mazes and flower beds were created. A church has been built on the territory of the park. The area of the park is 5.94 ha (park Yunist, 2022). Ecosystem services are linked to human activities, forming a kind of edge where people must have these services to survive and simultaneously be able to influence their provision (Radomska, 2022). The study of the parks began by assessing cultural ecosystem services of eight categories (aesthetics, recreation, nature awareness, social relations, cultural heritage, inspiration, sense of place, spiritual or religious enrichment) to test the relevant

categories of cultural ecosystem services for urban parks (since the values belonging to cultural ecosystem services vary according to individual preferences).After conducting the first survey of 60 respondents in two parks, it was established that visitors in Yunist and Sovky parks prefer ecosystem services such as recreation and social relations and get inspiration from communication with nature, while in Sovky park there are twice as many such respondents (Fig. 2).

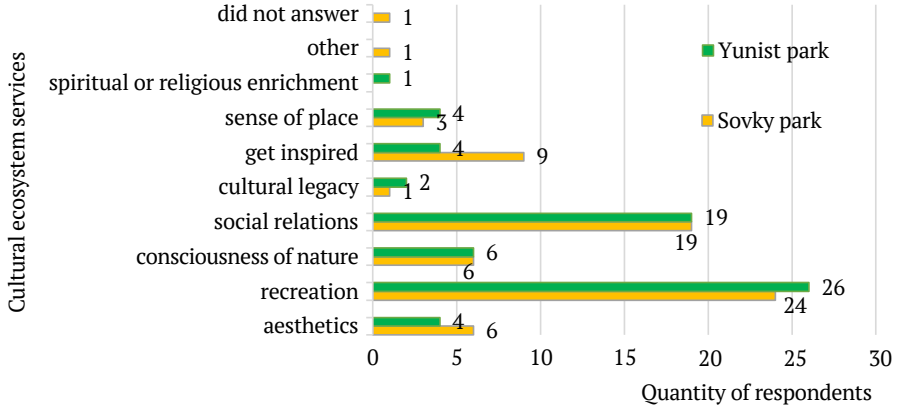

Figure 2. Results of the survey of respondents of the parks "Sovky" and "Yunist", on the provision of benefits to types of cultural ecosystem services

Source: compiled by the authors

Tables 2 and 3 show respondents' assessments of the importance and effectiveness of cultural ecosystem services in Yunist and Sovky parks. The results of the analysis confirmed differences in the importance and effectiveness of different cultural categories of ecosystem services. During the war, in Kyiv, the average value of importance (3.69) in Yunist park and (3.92) in Sovky park of cultural ecosystem services, which was perceived by all respondents, was lower than the level of their effectiveness (satisfaction) (4.08 and 4.38, respectively) (Table 2, 3).

Table 2. Cultural ecosystem services of the park-monuments of landscape art "Yunist"

Cultural ecosystem services		Importance			Satisfaction		
		Average	Mean square	Cronbach's alpha	Average	Mean square	Cronbach's alpha
A	Aesthetics	4.13	0.871	0.977	4.53	0.803	0.976
B	Recreation	4.34	0.653	0.980	4.47	0.842	0.973
C	Nature awareness	4.16	0.987	0.977	4.28	1.085	0.972
D	Social relations	3.36	1.157	0.974	4.28	1.170	0.971
E	Cultural heritage	3.36	1.100	0.972	4.59	1.292	0.976
F	Inspiration	3.36	1.100	0.972	4.22	0.975	0.970

Table 2, Continued

Cultural ecosystem services		Importance			Satisfaction		
		Average	Mean square	Cronbach's alpha	Average	Mean square	Cronbach's alpha
G	Sense of place	3.56	1.143	0.974	4.22	0.975	0.970
H	Spiritual or religious enrichment	2.47	1.218	0.978	3.06	1.268	0.979
Total		3.69	1.029	0.976	4.08	1.051	0.973

Source: compiled by the authors

Table 3. Cultural ecosystem services of the Sovky recreation park

Cultural ecosystem services		Importance			Satisfaction		
		Average	Mean square	Cronbach's alpha	Average	Mean square	Cronbach's alpha
A	Aesthetics	4.34	0.614	0.971	4.76	0.511	0.941
B	Recreation	4.38	0.622	0.971	4.83	0.468	0.944
C	Nature awareness	4.38	1.015	0.969	4.79	0.559	0.942
D	Social relations	3.83	1.071	0.963	4.45	0.985	0.929
E	Cultural heritage	3.59	1.181	0.965	3.79	1.177	0.939
F	Inspiration	4.00	1.102	0.963	4.52	0.738	0.932
G	Sense of place	3.93	1.132	0.963	4.45	0.870	0.935
H	Spiritual or religious enrichment	2.90	1.345	0.969	3.48	1.243	0.942
Total		3.92	1.010	0.967	4.38	0.819	0.938

Source: compiled by the authors

S. Gai *et al.* (2022) obtained opposite results when examining peacetime parks in China, meaning respondents' satisfaction with cultural ecosystem services was generally lower than their importance. Figures 3 and 4 show the distribution of importance and effectiveness (satisfaction) analysis by the score for all respondents in eight categories of cultural ecosystem services. In Yunist park, there are three categories of "supply-demand compliance zone" in the first quadrant: aesthetics (A), recreation (B), nature awareness (C), and the importance and effectiveness of all these categories are relatively high (Fig. 3). This shows that these three categories are the main ones that have a substantial impact on overall user satisfaction and that respondents are generally satisfied with these indicators. Among them, aesthetics (A) has a higher complex score than others. The aesthetics of the park during the war allows for distracting at least temporarily from the problems that arise.

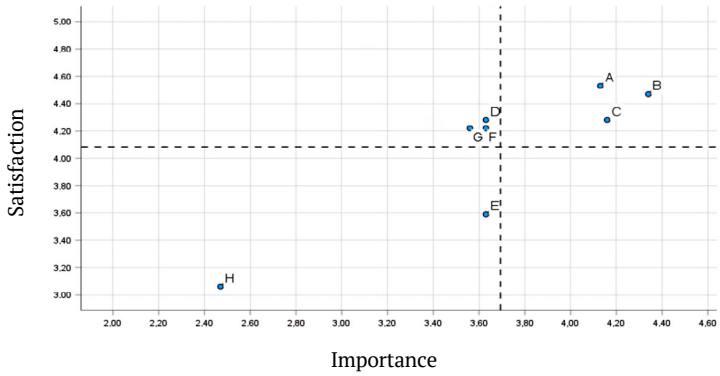

Figure 3. Scatter plot analysis of the importance and effectiveness of eight types of cultural ecosystem services for Yunist park respondents

Note: A – Aesthetics, B – Recreation, C – Consciousness of nature, D – Social Relations, E – Cultural legacy, F – Inspiration, G – Sense of place, H – Spiritual or religious enrichment

Source: compiled by the authors

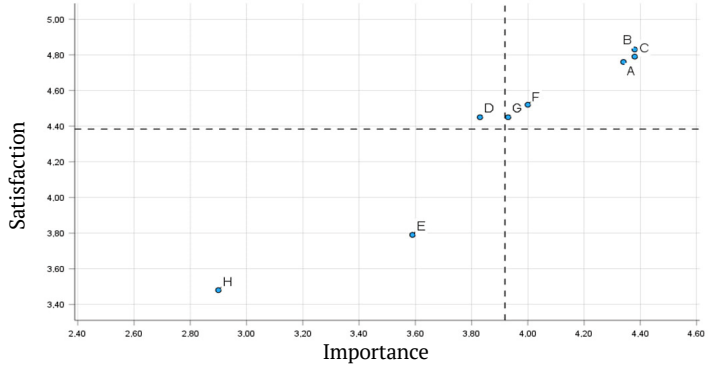

Figure 4. Scatter plot analysis of the importance and effectiveness of eight types of cultural ecosystem services for Sovky park respondents

Note: A – Aesthetics, B – Recreation, C – Consciousness of nature, D – Social Relations, E – Cultural legacy, F – Inspiration, G – Sense of place, H – Spiritual or religious enrichment

Source: compiled by the authors

The second quadrant also focuses on three categories – social relationships (D), inspiration (F), and sense of place (G) – the supply reservation zone. Their performance indicators are close to those of importance. Respondents rated the overall importance of the three categories as low, and their relative performance (satisfaction) was high. This result is partially similar to that of S. Gai *et al.* (2022), where urban parks only had inspiration in the second quadrant. This difference may be related to the purpose of most visitors and the environment of Yunist park. Many respondents wanted to relax in the park, and not continue to think and draw inspiration. The park is located between two roads with quite heavy traffic, there is a certain level of noise. In the park, all the plantings are visible and most of the territory is open and there are not enough quiet places where it is possible to stop to get inspired. Therefore, to a certain

extent, the environment and landscape caused respondents to have a relatively low need for inspiration. People pay a little less attention to social activities in the park and the sense of place. Due to the impact of the epidemic in 2020 and the war in 2022 in Ukraine, respondents began to communicate more on social networks, and their demand for personal social interaction decreased. Due to its relatively small scale and open landscape elements, Yunist park is difficult to transform into a place with a strong sense of place. Cultural heritage (E) and spiritual or religious enrichment (H) are located in the third quadrant – a zone of weak supply and demand. Yunist park was created in the 80s of the 20th century, on its territory there is a summer cinema, which has a satisfactory condition, other objects were created after Reconstruction at the beginning of the 21st century (Recreation park "Sovky", 2022). Although a church was built on the territory of the park, this also did not contribute to the importance and effectiveness of the above-mentioned cultural services of the ecosystem (Fig. 3).

In the park "Sovky" there is a slightly different trend, in the first quadrant there are five categories – "zone of conformity of supply and demand": aesthetics (A), recreation (B), nature awareness (C), the importance and effectiveness of these categories are relatively high and inspiration (F), sense of place (G) the importance and effectiveness of which are somewhat lower (Fig. 4). Sovky park is created based on natural plantings, and its area is more than 5 times the area of Yunist park, respectively, the majority of respondents visit the park for inspiration, which is facilitated by clean pine stands, and remote quiet places. Social relations (D), like in Yunist park, are located in the second quadrant and are a reserve area for the supply of services. After the war ends, their importance and effectiveness may increase. Cultural heritage (E) and spiritual or religious enrichment (H) are located in the third quadrant – a zone of weak supply and demand, similar to Yunist park. This is due to the fact that, assumably, during the war, people still need more rest, sensations, connection with nature, and aesthetics, which to a certain extent allow for restoring mental health. Respondents were divided into five groups by age, and differences in perception among these age groups of performance (satisfaction) in eight categories were compared. Among the respondents, young people and older people both in Yunist park and Sovky park had different feelings (Fig. 5, 6).

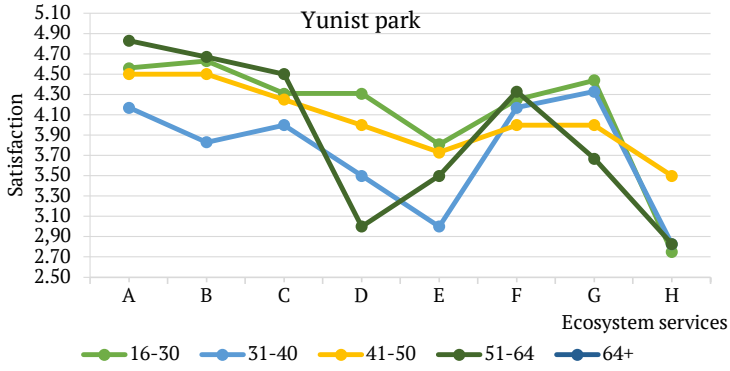

Figure 5. Satisfaction with cultural ecosystem services by age group in Yunist park
Note: A – Aesthetics, B – Recreation, C – Consciousness of nature, D – Social Relations, E – Cultural legacy, F – Inspiration, G – Sense of place, H – Spiritual or religious enrichment
Source: compiled by the author

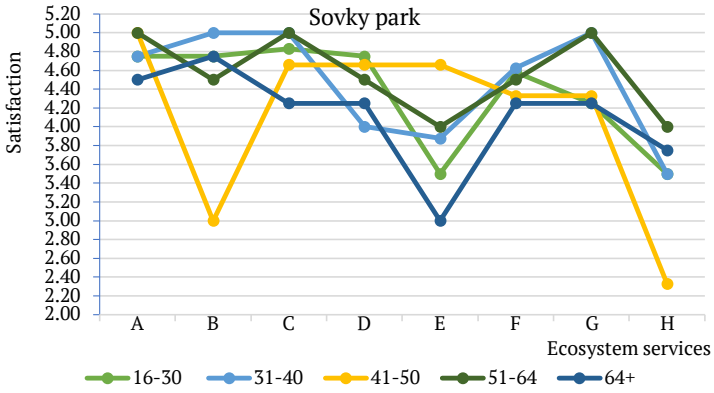

Figure 6. Satisfaction with cultural ecosystem services by age group in the park "Sovky"
Note: A – Aesthetics, B – Recreation, C – Consciousness of nature, D – Social Relations, E – Cultural legacy, F – Inspiration, G – Sense of place, H – Spiritual or religious enrichment
Source: compiled by the author

Respondents aged 16-30 and 41-50 in Yunist park and young people aged 16-30 and 31-40 in Sovky park had the highest degree of satisfaction – this indicates that they are more grateful for the provision of cultural ecosystem services from the park. Visitors aged 31-40 are less satisfied in Yunist park, while people aged 64+ are less satisfied in Sovky park. This result may be related to the park's landscape style, which tends to be natural rather than artificial. Most of the older people who live in the scoops park area come from rural areas, they are used to the natural environment and may be relatively less satisfied with this park. S. Gai *et al.* (2022), examining the parks in China, noted that the rates for people over 64 were much higher than in the 55-64 age group. They attribute these results to the fact that most older people over the age of 64 have retired from nearby colleges and universities, with a relatively high level of education, and are better able to perceive this style of park. In addition, S. Gai *et al.* (2022), having examined peoples' perception of the importance and effectiveness of nine types of cultural services in the urban park ecosystem Udaokou in Beijing, China, established that the importance score was substantially higher than the performance score.

M.M. Radomska (2022) noted that the importance of regulatory ecosystem services in parks created based on natural areas is more substantial than cultural ecosystem services. Therewith, in man-made urban parks of culture and recreation, ecosystem regulatory services have a somewhat limited potential, and cultural ecosystem services are becoming more important. A study of the Sovky and Yunist parks showed that the Sovky park, which is formed based on natural plantings, provides better cultural services, which indicates the satisfaction of visitors in three age groups of 16-30 years, 31-40, and 51-64 years (Fig. 6). Therewith, the results obtained in this study support the study by M.M. Radomska (2022), that the greatest ability to provide ecosystem services is characteristic of larger parks and parks with holistic green spaces. H. Ko & Y. Son (2018), after examining respondents' perceptions of cultural ecosystem services in the urban environment of Gwacheon, Republic of Korea, noted that green spaces are particularly valuable to urban residents and provide them with a variety

of cultural ecosystem services. V. Jennings *et al.* (2016) demonstrated that urban green areas also provide a range of ecosystem services that support the physical, psychological, and social health of residents. However, in many cases, these benefits are unevenly distributed among diverse urban populations. M. Dallimer *et al.* (2014) note that there is a positive association between how often people use green spaces and the well-being they rate. The researchers noted that availability (in the form of the time it takes to reach a green zone) is an important factor in determining how often users visit them. However, they did not find a clear link between the frequency of visits and the ecological state of green spaces (measured by the number of bird species and plantings). According to this study, in the park "Sovky", where pine stands grow, visitors of all age categories prefer aesthetics more compared to the park "Yunist" (Fig. 5, 6), although the parks are 2 km apart, residents prefer to visit Sovky park. This is confirmed by the data of study C.Y. Jim & V.Y. Chen (2006), arguing that the quantity and quality of ecosystem services depend on the composition of plantings, size, location, purpose of the park, etc. The authors after examining 25 ecosystem services, established that the citizens of the city of Guangzhou in southern China have a positive attitude to the ecosystem services of urban green spaces. They highly rate the importance of recreation as one of the categories of ecosystem services, attach less importance to ecosystem benefits associated with biotic-abiotic relationships, and evaluate the landscape as an aesthetic resource for recreation.

After investigating 18 ecosystem services and five challenges of local parks in Addis Ababa (Ethiopia), N.V. Vernihorova (2020) established that respondents prefer environmental, socio-cultural, and economic ecosystem services, but socio-cultural and environmental benefits are considered more important than economic ones. Socio-demographic characteristics of age, gender, and education level did not substantially affect the perception and attitude of parks to ecosystem services, in contrast to the parks examined, where the age of respondents affected the perception of services. Thus, in Yunist park, visitors aged 16-30 and 41-50 and respondents aged 16-30 and 31-40 in Sovky park were more satisfied with such cultural ecosystem services as aesthetics, recreation, and nature awareness. This study agrees with the opinion of N.V. Vernihorova (2020) that such studies point to the importance of conducting them to assess the benefits that attract people to use urban parks and the problems that hinder the use of parks.

K. Yeshitela (2020) believes that planning and management of urban parks should consider people's perceptions and attitudes about the benefits, challenges, and quality of parks. N. Kabisch *et al.* (2015) emphasise that green spaces have numerous environmental and social benefits for city residents, so it is important to preserve and develop them. Gardens and parks are a place of recreation, educational and scientific research and affect the value of real estate. Thus, ecologically sustainable natural plantings with ecosystem services can bring numerous benefits to various stakeholders.

Conclusions

The parks of Kyiv are a valuable centre for providing cultural ecosystem services. During the war, most people are stressed and need more communication with nature for physical and emotional recovery. The preference for certain types of cultural ecosystem services was influenced by such socio-demographic characteristics as age. In the Yunist and Sovky parks, a large proportion, 50.0% and 41.4%, respectively, were visitors aged 16 to 30 years. Respondents of the Yunist and Sovky parks noted

the relatively high importance and efficiency of cultural ecosystem services, such as recreation, aesthetics, and nature awareness. Young people between the ages of 16 and 30 and people between the ages of 51 and 60 are most in need of such services. 50% of visitors to Yunist park and 43% of visitors to Sovky park provided suggestions for improving the park environment and the quality of cultural services. Respondents of Sovky and Yunist parks need more cultural heritage and better territory improvement: installation of more benches, landfills, lanterns (Yunist park), premises for sending natural human needs, creating an additional entrance to the park and recreation areas (Sovky park), entertainment areas (Yunist park), increasing tree stands and flower beds to improve aesthetics. It was established that the size of the park, the origin of plantings and their number affect the satisfaction of city residents and the quality of cultural services in the park ecosystem.

Further research can be conducted to identify the importance and effectiveness of cultural ecosystem services in both urban and rural parks in other regions of Ukraine, including to identify the respondents' wishes to further consider the needs of different users when creating or reconstructing urban and rural parks, improve the quality of cultural ecosystem services. Research can also be aimed at investigating the effectiveness of other types of ecosystem services provided by park plantings, and the impact of plantings on the emotional state of people.

Conflict of Interest

None.

Acknowledgements

None.

References

[1] Chenmin, N., & Zhengming, Q. (2020). Value assessment of ecosystem service functions of xiamen park expo garden. *International Journal of Environmental Monitoring and Analysis*, 8(1), 1-10. doi: 10.11648/j.ijema.20200801.11.

[2] Dallimer, M., Davies, Z.G., Irvine, K.N., Maltby, L., Warren, P.H., Gaston, K.J., & Armsworth, P.R. (2014). What personal and environmental factors determine frequency of urban greenspace use? *International Journal of Environmental Research and Public Health*, 11(8), 7977-7992. doi: 10.3390/ijerph110807977.

[3] Ecosystem services of the regional landscape park "Znesinnia". (2019). Retrieved from http://epl.org.ua/wp-content/uploads/2019/10/Ekosystemni-poslugy-RLP-Znesinnya.pdf.

[4] Furdychko, O.I., Drebot, O.I., Kuchma, T.L., & Ilienko, T.V. (2019). Assessment of forest ecosystem services based on remote sensing data. *Agroecological Journal*, 4, 6-16. doi: 10.33730/2077-4893.4.2019.189436.

[5] Gai, S., Fu, J., Rong, X., & Dai, L. (2022). Users' views on cultural ecosystem services of urban parks: An importance-performance analysis of a case in Beijing, China. *Anthropocene*, 37, article number 100323. doi: 10.1016/j.ancene.2022.100323.

[6] Havadzyn, N., & Melnychuk, I. (2020). Improvement of tools for implementation of ecosystem service functions. *Economics of Nature Use and Environmental Protection*, 41, 251-219. doi: 10.32843/infrastruct41-35.

[7] Hochmalová, M., Červená, T., Purwestri, R., Hájek, M., & Sloup, R. (2021). Anchor of cultural forest services in the national forest policies of Central European countries. *Central European Forestry Journal*, 67(4), 212-229. doi: 0.2478/forj-2021-0013.

