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TREE SPECIES BIODIVERSITY IN SMALL UKRAINIAN TOWNS

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Abstract

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Biodiversity is one of the important indicators of ecosystem sustainability, which is less studied in relation to urban areas, particularly Ukraine, and even more so in small towns. Taking the example of three small Ukrainian towns, the biodiversity of tree species is compared in the article. The studied small towns are located in two geographic zones, mixed forests (Polissya) and forest-steppe, and administratively, in Chernihiv and Kyiv regions. An inventory of trees in the residential area of Ukrainka, in the central streets of Novhorod-Siverskyi, as well as in the central part and all streets of Vyshhorod was conducted. Thus, the species richness of trees both between the studied towns and between its central part and the whole territory of the town was compared. The species structure of tree plantings in terms of richness, diversity, dominance, alignment, and similarity was assessed. The obtained results were subjected to cluster and correlation analysis. It was found that the greatest diversity is characteristic for the dendroflora of the whole territory of Vyshhorod, which is the fastest growing town, located closest to the capital. The dendrofloras of small towns were quite similar to each other. The values of similarity indices varied in a wide range: Jacquard's index from 0.26 to 0.56 and Sørensen index from 0.41 to 0.66. The lowest degree of similarity was found with the dendroflora of the most distant Novgorod-Siverskyi town. Mainly the urban plantings require enrichment of the tree species composition, taking into account their resistance to anthropogenic impacts and climate change.

Key words: tree plantings, species richness, similarity coefficient.

Introduction

High species diversity is a necessary condition for maintaining the forest multifunctionality and increasing most of its functions (Sanaei et al., 2021) such as promoting productivity in forests (Morin et al., 2011), correlating with carbon stocks (Baul et al., 2021; Sintayehu et al., 2020; Wakhidah et al., 2020), potentially increasing the resilience of green plantations to disturbances and stresses, including drought (Palandrani et al., 2020), and reducing damage caused by insects and pathogens (Wang et al., 2021).

Currently, there is a growing interest in urban forests and their levels of biological diversity (Freitas et al., 2020; Falfán, MacGregor-Fors, 2021). However, there is no clear idea of the richness of tree species in cities, which may be higher than in natural forests (Gillespie et al., 2017).

Cities can be important sites of local and regional biodiversity, and biodiversity is adapted to human settlements in different ways (Bastian et al., 2020). Therefore, the choice of appropriate biodiversity assessment methods for practical purposes in city planning and decision-making is still a challenging problem.

The assessment of the state of plant communities is based on important indicators of diversity such as species richness index, species abundance, evenness index, dominance index, and diversity index (Grod, Shevchik, 2020). Species richness is a widely used surrogate for the more complex concept of biological diversity and is often central to ecological study (Hellmann, Fowler, 1999). Species richness is the easiest way to describe the diversity of communities and regions. Quantitative assessment of species richness is important not only for baseline comparisons, but also for addressing the saturation of local communities. Maximum increase in species richness is often the goal of conservation research, as well as the background of the rate of species extinction (Gotelli, Colwell, 2001). The terms «species richness» and «species diversity» are sometimes used interchangeably (Spellerberg, Fedor, 2003).

Species richness is an incomplete surrogate for diversity (Wilsey et al., 2005). The key difference between species richness and species diversity is that species diversity has two components, namely, species richness and species evenness, whereas species richness is a part of species diversity (Bock et al., 2007). Species richness and species diversity are two important measures in a particular region that give clear inference about the biodiversity of that region. Species diversity gives the number of species and the number of individuals in each species and compares them to measure the relative abundance of each species.

An obvious way to describe the composition of communities is diversity in terms of the number and abundance of species (Curado et al., 2020). Measurements of species diversity based on relative abundance as well as richness may be needed in studies on the conservation and functioning of ecosystems (Wilsey et al., 2005). The higher the diversity of a community, the greater the number of species in it and the higher its evenness.

Biodiversity can be quantified using evaluators whose effectiveness is still poorly defined. More than 40 indices have been

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proposed to assess biodiversity. Most of the differences between biodiversity indices are the importance they give to uniformity and species richness. The combination of species richness and abundance could be considered as the most important index for studying plant species diversity (Niu et al., 2017). More often, for the quantitative description of species diversity of groups, calculations are performed using generally accepted indices in ecology such as Shannon's species diversity, Simpson's dominance and diversity, Margalef species richness, and Piel's uniformity (Grod, Shevchik, 2020; Magurran, 2004). Other indices such as Berger–Parker index are seldom used in describing forest community attributes with species diversity indices (Yeom, Kim, 2011).

The Shannon index is the most commonly used index of species diversity. The Simpson index has the least offset, and the Shannon index shows a smaller relative root mean square error, even if the sample size is small (Pesenko, 1982). Shannon and Pielou estimates are sensitive to changes in species numbers and give a significant systematic error for small samples (Leprêtre, Mouillot, 1999). However, all estimates show better results than the number of species (Wei et al., 2010). The impact of sampling on the work of an appraiser is an important aspect to consider when selecting appraisers for environmental research.