[8] Jennings, V., Larson, L., & Yun, J. (2016). Advancing sustainability through urban green space: cultural ecosystem services, equity, and social determinants of health. *International Journal of Environmental Research and Public Health*, 13(2), article number 196. doi: 10.3390/ijerph13020196.

[9] Jim, C.Y., & Chen, W.Y. (2006). Perception and attitude of residents toward urban green spaces in Guangzhou (China). *Environmental Management*, 38, 338-349. doi: 10.1007/s00267-005-0166-6.

[10] Kabisch, N., Qureshi, S., & Haase, D. (2015). Human-environment interactions in urban green spaces – A systematic review of contemporary issues and prospects for future research, *Environmental Impact Assessment Review*, 50, 25-34. doi: 10.1016/j.eiar.2014.08.007.

[11] Ko, H., & Son, Y. (2018). Perceptions of cultural ecosystem services in urban green spaces: A case study in Gwacheon, Republic of Korea. *Ecological Indicators*, 91, 299-306. doi: 10.1016/j.ecolind.2018.04.006.

[12] Li, Z., Hu, B., & Ren, Y. (2022). the supply–demand budgets of ecosystem service response to urbanization: Insights from urban-rural gradient and major function-oriented areas. *Remote Sensing*, 14(22), article number 5670. doi: 10.3390/rs14225670.

[13] OpenStreetMap. (n.d.). Retrieved from https://www.arcgis.com/home/webmap/viewer.html.

[14] Pace, R., Biber, P., Pretzsch, H., & Grote, R. (2018). Modeling ecosystem services for park trees: Sensitivity of i-Tree eco simulations to light exposure and tree species classification. *Forests*, 9(2), article number 89. doi: 10.3390/f9020089.

[15] Park "Yunost" (Svyatoshinsky district). (2022). Retrieved from https://mesta.com.ua/park/park-junost-v-kieve.

[16] Pryshchepa, A.M. (2019). Ecosystem services of urbosystems green plantations. *Scientific Report of NULES of Ukraine*, 1(77), 1-12. doi: 10.31548/dopovidi2019.01.004.

[17] Radomska, M.M. (2022). Biodiversity based solutions for the support of ecosystem services, provided by urban green infrastructure. *Scientific Bulletin of UNFU*, 32(5), 50-58. doi: 10.36930/40320507.

[18] Recreation Park "Sovki". (2022). Retrieved from https://kyivmaps.com/ua/places/park-vidpochynku-sovky.

[19] Saadi, D., Schnell, I., & Tirosh, E. (2021). Ethnic differences in environmental restoration: Arab and Jewish women in Israel. *International Journal of Environmental Research and Public Health*, 18(23), article number 12628. doi: 10.3390/ijerph182312628.

[20] Shashula, L.O., Sakal, O.V., & Tretiak, N.A. (2019). Payment for ecosystem services in Ukraine: Priority direction of revitalization. *Mechanism of Economic Regulation*, 2, 6-16. doi: 10.21272/mer.2019.84.01.

[21] Soloviy, I. (2018). Concept of payments for ecosystem services: Global experiences and prospects of its implementation in forest sector. *Proceedings of the Forestry Academy of Sciences of Ukraine*, 14, 252-258. doi: 10.15421/411634.

[22] Vasyliuk, O., & Ilminska, L. (2020). *Ecosystem services*. Rzhyshchiv: Fund of Protection Biodiversity of the Ukraine.

[23] Vernihorova, N.V. (2022). Park ecosystem services and their evaluation. *Economic Innovations*, 24(2(83)), 53-65. doi: 10.31520/ei.2022.24.2(83).53-65.

[24] Vysotska, N., Kalashnikov, A., Sydorenko, S., Sydorenko, S., & Yurchenko, V. (2021). Ecosystem services of shelterbelts as the basis of compensatory mechanisms of their creation and maintenance. *Proceedings of the Forestry Academy of Sciences of Ukraine*, 22, 199-208.
[25] WMA Declaration of Helsinki – ethical principles for medical research involving human subjects (2013). Retrieved from https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/.
[26] Yeshitela, K. (2020). Attitude and perception of residents towards the benefits, challenges and quality of neighborhood parks in a Sub-Saharan Africa City. *Land*, 9(11), article number 450. doi: 10.3390/land9110450.

Важливість та ефективність культурних екосистемних послуг парків міста Києва під час війни в Україні

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Анотація. В Україні під час повномасштабної російсько-української війни відбулись швидкі економічні та соціальні зміни, війна спричинила масове зменшення та знищення міст, погіршилась екологічна ситуація за рахунок чого зменшились культурні послуги екосистеми. Такі зміни надають можливість містам, що залишились, покращити якість навколишнього середовища за допомогою міських зелених насаджень і вирішити проблему задоволення прагнень громади. Метою дослідження було виявлення важливості та ефективності восьми культурних екосистемних послуг під час війни для відвідувачів парків м. Києва. В досліджені було використано наступні наукові методи: натурні обстеження (маршрутний), аналітичний, систематизації, соціологічний, соціально-психологічний, статистичний. Використано психометричну шкалу Лайкерта для опитування відвідувачів двох парків м. Києва, щоб виявити важливість і ефективність восьми культурних екосистемних послуг, що надають парки. Дані було проаналізовано за допомогою описової статистики. Було встановлено, що під час війни відвідувачі парків «Юність» та «Совки» відмітили важливість і ефективність, таких культурних екосистемних послуг, як відпочинок, естетичність та свідомість природи. Виявлено, що найбільше потребують таких послуг молоді люди 16-30 років та люди віком 51-60 років, соціальні відносини як у парку «Юність» так і парку «Совки» для всіх вікових категорій знаходяться у резервній зоні постачання послуг. Підтверджена

ефективність та вважливість таких послуг як культурна спадщина та духовне збагачення найнижча для всіх вікових категорій. Майже половина відвідувачів у двох парках надала пропозиції щодо покращення якості середовища, найбільша потреба була у збільшенні кількості насаджень та покращенні благоустрою території, у парку «Совки» респонденти потребують культурної спадщини. З'ясовано, що якість насаджень та розташування парків вплинула на загальну задоволеність відвідувачів. Задоволеність респондентів культурними екосистемними послугами парку «Совки» вища ніж парку «Юність». Результати досліджень можуть бути використані для підвищення якості культурних послуг екосистеми в парках «Совки» та «Юність»

Ключові слова: зелені насадження; задоволеність; відпочинок; естетичність; соціальні відносини; духовність

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The current state of windbreaks in the Left Bank Forest-Steppe of Ukraine

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Abstract. The relevance of the study is related to the need to determine the current state of windbreaks as a component of the forest-agrarian landscape of a particular region. The purpose of the study is to conduct a comprehensive assessment of windbreaks. During the study, data from remote sensing of the Earth using satellite imagery was utilised, which allowed for determining field parameters, the placement of the windbreak system, and their characteristics. Forest inventory works were conducted using commonly accepted methods in forest mensuration, with adjustments made specifically for windbreaks. The quality class of windbreaks was determined based on the percentage of healthy trees out of the total number, and the sanitary condition index was calculated according to established categories. The analysis of the obtained data clearly shows

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a decline in the quality sequence of common oak from 9 to 3 units within the plantations. The windbreaks were created using the method of oak nest planting, with oak nests placed at a spacing of 5.0×3.0 m and a total windbreak width of 15.0 m. Two additional rows of companion trees were introduced in the wide 5-metre alleys, and companion and shrub species were added within the nest rows. The analysis of the characteristics of windbreaks showed that they have protective heights ranging from 19.6 m to 23.4 m and provide reliable protection for adjacent agricultural fields. Based on the range of effective protective effects of windbreaks, it can be noted that the calculated indicators provide protection with a reliable safety margin of up to 17%. If there is a need to create new windbreaks using the nest planting method in the future, a more efficient scheme is proposed, which involves placing companion tree species in the outer rows to prevent the crowns of the inner rows from spreading towards the field. As a result of the obtained findings, it became possible to conduct a comprehensive expert assessment of the state of windbreaks according to the following criteria: forestry and inventory parameters, meliorative properties, and the sanitary condition index

Keywords: plant composition; mixing schemes; design; protective effect; Condition Index; quality class

Introduction

The relevance of the chosen subject lies in the need to establish the existing parameters of windbreaks (WBs), ensure their effectiveness in protecting agricultural fields, and determine the sanitary condition of the plantations, which to some extent complements the current characterisation of the agroforestry landscape. The issue of ecological balance in the structure of land use in agrolandscapes, establishing an optimal ratio of arable land, pastureland, forests, and water resources, requires mandatory resolution. Global warming is irreversible, so the conservation, preservation, and restoration of WB systems, which play a key role in the complex adaptation of modern agriculture to changing climatic conditions, are of paramount importance. O. Tkachuk & N. Viter (2022) determined that windbreaks play a multifunctional role, supported by observations, research, and practical activities. To establish fast-growing and multifunctional plantations, I.V. Solomakha *et al.* (2022) proposed the use of multifunctional plant species that not only fulfil the functions of wind, water, and dust retention but also perform other economic tasks.

V.M. Maurer & A.P. Pinchuk (2019), considering the experience of European Union countries, explored the prospects of agroforestry development in Ukraine. It provides an opportunity to transition to landscape-ecological principles in agriculture and ensure maximum protective effects.

V.M. Malyuga (2020) concluded that it is necessary to consider the proper management of existing windbreaks (WBs) with a meliorative focus (cultivation, protection, conservation, utilisation), including a portion of forests that perform protective functions, such as field-edge forests, ravine forests, baulk forests, riparian forests, and other forested areas. The meliorative role of forest plantations is manifested in the genesis of eroded soils. Since the establishment of erosion-control plantations, these soils gradually undergo positive changes in agrophysical, agrochemical, and biological properties.

The WB system should be viewed as an integral part of agro-landscapes. Therefore, the optimisation of the WB system should be conducted based on physiographic principles, utilising the latest forest melioration zoning of Ukraine. S. Wehling & M. Diekmann (2009), G. Decocq *et al.* (2016) emphasised the importance and value of such systems in fulfilling the functions of ecological corridors, which contribute to biodiversity. According to the findings of D.V. Dubyna *et al.* (2023), while performing biotope functions, WBs create an optimal environment for the natural flora and fauna, facilitating the development of evolutionary processes. Over time, some of these plantations acquire characteristics of natural ecosystems, providing habitats and migration routes for biodiversity within anthropogenically modified landscapes.

Strip-shaped WBs, like large-scale plantations, directly influence forest cover and, consequently, the carbon balance of small-scale agricultural areas. Such plantings are capable of accumulating atmospheric carbon depending on the characteristics of their aboveground phytomass (Khodash, 2010; Ziegler *et al.*, 2016). S. Maksimtsev *et al.* (2021) noted that in addition to these factors, windbreaks, especially roadside windbreaks, play a crucial role in protecting adjacent areas from the spread of heavy metals generated by traffic emissions. These plantations serve a dual function: on one hand, they protect transportation routes from adverse natural and climatic factors and the dispersion of harmful emissions from vehicles, and on the other hand, they provide protection for adjacent agricultural fields.

To maintain the sustainability of agricultural landscapes, it is necessary to implement systematic anti-erosion and land reclamation measures on field land. Windbreaks (WBs) ensure the long-term, reliable, and safe functioning of agro-landscapes while enhancing natural biodiversity. Therefore, the purpose of the study is to conduct a comprehensive expert assessment of the state of windbreaks based on defined criteria: forestry and inventory parameters, meliorative properties, and the sanitary condition index.

Materials and Methods

The current state of windbreaks in the Left-Bank Forest-Steppe of Ukraine was investigated using the example of the municipal enterprise (ME) "Pyriatyn-Agrolis" located in the Lubny district of the Poltava region. According to physiographic zoning, the territory of the enterprise is situated in the northwestern part of the Poltava region within the forest-steppe zone of the Prydniprovskyi Lowland. The research was conducted during October-November 2022.

During the study, land survey data from satellite imagery were used. The use of remote sensing provided an opportunity to determine field parameters, the arrangement of the windbreak system, and establish their characteristics (length, width in crown projection, etc.). A similar method is found in the study by X. Yang *et al.* (2017). Additionally, the WBs lengths were determined using a rangefinder.

The soil and vegetation cover of the studied area is largely influenced by a moderate continental climate and near-optimal moisture conditions. Such circumstances led to the formation of chernozem and podzolic soils in this area, which was a consequence of the influence of forest and steppe vegetation. The Lubny district is characterised as a region with low forest cover and a deficit of forests.

The studied objects consisted of eight windbreaks located within the territory of the mentioned enterprise (Fig. 1). The current state of the windbreaks was assessed based on forestry and meliorative characteristics, and sanitary indicators.

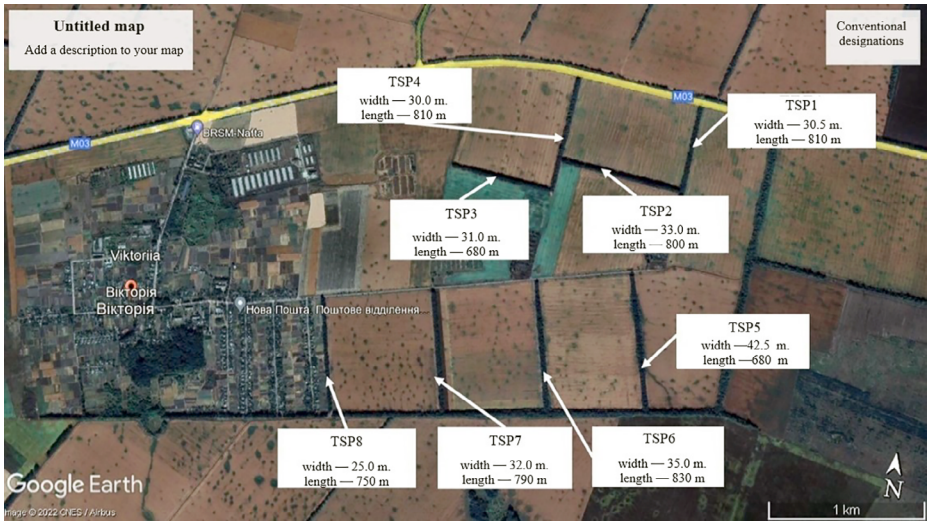

Figure 1. Location of temporary sample plots (TSP) in the windbreaks of the "Pyriatyn-Agrolis" ME

The forest inventory work was performed in accordance with the "Instructional Requirements for the Forest Melioration of Windbreaks" with clarifications provided in the "Guidelines for the Forest Melioration of Linear-Type Windbreaks" (Pylypenko, 2004; Yukhnovsky, 2013). The windbreaks were differentiated based on their construction, composition, mixing scheme, age, and protective height.

Considering the distance of the protective effect of the windbreaks depending on the existing structures in the mentioned farms, the average protective influence of 1 hectare of windbreak on adjacent fields was analysed. Based on the distance of influence of the windbreaks, their width, and protective height, the area of the field within the effective zone of influence of 1 hectare of windbreak was calculated using the formula (1) (Furdychko & Stadnyk, 2012):

$$S = 10000/A \cdot B, \quad (1)$$

where S – the area of the field within the protective influence zone of 1 hectare of the windbreak, ha; B – range of protective action (30 N for windward effect, where N is the protective height, m); A – width of the windbreak, m.

The quality class of the windbreaks was determined based on the scale of assessing their condition according to the percentage of healthy trees from the total number of trees (Pylypenko, 2004). The sanitary condition index was determined based on the obtained list of trees and their distribution into six categories: I – healthy, II – weakened, III – severely weakened, IV – dying, V – fresh dead, VI – dead from previous years (On the approval ..., 1995). Based on their ratio, the general index of the sanitary condition of plantings was calculated (Formula 2):

$$I = \frac{n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5 + 6n_6}{n_1 + n_2 + n_3 + n_4 + n_5 + n_6}, \quad (2)$$

where I – index of sanitary condition; (n_1.... n_6) – number of trees within the category, digits 1....6 – status category numbers.

The forestry and inventory parameters of the plantations were established with a focus on achieving the protective height. The distances of effective protective influence and the area

of protected farmland were calculated, considering the structural features of the plantations. The assessment of plantings was conducted according to the index of their sanitary condition.

Results and Discussion

The summarised forestry and inventory characteristics of the plantations are presented in Table 1. As can be seen from the data provided, the main tree species is the common oak (*Quercus robur* L.). This species is characterised by frost and drought resistance, and low sensitivity to air humidity. Due to its high protective properties, longevity, and ability to regenerate through coppicing, the common oak is considered one of the effective species for protective afforestation. Another main species represented is the common ash (*Fraxinus excelsior* Michx.), which is light-demanding and thrives in fertile and moist soil conditions, often in combination with other tree species. The accompanying species include the Norway maple (*Acer platanoides* L.) and the European white elm (*Ulmus laevis* L.).

Table 1. Summarised forestry and inventory characteristics of the plantations

TSP	Composition of plantings	Tree species	Medium		Number of trees, pcs./ha	Density, m^2/ha	Bonitet class	Stock, m^3/ha
			height, m	Diameter, cm				
1	7CO3CA	CO	19.9	39.8	430	53.4	II	516
		CE	18.5	33.2	283	24.4		208
Total stock								724
2	5CA5CO	CO	20.3	45.2	303	48.6	I	452
		CA	23.4	30.8	573	42.8		498
Total stock								950
3	5SLM3CO2CE+ +CA	SLM	18.8	29.5	474	32.3	II	292
		CO	18.9	39.7	186	22.9		212
		CE	17.2	30.6	154	11.3		86
		CA	18.9	28.9	29	1.9		29
Total stock								619
4	6CA4CO+ VZ, SLM	CA	22.1	30.4	372	37.5	I	495
		CO	21.6	43.3	255	27.1		407
		CE	18.7	34.6	26	0.2		22
		SLM	19.4	9.8	23	2.4		2
Total stock								926
5	9CO1CA	CO	21.1	36.6	555	58.2	II	569
		CA	19.1	23.7	108	4.8		50
Total stock								619
6	5CO5CA	CO	18.6	36.8	250	26.6	II	233
		CA	19.0	47.8	132	24.7		235
Total stock								468
7	6CO4CA+CA	CO	21.2	40.1	431	54.4	II	541
		CA	20.8	33.7	271	24.2		338
		CE	18.2	26.2	64	3.5		28

Table 1, Continued

TSP	Composition of plantings	Tree species	Medium		Number of trees, pcs./ha	Density, m^2/ha	Bonitet class	Stock, m^3/ha
			height, m	Diameter, cm				
Total stock								907
8	8CO2CA+CE	CO	18.9	46.0	222	36.9	II	332
		CA	18.6	28.1	114	7.1		78
		CE	17.5	32.0	19	1.5		12
Total stock								422

Note: CO – common oak, CE – common elm, CA – common ash, SLM – sharp-leaved maple
Source: compiled by the authors

Experimental plantings are of the same age (71 years) and grow in the conditions of fresh oak forests (D_2), which is confirmed by corresponding indicators of the living understory cover. During the research period, the proportion of common oak in the plantations varied from 3 (TSP 3) to 9 (TSP 5) units in plantings. From the provided list of inventory indicators for protective windbreaks, the main factor determining their protective effect is the average height. The study showed that the current composition of the plantations is not always the result of a successful selection of tree species and timely forest management practices.

Based on the analysis of tabular data, a clear decline in the proportion of common oak in the plantations can be observed. The highest proportion of 9 units (approximately 90%) of oak is found in TSP 5, where it reached an average height of 21.1 m due to timely forest management and outperformed ash (19.1 m) in height. With a proportion of 8 units in TSP 8, oak reached a height of 18.9 m and slightly exceeded ash (18.6 m). With a proportion of 7 units in TSP 1, oak reached a height of 19.9 m due to the absence of competition from elm. With a proportion of 6 units of oak in TSP 7, it reached a height of 21.2 m and slightly outpaced the second dominant species, ash (20.8 m), in growth. In the latter case, oak achieved its height advantage through timely forest management practices. The same composition was found in TSP 2 and 6, where oak and ash both had a proportion of 5 units, but different height indicators (23.4 and 19.0 m, respectively). Ash exhibited particularly dominant growth in TSP 2, where the height difference with oak was 3.1 m. In TSP 4, oak accounted for only 4 units, and the second dominant species (ash) reached a height of 22.1 m, slightly surpassing oak in this indicator. With a proportion of 3 units in TSP 3, with maple dominating, both species reached nearly the same height (18.9 and 18.8 m, respectively). Common oak consistently grows according to bonitet class II, while common ash grows according to bonitet class I (TSP 2 and 4). Norway maple, which also grows according to bonitet class II, can compete with common oak under certain circumstances.

The studied protective windbreaks were established in the pattern of oak clumps, with oak clusters spaced at 5.0×3.0 m and a total windbreak width of 15.0 m (Fig. 2a). Two additional rows of companion trees were introduced in the wide 5-metre alleys, and companion and shrub species were added within the nest rows.

Along with determining the main taxonomic characteristics, calculations of the protective influence of PFSs were performed based on their structural features. Analysis of the forest meliorative characteristics of windbreaks (Table 2) revealed that the experimental windbreaks have protective heights ranging from 19.6 m (TSP 6) to 23.4 m (TSP 2) and provide reliable protection for agricultural crops (Table 2). According to the instructional requirements, the width

of the fields in the main crop rotation is set at 600 m (Pylypenko, 2004). Considering the effective protective influence zone within a 30 H distance (H – protective height of the windbreak), the calculated values ranged from 588 to 702 m. Thus, practically all the studied windbreaks (except TSP 6) provide protection with a reliable overlap (safety margin) of up to 17%.

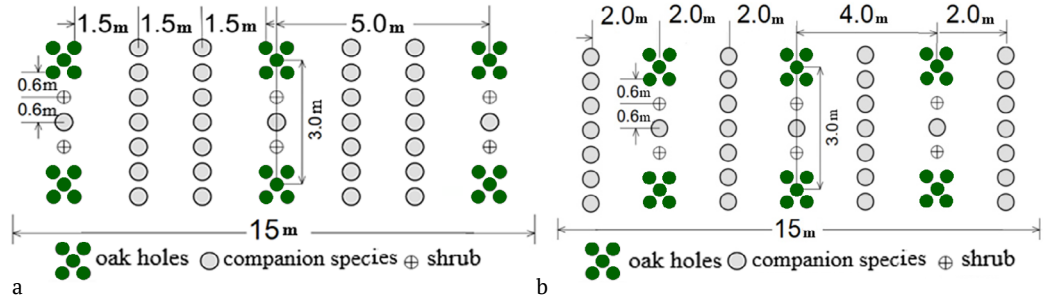

Figure 2. Mixing schemes for oak clump windbreaks
Notes: a – ready-created windbreaks; b – recommended modified version
Source: compiled by the authors

Table 2. Silvicultural characteristics of plantations

TSP	Composition of plantings	Protective height, m	Range of effective protective action of the windbreak, m	Protected area of field land 1 ha windbreak, ha	Protection of field land, % of the standard value
1	7CO3CA	21.7	651	43.4	108
2	5CA5CO	23.4	702	46.8	117
3	5SLM3CO2CE+CA	20.4	612	40.8	102
4	6CA4CO+ VZ, SLM	21.7	651	43.4	108
5	9CO1CA	22.3	669	44.6	112
6	5CO5CA	19.6	588	39.2	98
7	6CO4CA+CA	20.5	615	41.0	103
8	8CO2CA+CE	20.3	609	40.6	102

Note: CO – common oak, CE – common elm, CA – common ash, SLM – sharp-leaved maple
Source: compiled by the authors

In case of practical necessity for creating windbreaks using the nesting method (considering the drawbacks), it is advisable to use a modified scheme (Fig. 2b) for future use. Its features lie in the need to place accompanying tree species in the outer rows to prevent crown growth towards the field. Under such conditions, the crowns of the accompanying tree species can be easily pruned, or if necessary, these trees can be removed without disturbing the overall structure of the windbreak.

Regarding the structures, it is worth noting that all of them are dense, and therefore do not meet the conditions for effective protection of agricultural crops. The reason is that over the past 30 years, forest care measures concerning windbreaks have not been implemented. This has led to the proliferation of understory and vegetative shoots from self-felled trees, resulting in densification, especially in the lower layer of the plantation (Fig. 3). To increase the effectiveness of the protective

influence of windbreaks, it is recommended to conduct thinning operations to create optimal airflow patterns. The current state of windbreaks is often unsatisfactory. This situation is especially prevalent in plantations that have not been transferred under the control of local territorial communities or municipal enterprises and sometimes suffer from unauthorised logging. Maintenance and restoration work are not conducted in these windbreaks, resulting in their degradation and loss of protective properties.

Figure 2. General view of PFS with a dense structure (TSP 1)

As a result of the thinning of windbreaks due to unauthorised logging, processes of soil compaction and erosion develop, accompanied by the growth of shrubs and woody vegetation, which weakens the plantations. As a result, the action of pathogens and forest pests is activated which negatively affect the sanitary condition of plantings. The results of the assessment of the sanitary condition of plantings are represented in Table 3. Tree weakening can also be caused by ice and snow loads (Stadnik, 2003).

Table 3. Sanitary condition of windbreaks

TSP	Composition of plantings	Condition index	Condition	Healthy, %	Quality class	Number of trees, pcs./ ha
1	7CO3CA	1.85	weakened	72.3	2	289
2	5CA5CO	1.50	healthy	76.4	1	263
3	5SLM3CO2CE+CA	1.65	weakened	65.4	2	295
4	6CA4CO+ VZ, SLM	1.46	healthy	70.4	2	318
5	9CO1CA	2.62	very weakened	49.2	3	325
6	5CO5CA	3.08	very weakened	41.7	3	362
7	6CO4CA+CA	1.93	weakened	60.2	2	359
8	8CO2CA+CE	2.37	weakened	59.0	2	217

Note: CO – common oak, CE – common elm, CA – common ash, SLM – sharp-leaved maple
Source: compiled by the authors

Analysis of the results of the assessment of the sanitary condition of eight windbreaks showed the following results: two healthy ones with a sanitary condition index of 1.50 and 1.46, respectively (TSP 2 and 4); four weakened ones (with an indicator from 1.65 to 2.37, TSP 1, 3,

7, 8); two very weakened ones (2.62 and 3.08, respectively, TSP 5 and 6). By quality class, the distribution turned out to be somewhat different. The first quality class in the presence of 76.4% of healthy tree species was found at TSP 2, and the third quality class was found at TSP 5 and 6, where the number of healthy plants is 49.2 and 41.7%, respectively. The second quality class is the remaining plantings with an indicator of healthy plants from 59.0 to 72.3% (TSP 1, 3, 4, 7, 8).

Similar objects (PFSs) have been considered in a number of papers over the past period. In particular, the impact of global climate change on the current state and biological stability of PFS is indicated in paper O. Tkachuk & N. Viter (2023). The authors note that these climate changes may have a negative impact on the functioning of windbreaks within the Vinnytsia region. This can result in the suppression of certain tree species that are vulnerable to drought, high temperatures, pests, and diseases, especially those with shallow root systems. Special suppression will occur in species with shallow root systems. Such tree species mentioned by the authors include common oak, Scots pine, European fir, European beech, silver birch, and grey alder. Such suppression can considerably affect the environmental functions of PFSs. Therefore, the decisive role in this ratio belongs to tree species with less sensitivity to humidity and higher resistance to elevated temperatures. It is worth mentioning that the research objects of these authors are located in the same natural-climatic zone of the Forest-Steppe and should be considered in the context of climate change. In the process of studying the most common forest protective windbreaks in the Southern Steppe, Y. Bila (2022) emphasises their positive impact on the microclimate of adjacent agricultural fields.

Regarding the historical value of FPSs created in Ukraine, the so-called "Dokuchaev" windbreaks studied by P.A. Hetman (2023) have great importance based on more than 120 years of experience in their creation and functioning. These windbreaks are a unique forest meliorative object that systematically attracts the attention of researchers. The author, based on the analysis of cenotic characteristics of the studied windbreaks, notes the similarity of their species composition and structure of groups, where common oak (*Quercus robur* L.) and common ash (*Fraxinus excelsior Michx*.) are used as forest-forming species. Compared to this study's object, they are notably older in age and give confidence in the prospects for their further use. It is necessary to note the similarity of the structural features of FPSs, particularly in terms of their dense construction. The herbaceous layer of the windbreaks investigated by P.A. Hetman (2023) is characterised by moisture-loving, moisture-resistant, and shade-tolerant species compared to the herbaceous cover of field edges. Similar results in the formation of forest biocenosis were obtained by G.O. Lobchenko (2015).

In the studies conducted by O.P. Polishchuk (2009) and D. Řeháček *et al.* (2016), it was also found that the maximum effect of protective windbreaks is achieved when optimal structures are formed. These structures show the best results in reducing the speed of damaging winds (Böhm *et al.*, 2014). The density of these plantings correlates with their construction (Ostapchuk & Sovakov, 2016). M. Bogoslovska & Yu. Yelisavenko (2022) conducted a study on protective windbreaks as integral biocenoses in the Vinnytsia region. They conducted examinations of these windbreaks in areas of the region that are characterised by steppe-like natural and climatic conditions. These objects perform important eco-stabilising functions in preserving agro-landscapes from negative natural factors. The majority of windbreaks in the studied region were created using a combined type of

mixing, with the presence of main, accompanying, and shrub species. Similarly to this study, the authors also examined tree species such as common oak, common ash, sycamore maple, and silver birch. The predominant number of tree species in these plantings belong to the I class of site quality, have a satisfactory condition, and are characterised by an age interval of 60 to 75 years. The authors also emphasise the need for silvicultural management in windbreaks to maintain the initial structure and ensure effective forestry and ameliorative impact on adjacent agricultural lands.

PFSs are an important component of the agricultural landscape, which provides protection of field land from adverse natural factors and, as a result, contributes to the increase in crop yields (Sovakov, 2010; Sytnyk, 2005). In this context, N. Zvorska & V. Shlapak (2022) investigated the effect of PFSs on sunflower yield for the Cherkasy region in 2019-2021. In their study, the authors note that the impact of windbreaks on the yield of agricultural crops in ecotone landscapes is influenced by multiple factors. The yield depends on the plant varieties, their resistance to disease pathogens, the natural-climatic conditions of the locality, the type of windbreak structures and their sanitary condition. Thus, the results of these studies fully correlate with the given study regarding the range of effective protective effects of PFSs.

To improve legislation in the context of optimising the area of linear windbreaks and to ensure effective management practices, the Order of the Cabinet of Ministers of Ukraine No. 725-r "On Approval of the Concept for the Development of Agroforestry in Ukraine" (2013) has been developed. This concept identifies the main factors of inefficient protection of agricultural fields and proposes key measures to address them. Legislative support for agroforestry implementation in Ukraine is being provided to implement this concept (Yukhnovsky *et al.*, 2016).

Recent studies highlight various aspects of the condition and protective effect of PFSs. The conducted studies in the windbreaks of the "Pyriatyn-Agrolis" ME are distinguished for their comprehensive approach to assessing their condition.

Conclusions

Despite a number of objective and subjective factors (lack of management, proper protection, efficient management, etc.), a forest environment has developed by the age of 70, capable of providing suitable conditions for plant growth in the plantations and fulfilling their protective functions.

The experimental windbreaks were found to be monoclonal, growing in the type of forest vegetation conditions known as fresh oak forests. In the course of the study, it was determined that the proportion of common oak in their composition ranged from 3 (TSP 3) to 9 (TSP 5) units. The average height was identified as a determining parameter for the assessed windbreaks, ranging from 18.6 to 21.6 m for the second bonitet class. Protective heights, which usually have higher values compared to the averages, ranged from 19.6 to 23.4 m.

Considering the distance of effective protective influence of the windbreaks, the calculated indicators ranged from 588 to 702 m. Therefore, all the researched windbreaks (except TSP 6) provide reliable protection for agricultural crops with a safety margin of up to 17%. According to the existing structures, windbreaks are dense and do not meet the conditions for effective protection of field land and require silvicultural measures to create an optimal windbreak structure. Additionally, the investigated windbreaks require forest melioration measures.

Assessment of eight windbreaks based on the sanitary condition index yielded the following: two healthy windbreaks (TSP 2 and 4), four

weakened windbreaks (TSP 1, 3, 7, 8), and two severely weakened windbreaks (TSP 5 and 6). According to the quality class, the distribution was as follows: the first quality class was observed in TSP 2, the third class in TSP 5 and 6, and the second quality class was characteristic of the remaining plantations (TSP 1, 3, 4, 7, 8).

The prospects for further studies on these objects are determined by the need for inventorying considering their condition and meliorative properties, implementing a complex of silvicultural measures to form optimal structures, and addressing the legal issue regarding their subordination to specific landowners. Monitoring WBs in terms of their condition will allow systematic observation of the effective protection of field land. The condition of windbreaks growing in areas where combat actions took place can be determined using unmanned aerial vehicles before their demining.

Conflict of Interest

The authors declare no conflict of interest.

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References

[1] Bila, Y. (2022). The most common windbreaks of the Southern Steppe. In *Forestry, woodworking and landscaping: status, achievements and prospects: Additional materials. participation All-Ukrainian science and practice conference* (p. 23). Kharkiv: State Biotechnological University.

[2] Bogoslovska, M., & Yelisavenko, Yu. (2022). Windbreaks of the Vinnytsia region as a forest biocenosis. In *Interdisciplinary research: Humanities and natural sciences: Materials of scientific-practical conference* (pp. 85-87). Odesa: Young Scientist.

[3] Böhm, C., Kanzler, M., & Freese, D. (2014). Wind speed reductions as influenced by woody hedgerows grown for biomass in short rotation alley cropping systems in Germany. *Agroforestry Systems*, 88, 579-591. doi: 10.1007/s10457-014-9700-y.

[4] Decocq, G., *et al.* (2016). Ecosystem services from small forest patches in agricultural landscapes. *Current Forestry Reports*, 2, 30-44. doi: 10.1007/s40725-016-0028-x.

[5] Dubyna, D.V., Ustymenko, P.M., Dziuba, T.P., Iemelianova, S.V., & Datsyuk, V.V. (2023). Protective forest belts of Ukraine: Review and analysis assessment and action plan. *Bulletin of Sumy National Agrarian University. The Series: Agronomy and Biology*, 51(1), 44-52. doi: 10.32782/agrobio.2023.1.6.

[6] Furdychko, O.I., & Stadnyk, A.P. (2012). *Basics of management of agricultural landscapes of Ukraine*. Kyiv: Agrarian Science.

[7] Hetman, P.A. (2023). Ecological and coenotic characteristics of the Dokuchaev windbreaks and shelterbelts of Kirovohrad Region. *Ukrainian Botanical Journal*, 80(1), 84-93. doi: 10.15407/ukrbotj80.01.084.

[8] Khodash, A.M. (2010) *Above-ground phytomass of common oak in the field protection forest strips of the Eastern Polissia and the Central Forest Steppe* (PhD thesis, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine).

[9] Lobchenko, G.O. (2015). *Phytoindication of windbreks of the Right Bank Forest Steppe* (PhD thesis, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine).

[10] Maksimtsev, S., Dudarets, S., & Yukhnovskyi, V. (2021). Accumulation of heavy metals in soil and litter of roadside plantations in Western Polissia of Ukraine. *Folia Forestalia Polonica*, 63(3), 232-242. doi: 10.2478/ffp-2021-0024.

[11] Malyuga, V.M. (2020). *Phytomeliorative foundations of the functioning of windbreaks on the log-beam lands of the plain part of Ukraine* (Doctoral thesis, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine).

[12] Maurer, V.M., & Pinchuk A.P. (2019). Risks and causes of weakening of forest cultivation at the stage of creation and ways of its to prevent it. In *Regeneration of forests and forest reclamation in Ukraine: Origins, current state, current challenges and prospects in the conditions of the Anthropocene* (pp. 52-53). Kyiv: Editorial and Publishing Department of NUBiP of Ukraine.

[13] Order of the Cabinet of Ministers of Ukraine No. 725-p "On Approval of the Concept for the Development of Agroforestry in Ukraine". (2013, September). Retrieved from https://zakon.rada.gov.ua/laws/show/725-2013-%D1%80#Text.

[14] Ostapchuk, O.S., & Sovakov, O.V. (2016). The influence of the density of oak (*Quercus robur* L.) cultures on their productivity. *Scientific Bulletin of NULES of Ukraine*, 238, 147-154.

[15] Polishchuk, O.P. (2009). *Forestry and reclamation effectiveness of windbreaks of various structures formed by maintenance fellings in the conditions of the Kyiv highland region* (PhD thesis, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine).

[16] Pylypenko, O.I. (2004). *Instructive requirements for forest improvement management of windbreaks*. Kyiv: Ukrderzhlisproekt.

[17] Řeháček, D., Khel, T., Kučera, J., Vopravil, J., & Petera, M. (2016). The character of windbreaks and their influence on mitigation of soil erosion. *Glasnik Sumarskog Fakulteta*, 114, 219-226. doi: 10.2298/GSF1614219R.

[18] Solomakha, I.V., Sabluk, V.T., Gumentyk, M.Ya., & Solomaha, V.A. (2022). Peculiarities of creating fast-growing and multifunctional plantations in the Forest-Steppe zone of Ukraine. *Agroecological Journal*, 4, 6-15. doi: 10.33730/2077-4893.4.2022.273244.

[19] Sovakov, O.V. (2010). *Forest protection efficiency of the system of windbreaks in the conditions of the Right Bank Forest Steppe* (PhD thesis, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine).

[20] Stadnyk, A.P. (2003). Increasing the remedial properties of windbreaks affected by ice and snowfall. In *Optimization of agricultural landscapes: Rational use, reclamation, protection*: *Materials of international science and practice conference* (pp. 86-87). Dnipropetrovsk, Ukraine.

[21] Sytnyk, O.S. (2005). *Forestry features and the field protection role of windbreaks of various structures in the conditions of the Right-Bank Forest-Steppe* (PhD thesis, National Agrarian University of Ukraine, Kyiv, Ukraine).

[22] Tkachuk, O., & Viter, N. (2023). Prospects for the functioning of windbreaks in the Vinnytsia region under conditions of global climate change. *Taurian Scientific Bulletin*, 129, 146-153. doi: 10.32851/2226-0099.2023.129.19.

[23] Tkachuk, O.P., & Viter, N.G. (2022). Ecological problems of the functioning of field protection forest strips in the conditions of climate change. *Scientific Reports of NUBiP of Ukraine*, 96(2), 1-14. doi: 10.31548/dopovidi2022.02.001.

[24] Wehling, S., & Diekmann, M. (2009). Importance of hedgerows as habitat corridors for forest plants in agricultural landscapes. *Biological Conservation*, 142(11), 2522-2530. doi: 10.1016/j.biocon.2009.05.023.

[25] Yang, X., Yu, Y., & Fan, W. (2017). A method to estimate the structural parameters of windbreaks using remote sensing. *Agroforestry Systems*, 91, 37-49. doi: 10.1007/s10457-016-9904-4.

[26] Yukhnovsky, V.Yu. (2013). *Guidelines for forest reclamation management of windbreaks of the linear type and located in the right-of-way of canals, railways, and highways*. Kyiv, Ukrderzhlisproekt.
[27] Yukhnovsky, V.Yu., Malyuga, V.M., & Dudarets, S.M. (2016). Current state and legal status of field protection forest strips in the context of land reform. *Scientific Bulletin of the National University of Bioresources and Nature Management of Ukraine. "Forestry and Ornamental Horticulture"*, 255, 186-193.
[28] Ziegler, J., Easter, M., Swan, A., Brandle, J., Ballesteros, W., Domke, G., Chambers, A., Eve, M., & Paustian, K. (2016). A model for estimating windbreak carbon within COMET-Farm™. *Agroforestry Systems*, 90, 875-887. doi: 10.1007/s10457-016-9977-0.
[29] Zvorska, N. V., Shlapak, V. P. (2022). Influence of field windbreaks within ekoton effect on sunflower yield on the Right Bank Forest Steppe of Ukraine. *Scientific Bulletin of UNFU*, 32(2), 13-18. doi: 10.36930/40320202.