Species richness estimation is one of the most widely used analyses carried out by ecologists, and nonparametric estimators are probably the most used techniques to carry out such estimations. It was found that nonparametric estimators are not suitable to estimate species richness in tropical forests, where sampling intensity is usually low and richness is high. The log series, while also requiring substantial sampling, is much more effective in estimating species richness than the commonly used nonparametric estimators, and its assumptions better match the way field data is being collected (ter Steege et al., 2017)

Combining richness and abundance into a single diversity index using matrix analogs of Shannon's and Simpson's indices was suggested (Keylock, 2005). Modifications of the Shannon and Simpson indices make it possible to compare the biodiversity of communities. However, matrix diversity indices will never answer all questions about diversity. Biology has yet to dictate the interpretation of these indicators.

Understanding the richness of plant species in cities is a priority for urban vegetation management and biodiversity conservation. The assessment of the difference between street trees and shrubs by the Sørensen dissimilarity index reflects the role that citizens and local authorities play in the configuration of the species composition of street trees and shrubs (Falfán, MacGregor-Fors, 2021).

Weak development of the general theory of diversity measures and the methodology of their practical application makes it difficult to make an informed choice of indicators to measure the diversity of the studied ecosystems.

The choice of one or another index usually does not have objective criteria. However, from a theoretical point of view, they can be subject to a number of requirements (Pesenko, 1982). That is why the works aimed at comprehensive comparison of different indices in terms of compliance with specific data are of particular interest (Shitikov, Rozenberg, 2005).

Cities are important objects of local and regional biodiversity. It is very important to assess the current state of biodiversity in cities in order to draw appropriate conclusions for planning and management (Bastian et al., 2020). Selection of suitable biodiversity assessment methods for practical purposes in urban planning and decision-making is still a complex issue.

This article is part of a series of scientific studies of the dendroflora of the world's most widespread and least studied category of cities, namely, small towns. Our previous articles have already covered the issues of green space systems of small towns, the characteristics of tree plantations, and biometric indicators of woody plants. This is the first time we have assessed the biodiversity of tree plantations in small towns.

The objectives of the study were as follows: 1) definition and quantification of biodiversity and similarity of dendroflora of small towns taking the example of three small Ukrainia towns; 2) comparison of the obtained values with similar indicators of biodiversity of large cities (according to references) and 3) attempt to analyze the interchangeability of biodiversity indicators in order to rationally use them in practice.

Material and methods

Small towns (according to the Ukrainian classification, small cities are towns with a population of up to 50,000 inhabitants) make up more than 75% of the total number of Ukrainian cities and are the least studied category. The research was carried out in tree plantings of three small Ukrainian towns: Ukrainka (Kyiv oblast, forest-steppe zone), Vyshhorod (Kyiv oblast, mixed forests [Polissya] zone), and Novhorod-Siverskyi (Chernihiv oblast, mixed forests [Polissya] zone). To compare the diversity of tree species of urban ecosystems, an inventory of trees was conducted in the central part of these small towns: Ukrainka, Vyshhorod, and Novhorod-Siverskyi (Fig. 1).

The characteristics of tree plantings in these towns were presented earlier (Zibtseva, 2012, 2014a,b; Zibtseva, Zakharov, 2015). Among the studied towns, Vyshhorod town is economically more developed due to its proximity to the capital (Kyiv) and having a population twice as large (more than 27,000) compared to two other towns (Table 1).

The studied cities Vyshhorod and Novhorod-Siverskyi are historical towns; at the same time, Vyshhorod and Ukrainka are similar towns in terms of economic profile (they are energy towns). All three towns have similar geomorphologic characteristics as they are located on the right high bank of rivers: Vyshhorod and Ukrainka on the Dnieper river and Novhorod-Siverskyi on the Desna river. The modern green space systems of all three towns were created at about the same time, after World War II. In Novhorod-Siverskyi, there is a park with an area of 10.0 ha; in the other two towns, there are no parks (according to Ukrainian standards, parks are landscaped public green areas with an area of more than 2.0 ha).