Сучасний стан полезахисних лісових смуг Лівобережного Лісостепу України

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Анотація. Актуальність дослідження пов'язана із необхідністю визначення сучасного стану полезахисних лісових смуг, як складової лісоаграрного ландшафту конкретного регіону. Мета роботи полягала у проведенні комплексної оцінки полезахисних лісових насаджень. Під час досліджень використані дані дистанційного зондування землі за космічними знімками, що надало можливість визначити параметри полів, розміщення системи полезахисних лісових смуг і їхні параметри. Лісотаксаційні роботи виконувалися за загальноприйнятими у лісовій таксації методиками з уточненнями для смугових насаджень. Клас якості полезахисних смуг

визначали за відсотком здорових дерев від загальної їх кількості, а індекс санітарного стану розраховували відповідно встановлених категорій. На підставі аналізу отриманих даних чітко прослідковується спадна послідовність дуба звичайного від 9 до 3 одиниць у складі насаджень. Полезахисні смуги створювалися за типом дубових гніздових із розміщенням гнізд дуба 5,0×3,0 м і загальною шириною смуги 15,0 м. У широкі 5-метрові міжряддя додатково вводилися два ряди супутніх, а в ряди гнізд – супутні та чагарникові види рослин. Аналіз характеристики смугових насаджень показав, що вони мають захисні висоти від 19,6 м до 23,4 м та створюють надійний захист прилеглих польових угідь. Виходячи із дальності ефективного захисного впливу лісосмуг можна відмітити, що розрахункові показники забезпечують захист з надійним запасом міцності до 17 %. За необхідності створення нових лісових смуг гніздовим способом на перспективу пропонується використання ефективнішої схеми, особливості якої полягають у розміщенні супутніх деревних видів у крайніх рядах з метою запобігання розростанню крон узлісних рядів у сторону поля. Завдяки отриманим результатам виникла можливість провести комплексну експертну оцінку стану полезахисних лісових смуг за такими критеріями: лісівничо-таксаційні параметри, меліоративні властивості та індекс санітарного стану

Ключові слова: склад насаджень; схеми змішування; конструкція; захисний вплив; індекс стану; клас якості

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Assessment of the durability of the adhesive bond in a carpentry product to atmospheric fluctuations

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Abstract. Wood and wooden glued products are widely used as building structures in various construction industries that operate within a wide range of atmospheric factors and require

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stability and durability. Therefore, the goal was to conduct experimental studies to determine the stability of the adhesive bond of a window element made of wood under the influence of temperature and moisture static fluctuations. In this regard, a comprehensive approach was applied to experimentally establish the effectiveness of the glued wood layer by investigating the resistance of the adhesive layer to destruction when changing temperature and humidity fields within a wide range. According to the experimental values of the adhesive layer boundary after exposure to temperature and humidity fields such as glued wood, it was established that the best result of the tensile strength (0.29 N/mm^2) was obtained for polyurethane adhesive. For rubber glue and PVA, the tensile strength was 0.17 N/mm^2, which provides adhesion quite well due to its properties. This is due to the fact that the adhesive composition must have sufficient elasticity to allow the wood to expand and dry out under the influence of temperature. In turn, the glued layer based on bustilate and liquid glass, has the tensile strength set at a preasure of 0.07 N/mm^2 and 0.12 N/mm^2 accordingly. A decrease in the adhesive capacity for bustilate is due to the fact that at a low-temperature level, it loses its properties. The liquid glass-based adhesive has an alkaline environment and interacts with the components of wood resin acids, reducing adhesion. The results obtained allow selecting effective adhesives for the production of composite materials from wood, depending on the operating conditions, and provide for the properties of glued wood

Keywords: glued wood; technological parameters; temperature and humidity fields; stability; strength of the adhesive layer

Introduction

Wood, as a building material, is widely used in construction and architecture due to its mechanical and operational properties. For more efficient use of wood, composite products are widely used (Frederick *et al.*, 2007), which are a combination of wood itself and various adhesives.

When these products are operated under the influence of atmospheric fluctuations, the stability of geometric dimensions and resistance to the external environment change (Frihart, 2011). Therefore, the operational reliability and efficiency of using effective wood adhesives depend on the wood itself (Treu *et al.*, 2019), the quality and reactivity of the adhesive (Gavrilović-Grmuša *et al.*, 2016), and the class of operating conditions of the facility where these materials are used. The reliability of wooden structures is also necessary for objects of mass stay of people that are operated in different temperature conditions (Kol *et al.*, 2009; Perçin & Uzun, 2014).

V. Sebera *et al.* (2020) investigated the properties of the adhesive bond during the three-point bending test with incisions at the end and the pliability-based beam method. The three-point test with incisions at the ends was established to be suitable for emulsion polymer-isocyanate, urea-formaldehyde, phenol-resorcinol-formaldehyde adhesives, while it is less suitable for bonding with polyurethane adhesives due to its noticeable plastic behaviour. However, the resistance of adhesives to atmospheric fluctuations is not indicated and the adhesive properties of the adhesive layer are not given.

Determining the effectiveness of an adhesive bond for chemically modified wood is important not only for commercial applications but also for understanding the durability of wood element joints. C.R. Frihart *et al.*

(2021) investigated two modifications of yellow poplar (*Liriodendron tulipifera L.*): acetylation (Ac), which bulk converts the hydroxyl group of wood to an ester, and butylene oxidation (BO), which preserves the hydroxyl group. The effect of these chemical modifications of wood on the efficiency of the compound using four adhesives was investigated: resorcinol-formaldehyde (RF), melamine-formaldehyde (MF), emulsion polymer isocyanate (EPI), and epoxy. The shear strength of ASTMD 905 for both dry and wet samples showed that the results of BO were fairly similar to unmodified wood, but melamine-formaldehyde and emulsion-polymer-isocyanate adhesives showed poor results for Ac-modified wood, in contrast to the results for resorcinol-formaldehyde and epoxy resins. This is not said about the mechanism of formation of adhesive bonds of the obtained wood-polymer materials.

A. Can *et al.* (2021) investigated the effect of heat treatment in open (atmospheric pressure) and closed (under pressure) systems on the shear strength and adhesion of Scots pine wood (*Pinus sylvestris*). Thermal modification substantially reduced the strength by 31% to 39% in an open system. In the closed system, a decrease from 2% to 38% was recorded. The lower shear strength of modified wood can be explained by reduced chemical bonding or mechanical adhesion of adhesives and reduced strength of the modified wood base itself. Therefore, it becomes necessary to examine the conditions of barrier formation to ensure adhesion and establish the effective action of the adhesive of a certain concentration.

Previous studies show that the mechanical properties of low-industrial wood species, such as Poplar, can be improved by mechanical compaction. In addition, in studies I. Yalçın & R. Esen (2023) established that the bonding process further improves the mechanical properties of wood material. But there are still unresolved issues related to the effect of fibre on the rigidity of the product. The reason for this may be the principles of operation of the reinforcing material, which accordingly makes such studies difficult.

X. Tao *et al.* (2023) identified an environmentally friendly emulsion polymer-isocyanate (EPI) adhesive that was used to prepare electrothermal plywood with embedded carbon fibre paper. The authors established that wet treatment has a substantial effect on the joint strength and electrothermal performance of electrothermal plywood bonded with an emulsion polymer-isocyanate adhesive. However, the corresponding physical and chemical data on changes in the strength of the compound during changes in temperature and humidity fields are not given.

A. Bilik & R. Trianoski (2022) evaluated the potential of the breed *Pinus glabra* for the production of laminated panels, and the influence of veneer density and their combination on product quality. Plywood was examined by testing the apparent specific gravity, static bending, and shear strength of the adhesive in accordance with European standards. It is established that the combination of veneer of different densities provides an increase in the strength and rigidity of the material. However, the effect of changing the adhesive layer on reducing the strength and durability of the resulting material has not been examined, and it is not said about the environmental friendliness of the adhesive.

Thus, from the analysis, it can be seen that the use of wood adhesives is their reliability with the formation of resistant adhesives and should be characterised by non-toxicity, cost-effectiveness, ease of application and weather resistance. All this gives grounds for conducting a study dedicated to determining the parameters that ensure the use of wood adhesives.

The purpose of the study was to exper-

imentally substantiate the stability of the adhesive bond of a window element made of wood under the influence of temperature and humidity fluctuations.

The task was set to conduct a complex of experimental studies of the adhesive bond of a window corner made of wood under the influence of temperature and humidity fluctuations to achieve this goal.

Materials and Methods

A study to determine the resistance of the glued layer to temperature and humidity fluctuations was conducted in 2023 at the National University of Life and Environmental Sciences of Ukraine.

For the research, lumber made of pine wood with a thickness of 40 mm was used, which was dissolved into blanks with a width of 65 mm, planed, and milled, grooves were selected and window elements with a connection area of 0.022 m^2 were obtained (Fig. 1, 2).

The prefabricated parts with a tongue and a groove are joined by a corner end-to-end connection using a single tongue (Fig. 3).

Accordingly, 15 pairs of corner joints were manufactured for research. Table 1 shows the amount of adhesive applied to the samples.

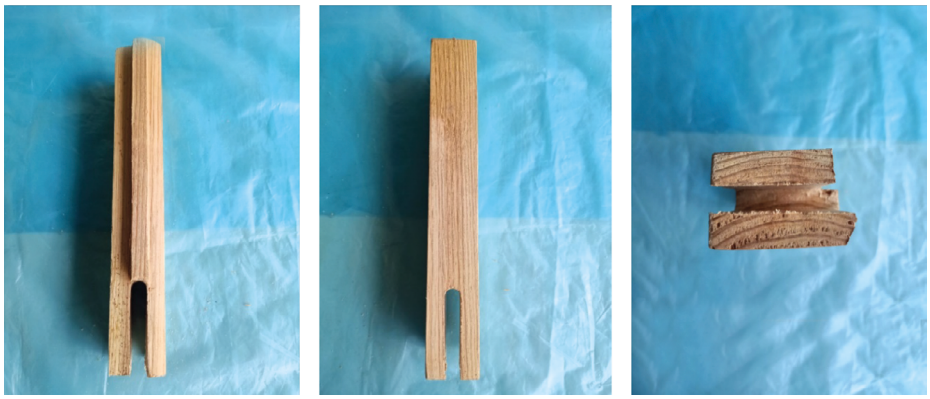

Figure 1. Detail of a wooden window with a groove

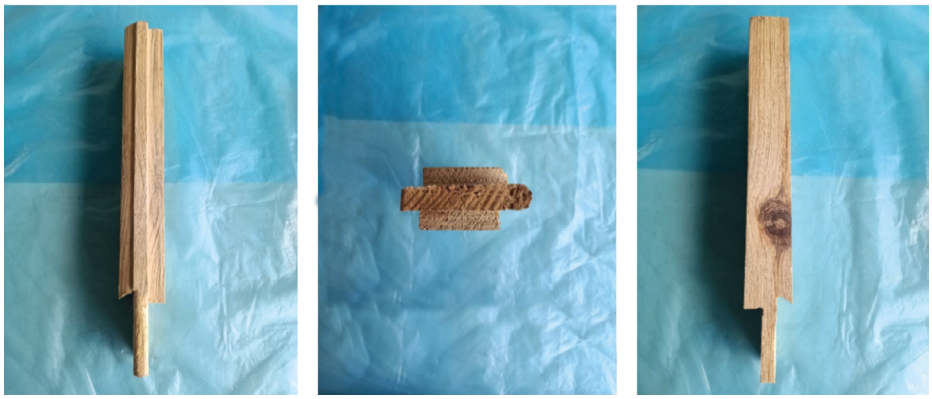

Figure 2. Detail of a wooden window with a tongue

Figure 3. Connecting parts through a tongue

Table 1. Results of determining the amount of glued agent per sample

No.	Name of the adhesive product	Weight before bonding, g	Weight after bonding, g	Glue consumption per sample, g	Amount of product applied, kg/m^2
1	PVA "Lux" D4 (Ukraine)	421.15	444.15	23.00	1.04
2	Polyurethane adhesive Soudal 66A D4 (European Union)	473.54	490.79	17.25	0.78
3	Tytan Classic FIX rubber adhesive (European Union)	456.87	477.57	20.70	0.94
4	Construction glue "BUSTILAT-D" (Ukraine)	428.60	497.60	69.00	3.13
5	Liquid glass (Ukraine)	433.19	467.69	34.50	1.57

Source: compiled by the authors

A freezer was used to keep wood at subzero temperatures (Fig. 4.), the inner surface of which is heat-insulated with polystyrene, with a refrigeration unit and a temperature control unit.

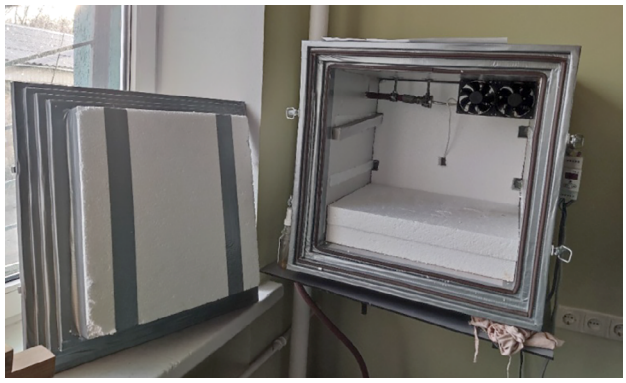

Figure 4. Freezer compartment

The essence of the method of testing resistance to atmospheric fluctuations was to simulate the processes of destruction of the adhesive layer by artificial means and determine changes in the estimated indicators before and after the action of changes in temperature and humidity fields (Tsapko *et al.*, 2021a).

The technique involved several stages of laboratory tests of the adhesive layer according to estimated indicators: appearance, the presence of cracking, weathering, peeling, dissolution, blistering, moisture absorption, and salt formation.

The test cycle for changing temperature and humidity fields on the wood adhesive layer included the following stages:

- first stage: the samples are moistened with a spray gun and kept at a temperature of (20 ± 2)°C and relative humidity (97 ± 3)% for 10 minutes;
- second stage: samples are transferred to the cold chamber and kept at a temperature of minus (15 ± 3)°C within 6 hours;
- third stage: samples are transferred from the refrigerator to the room and conditioned at a temperature of (20 ± 2)°C and relative humidity (97 ± 3)% for 6 hours;
- fourth stage: samples are kept in the air at a temperature of (20 ± 2)°C and relative humidity (97 ± 3)% for 9 hours.

After exposure to temperature and humidity fluctuations, the samples were left for 4 days, after which they were re-weighed, humidity measured, and the results were recorded.

The strength of the adhesive bond was determined using an experimental destructive machine R-5 (manufactured by LLC Scientific-production company "Standard-M", Ukraine) (Fig. 5, 6).

The fracture sample was placed in a special structure designed to break the corner joints in the same way as shown in Figure 6.

Figure 5. Experimental destructive machine P-5

Figure 6. Structure for destructive testing of corner joints

This machine belongs to the type of tearing machines with a constant deformation speed. It is equipped with a recording device for the testing process on a diagram apparatus in the "preasure-deformation" coordinates. The absolute elongation of the specimen is determined by a deformation counter. The machine is equipped with an electric drive with smooth speed regulation.

The process of determining the maximum destructive forse was conducted by destroying samples (Fig. 7).

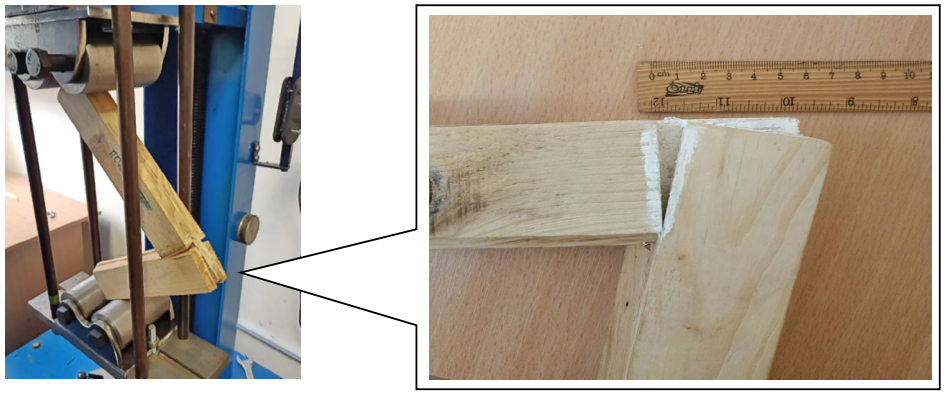

Figure 7. Destruction of the window corner sample

Using the three-factor simplex-centroid method of experimental design in the statistical software Statistica 12, the statistical analysis of the results for determining the strength of the wood adhesive layer was performed.

The mathematical modelling of the strength of the wood adhesive layer was conducted by determining the optimal conditions for the bonding process of the specimen, controlling the fracture process based on the mathematical model, and transferring the results to the research object in the form of a regression equation.

Results and Discussion

In the first stage, the samples were exposed to a temperature-humidity environment. Table 2 presents the results of determining the weight of the specimens after exposure to temperature and humidity fluctuations, and their moisture content.

Table 2. Results of determining the stability of the adhesive bond under the influence of temperature-humidity fluctuations, depending on the number of cycles

Glue type	Number of test cycles	Average sample weight, g		Change in sample mass, G	Humidity, %
		before the test	after the test		
Bustilat	6	497.60	535.30	37.70	22
	12	535.30	528.10	-7.20	21
	24	528.10	531.50	3.40	23
	34	531.50	536.80	5.30	20
Liquid glass	6	467.69	499.30	31.56	19
	12	499.25	503.60	4.35	23
	24	503.60	502.10	-1.50	22
	34	502.10	506.40	4.30	20
PVA	6	444.15	480.20	36.05	20
	12	480.20	478.60	-1.60	22
	24	478.60	482.90	4.30	21
	34	482.90	481.50	-1.40	23

Table 2, Continued

Glue type	Number of test cycles	Average sample weight, g		Change in sample mass, G	Humidity, %
		before the test	after the test		
Rubber	6	477.57	511.10	33.53	22
	12	511.10	508.80	-2.30	24
	24	508.80	514.70	5.90	22
	34	514.70	512.20	-2.50	20
Polyurethane	6	490.79	524.50	33.71	20
	12	524.50	527.10	2.60	20
	24	527.10	525.60	-1.50	21
	34	525.60	528.30	2.70	22

Source: compiled by the authors

From the appearance and results of determining the resistance of the adhesive bond to the effects of temperature and humidity fluctuations, no evident signs of the destruction of the glued wood layer were established. In this regard, experimental studies were conducted to determine the strength of the glued layer.

The results of studies on maximum destructive preasure are shown in Table 3.

Table 3. Research results maximum destructive preasure

Glue type	Tensile strength, N/mm^2	Maximum force, N	Elongation by L_0, %	Elongation by L_1, %
Polyurethane	0.29	2125.42	6.83	968.30
Rubber	0.17	1236.64	8.71	987.10
PVA	0.17	1248.87	10.21	1002.00
Liquid glass	0.12	885.94	5.60	956.00
Bustilat	0.07	515.68	14.23	1042.00

Source: compiled by the authors

Experimental studies conducted to determine the maximum force for the destruction of the adhesive layer of the corner of a wooden window showed that the use of an adhesive based on bustilate and liquid glass showed a tensile strength at a preasure of 0.07 N/mm^2 and 0.12 N/mm^2 accordingly. The decrease in the adhesive capacity for bustilate is due to the fact that it is a water-dispersion adhesive that is not frost-resistant and loses its properties at low temperatures. The glue based on Liquid Glass has an alkaline environment (pH more than 10), wood contains individual components of resin acids that interact with the adhesive layer, reducing adhesion.

The application of rubber adhesive and PVA showed a strength limit of 0.17 N/mm^2, which ensures good adhesion due to their properties since the adhesive composition should have sufficient elasticity to allow the wood to expand and contract under the influence of temperature. An even better result was obtained for polyurethane glue, which showed the highest tensile strength (0.29 N/mm^2), which allows asserting that the identified mechanism of formation corresponds to the properties of the

adhesive layer and its practical attractiveness. Considering the results of Table 2, statistical processing of the results was performed. The following factors were chosen as variation factors: elongation of the angular joint sample by L_0, % (factor X_1); maximum force, N (Table 4).

Table 4. Factors of variation

Factors	Code	Variation levels			Variation interval
		-1	0	+1	
Elongation of the angular joint sample by L_0, %	X_1	5	10	15	5
Maximum force, N	X_2	500	1700	2200	1700

Source: compiled by the authors

The tensile strength (N/mm^2) was chosen as the initial parameter (response function), the value of which was recorded during the testing of samples. The experiment planning matrix and its mathematical interpretation are shown in Table 5.

Table 5. Experiment matrix and its implementation

No.	Factors, type		Planning matrix		Response function	
	X_1	X_2	elongation of the angular joint sample by L_0, %	Maximum force, N	Y factor	Y calc.
1	1	1	7	2200	0.29	0.28
2	1	-1	15	500	0.70	0.59
3	-1	1	6	2200	0.27	0.34
4	-1	-1	13	500	0.08	0.06
5	1	0	15	1200	0.26	0.38
6	-1	0	8	1200	0.19	0.14
7	0	1	9	2200	0.24	0.18
8	0	-1	17	500	0.06	0.19
9	0	0	10	1200	0.21	0.13
10	0	0	10	1200	0.16	0.13
11	0	0	10	1200	0.22	0.13

Source: compiled by the authors

The F-criterion is calculated, which for this system is $F_{R.} = 15.78$ and a tabular F-criterion is defined, the value of which is $F_{T.} = 19.3$, which is greater than the calculated one, and therefore the equation is adequate.

As a result of modeling, regression equations are obtained and ternary surfaces of changes in the initial parameter are constructed depending on changes in variation factors (Fig. 8).

Regression equation:

$$Y_{p.} = 0{,}127 + 0{,}118 \cdot X_1 - 0{,}007 \cdot X_2 + \\ + 0{,}133 \cdot X_1 \cdot X_1 + 0{,}058 \cdot X_2 \cdot X_2 - 0{,}150 \cdot X_1 \cdot X_2. \quad (1)$$

Thus, based on the computer modelling performed, the lowest elongation value of the angular joint sample by L_0 is determined, which is 5.2%. This ensures that the task is completed and the maximum breaking force is about 30.0 H.

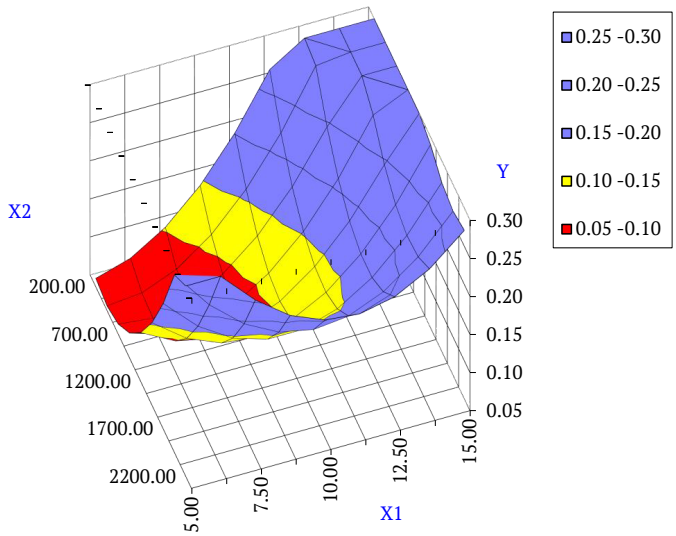

Figure 8. Ternary surfaces of changes in the output parameter depending on changes in the factors of variation in the elongation of the angular joint sample by L_0 and maximum breaking force

Source: compiled by the authors

Wood and wood products are widely used in building structures. The problem lies in ensuring their stability and durability since they have a number of disadvantages that limit their use. In this sense, there is an interpretation of the results for determining the quality of the film, namely, inherent adhesion as the ability to glue wood. The absence of delamination of the adhesive contact on the wood surface during the action of the maximum destructive preasure indicates a positive result (Ülker, 2016).

When considering adhesive layers or surfaces, cohesive rigidity and the possibility of delamination during operation are usually neglected, which leads to a reassessment of the preasure-bearing capacity of the structure. Therefore, B. Kawecki (2023) developed guidelines for complex nonlinear modelling of adhesive bonds in wood composite materials.

When investigating the adhesive layer on pine wood after temperature and humidity fluctuations, as follows from the results obtained (Fig. 8, Table 3), the process of forming a solid smooth coating with high adhesive contact is natural. In this sense, there is an interpretation of the results of determining the quality of the film, namely, the inherent adhesion to the ability to glue wood. This indicates that there is no stratification of the adhesive contact on the wood surface, which can be identified under the maximum destructive preasure. This means that considering the fact of wood sticking opens up the possibility for effective regulation of the properties of wood products in industrial production conditions.

Modification does not always improve the characteristics of the adhesive. Thus, D.R. Trisatya *et al.* (2023) evaluated the use of tannin resorcinol formaldehyde (TRF) for the manufacture of Cross-laminated timber (CLTs). According to the results, the rupture modulus met the standard, but the moisture content and elastic modulus did not. In addition, the compositions showed low formaldehyde emissions in the extreme ranges of 0.001-0.003 mg/L.

F. Stoeckel *et al.* (2013) also claimed a substantial difference between solid wood adhesives and composite materials. Moreover, the latter show stronger connections. It is necessary to consider factors affecting the adhesive properties – temperature, humidity or aging of joints.

A study conducted by I. Gavrilović-Grmuša *et al.* (2016) focused on investigating the effect of specific pressure during the pressing process on the penetration of urea-formaldehyde (UF) adhesive into Poplar materials, and on the shear strength of compounds formed at different pressures. An epifluorescence microscope was used to measure adhesive penetration, and penetration was examined by analysing microtome sections (20 microns thick) cut from compound samples. The total penetration depth (dap) and the size of the interfacial region (I) increased with increasing pressure from 0.5 to 1.0 N/mm^2. A further increase in pressure to 1.5 N/mm^2 did not lead to substantial changes in dap or I. On the other hand, the area of filled lumens and rays (A) showed a constant decrease with increasing specific pressure. This behaviour also affected the filled interfacial region (If), which decreased with increasing pressure. Samples, where penetration occurred in the tangential direction, had higher shear strength values and showed a lower dependence on specific pressure compared to radial penetration. The higher shear strength based on radial penetration corresponded to the larger interfacial region of these samples. The highest shear strength in both directions of penetration was obtained at a specific pressure of 1.0 N/mm^2.

Analysis of the nature of adhesives and the results of research data to determine the tensile strength, maximum force and effects of temperature and humidity fluctuations indicates changes in the quality of the adhesive layer, since the stability of polyurethane glue is more stable compared to bustilate and liquid glass. N. Hariz *et al.* (2023) also claimed the effectiveness of using polyurethane (PU 1.2) adhesives in the manufacture and operation of cross-laminated wood (CLT) from the wood of Mangium (*Acacia mangium*) and Schima (*Schima wallichii*). Despite the different physical and chemical properties of Mangia and Schima wood, they have the same wettability with PU 1.2. Thus, the Schima-Mangium-Schima CLT hybrid has the potential to improve dimensional stability and mechanical properties. Along with high mechanical performance for glued structures, considerable attention is paid to the safety of operation of such products. Y. Jang & K. Li (2015) investigated a new adhesive made from natural materials – low-fat soy flour (SF) and magnesium oxide (MgO). The resulting structural material met the industrial water resistance requirements for Interior plywood. The high strength of the composition was noted, assumably due to the low solubility of SF-MgO in water.

This does not differ from the practical data well known from the study by Yu. Tsapko *et al.* (2021b), which also links a decrease in the quality of the glued wood layer with a change in the structural composition. The obtained data on the influence of the adhesive layer on the properties of wood products, in particular, on adhesion and environmental friendliness, allow stating the following:

- the main regulator of the process of resistance to destruction is not only the formation of an adhesive coating layer but also the chemical transformations of components that provide resistance to destruction;
- a substantial impact on the environmental friendliness of wood products is conducted in the area of the use of safe substances.

Such conclusions can be considered appropriate from a practical standpoint since they allow a reasonable approach to both the formation of the adhesive layer and the determination of the required amount of it. From a

theoretical standpoint, they allow asserting the determination of the mechanism of adhesive action processes, which are certain advantages of this study. However, the results of determining the adhesion of the wood adhesive layer (Table 1) indicate an ambiguous influence of the structure of the wood product. This is primarily manifested in the nature of the destruction of the adhesive layer when the strength limit is determined in tests. Such uncertainty imposes certain restrictions on the use of the results obtained, which cannot be interpreted as shortcomings of this study. The inability to remove these restrictions in the framework of this study creates a potentially interesting area for further research. In particular, tests can be focused on identifying the time point at which an intense decrease in the adhesion of the adhesive layer on wood begins. This detection will allow examining the structural transformations of wood that begin to occur at this time, and identify the input variables of the process that substantially affect the beginning of such a transformation.

Conclusions

When using wooden building materials, the stability of the adhesive layer to the action of atmospheric factors is important, as over time, the building structure can deteriorate which necessitates the use of reliable adhesive materials and prompts the search for them. Therefore, the mechanism of wood bonding with various adhesive mixtures, the influence of moisture and temperature changes on the adhesive layer, has been thoroughly substantiated. However, there is also a need to assess this process. The research results showed that the application of adhesive based on butylate and liquid glass, after exposure to temperature and moisture fields, resulted in a strength limit of 0.07 N/mm^2 and 0.12 N/mm^2 accordingly. The decrease in adhesive capacity for butylate is due to its non-frost-resistant water-based adhesive nature, which loses its properties at low temperatures. The adhesive based on liquid glass has an alkaline environment (pH greater than 10), and wood contains individual components of resinous acids that interact with the adhesive layer, reducing adhesion.

The application of rubber adhesive and PVA showed a strength limit of 0.17 N/mm^2, which ensures good adhesion due to their properties since the adhesive composition should have sufficient elasticity to allow the wood to expand and contract under the influence of temperature. The best result was obtained for polyurethane adhesive, which showed the highest strength limit (0.29 N/mm^2), confirming the correspondence of the identified mechanism of adhesive layer formation.

The scientific originality consists in determining the quality of the adhesive layer on the surface of wood formed by polymerisation of adhesives by assessing adhesion and stability to justify its use for wood.

Thus, the analysis of various types of adhesives and experimental studies to determine the strength limit, maximum destructive preasure, and the influence of temperature and moisture fluctuations on the adhesive layer indicate changes in the quality of the wood adhesive bond. This fact allows examining the surface transformation of the adhesive contact of wood affected by temperature and moisture fluctuations and identifying parameters that considerably affect the initiation of the transformation process of the adhesive layer's destruction. This opens up a new area for investigating the interrelation between adhesive components, properties, and their impact on wood adhesion processes.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgements

None.

References

[1] Bilik, A.C.B., & Trianoski, R. (2022). Evaluation of the physico-mechanical properties of plywood panels and laminated veneer lumber of *Pinus glabra Walt*. *Floresta*, 52, 323-331. doi: 10.5380/rf.v52 i2. 80147.

[2] Can, A., Krystofiak, T. & Lis, B. (2021). Shear and adhesion strength of open and closed system heat-treated wood samples. *Maderas. Ciencia y Tecnología*, 23, article number 32. doi: 10.4067/S0718-221X2021000100432.

[3] Frederick, A., Kamke, J., & Lee, N. (2007). Adhesive penetration in wood – a review. *Wood and Fiber Science*, 39(2), 205-220.

[4] Frihart, C.R. (2011). Wood adhesives: Vital for producing most wood products. *Forest Products Journal*, 61(1), 4-12. doi: 10.13073/0015-7473-61.1.4.

[5] Frihart, C.R., Brandon, R., Ibach, R.E., Hunt, C.G., & Gindl-Altmutter, W. (2021). Comparative adhesive bonding of wood chemically modified with either acetic anhydride or butylene oxide. *Forests*, 12(5), article number 546. doi: 10.3390/f12050546.

[6] Gavrilović-Grmuša, I., Dunky, M., Djiporović-Momčilović, M., Popović, M., & Popović, J (2016). Influence of pressure on the radial and tangential penetration of adhesive resin into poplar wood and on the shear strength of adhesive joints. *Bioresources*, 11(1), 2238-2255. doi: 10.15376/biores.11.1.2238-2255.

[7] Hariz, T.M.R., Hadi, Y.S., Lubis, M.A.R., Sari, R.K., & Hidayat, W. (2023). Physical and mechanical properties of cross-laminated timber made of a combination of mangium-puspa wood and polyurethane adhesive. *Jurnal Sylva Lestari*, 11(1), 37-65. doi: 10.23960/jsl.v11i1.645.

[8] Jang, Y., & Li, K. (2015). An all-natural adhesive for bonding wood. *Journal of the American Oil Chemists' Society*, 92, 431-438. doi: 10.1007/s11746-015-2610-y.

[9] Kawecki, B. (2023). Numerical modelling and experimental testing on polyurethane adhesively bonded joints behaviour in wood-wood and wood-carbon fibre reinforced polymer layouts. *Advances in Science and Technology Research Journal*, 17(2), 36-52. doi: 10.12913/22998624/159723.

[10] Kol, H.S., Özbay, G., & Altun, S. (2009). Shear strength of heat-treated tali (*Erythrophleum ivorense*) and iroko (*Chlorophora excelsa*) woods, bonded with various adhesives. *Bioresources*, 4(4), 1545-1554. doi: 10.15376/biores.4.4.1545-1554.

[11] Perçin, O., & Uzun, O. (2014). Determination of bonding strength in heat treated some wood materials. *Faculty of Forestry Journal*, 15, 72-76. doi: 10.18182/tjf.91069.

[12] Sebera, V., Pečnik, J.G., Azinović, B., Milch, J., & Huč, S. (2020). Wood-adhesive bond loaded in mode II: experimental and numerical analysis using elasto-plastic and fracture mechanics models. *Holzforschung*, 75(7), 655-667. doi: 10.1515/hf-2020-0141.

[13] Stoeckel, F., Konnerth, J., & Gindl-Altmutter, W. (2013). Mechanical properties of adhesives for bonding wood – A review. *International Journal of Adhesion and Adhesives*, 45, 32-41. doi: 10.1016/j.ijadhadh.2013.03.013.

[14] Tao, X., Tian, D., Liang, S., Li, S., & Fu, F. (2023). Effects of wet treatment on bonding strength and electrothermal performance of electrothermal plywood bonded with emulsion polymer-isocyanate adhesive. *Polymer Composites*, 44(2), 1331-1342. doi: 10.1002/pc.27173.

[15] Treu, A., Bredesen, R., & Bongers, F. (2019). Enhanced bonding of acetylated wood with an MUF-based adhesive and a resorcinol-formaldehyde-based primer. *Holzforschung*, 74(4). doi: 10.1515/hf-2019-0056.

[16] Trisatya, D.R., Santoso, A., Abdurrachman, A., & Prastiwi, D.A. (2023). Performance of six-layered cross laminated timber of fast-growing species glued with tannin resorcinol formaldehyde. *Journal of the Korean Wood Science and Technology*, 51(2), 81-97. doi: 10.5658/WOOD.2023.51.2.81.

[17] Tsapko, Y., Horbachova, O., Bondarenko, O., & Mazurchuk, S. (2021a). Justification of conditions of application of thermo modified veneer for protection of wooden products from moisture. *IOP Conference Series: Materials Science and Engineering*, 1164, article number 012050. doi: 10.1088/1757-899X/1164/1/012050/.

[18] Tsapko, Yu., Vasylyshyn, R., Melnyk, O., Lomaha, V., Tsapko, A., & Bondarenko, O. (2021b). Regularities in the washing out of water-soluble phosphorus-ammonium salts from the fire-protective coatings of timber through a polyurethane shell. *Eastern-European Journal of Enterprise Technologies*, 2(10(110)), 51-58. doi: 10.15587/1729-4061.2021.229458.

[19] Ülker, O. (2016). Wood adhesives and bonding theory. In *Adhesives – applications and properties* (pp. 271-288). London: InTechOpen. doi: 10.5772/65759.

[20] Yalçın, İ., & Esen, R. (2023). Adhesive type's effects on adhesive strength of densified reinforced laminated wood obtained from black poplar (*Populus nigra* L.). *BioResources*, 18(1), 1155-1165. doi: 10.15376/biores.18.1.1155-1165.

Оцінка стійкості клейового з'єднання столярного виробу до атмосферних коливань

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Анотація. Деревина та деревинні клеєні вироби широко застосовуються як будівельні конструкції в різних галузях будівництва, що експлуатуються в широких межах впливу атмосферних чинників та потребують забезпечення стійкості та довговічності. Тому мета полягала у проведенні експериментальних досліджень для визначення стійкості клейового з'єднання віконного елемента з деревини під впливом температурних та волого статичних коливань. У зв'язку з цим застосовано комплексний підхід для експериментального встановлення ефективності клеєного шару деревини шляхом вивчення стійкості адгезійного шару до руйнування при зміні температурно вологісних полів в широких межах. За експериментальними значеннями межі клейового шару після дії температурно вологісних полів на зразок клеєної деревини встановлено, що найкращий результат межі міцності (0,29 Н/мм^2) отримано для поліуретанового клею. Для каучукового клею та ПВА межа міцності склала 0,17 Н/мм^2, що досить добре забезпечує адгезію завдяки своїм властивостям. Це пояснюється тим, що клейовий склад повинен володіти достатньою еластичністю, щоб дозволяти деревині розширюватися і всихати під впливом температури.

Натомість для клеєного шару на основі бустилату та рідкого скла встановлено межу міцності при навантажені 0,07 Н/мм^2 та 0,12 Н/мм$_2$ відповідно. Зниження адгезійної здатності для бустилату пов'язано з тим, що при низькому рівні температури він втрачає свої властивості. Клей на основі рідкого скла має лужне середовище та взаємодіє з компоненти смоляних кислот деревини, знижуючи адгезію. Отримані результати дозволяють підібрати ефективні клеї для виготовлення композиційних матеріалів з деревини залежно від умов експлуатації та передбачити властивості клеєної деревини

Ключові слова: клеєна деревина; технологічні параметри; температурно-вологісні поля; стійкість; міцність адгезійного шару

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The experience of preserving ancient trees in Vienna, Austria

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Abstract. Ancient trees hold considerable aesthetic and ecological value within urban environments. The examination of ancient trees and their overall health and condition is an integral part of a comprehensive assessment aimed at preserving these trees and conserving the natural environment within urban spaces. The purpose of the study was to examine the experience of preserving valuable trees growing in urban space. General scientific theoretical methods – analysis and synthesis – were used to work with lists of tree inventory. Heritage trees grow in all districts in Vienna. It was established that ancient trees were given the status of natural monuments since 1936, the dynamics of bequests were traced, and the decades of Vienna's most active nature conservation activities were determined. The most famous heritage trees in the city were described. The species diversity of monumental trees was analysed, and their taxonomic affiliation was summarised. The heritage trees in Vienna are represented by 49 genera, most of which belong to the phylum of *Magnoliophyta*. The most common species among protected trees are *Platanus orientalis* L., *Pinus*

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nigra J.F. Arnold, *Aesculus hippocastanum* L., *Quercus robur* L., *Taxus baccata* L., *Tilia platyphyllos* Scop. Most of heritage trees (60%) are solitary trees. It was evaluated that the general sanitary condition of protected trees is excellent; almost all trees have high vitality and play a leading role in shaping urban landscapes. Every heritage tree possesses a commendable and elevated aesthetic rating. Analysis of the existing inventory of ancient trees in Vienna, their sanitary condition and aesthetic condition will contribute to the environmental awareness of communities and the improvement of management measures for such trees. The obtained results can be used to share the experience of researchers from different countries regarding preserving ancient trees and forming European databases of heritage trees

Keywords: natural monument; status of natural monuments; woody species; city district; urban greening

Introduction

Many unique trees have survived in European cities. Identifying such natural monuments, collecting the necessary information about them, and protecting them is an extremely important issue for every city. Such trees are national property and must be protected by the government. According to I.I. Vakulyk & O.Yu. Balalaieva (2018), the majority of these trees are linked to prominent individuals, historical events, or they are ancient trees that have managed to endure and remain in excellent condition until the present time. In the investigation of aged trees, J. Dreslerová (2017) observed that it was during a scientific expedition to North America when Alexander von Humboldt, a professor at the University of Berlin, first designated ancient trees as natural monuments. Additionally, G. Piovesan *et al.* (2022) conducted studies affirming that ancient trees possess substantial educational, aesthetic, historical, and cultural worth. Nowadays, the ancient trees give the greatest expressiveness to cities.

Trees can live many centuries with sustained fecundity. C.H. Cannon *et al.* (2022) observed that only 1% of trees achieved ages that were 10-20 times greater than the median age. A quarter of all trees reached an age that was 3-4 times greater than the median age. S. Munné-Bosch (2018) pointed that there were three age classes: mature, old, and ancient. Ancient trees have developed several mechanisms to ensure their longevity, including plasticity, continuous growth, dormancy, modularity, and stress tolerance. These adaptations enable ancient trees to defy the process of ageing and sustain some level of growth capacity despite their extreme longevity. Ancient trees in cities play critical ecological roles (e.g. in carbon storage, oxygen provision, hydrological regimes, nutrient cycles, numerous ecosystem processes, and provision of wildlife habitat). Ancient trees are a real factory of oxygen. According to D.B. Lindenmayer (2017), the crown of one tree is able to provide oxygen to about 200 people a year. Merit of trees is also great as dust absorbers. The average concentration of dust where trees grow is 33% less than where these old trees do not exist. In areas where old trees are present, the level of street noise is reduced by 4-5 times compared to locations where these trees are absent. The protection and management of trees as natural monument features are essential to maintain these roles. It is important and necessary to save trees of varying ages to replace existing ancient trees as they will eventually die.

Austria has a unique beauty, a special landscape, and rare species of public interest. Heritage trees are officially designated by the nature protection authority based on their scientific or cultural value, uniqueness or rarity, the distinctive characteristics they contribute to the landscape, and the various functions they fulfil. Important is that at least one of these conditions is met. There are relevant laws regulating the protection of heritage trees in Austria. The main goal of Vienna Nature Conservation Law is the protection and care of nature in all its manifestations throughout the city, ensuring sustainable urban ecological functions by establishing the necessary measures to maintain, supplement, and renew (Landesrecht konsolidiert Wien..., 2022). According to the Law, trees, groups of trees or plant communities, and other forms of nature can be declared natural monuments. It is not allowed to interfere with protected objects, which may jeopardise or worsen their existence or appearance. Criteria for the recognition of a tree as a natural monument are age, dimensions, rarity, botanical curiosity, and connection with a legend or historical event. There is no information on the total number of natural monuments in Austria. According to official information, in 2023, there are more than 700 natural monuments in Vienna (Official website of the City Vienna..., n.d.). These include solitary trees, tree groups, alleys, groves, small reservoirs, remnants of alluvial forests, and significant rock formations with geological importance. The heritage trees in Vienna are characterised by direct aesthetic access.