The model plots were the entire residential part of Ukrainka town (including streets), the streets of the central part of Novhorod-Siverskyi town and Vyshhorod downtown (including streets), and also, all streets of Vyshhorod town. Street trees were defined as trees either found on the road verge located between the street and the sidewalk, or, in the case where there was no sidewalk, located between the curb and private residential properties (Nitoslawski, 2016). The survey and valuation of the model sites was carried out by the route method, while taking into account all the available trees. An inventory of green spaces in small Ukrainian cities has never been conducted, and currently, there is no data on their quality. Therefore, this study was based

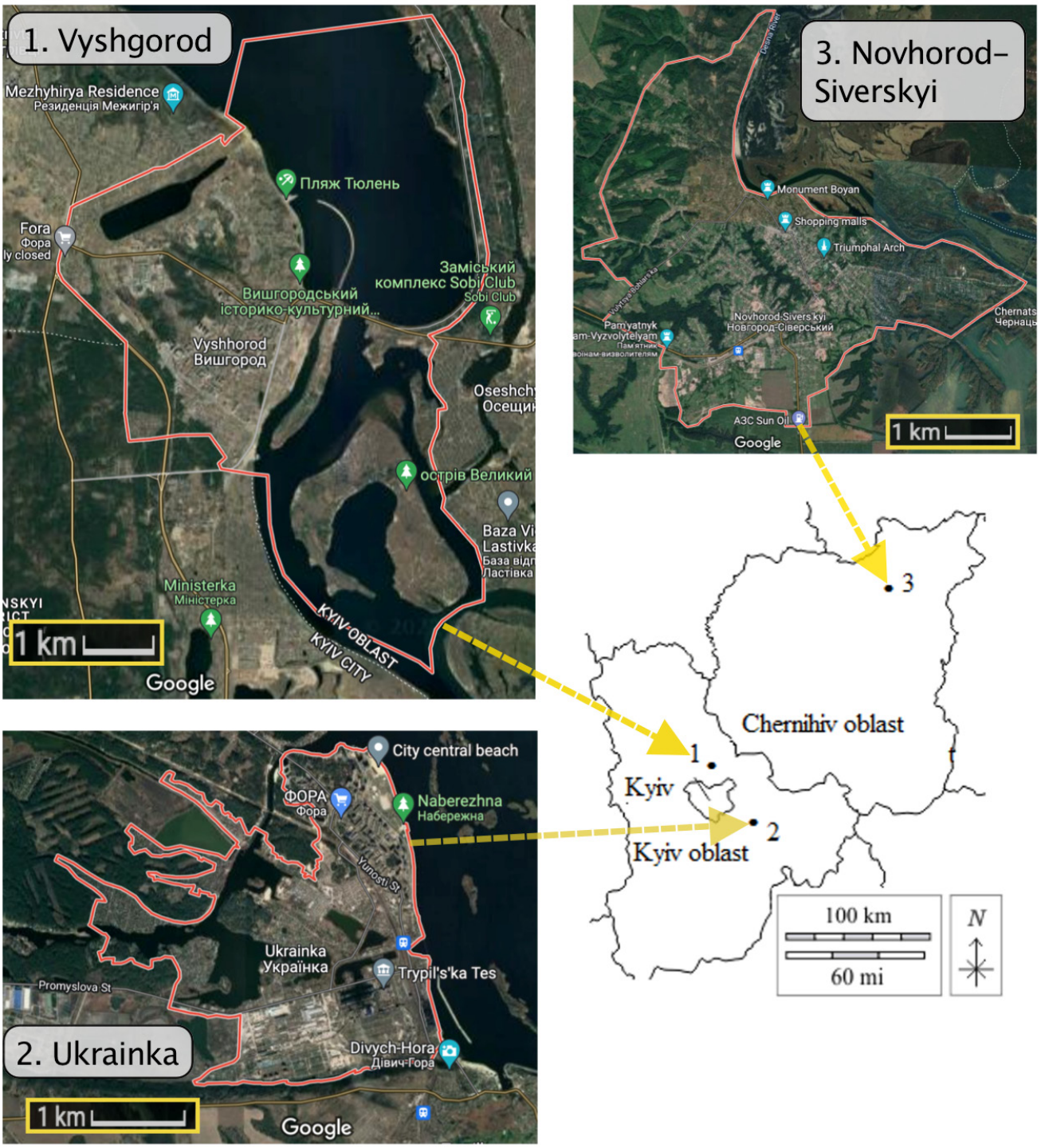


Fig. 1. Schematic location of the studied small towns: 1 – Vyshhorod; 2 – Ukrainka; 3 – Novhorod-Siverskyi.

on our inventory of greenery (conducted in 2012–2015). The species composition of dendroflora in the research plot of each town was determined. The number of surveyed trees and shrubs in the study areas ranged from 266 (Vyshhorod downtown) to 1911 (Ukrainka).

The analysis of the species structure of the community of woody plants was carried out using generally accepted quantitative indicators. The share of tree species in plantations was calculated as the ratio of the number of stems of each species to the total number of surveyed tree plants in the plot. When analyzing the data obtained, the indices of species richness (including the average number of species – Zhivotovsky index and the proportion of rare species, Margalef richness, Menchinik richness), indices of species diversity (Simpson diversity, Shannon diversity), indices of dominance (Berger–Parker dominance, Simpson dominance), and indices of evenness (Shannon–Pielou evenness,

Table 1. Characteristics of researched towns.