The purpose is to examine the experience of preserving valuable trees growing in the urban space of Vienna. To accomplish this, it was essential to identify tree species capable of attaining significant age within the urban environment and determine the specific characteristics of their location.

Materials and Methods

The study was carried out in the territory of all 23 districts of Vienna in 2022. First, an analysis of the heritage tree inventory, which is freely available, (Official website of the City Vienna..., n.d.) and the selection of trees for the study were conducted. These were single trees, small alleys and groups of trees numbering up to 20. The total number was 723 trees. The sanitary and aesthetic condition of trees were examined and assessed. The sanitary condition of the trees involved the determination of the category according to the following gradation: I – no signs of weakening, II – weakened, III – very weakened, IV – dying, V – fresh dead trees, VI – old dead trees. The aesthetic condition of heritage trees was assessed using a scale:

1. The plant is proportionally developed, and aesthetic qualities correspond to its species and phenophase. There are no dry branches in the crown, or they can be found in small quantities, as a result of natural growth processes; mechanical damage to the trunk and branches does not affect the appearance of the plant; no visible signs of disease damage, no visible damage by pests, species do not cause negative emotions of the observer.

2. The plant has high aesthetic properties, but the first signs of a decrease in its aesthetic qualities are observed.

3. The plant has deviations in development: the inclination of the trunk, the asymmetry of the crown, the number of dry branches is more than 30%, mechanical damage to the trunk and crown, visible traces of damage by pests and diseases.

4. The plant completely lost its aesthetic qualities, which are impossible to restore.

The selected trees for research made up 90% of the general sample. Representative samples of ancient trees included all solitary trees, the vast majority of trees growing in alleys and groups.

Results and Discussion

The history of bequeathing trees in Vienna

The first nature law of Austria was the "City Law on the Protection of Nature" from 5 July 1935 (Mülleder & Kapl, 1989). The practice of preserving trees remained in all subsequent conservation laws. In 1936, trees began to be given the status of natural monuments (Tiefenbach, 1998). The bequest of ancient trees in Vienna has been going on for over 80 years. During this time, 382 places of ancient tree growth were taken under protection. Trees listed as natural monuments have a number of advantages. These trees are under special state protection in Austria. For such trees, there is a special campaign during pruning or in case of pest infestation. Nature monuments are provided with suitable signage, and each tree of such significance bears a plaque on its trunk containing a concise description of its unique qualities.

In the Vienna Nature Conservation Act of 1984, heritage trees (Sima & Büchl-Krammerstätter, 2009) were an important component because, by that time, the number of protected trees had increased considerably. The largest number of trees got the status of natural monument in the 1970s (Fig. 1). A. Schmied & W. Pillmann (2003) found that most of the laws were adopted in the 1970s due to the rising ecological awareness at that time. According to the diagram over the past 10 years, 28 trees in Vienna got this status.

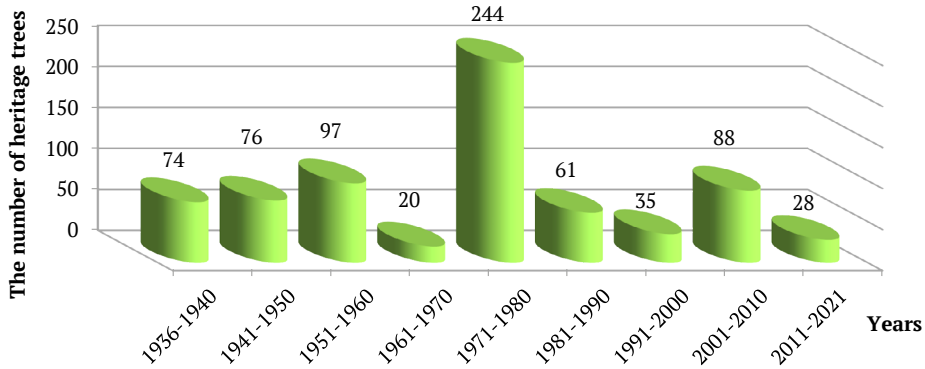

Figure 1. The history of trees bequeathing in different decades

Source: developed by the authors based on the official website of Vienna (n.d.)

The heritage trees in Vienna are found almost everywhere in the city. They are in the many historical squares, in front gardens, in courtyards, and in large parks in the middle of the city.

Each natural monument has its own uniqueness. *Taxus baccata* L. is the oldest tree in Vienna (1936 year of bequest). It is about 1000 years old, and the circumference of the trunk is 3.20 m (Sima & Büchl-Krammerstätter, 2009). This tree is one of the yew groves from Roman times.

The longest alley in Vienna, which has the status of a natural monument, leads from Schönbrunn Palace to Getzendorf Castle. Its length is 750 metres, and the trees grow in four rows, including *Aesculus hippocastanum* L., *Acer platanoides* L., *Tilia platyphyllos* Scop.

The heritage tree *Platanus orientalis* L. has been growing at Rennweg, 14 (Vienna) since the time of Wolfgang Amadeus Mozart (Fig. 2), who lived near this place (1936 year of the bequest). This tree is over 240 years old.

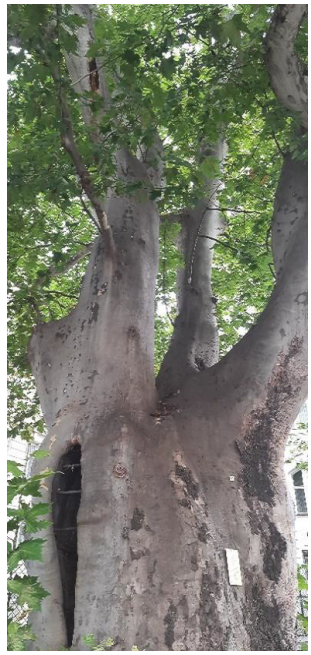

Figure 2. Mozart's plane (*Platanus orientalis* L.)

Source: developed by the authors

There is an ancient liana, which is included in the general list of natural monuments of Vienna (Fig. 3). This is *Hedera helix* L. (1950 – the year of the bequest), the branches of which spread at a distance up to 10 m and formed a crown at a height up to 7 m above the ground.

Figure 3. Ancient liana (*Hedera helix* L.)

Source: developed by the authors

Despite their rarity in urban landscapes, old trees make a disproportionate contribution to biodiversity conservation and the development of human society. For historical, urban planning, and other reasons, the distribution of ancient trees in Vienna is uneven and does not depend on the area of the district. The number of trees growing individually in the districts varies from 2 to 131. The lowest number of trees is in the following districts: Mariahilf, Margareten, Wieden, Ottakring, and the highest number is in Döbling and Hietzing (Fig. 4).

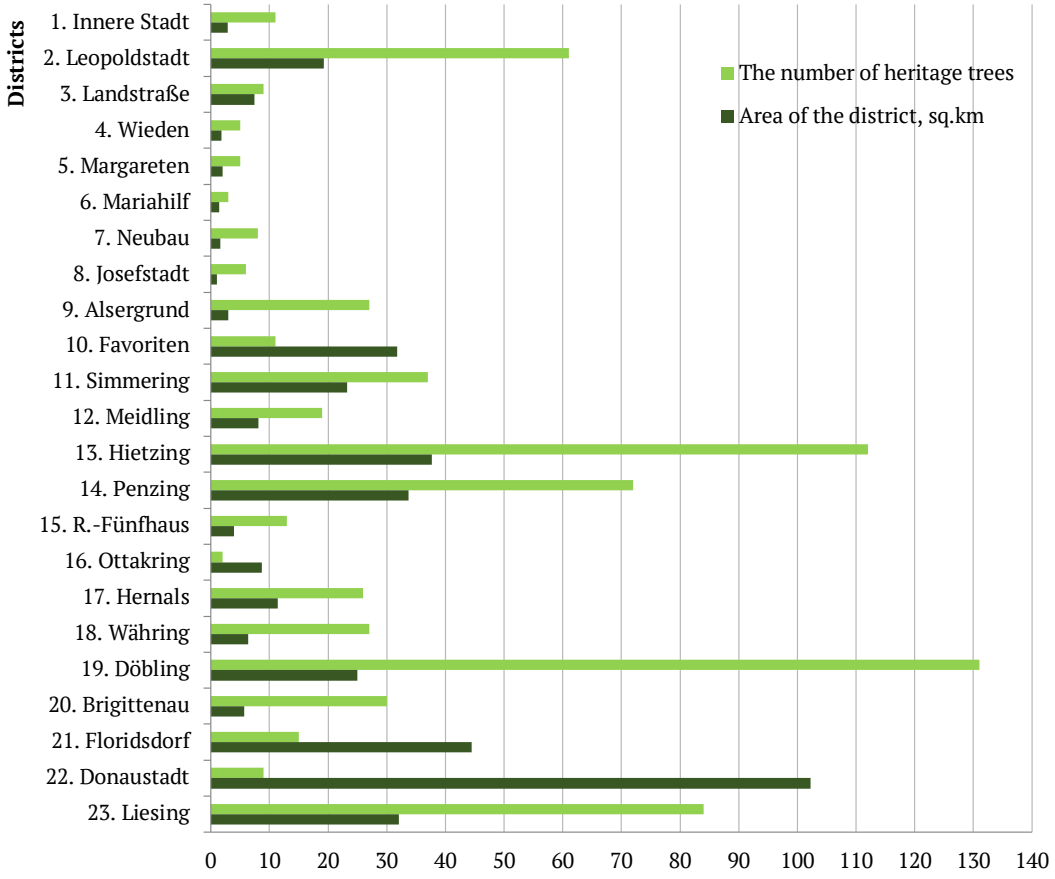

Figure 4. The number of heritage trees in districts of Vienna

Source: developed by the authors based on the official website of Vienna (n.d.)

The value of individual monumental trees is unique to each district. The presence of such trees develops the environmental awareness of the residents of the districts. Knowledge of the location of protected trees can be used to plan excursions.

Species diversity and types of plantings

In biological sciences, woody species are characterised by the longest life cycle, which can be measured in hundreds or even thousands years. Yet not all tree species can reach hundreds or even thousands of years. Dragon tree and baobab

live up to 6000 years, cypress and Lebanese cedar – to 2000 years. The oldest tree on the planet is the long-lived pine, which grows in the Sierra Nevada mountains and is 4,600 years old (Shlapak *et al.*, 2010). It is impossible to determine the exact age of ancient trees. There are known ages only of several heritage trees in Vienna.

The heritage trees in Vienna are represented by 49 genera, most of which belong to the phylum of *Magnoliophyta* (Fig. 5). The most common species among heritage trees are *Aesculus hippocastanum* L., *Pinus nigra* J.F. Arnold, *Platanus orientalis* L., *Taxus baccata* L., *Tilia platyphyllos* Scop., *Quercus robur* L.

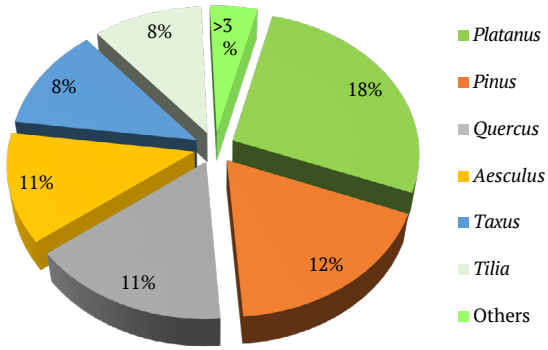

Figure 5. Distribution of heritage trees by genera in Vienna

Source: developed by the authors based on the official website of Vienna (n.d.)

Vienna is home to a diverse array of heritage trees, representing various species that exist in only one individual: *Ailanthus altissima* (Mill.) Swingle, *Buxus sempervirens* L., *Celtis australis* L., *Cornus mas* L., *Gleditsia triacanthos* L., *Hedera helix* L., *Metasequoia glyptostroboides* Hu & W. C. Cheng, *Parrotia persica* C. A. Mey., *Prunus laurocerasus* L., *Sambucus nigra* L., *Styphnolobium japonicum* (L.) Schott.

Most of the heritage trees (60%) are solitary trees (Fig. 6). Trees growing in groups make up 37% of all heritage trees. The smallest number of heritage trees (3%) grow in the alleys.

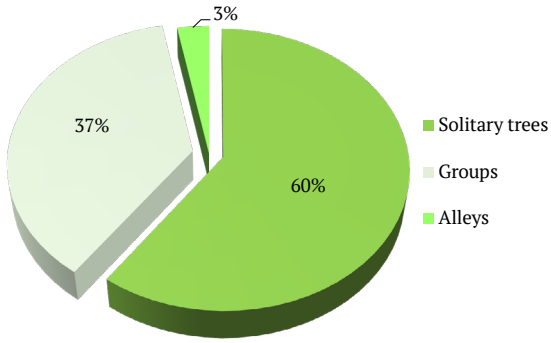

Figure 6. Distribution of heritage trees by types of planting

Source: developed by the authors based on the official website of Vienna (n.d.)

The identification and protection of natural monuments in Vienna has several features. Trees that receive the status of natural monuments would not always be ancient or historical. Quite often, in the central districts of Vienna, which do not have large areas of vegetation, promising trees are allocated to this category to preserve the green space in the area. In addition, properly shaped trees with a spreading crown, which play an important role in the formation of a particular landscape, become protected.

Sanitary and aesthetic condition of trees

Part of heritage trees are located in the immediate vicinity of buildings, in places with significant city traffic. Other trees grow in conditions that are more favourable – in parks, squares, arboretums, etc. Negative factors have a complex influence in nature on the vital state of plants (Galkin *et al.*, 2013). Ancient trees are some of the most vulnerable biotas, especially in urban environments (Dudyn, 2001). The diameter, height, and longevity of large trees vary greatly depending on their species. Such trees are vulnerable to threats ranging from droughts, pests, and pathogens, and climate change (Lindenmayer & Laurance, 2017).

Despite this, Vienna's general sanitary condition of protected trees is excellent (Table 1). Alleys growing along the roads are often threatened by their users (Pietrzak-Zawadka, 2020). Therefore, the sanitary condition of the alleys in Vienna is rated lower compared to solitary trees and groups.

Table 1. Sanitary condition of heritage trees in Vienna in 2023

Types of street plantings	Part of the trees, %	The category of tree condition
Solitary trees	93	I
	7	II
Groups	84	I
	16	II
Alleys	53	I
	47	II

Source: developed by the authors

The category of the sanitary condition of trees in the alleys was lower because of cracks, wounds, callus formation, and tree cavities. A feature of heritage tree is their exceptionally high aesthetic properties. In addition, each such tree has its own uniqueness.

Heritage trees mostly have great aesthetic properties, adequately developed. There are no dry branches in the crown, or they can be found in small quantities, visible signs of pest damage are absent. It can be concluded that trees with obvious signs of defects and the presence of pests are not distinguished as heritage trees. Therefore, the general sanitary and aesthetic condition of the heritage trees is excellent; almost all trees have a high vitality, and play a leading role in the city landscapes.

The engagement of society has an important role in the identification, and inventory of ancient trees. M. Kowalski (2020) found collaboration between society and nature protection authorities to be an essential element in the protection of ancient trees. The popularisation of information about heritage trees is an important issue, which draws social attention to the recognition of their unique value. M. Suchocka *et al*. (2022) investigated social aspects, in particular the visual perception of

old trees, and proved the unequivocal importance of such trees for people.

According M. Blicharska & G. Mikusiński (2014), in addition to providing key ecological functions, especially in cities, ancient trees are part of a social realm with numerous social and cultural benefits to people.

Residents sometimes neglect social and cultural value of heritage trees. Awareness of ancient trees as a part of cultural heritage is essential when addressing the issue of their decline worldwide. Ancient trees provide humans with aesthetic, religious, symbolic, and historic values. In many cultures, particularly ancient trees are treated with reverence.

The ancient trees can serve as a home for many representatives of the animal world, and a place for plant organisms to settle. Studies of C.Y. Jim (2017) confirm that the ancient trees create various micro-habitats to support a surprising assemblage of different organisms. Preservation of ancient trees contributes to the preservation of biodiversity. S.L. Shnayder *et al.* (2011) noted that the value of ancient trees lay not only in their historical importance, but also in the fact that they had passed the test of time and city life, and they had immunity from many pests.

All European countries have legal regulations to protect ancient trees. The issue of ancient trees has been placed in many countries and is embodied in the law of environmental protection and nature conservation. While examining the criteria applied to the trees that are the candidates to become natural monuments, J. Pietrzak-Zawadka (2016) established that they were different between countries. Currently, in the world, natural monuments are mainly trees exceptional for their age or appearance, but mostly dimensional criteria are used to determine the status. Protection and preservation of ancient and historical trees in Europe is a manifestation of culture and respect for national heritage. N. Oleksiichenko & S. Pidkhovna (2018) showed that countries with long-standing and strong nature conservation traditions (Austria, Germany, England, Poland, Lithuania, and Latvia) had been successfully engaged in the inventory and protection of ancient and other outstanding trees. In general, the tradition of bequeathing old trees is very widespread in Europe: more than 36,000 trees were bequeathed in Poland, 4,000 trees – in Italy, 22,000 trees – in Great Britain, 2648 trees – in France, 1433 trees – in Sweden, 300 trees – in Slovakia, and 1300 trees – in Czech Republic (Pietrzak-Zawadka, 2016; Zarzyński & Grzywacz, 2019). V.E. Boreiko (2010) is certain that the number of potential trees that can receive the status of natural monuments is much larger. There are 3,295 unique trees that are over a hundred years old registered in Ukraine. A.I. Kushnir & I.I. Vakuluk (2018) explored ancient trees in Ukraine, they assured that about 50 of the trees were connected by historical events, human destinies and legends. Considering research of European scientists – S.L. Shnaider *et al.* (2011), J. Dreslerová (2017), P. Zarzyński, & A. Grzywacz (2019), the most common species of heritage trees can be distinguished: *Aesculus hippocastanum* L., *Platanus orientalis* L., *Taxus baccata* L., *Tilia cordata* L., *Quercus robur* L., and others.

An important aspect of preserving ancient trees is the formation of optimal conditions for their growth and implementation of special measures to strengthen their stability. To preserve the vitality of old trees in the city, A.I. Kushnir & I.I. Vakuluk (2018) recommend the installation of openwork-style fences to reduce recreational impact on the root system, and conducting regular crown maintenance through the removal of dry, diseased, and broken branches.

Austria is a country with a long history, including in the field of landscaping, which has been preserved and adapted to modern

requirements. Specialists in other countries can use the example of the inventory of ancient trees in Vienna. This study also contributes to increase community awareness and improve the management of these unique trees.

Conclusions

Protection and preservation of ancient, rare, and historical trees in Europe is a manifestation of culture and respect for national heritage. The bequest of ancient trees in Vienna has been going on for over 80 years. The law regulates the issues of bequest rules and mechanisms. An important experience of bequeathing old trees in Vienna is open access to the cadastre of these trees. In this way, people have the opportunity to participate in research and preservation of heritage trees. Due to its rich history, Vienna has preserved extremely old treesthat are closely related to the history of the city or notable individuals of considerable ecological importance in preserving unique ecosystems within an urbanised environment. All districts of Vienna have certain number of heritage trees. However, the largest number of the trees grows in Döbling (13) and Hietzing (19) districts. The species diversity of heritage trees is diverse, but mainly represented by six genera: *Aesculus, Platanus, Pinus, Quercus, Taxus, Tilia*. Most heritage trees are solitary. Despite their respectable age, the sanitary aesthetic and condition of the trees are excellent.

The development of methods for monitoring the sanitary condition of ancient trees, the introduction of new arboriculture measures, and the promotion of a responsible attitude of the public can be among the promising areas of research on ancient and heritage trees.

Conflict of Interest

None.

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None.

References

[1] Blicharska, M., & Mikusiński, G. (2014). Incorporating social and cultural significance of large old trees in conservation policy. *Conservation Biology*, 28, 1558-1567. doi: 10.1111/cobi.12341.

[2] Boreiko, V.E. (2010). The esthetic of ancient trees. *Humanitarian Ecological Journal*, 2, 37-38.

[3] Cannon, C.H., Piovesan, G., & Munné-Bosch, S. (2022). Old and ancient trees are life history lottery winners and vital evolutionary resources for long-term adaptive capacity. *Nature Plants*, 8(2), 136-145. doi: 10.1038/s41477-021-01088-5.

[4] Dreslerová, J. (2017). Memorial trees in the Czech landscape. *Journal of Landscape Ecology.* 10 (2), 79-108. doi: 10.1515/jlecol-2017-0019.

[5] Dudyn, R.B. (2001). The oldest trees of the old parks. *Scientific Bulletin of the Ukrainian National Forestry University*, 11.4, 29-32.

[6] Galkin, S.I., Dragan, N.V., & Doiko, N.M. (2013). Experience of the conservation of ancient trees and historical compositions in arboretum Olexandria of the NAS of Ukraine. *Plant Introduction*, 4, 42-50.

[7] Jim, C.Y. (2017). Urban heritage trees: Natural-cultural significance informing management and conservation. In P. Tan, C. Jim (Eds.) *Greening cities* (pp. 279-305). Singapore: Springer. doi: 10.1007/978-981-10-4113-6_13.

[8] Kowalski, M. (2020). Czego pomnikiem jest drzewo “pomnik przyrody”? *Stan Rzeczy*, 2(19), 261-297. doi: 10.51196/srz.19.11.

[9] Kushnir, A.I., & Vakulyk, I.I. (2018). Value of unique old trees – a natural monument. *Biological Resources and Nature Management*, 10(3-4), 176-182. doi: 10.31548/bio2018.03.023.

[10] Landesrecht konsolidiert Wien: Gesamte Rechtsvorschrift für Wiener Naturschutzgesetz. (2022, May). Retrieved from https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=LrW&Gesetzesnummer=20000454.

[11] Lindenmayer, D.B. (2017). Conserving large old trees as small natural features. *Biological Conservation,* 211, 51-59. doi: 10.1016/j.biocon.2016.11.012.

[12] Lindenmayer, D.B., & Laurance, W.F. (2017). The ecology, distribution, conservation and management of large old trees. *Biological Reviews Cambridge Philosophical Society*, 92, 1434-1458. doi: 10.1111/brv.12290.

[13] Mülleder, H., & Kapl, S. (1989). *Naturdenkmale in Oberösterreich*. Linz: Agrar- und Forstrechts Abteilung.

[14] Munné-Bosch, S. (2018). Limits to tree growth and longevity. *Trends in Plant Science*, 23(11), 985-993. doi: 10.1016/j.tplants.2018.08.001.

[15] Official website of the City Vienna. (n.d.). Stadt Wien. Naturdenkmäler. Retrieved from https://www.wien.gv.at/umweltschutz/naturschutz/gebiet/naturdenkmaeler/.

[16] Oleksiichenko, N., & Pidkhovna, S. (2018). The old-age trees of the parks-monuments as park and garden art objects a in Ternopil region. *Proceedings of the Forestry Academy of Sciences of Ukraine*, 16, 41-49. doi: 10.15421/411805.

[17] Pietrzak-Zawadka, J. (2016). Protection of trees – monuments of nature in selected European countries. *Zarządzanie Ochroną Przyrody w Lasach*, 10, 17-28. doi: 10.5604/01.3001.0010.0494.

[18] Pietrzak-Zawadka, J. (2020). Alleys – monuments of nature element of the rural landscape. *Open Access Journal of Agricultural Research*, 5(2), article number 000243. doi: 10.23880/oajar-16000243.

[19] Piovesan, G., Cannon, C.H., Liu, J., & Munné-Bosch, S. (2022). Ancient trees: irreplaceable conservation resource for ecosystem restoration. *Trends in Ecology & Evolution*, 37(12), 1025-1028. doi: 10.1016/j.tree.2022.09.003.

[20] Schmied, A., & Pillmann, W. (2003). Tree protection legislation in European cities. *Urban Forestry & Urban Greening*. 2(2), 115-124. doi: 10.1078/1618-8667-00028.

[21] Shlapak, V.P., Myzuka, G.I., Vitenko, V.A., Marno, L.I., & Gonchar, N.O. (2010). The evaluation methods of aesthetic conditions of the age-old plantations of trees in the national dendrological park "Sofiyivka" NAS of Ukraine. *Scientific Bulletin of the Ukrainian National Forestry University*, 20.6, 8–13.

[22] Shnayder, S.L., Boreiko, V.E., & Stetsenko N.F. (2011). *500 exceptional trees of Ukraine*. Kiev: LOGOS.

[23] Sima, U., & Büchl-Krammerstätter, K. (2009). *Naturdenkmal. Stadt Wien*. Retrieved from https://www.wien.gv.at/umweltschutz/pdf/naturdm-folder.pdf.

[24] Suchocka, M., Wojnowska-Heciak, M., Błaszczyk, M., Gawłowska, A., Ciemniewska, J., Jarska, A., Heciak, J., & Pachnowska, B. (2022). Old trees are perceived as a valuable element of the municipal forest landscape. *PeerJ,* 10, article number e12700. doi: 10.7717/peerj.12700.

[25] Tiefenbach, M. (1998). *Naturschutz in Österreich*. Wien: Bundesministerium für Umwelt, Jugend und Familie.

[26] Vakulyk, I.I., & Balalaieva, O.Yu. (2018). Century-old trees of modern metropolis park zones as a means of communication. *Biological Resources and Nature Managment*, 10(5-6), 156-162. doi: 10.31548/bio2018.05.019.

[27] Zarzyński, P., & Grzywacz, A. (2019). Kategoryzacja drzew jako pomników przyrody na podstawie ich walorów przyrodniczych, historycznych i społecznych. *Sylwan*, 163(4), 338-347. doi: 10.26202/sylwan.2018143.

Досвід збереження вікових дерев у м. Відні, Австрія

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Анотація. Вікові дерева займають важливе естетичне та екологічне місце в міському просторі. Вивчення вікових дерев, визначення їх життєвого та санітарного стану є частиною комплексної оцінки збереження цих дерев та охорони природи міського простору. Метою дослідження було вивчення досвіду збереження цінних дерев, що ростуть у міському просторі м. Відня. Для роботи з кадастром дерев-пам'яток природи м. Відня використовувалися загальнонаукові теоретичні методи – аналіз та синтез. В результаті проведеного дослідження було визначено, що історичні дерева ростуть у всіх районах м. Відня. Встановлено, що надання віковим деревам статусу пам'яток природи почали з 1936 року, була простежена динаміка заповідання, визначені періоди найбільш активної природоохоронної діяльності у Відні. Описані найбільш відомі дерева спадщини в місті. Проаналізований видовий склад пам'ятних дерев, узагальнена їхня таксономічна приналежність. Дерева спадщини у Відні представлені 49 родами, більшість із яких належить до відділу *Magnoliophyta*. Було виявлено, що серед дерев, які мають охоронний статус, найпоширенішими видами є *Aesculus hippocastanum* L., *Pinus nigra* J.F. Arnold, *Platanus orientalis* L., *Quercus robur* L., T*axus baccata* L., *Tilia platyphyllos* Scop. Більшість дерев-пам'яток природи (60 %) є солітерами. Встановлено, що загальний санітарний стан таких дерев відмінний; майже всі дерева мають високу життєстійкість і відіграють провідну

роль у формуванні міських ландшафтів. Усі дерева спадщини мають високу та добру естетичну оцінку. Аналіз існуючої інвентаризації вікових дерев у Відні, їх санітарний стан та естетичний стан сприятимуть екологічної обізнаності громад та покращенню заходів з управління такими деревами. Отримані результати можуть бути використані для обміну досвідом науковців різних країн щодо збереження вікових дерев та формування європейських баз даних дерев-пам'яток природи

Ключові слова: пам'ятка природи; статус пам'ятника природи; деревні породи; район міста; озеленення міст

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Influence of winter storage methods of acorns on the development and growth processes of common oak

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Abstract. The economic value and biological stability of common oak stands (*Quercus robur* L.), grown from acorns is substantially higher in comparison with plantings of undergrowth origin.

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Therefore, the cultivation of acorn oak stands is relevant and promising, especially where there is no natural restoration of oak. The purpose of the study was the improvement of seed production technology and cultivation of high-quality planting material of common oak seeds with various methods of winter storage to expand the area of oak forests. In the course of the study, forest-cultural (determination of quality indicators of acorns, planting material, and forest cultures), biometric (determination of growth indicators and mass of planting material), and classical statistical research methods were used. The study was conducted on the territory of the forest fund of the Hertsaevsky state special Forestry and Kuzmynsky Forestry branches of "Chernivtsi Forestry" of the state specialised economic enterprise "Forests of Ukraine". It is shown that each of the winter storing methods of acorns of common oak has its own advantages and disadvantages, which are more or less manifested in different methods of cultivation. As a result of comparing the influence of different cultivation methods on the development of common oak plants grown from seeds stored in a trench method, it was determined that the best growth parameters of the aboveground part of plants were observed when using the larding method. However, the least intensive development of the root system was observed when growing oak with a closed root system. It was found that the weighted average biometric indicators of the growth processes of common oak plants grown from seeds that were stored in tap water were the highest when growing acorns by larding. It is proved that the experimental plants of common oak grown from seeds that were stored in a cellar with sand lagged behind in the development of the aboveground part when grown by a landing method. It was established that the root system developed worse when growing plants with an open root system. The proposed acorn storage technology can be applied to improve the efficiency and quality of reproduction of oak stands by forestry enterprises in Ukraine

Keywords: *Quercus robur* L.; seed material; seedlings; root system; aboveground part; reforestation

Introduction

The main task of forestry activities on the territory of Ukraine is to obtain high-quality wood raw materials. When performing this task, both economic and typological features of forest stands, as well as microclimatic and soil-hydrological features of a particular region are fully considered. Therewith, during the process of growing seed and planting material of the main types of forest-forming woody plants, such as Scots pine (*Pinus sylvestris* L.) and common oak (*Quercus robur* L.), usually, only at an early age the negative impact of environmental factors on plants is considered. Subsequently, at the age of 5-6 years, they die en masse, in particular, due to natural selection and the lack of effective preventive and active extermination protection measures (Bilous, 2016; Kulbanska *et al.*, 2023). For this reason, Z.W. Beer *et al.* (2017), S. Bilous *et al.* (2023) note in their papers that even at an early age, it is necessary to start taking care of a healthy generation of the forest, in particular at the stage of harvesting and storing seed material.

According to S. Sydorenko *et al.* (2021), R.V. Hurzhii *et al.* (2021), increasing the forest cover of the territory in all forest-growing zones of the country by creating additional areas of artificial forest stands has always been the priority area of Forestry in Ukraine, which is possible only if a sufficient amount of high-quality seed and planting material is provided for the main forest-forming species of woody plants. Authors P. Baldi & N. La Porta (2017), L. Gathercole *et al.* (2021) in their study argue that in

the process of growing high-quality seed and planting material, it is extremely important to combine and optimise all elements of the production process: the use of high-quality seeds, the selection of safe storage methods, reasonable standards, and seeding schemes (Jiang *et al.*, 2019), improving the physical and chemical properties of the soil (Kulbanska *et al.*, 2021; Matsiakh *et al.*, 2021), the use of preventive and extermination protection measures in pest, pathogen, and weed control (Brady *et al.*, 2017; Kulbanska *et al.*, 2021), the application of mineral composite fertilisers and growth regulators (Nones *et al.*, 2022), etc.

R.A. Sitz *et al.* (2018), J. Doonan *et al.* (2019) described that the life biological cycle of oak stands alternates between periods of accelerated dying-off and stabilisation of the sanitary condition. Notably, researchers have established a certain chronology and noted the cyclicity of this natural phenomenon. In general, over the past 100 years, three periods of digression can be distinguished, as a result of which there was a massive weakening and dying off of oak: 1927-1946, 1964-1983, and 1982-1911. In particular, during the period of mass degradation of oak forests in the 70s of the 20th century, forest cultures that were planted in a permanent place of forest plots by seedlings (Grünwald *et al.*, 2008; Kulbanska *et al.*, 2021). Therewith, oak cultures that were sown from acorns were determined to be much more resistant to the influence of climatic and other environmental factors. Thus, forest oak cultures can be created both by sowing acorns and planting seedlings. In forest-growing conditions with available soil moisture and a sufficient amount of precipitation, forest oak cultures can be laid in a permanent place of forest plots by planting seedlings. Y. Li *et al.* (2014), S. Liu & Y. Tang (2016) noted that when creating forest oak cultures on dry soils or in an area with insufficient precipitation, within all forest zones, it is more appropriate to give preference to sowing acorns. It is possible to form highly productive and biologically resistant oak stands only considering the above conditions for creating forest cultures of common oak.

Common oak can also be restored in a vegetative way, but not always successfully. N.S. Mukhamadiyev *et al.* (2021), S. Bilous *et al.* (2023) proved that sprout plantings are usually characterised by reduced biological resistance and short duration compared to seed plantings, but they begin to bear fruit earlier. oak stumps with a diameter of more than 50 cm practically do not produce growth, but in fresh and moist forest types of conditions, they are sometimes able to form root sprouts. Due to the work already started in Ukraine on forest certification, the European experience of reforestation is being actively introduced into the forestry practice of leading enterprises in the industry. In particular, testing in the production conditions of certain methods and techniques of reforestation inherent in environmentally oriented Forestry is being conducted, namely: focus on the plantation or positive seed production; introduction of narrow-cutting, gradual, and selective methods of logging of the main use; use of sowing seed material (especially autumn) for the formation of artificial forest stands; conducting a forestry complex of works to improve natural renewal, considering such forest-cultural measures as seed sowing and tillage. (Kulbanska, 2021; Bilous *et al.*, 2023). Methods of long-term storage of seeds and cultivation of high-quality seedlings of forest woody plant species are still insufficiently studied, and the characteristics given in the literature are not equivalent and incomplete.

The problem of studying long-term storage of seeds, including oak acorns, remains relevant, despite certain developments of foresters in this area. Thus, it was quite natural to set the goal of the study as such – scientific justification

of the technology of winter storage of acorns of common oak for growing high-quality planting material and improving seed production technology during reforestation of oak stands.

Materials and Methods

The object of the study was the seed potential and planting material of common oak. Accordingly, the subject of the study was the features of seed production technology and the cultivation of high-quality planting material of common oak, obtained by various methods of winter storage of acorns. To grow high-quality planting material and reproduce and expand the area of oak stands in the fall of 2021, 4,500 acorns of common Oa were collected from under the tent of positive ripe high-quality oak stands within the Hertsaivsky state special Forestry and Kuzmynsky Forestry branches of the state specialised economic enterprise "Forests of Ukraine". Features of the selection of acorns of common oak were conducted under laboratory conditions according to the Resolution of the Cabinet of Ministers of Ukraine No. 977 "On Approval of the State Programme "Forests of Ukraine" for 2002-2015" (2009).

The corresponding acorns were selected and calibrated so that they were the same size and quality characteristics. The dimensions were measured using a calliper with a permissible deviation in diameter ±0.1 mm and a length of ± 0.5 mm. The next step was to divide the acorns into three parts (1500 acorns each): the first was stored in a cellar in the sand, observing the level of its moisture capacity at the level of 60-65% TM (total moisture capacity), the second – in a trench in a conventional way and the third – in tap water. In April, after winter storage, acorns of common oak were examined, measurements, weighing, and a comparative empirical analysis of storage was conducted. The next stage was the preparation of the soil and sowing acorns of common oak in the ground. Acorns were sown on the territory of a temporary nursery of the Kuzmynsky Forestry district. Three methods of growing oak seedlings were used: with an open root system, a closed root system, and the larding method.

After the analysis of acorns, conditions were created for sowing and growing 1,500 seedlings with an open root system in the sowing unit of the nursery in the open ground. In the first decade of May 2021, 1500 pcs. of acorns were sown in ten rows 75 m long, each, after 1 m, with a row spacing of 0.5 m. Therewith, seedlings aged half a year with a closed root system were sown and grown in a greenhouse in the amount of 1590 pcs., in containers sized 30×53 with a pre-sifted soil mixture in the proportions of 33.3% chernozem, 33.3% sand, 33.4% mycorrhiza soil collected from under the canopy of oak stands. Thus, 1500 pcs. of acorns were sown and were grown, from larded acorns on a forest-cultivated area on a plot with no natural restoration of common oak.

Thus, the main research methods for performing this experiment were forest-cultural – to study the technology and methods of winter storage of acorns of common oak; biometric – to determine the biometric indicators of common oak plants grown with different methods of winter storage of acorns; classical statistical – to analyse and process the results obtained, graphic – to identify trends, patterns of analytical dependencies.

Results and Discussion

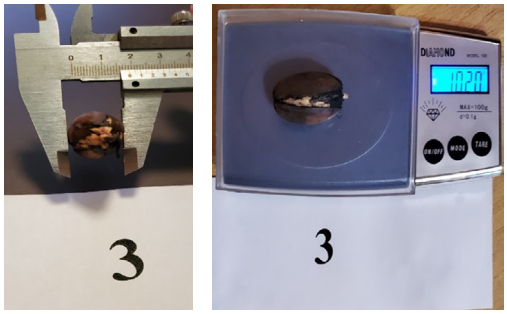
Analysis based on the results obtained (Fig. 1), allows assuming that in acorns that were stored in the trench in winter, the state of forced dormancy is longer than in other samples since the so-called root of the future plant barely hatched and the seeds accumulated moisture to a lesser extent (this is evidenced by the germination rate of plants). The acorn seedling, which was stored in a trench above the soil level of the container,

was visualised only on the seventh day of the experiment, in contrast to the acorn seedling, which was stored in tap water, which showed germination on the third day after sowing.

The results of this experiment are presented in the form of a table (Table 1).

a – after storage in the cellar in the sand

b – after storage in the trench



c – after storage in tap water

Figure 1. Results of winter storage of acorns of common oak

Note: a – storage in a cellar in the sand; b – storage in a trench; c – storage in tap water

Table 1. Analysis of plants of common oak aged half a year grown with different methods of winter storage of acorns

Methods of growing common oak	Total mass, g	Aboveground part		Root system		Diameter near the roots, mm
		height, cm	weight, g	length, cm	weight, g	
After the trench storage method						
with the ORS	173 ± 0.65	31.22 ± 2.22	1.12 ± 0.25	25.22 ± 1.95	2.34 ± 0.40	3.33 ± 0.77
with the CRS	372 ± 1.80	25.8 ± 1.01	0.98 ± 0.51	16.26 ± 0.50	6.46 ± 1.29	4.3 ± 0.89
larding method	273 ± 1.98	32.05 ± 2.35	1.78 ± 0.68	26.05 ± 2.10	3.68 ± 1.30	3.95 ± 0.87
After storage in tap water						
with the ORS	209 ± 0.55	32.42 ± 2.31	1.15 ± 0.20	28.64 ± 2.06	3.03 ± 0.35	2.87 ± 0.70
with the CRS	405 ± 2.05	32.2 ± 1.,00	1.34 ± 0.50	17.84 ± 0.45	6.76 ± 1.55	4.4 ± 0.95
larding method	779 ± 2.50	33.0 ± 2.40	3.03 ± 1.20	43.0 ± 2.15	12.55 ± 1.40	5.4 ± 2.00

Table 1, Continued

After storage in a sand cellar						
with the ORS	220 ± 0.60	28.42 ± 1.70	1.0 ± 0.20	26.42 ± 1.20	3.40 ± 0.40	3.32 ± 0.76
with the CRS	324 ± 1.72	28.28 ± 1.56	1.02 ± 0.57	16.72 ± 0.50	5.46 ± 1.14	4.54 ± 0.92
larding method	262 ± 0.65	24.0 ± 2.02	0.94± ± 0.21	41.0 ± 1.41	4.30 ± 0.43	3.9 ± 0.85

Note: ORS – open root system; CRS – closed root system
Source: ccompiled by the authors

Analysis of the examination of weighted average biometric indicators, in particular, the total mass, height and mass of the aboveground part, the length and mass of the root system, and the diameter at the root neck of the plants aged half a year of common oak grown by various methods allows stating that each of the winter methods of storing oak acorns has its own advantages and disadvantages. Notably, the highest parameters of common oak seedlings were obtained by the method of storing acorns in tap water and larding: the indicator "total mass" (g) is 779 ± 2.50, the indicator "height of the aboveground part" (cm) is 33.0 ± 2.40, the indicator "mass of the aboveground part" (g) is 3.03 ± 1.20, the indicator "length of the root system" (cm) is 43.0 ± 2.15, the indicator "mass of the root system" (g) is equal to 12.55 ± 1.40, the indicator "diameter at the root neck" (mm) is 5.4 ± 2.00. The lowest parameters of common oak seedlings are noted when storing acorns in a cellar with sand with an open root system: the indicator "total mass" (g) is 220 ± 0.60, the indicator "height of the aboveground part" (cm) is 28.42 ± 1.70, the indicator "mass of the aboveground part" (g) is 1.00 ± 0.20, the indicator "length of the root system" (cm) is 26.42 ± 1.20, the indicator "mass of the root system" (g) is equal to 3.40 ± 0.40, the indicator "diameter at the root neck" (mm) is 3.32 ± 0.76. The influence of cultivation methods on the development of common oak plants grown from seeds that were stored in different ways is also analysed and presented in the form of graphs (Fig. 2, 3, and 4).