Town	Year of foundation	Distance to Kyiv, km	Area, ha	Population, thousand	Landscapinlevel, %
Vyshhorod	946	20	874.1	27.8	Over 40
Ukrainka	1967	38	907.5	15.5	Near 20
Novhorod-Siverskyi	980	320	1200. 0	15.0	Over 50

Table 2. Biodiversity indicators and formulas for their calculation.

	Index	Formula
Richness	Margalef (D_{Mg})	$D_{Mg} = (S - 1)/Ln\ N$
	Menchinik (D_{Mn})	$D_{Mn} = S/\sqrt{N}$
Average number of species	Zhivotovsky (μ)	$\mu = (\Sigma \sqrt{p_i})^2$
	Share of rare species (h)	$h = 1 - \mu/S$
Diversity	Simpson (C)	$C = 1/\Sigma p_i^2$
	Shannon (H¢)	$H¢ = -\Sigma(p_i \cdot Ln\ p_i)$
Dominance	Berger–Parker (d)	$d = N_{max}/N$
	Simpson (D_{Sm})	$D_{Sm} = \Sigma p_i^2$
Evenness	Shannon–Pielou (E_p)	$E_p = H¢/Log\ S$
	Simpson (E_{Sm})	$E_{Sm} = 1/S\Sigma\ p_i^2$
Similarity	Jaccard's (K_j)	$K_j = c/(a + b - c)$
	Sørensen–Chekanovsky (K_s)	$K_s = 2c/(a + b)$

Notes: S – the number of species; N_i – the number of specimens of the species; N – the total number of all species; $p_i = N_i/N$ – relative abundance of the species; N_{max} is the number of specimens of the most abundant species; a – number of species in object 1; b – number of species in object 2; c – number of common species in both objects.

Simpson evenness) were determined. In this study, to obtain more reliable results, 10 different species diversity indices were used for comparative estimation. In addition, similarity indices were calculated (Jaccard's coefficient of community, Sørensen–Chekanovsky similarity index) (Table 2).

Similarity coefficients are used to assess floristic similarity. The Jaccard's coefficient is more convenient for comparing habitats with a high degree of similarity, and the Sørensen–Chekanovsky coefficient, which is more often used in biogeographic studies, is more convenient to compare habitats with a very low value of similarity. Jaccard's coefficient has the greatest mathematical correctness, and using Sørensen–Chekanovsky coefficient does not have any advantages over it.

The obtained data were subject to clustering in the Statistica 10 (StatSoft) program with the construction of dendrograms and the k-means method.

When calculating the indices, all woody plants growing in each investigated model plot were taken into account.

In the absence of domestic analogs, data from studies of the dendroflora of large cities, parks, and other sites of different countries were used to compare the biodiversity of the dendroflora of small towns.

Results

All dendroflora in the model plots of studied small towns was represented by 54 species of woody plants. The number of tree species in each of the studied towns differed markedly and varied from 20 (Novhorod-Siverskyi town) to 35 (Vyshhorod town) (Table 3).

The most widespread tree species in the towns were *Tilia cordata* Mill. and *Aesculus hippocastanum* L. Six species were common for all studied territories, which were *A. hippocastanum*, *Tilia cordata*, *Acer platanoides* L., *Betula pendula* Roth., *Prunus armeniaca* L., and *Thuja occidentalis* L. As a rule, these species are dominant in towns.

The number of common species for the Ukrainka town were as follows: with Novhorod-Siverskyi – 10, with Vyshhorod downtown – 12, and with the entire Vyshhorod – 18. Fifteen common species between Novgorod-Seversky and the Vyshgorod town and also with the Vyshhorod downtown were identified.

The relatively dominant species of trees were *Tilia cordata* (45.2%) and *Aesculus hippocastanum* (38.0%) in Novgorod-Seversky town; *Populus nigra* var. *pyramidalis* (20.3%), *Tilia cordata* (12.0%) and *Aesculus hippocastanum* (10.5%) in Vyshhorod downtown; *A. hippocastanum* (17.5%), *Tilia cordata* (13.6%), and *Betula pendula* (11.8%) in the entire Vyshgorod; and *Acer saccharinum* L. (15.6%), *Pinus sylvestris* L. (11.7%), and *P. nigra* var. *piramidalis* Spach. (11.4%) in the Ukrainka town. These data fully correspond to the values of the dominance (Berger–Parker index) for the dendrocommunities of the studied towns, which expresses the relative significance of the most abundant species.

The greatest dendrological similarity was observed using both the Jaccard's coefficient and the Sørensen–Chekanovsky coefficient, naturally, between the center of Vyshhorod and the whole of Vyshhorod town, as well as between the centers of Vyshgorod and Novhorod-Siverskyi towns (Table 4).

The least similarity (0.26 and 0.27) was found between Ukrainka town and the centers of Vyshgorod town and also Novhorod-Siverskyi town.

Table 3. List of tree species occurring in the studied small Ukrainian towns.

Scientific name of the tree species	Availability of tree species (+/-)			
	Ukrainka	**Novhorod-Siverskyi**	**Vyshhorod downtown**	**Vyshhorod**
1	2	3	4	5
Betula pendula Roth.	9.8	+	+	11.8
Aesculus hippocastanum L.	6.9	38	10.5	17.5
Tilia cordata Mill.	+	45.2	12	13.6
Acer platanoides L.	+	+	+	+
Prunus armeniaca L.	+	+	+	+
Thuja occidentalis L.	+	+	+	+
Acer pseudoplatanus L.	15.6	-	+	7
Populus nigra var. *pyramidalis* Spach.	11.4	-	20.3	9.4
Tilia platyphillos Scop.	+	-	+	+
Salix alba L.	+	-	+	+
Populus nigra L.	-	+	+	+
Sorbus aucuparia L.	-	+	+	+
Prunus cerasus L.	-	+	+	+
Pyrus communis L.	-	+	+	+
*Syringa vulgar*is L.	-	+	+	+
Prunus domestica L.	-	+	+	+
Morus alba L.	+	+	-	+
Malus domestica Borkh.	-	+	+	+
Juglans nigra L.	+	+	-	-
Spiraea vanhouttei Zab.	15.6	+	-	-
Picea pungens L.	+	-	+	-
Acer platanoides f. "Globosa"	-	-	+	+
Picea abies (L.) Karsten	-	-	+	+
Robinia pseudoacacia L.	+	-	-	+
Juglans regia L.	-	-	+	+
Acer negundo L.	-	-	+	+
Quercus robur L.			+	+
Picea pungens Engelm. f. glauca			+	+
Forsythia suspensa (Thunb.) Vahl.	+	+	-	-
Acer tataricum L.	-	-	+	+
Buxus sempervirens L.	+	-	+	-
Parthenocissus quinquefolia Planch.	+	-	+	-
Elaeagnus commutata Bernh. ex Rydb.	-	-	+	+
Rosa canina L.	-	+	+	-
1	2	3	4	5
Pinus sylvestris L.	11.7	-	-	-
Quercus rubra L.	+	-	-	-
Juniperus sabina L.	+	-	-	-
Prunus pissardi Carr.	-	-	-	+
Picea glauca Moench.	+	-	-	-
Fagus sylvatica L.	+	-	-	-
Fraxinus excelsior L.	+	-	-	-
Platycladus orientalis (L.) Franco.	-	-	+	-
Ulmus laevis Pall.	-	-	-	+
Acer campestre L.	-	-	-	+
Sambucus nigra L.	-	-	-	+
Prunus cerasifera Ehrh.	-	+	-	-
Alnus glutinosa (L.) Gaertn.	-	-	-	+
Acer saccharinum L.	+	-	-	+
Berberis thunbergii DC.	-	-	+	+
Cornus mas L.	-	-	+	-
Robinia viscosa Vent.	-	-	-	+
Carpinus betulus L.	+	-	-	-
Ulmus glabra Huds.	-	+	-	-
Spiraea media f. Schmidt.	+	-	-	-
Total number of stems	1911	305	266	668
Total number of species	27	20	32	35

Note: Numbers indicate relative abundance (based on stem count) of species in the town.

Table 4. The similarity indices values between the tree species populations of the small towns.

Towns	Ukrainka (A)	Novhorod-Siverskyi (B)	Vyshhorod downtown (C)	Vyshhorod all over the town (D)
Jaccard's coefficient of community				
A	1	0.27	0.26	0.35
B	0.27	1	0.40	0.38
C	0.26	0.40	1	0.56
D	0.35	0.38	0.56	1
Sørensen–Chekanovsky similarity index				
A	1	0.43	0.41	0.61
B	0.43	1	0.58	0.55
C	0.41	0.58	1	0.66
D	0.61	0.55	0.66	1