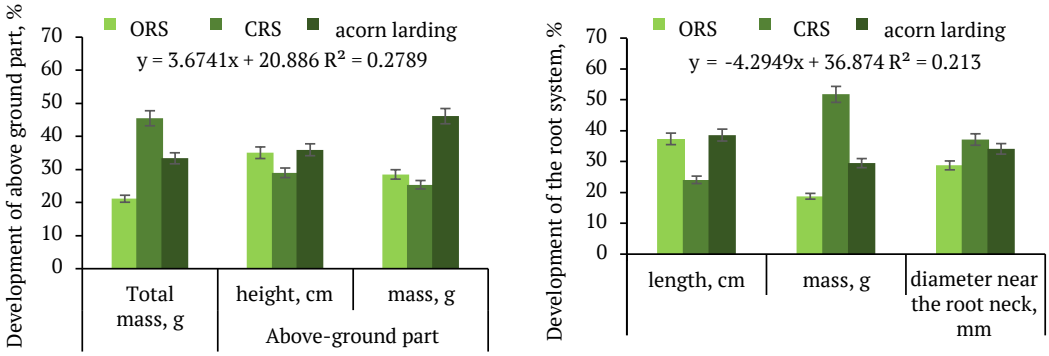


Figure 2. Development of common oak plants after trench winter storage of acorns with different cultivation methods, %

Note: ORS – open root system, CRS – closed root system
Sourse: compiled by the authors

Having analysed the influence of cultivation methods on the development of common oak plants grown from seeds that were stored by trench method, the best growth parameters

of the aboveground part of plants were observed when growing by larding (the indicator "height" (cm) is 32.05 ± 2.35, the indicator "weight" (g) is 1.78 ± 0.68), and the development of the root system was the least intensive when growing oak with a closed root system (the indicator "length" (cm) is 16.26 ± 0.50, the indicator "the mass" (g) is 6.46 ± 1.29). Therewith, experimental plants of common oak lagged behind in growth in all experimental parameters when growing plants with an open root system.

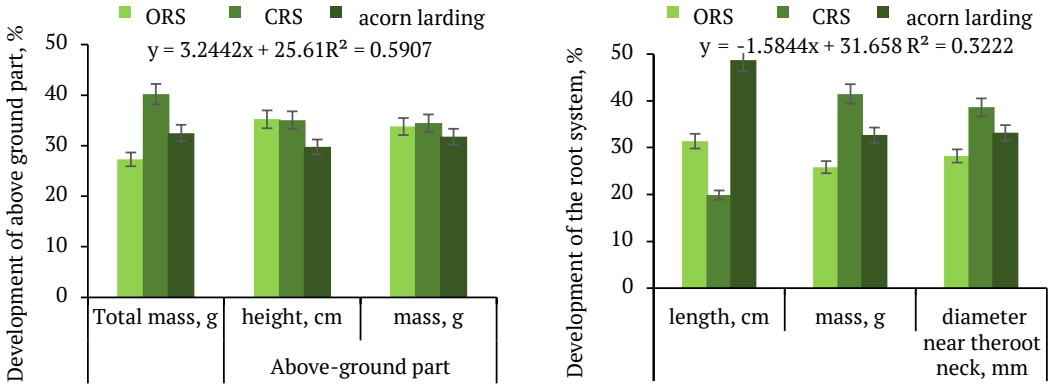


Figure 3. Development of common oak plants after storing acorns in tap water using different methods of cultivation, %

Note: ORS – open root system, CRS – closed root system
Sourse: compiled by the authors

Analysing the influence of various cultivation methods on the development of common oak plants grown from seeds that were stored in tap water, it was noted that the best growth parameters of the aboveground part (the indicator "height" (cm) is 33.0 ± 2.40, the indicator "mass" (g) is 3.03 ± 1.20) and the root system of plants (the indicator "length" (cm) is 43.0 ± 2.15, the indicator "mass" (g) is 12.55 ± 1.40) were observed when growing acorns by larding. Therewith, experimental plants of common oak lagged behind in growth in all experimental parameters when growing plants with an open root system.

Analysing the influence of various cultivation methods on the development of common oak plants grown from seeds that were stored in a cellar with sand, it is noted at the best growth parameters of the aboveground part and the root system of plants were observed when growing by the method with a closed root system. Therewith, the experimental plants of common oak lagged behind in the development of the aboveground part (the indicator "height" (cm) is 24.0 ± 2.02, the indicator "mass" (g) is 0.94 ± 0.21) when grown by larding, and the root system (the indicator "length" (cm) is 26.42 ± 1.20 the indicator "mass" (g) is 3.40 ± 0.40) developed worse when growing plants with an open root system.

Good quality of common oak seeds in forest stands of Ukraine, according to researchers V.M. Bilous (2016), Z. Moussa *et al*. (2021), is approximately 45% in harvest years and substantially depends on abiotic and biotic environmental factors, and on the influence of endophytic and epiphytic microbiota (Moradi-Amirabad *et al*. 2019; Kulbanska *et al.*, 2021). In addition, germination is affected by the

supply of nutrients in acorns. This was most evident in this study when storing acorns in tap water. Absorbing water, acorns increased their size and their upper crust was broken. In addition, the water transferred nutrients to the state in which they were involved, while the water reduced the seed dormancy of acorns. According to G.O. Boyko & O.V. Bashta (2015), seed germination rate and other quality indicators are largely influenced by the storage method. Ultimately, even under optimal conditions in the process of respiration (metabolism), the spare nutrients of seeds are gradually consumed without their subsequent intake, the solubility of protein substances decreases, as a result of which the mass of seeds decreases, and therefore – the germination rate. High humidity and temperature, on the one hand, enhance the processes of metabolism, that is, the weakening of seeds, and on the other – contribute to the development and change of the ratio of saprotrophic and pathogenic microflora and forest conditions, which substantially affect the quality indicators of seeds.

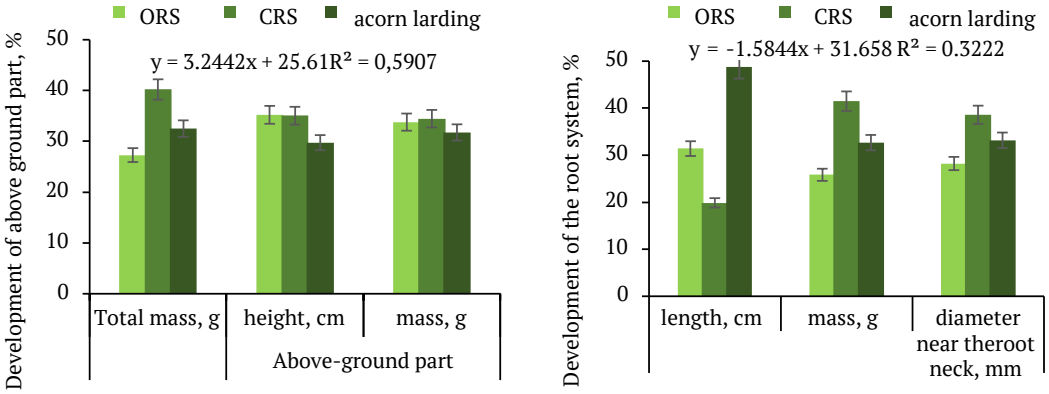


Figure 4. Development of common oak plants after storing acorns in a sand cellar using various methods of cultivation, %

Note: ORS – open root system, CRS – closed root system
Sourse: compiled by the authors

Researchers G.O. Boyko, & N.V. Puzrina (2015) established that the dark-seeded form of Scots pine is promising for sowing since it is least populated with harmful microorganisms during storage and has the highest qualitative and quantitative indicators. According to S. Nones *et al.* (2022), a substantial impact on the quality of acorns and deterioration of storage cause damage – microtrauma with intoxication and mechanical damage to the embryo or shell in the embryo area. They divide the source of injury into two groups. The first category includes environmental factors and morphological features of the plant – this is the lesion of seeds by microorganisms, pests, and early autumn frosts. In the course of this study, acorns that had black, bluish-black, or other spots on cotyledons, especially the germ circle, which occupied more than a third of the entire cotyledon and acorns that did not sink badly in water, were of poor quality. Thus, in the general analysis, it can be argued that a large weight and germination rate affect the quality of sproutings and is one of the signs of high seed quality. It is also known that acorns of common oak are a good food product for

wild and domestic animals, which is why the number of quality acorns on the soil surface is substantially reduced. Similar studies were also conducted by such researchers as: N.M. Voloshchuk & V.M. Bilous (2012), V.M. Bilous (2016). Therewith, systematic studies on the method of winter storage of acorns and the impact on development and growth processes have not been fully conducted.

The totality of organisational and technological errors made in the past when harvesting and storing seed material, planting, and laying woody plants and plantings of various purposes are undoubtedly the root causes of the deterioration of their sanitary condition in the future. Therefore, the study of the influence of winter storage methods of acorns on the development and growth processes of common oak is now a promising area of research and an important urgent Forestry problem that requires further thorough research and analysis of the results obtained.

Conclusions

After analysing the data obtained during the study, it was concluded that each of the winter methods of storing acorns of common oak has its own advantages and disadvantages, which are more or less manifested with different methods of cultivation. However, comparing the influence of different cultivation methods on the development of common oak plants grown from seeds that were stored by trench method, it was noted that the best growth parameters of the aboveground part of plants were observed when growing by larding (the indicator "height" (cm) is 32.05 ± 2.35, the indicator "weight" (g) is 1.78 ± 0.68), and the development of the root system was the least intense when growing oak with a closed root system (the indicator "length" (cm) is 16.26 ± 0.50, the indicator "mass" (g) is 6.46 ± 1.29). Weighted average biometric indicators of growth processes of common oak plants grown from seeds that were stored in tap water were the highest when growing acorns by the larding method, in particular, the following parameters of the aboveground part (indicator "height" (cm) is 33.0 ± 2.40, indicator "mass" (g) is 3.03±1.20) and the root system of plants (indicator "length" (cm) is 43.0 ± 2.15, indicator "mass" (g) is 12.55 ± 1.40). Therewith, experimental plants of common oak grown from seeds that were stored in a cellar with sand lagged behind in the development of the aboveground part (the indicator "height" (cm) is 24.0 ± 2.02, the indicator "mass" (g) is 0.94 ± 0.21) when grown by the larding method, and the root system (the indicator "length" (cm) is 26.42 ± 1.20 the indicator "mass" (g) is 3.40 ± 0.40) and developed worse when growing plants with open the root system. The results of the conducted experiments indicate the timeliness and expediency of using the examined methods of winter storage of acorns to intensify the development and growth processes of common oak and their further use in reforestation and afforestation. In the future, it is advisable to examine the further growth of acorns depending on the geographical environment, that is, on a certain combination of external factors – climate and soil, and the action of various growth stimulators. This will allow growing oak cultures more efficiently in the future.

Conflict of Interest

None.

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References

[1] Baldi, P., & La Porta N. (2017). *Xylella fastidiosa*: Host range and advance in molecular identification techniques. *Frontiers in Plant Science,* 8. doi: 10.3389/fpls.2017.00944.

[2] Beer, Z.W., Marincowitz, S., Duong, T.A., & Wingfield, M.J. (2017). *Bretziella*, a new genus to accommodate the oak wilt fungus, *Ceratocystis Fagacearum* (*Microascales*, Ascomycota). *MycoKeys*, 27, 1-19. doi: 10.3897/mycokeys.27.20657.

[3] Bilous, S., Likhanov, A., Boroday, V., Marchuk, Y., Zelena, L., Subin, O., & Bilous, A. (2023). Antifungal activity and effect of plant-associated bacteria on phenolic synthesis of *Quercus robur* L. *Plants*. 12(6), article number 1352. doi: 10.3390/plants12061352.

[4] Bilous, V.M. (2016). The effect of a strong electric field on rice and the development of common oak seedlings. *Forestry and Horticulture,* 9, 1-11.

[5] Boyko, G.O., & Bashta, O.V. (2015). Mycobiota of Scots pine (*Pinus sylvestris* L.) seeds. *Scientific Bulletin of the National Forestry University of Ukraine*, 25(9), 28-34. doi: 10.15421/40250905.

[6] Boyko, G.O., & Puzrina, N.V. (2015). Species diversity of Scots pine (*Pinus sylvestris* L.) seed mycobiota. *Scientific bulletin of the National Forestry University of Ukraine,* 25(5), 42-48.

[7] Brady, C., Arnold, D., McDonald, J., & Denman, S. (2017). Taxonomy and identification of bacteria associated with acute oak decline. *World Journal of Microbiology and Biotechnology*, 33(7), article number 143. doi: 10.1007/s11274-017-2296-4.

[8] Doonan, J., Denman, S., Pachebat, J.A., & McDonald, J.E. (2019). Genomic analysis of bacteria in the Acute Oak Decline pathobiome. *Microbial Genomics*, 5(1). doi: 10.1099/mgen.0.000240.

[9] Gathercole, L.A.P., Nocchi, G., Brown, N., Coker, T.L.R., Plumb, W.J., Stocks, J.J., Nichols, R.A., Denman, S., & Buggs, R.J.A. (2021). Evidence for the widespread occurrence of bacteria implicated in Acute Oak Decline from incidental genetic sampling. *Forests*, 12(12), article number 1683. doi: 10.3390/f12121683.

[10] Grünwald, N.J., Goss, E.M., & Press, C.M. (2008). *Phytophthora ramorum*: A pathogen with a remarkably wide host range causing sudden oak death on oaks and ramorum blight on woody ornamentals. *Molecular Plant Pathology*, 9(6), 729-740. doi: 10.1111/j.1364-3703.2008.00500.x.

[11] Hurzhii, R.V., Yavorovskyi, P.P., Sydorenko, S.H., Levchenko, V.B., Tyshchenko, O.M., Tertyshnyi, A.P., & Yakubenko, B.Ye. (2021). Trends in forest fuel accumulation in pine forests of Kyiv Polissya in Ukraine. *Folia Forestalia Polonica. Series* A *& Forestry,* 63(2), 116-124. doi: 10.2478/ffp-2021-0013.

[12] Jiang, N., Fan, X.L., Crous, P.W., & Tian, C.M. (2019). Species of *Dendrostoma* (Erythrogloeaceae, Diaporthales) associated with chestnut and oak canker diseases in China. *MycoKeys*, 48, 67-96. doi: 10.3897/mycokeys.48.31715.

[13] Kulbanska, I., Shvets, M., Goychuk, A., Sporek, M., Pasicnhyk, L., Patyka, V., Kalinichenko, A., & Bąk, M. (2023). Phytopathogenic bacteria associated with bacterioses of common oak (*Quercus robur* L.) in Ukraine. *Forests,* 14(1), article number 14. doi: 10.3390/f14010014.

[14] Kulbanska, I.M., Shvets, M.V., Goychuk, A.F., Biliavska, L.H., & Patyka, V.P. (2021). *Lelliottia nimipressuralis* (Carter 1945) Brady *et al*. 2013 – the causative agent of bacterial dropsy of common oak (*Quercus robur* L.) in Ukraine. *Mikrobiolohichnyi Zhurnal*, 83(5), 30-41. doi: 10.15407/microbiolj83.05.030.

[15] Li, Y., He, W., Ren, F., Guo, L., Chang, J., Cleenwerck, I., Ma, Y., Wang, H. (2014). A canker disease of *Populus* × *euramericana* in China caused by *Lonsdalea quercina* subsp. *populi*. *Plant Disease*, 98(3), 368-378. doi: 10.1094/PDIS-01-13-0115-RE.

[16] Liu, S., & Tang, Y. (2016). Identification and characterization of a new *Enterobacter* onion bulb decay caused by *Lelliottia amnigena* in China. *Applied Microbiology: Open Access*, 2(2), article number 1000114. doi: 10.4172/2471-9315.1000114.

[17] Matsiakh, I., Kramarets, V., & Cleary, M. (2021). Occurrence and diversity of *Phytophthora* species in declining broadleaf forests in western Ukraine. *Forest Pathology*, 51(1), article number e12662. doi: 10.1111/efp.12662.

[18] Moradi-Amirabad, Y., Rahimian, H., Babaeizad, V., & Denman, S. (2019). *Brenneria* spp. and *Rahnella victoriana* associated with acute oak decline symptoms on oak and hornbeam in Iran. *Forest Pathology*, 49(4). doi: 10.1111/efp.12535.

[19] Moussa, Z., Choueiri, E., & Hanna, A. (2021). New invasive insects associated with oak forests in Lebanon. *Arab Society for Plant Protection*, 39(2), 164-172. doi: 10.22268/AJPP-039.2.164172.

[20] Mukhamadiyev, N.S., Mengdibayeva, G.Z., Nizamdinova, G.K., & Shakerov, A. (2021). Harmfulness invasive pest-oak mining sawfly (*Profenusa pygmaea*, Klug, 1814). *Reports of the Academy of Sciences of the Republic of Kazakhstan*, 6, 44-49. doi: 10.32014/2021.2518-1483.109.

[21] Nones, S., Fernandes, C., Duarte, L., Cruz, L., & Sousa, E. (2022). Bacterial community associated with the ambrosia beetle *Platypus cylindrus* on declining *Quercus suber* trees in the Alentejo region of Portugal. *Plant Pathology*, 71(4), 966-979. doi: 10.1111/ppa.13536.

[22] Resolution of the Cabinet of Ministers of Ukraine No. 977 "On Approval of the State Programme "Forests of Ukraine" for 2002-2015". (2009, April). Retrieved from https://zakon.rada.gov.ua/laws/show/581-2002-%D0%BF#Text.

[23] Sitz, R.A., Zerillo, M.M., Snelling, J., Caballero, J.I., Alexander, K., Nash, K., Tisserat, N.A., Cranshaw, W.S., & Stewart, J.E. (2018). Drippy blight, a disease of red oaks in Colorado, U.S., produced from the combined effect of the scale insect *Allokermes galliformis* and the bacterium *Lonsdalea quercina* subsp. *quercina*. *Arboriculture & Urban Forestry*, 44(3), 146-153.

[24] Sydorenko, S., Voron, V., Koval, I., Sydorenko, S., Rumiancev, M., & Hurzhii, R. (2021). Postfire tree mortality and fire resistance patterns in pine forests of Ukraine. *Central European Forestry Journal,* 67(1), 21-29. doi: 10.2478/forj-2020-0029.

[25] Voloshchuk, N.M., Bilous, V.M. (2012). Epiphytic and endophytic mycobiota of *Quercus robur* L. acorns for different storage conditions. *Scientific Bulletin of National Technical University of Ukraine*, 22(10), 29-35.

Вплив способів зимового зберігання жолудів на розвиток та ростові процеси дуба звичайного

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Анотація. Господарська цінність та біологічна стійкість насаджень дуба звичайного (*Quercus robur* L.), вирощених із жолудів є вагомо вищою у порівнянні із насадженнями порослевого походження. Тому, актуальним та перспективним є вирощування дубових насаджень із жолудів, особливо там, де відсутнє природне відновлення дуба. Метою дослідження було удосконалення технології насінництва та вирощування високоякісного садивного матеріалу дуба звичайного насінням при різних способах зимового зберігання для розширення площ дубових лісів. Під час наукового дослідження використано лісокультурні (встановлення показників якості жолудів, садивного матеріалу та лісових культур), біометричні (визначення показників росту та маси садивного матеріалу), та класичні статистичні методи дослідження. Дослідження проводили на території лісового фонду Герцаївського держспецлісництва та Кузьмінського лісництва філії «Чернівецьке лісове господарство» державного спеціалізованого господарського підприємства «Ліси України. Показано, що кожен із зимових способів зберігання жолудів дуба звичайного має свої переваги і недоліки, які у більшій чи меншій ступені проявляються при різних методах

вирощування. В результаті порівняння впливу різних методів вирощування на розвиток рослин дуба звичайного, вирощеного із насіння, що зберігалося траншейним способом, було встановлено, що найкращі ростові параметри надземної частини рослин спостерігалися при використанні методу шпигування. Проте, найменш інтенсивний розвиток кореневої системи спостерігався при вирощуванні дуба з закритою кореневою системою. Виявлено, що середньозважені біометричні показники ростових процесів рослин дуба звичайного, вирощеного із насіння, яке зберігалося у проточній воді, були найвищими при вирощуванні методом шпигування жолудів. Доведено, що дослідні рослини дуба звичайного, вирощеного із насіння, яке зберігалося у погребі із піском відставали у розвитку надземної частини при вирощуванні методом шпигування. З'ясовано, що коренева система розвивалась найгірше при вирощуванні рослин із відкритою кореневою системою. Запропонована технологія зберігання жолудів може бути застосована для підвищення ефективності та якості відтворення дубових насаджень лісогосподарськими підприємствами України

Ключові слова: *Quercus robur* L.; насіннєвий матеріал; сіянці; коренева система; надземна частина; лісовідтворення

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