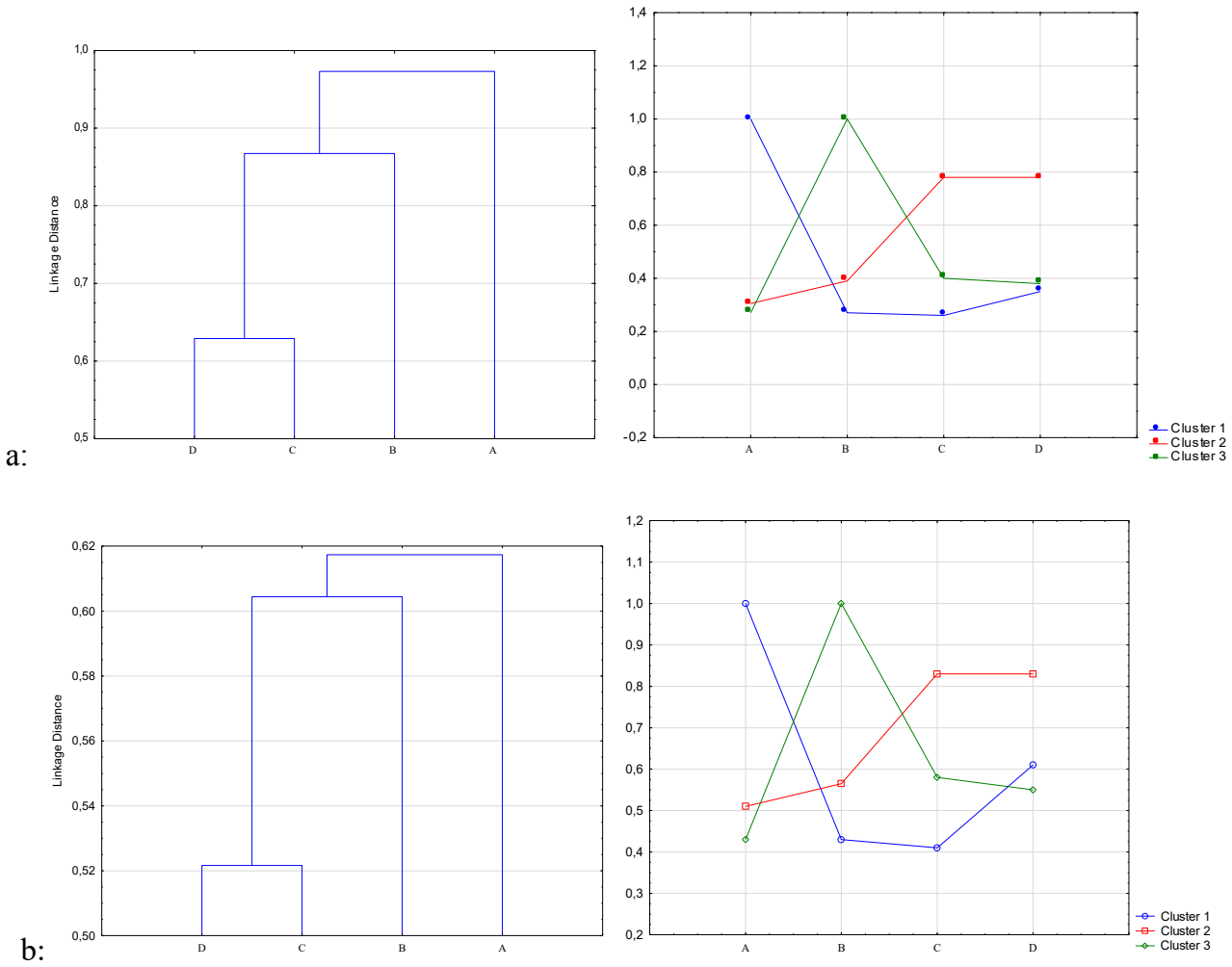


Fig. 2. (a,b) Dendrograms of similarity and graphs of averages for towns clusters (k-means method): (a) by the Jacquard's coefficient and (b) by the Sørensen–Chekanovsky index. The designations of the model plots in the figure are identical to those in Table 2.

Cluster analysis of the obtained values of the similarity coefficients of Jacquard's and Sørensen–Chekanovsky (Figs 2a,b) divided the model objects into three clusters: cluster 1 – Ukrainka (A); cluster 2 – Novhorod-Siverskyi (B); and cluster 3 – Vyshhorod (D) and Vyshhorod downtown (C).

According to the variance for k-means analysis, the difference was significant (P = 0.0493) only for Novhorod-Siverskyi town by the Sørensen–Chekanovsky similarity index.

We often prefer to characterize the diversity aspects separately: the richness with the Margalef or Menchinik index and

Table 5. Species richness and biodiversity of woody plants in small towns.

Index		Town			
		A	B	C	D
Total number of species	S	27	20	32	35
Total number of specimens	N	1911	305	266	668
Richness	D_{Mg}	3.31	3.32	5.55	5.23
	D_{Mn}	0.59	1.14	1.96	1.35
Average number of species	μ	18.12	16.83	22.24	20.88
	H	0.30	0.16	0.30	0.40
Diversity	C	11.1	2.63	11.1	11.1
	H¢	2.65	2.38	2.63	2.71
Dominance	D	0.15	0.45	0.20	0.17
	D_{Sm}	0.09	0.36	0.09	0.09
Evenness	E_{Sm}	0.41	0.14	0.35	0.32
	E_p	0.56	0.20	0.53	0.53

the complexity with the evenness indices. Species richness indices make it possible to estimate how many species are there in the total number of individuals. The highest values of the species richness indexes were characteristic for the downtown of Vyshhorod (5.55 Margalef index and 1.96 Menchinik index), and with an increase in the sample and coverage of most of the town, the value of the indices was decreased (Table 5).

The Menchinik index, which is recommended for comparing collections of different sizes, was also the highest for Vyshhorod downtown. The minimum Menchinik index value (0.59) was typical for Ukrainka town.

The smallest average number of species was typical for Novhorod-Siverskyi town (16), and a slightly higher value of Zhivotovsky index (18) was typical for Ukrainka town. With the expansion of the studied urban area (in Vyshhorod town), the number of species was increased (from 32 to 35), but the average number of specimens of each species was decreased (from 22 to 20). Since a decrease in the share of rare species by Zhivotovsky index indicates an increase in the leveling of communities (Gelashvili et al., 1999); the plantings in Novhorod-Siverskyi town can be considered as the most leveled. The evenness of the plantings in Ukrainka town and in Vyshhorod downtown was the same, and under increased scope of the researched plot of the town, it decreased (the value of the Shannon Index increased to 0.40).

Species diversity indices also take into account the abundance of each species. The Simpson index gives more weight to aboriginal species. The Shannon index is the most popular in assessing diversity data. The Shannon index practically does not depend on the sample size and gives weight to rare species. This index characterizes the importance of rare introduced species (Gelashvili et al., 1999). The values of the Simpson index and Shannon index were minimal for Novhorod-Siverskyi town (2.63 and 2.38, respectively).

For an in-depth assessment of biodiversity, indices based on the relative abundance of species are used – heterogeneity indices or dominance indices that take into account both evenness and species richness. Dominance measures focus on the abundance of common species. The Simpson index gives more weight to common species and characterizes the "concentration" of dominance (Gelashvili et al., 1999). The best measure of diversity, the Berger–Parker index, expresses the relative relevance of the most abundant species: an increase in its value means a decrease in diversity and an increase in the degree of dominance of one species. Only the share of the dominant species is taken into account for calculating that dominance index.

High index value means that one species dominates in tree plantations and it is necessary to take measures to enrich the species composition. This is especially true for Novhorod-Siverskyi town. Apparently, ideally, according to the Santamour's 10–20–30 rule, this index value should not exceed 0.10 for urban plantings. Therefore, Berger–Parker index value is necessary for assessing the potential sustainability of tree plantations. The Simpson dominance index was less sensitive and practically equal for the other three cases.

Evenness indices (uniformity of species distribution) show the relative distribution of individuals among species. The most widely used measure of species spectrum evenness is the Pielou index. Low leveling, judged by the Pielou index, was typical for Novgorod-Seversky (0.20; it indicates that tree species are unevenly distributed and shows an imbalance, with the presence of taxa sharply differing in the number of individuals), while for the other three cases, it was average (0.53–0.56). In all cases, evenness indices were far from 1, which indicates that species are characterized by unequal abundance at all researched sites.

All indexes have their own specifics. The Simpson index gives relatively little weight to the rare species and more weight to the common species (Yeom, Kim, 2011). A higher value of the Simpson dominance measure (Simpson index) for Novhorod-Siverskyi (0.36) indicates the presence of species with a large number of individuals and an imbalance in favor of the abundance of a small number of species. In other cases, the shares of individual taxa were more evenly distributed. Lower values of the Margalef index for Novhorod-Siverskyi and Ukrainka indicate a relatively small number of species against the background of a relatively large number of individuals. The advantage of the Shannon index is its complexity, since it takes into account both the number of species (species density) and their evenness. Its lowest value is characteristic of the green spaces of Novhorod-Siverskyi town.

With the division of towns based on their diversity into two clusters, cluster 2 consists of only Novhorod-Siverskyi town. Analysis of variance revealed that towns significantly differ by

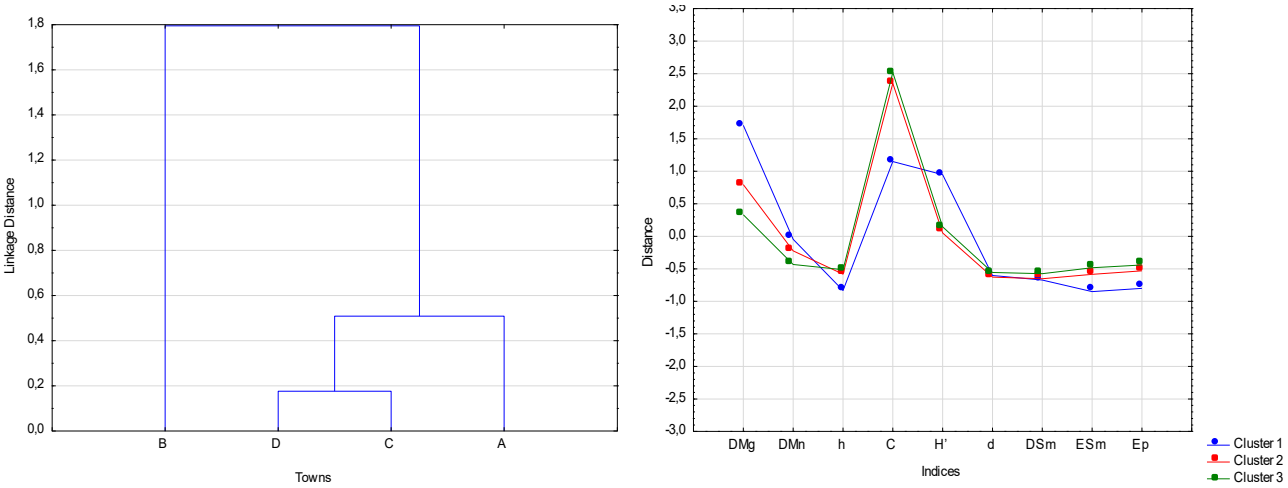


Fig. 3. Dendrograms of diversity and graphs of averages (k-means method) for town clusters by diversity index values. The designations of the model plots in the figure are identical to those in Tables 1 and 2.

C, E_{Sm}, D_{Mg}, and H¢ (P = 0.023–0.044). When dividing towns by diversity indicators into three clusters, cluster 1 consists only Ukrainka town, cluster 2 includes Vyshhorod downtown (C) and the entire Vyshhorod (D), and cluster 3 also consists of only Novhorod-Siverskyi town (Fig. 3). The values of several indices were highly correlated (Table 5).

A high degree of correlation (0.82–0.99) was found, as a rule, between six indicators out of 11. In particular, correlation was found between Berger–Parker index (d) and the number of species (S), the Simpson's index (D_{Sm}), the Simpson evenness index (E_{Sm}), the Shannon–Pielou evenness index (E_p), the Shannon diversity index (H¢), and the share of rare species (h).

Discussion

Street tree diversity has been assessed at a variety of geographic levels. It has most commonly been assessed at the level of the individual municipality (Cowett, Bassuk, 2017). Sjöman et al. (2012) assessed street tree diversity in 10 Nordic cities, and Kendal et al. (2014) assessed global street tree diversity from 108 cities in six continents.

The study of the urban center allows inter-city comparison, independent of their size (Dobbs et al., 2013). Species composition of the urban forest of Melbourne city center, which was analyzed using the Shannon–Wiener and Jaccard's similarity indices, showed that the urban forest is rich in species (2.9) and is dominated by native species (Table 5). In our studies, the value of the Shannon diversity index ranged from 2.38 (Novhorod-Siverskyi) to 2.71 (Vyshhorod), which also indicated that the studied small towns are quite rich in tree species. Although the species diversity in the center of Vyshhorod is quite high, nevertheless, it is somewhat lower than the species diversity of larger urban area.

Studies of various ecosystems of St. Petersburg (Kovyazin, Belyaeva, 2008) showed that the tree species composition differed significantly by all parameters. Street plant communities were usually monocultural. At the same time, many indicators' values were close to those obtained by us: species richness according to the Margalef index (2.52–5.9), Simpson species diversity index (4.53–11.55), Simpson dominance index (0.09–0.22), and share of rare species (0.19–0.39). Shannon index fluctuated within 1.90–2.62, Pielou evenness index was within 0.72–0.85, and the average number of species by Zhivotovsky was 8.15–15.89 (Table 6).

In our studies, the species richness did not show such low values and the evenness index values had a wider range. The species richness by the Margalef index in the sanitary zones of industrial enterprises in Zaporozhye city was significantly lower (1.49–3.68) (Sklyarenko, Bessonova, 2019). In all the studies, deficiencies were found in street tree diversity on using a variety of metrics (Cowett, Bassuk, 2017).

In the peri-urban and urban forests of southeastern USA, the Shannon species richness index was 2.3 and 3.2, respectively (Blood et al., 2016), in the parks of Bangalore (India), it was from 0.9 to 1.1 (Nagendra, Gopal, 2009), in Pavlovsky Park of St. Petersburg, it ranged from 2.41 to 3.73 (Kovyazin et al., 2017), in the parks of Zaporozhye, it was from 3.76 to 4.21 (Chongova, 2013), and in the sanitary zones of industrial enterprises in Zaporozhye city, it was 0.432–1.181 (Sklyarenko, Bessonova, 2019) (Table 7).

Naturally, the species richness of trees in parks was higher than in the streets or industrial areas of cities. At the same time, the urban forest in the towns studied by us had a lower species diversity than the urban forests of the USA and was characterized by a high dominance of several tree species.

Comparisons with other studies have shown that the Margalef richness index is more commonly used to assess the richness of tree species in urban areas. The values of this index obtained by us were comparable and higher than those for the sanitary protection zone of industrial enterprises in Zaporozhye and fluctuated within narrower limits than the values for St. Petersburg. The Pielou evenness index is used much less frequently in research and our figures for small towns were lower. In many studies, the Simpson diversity index probably calculated the Simpson dominance index or the Simpson similarity index, which complicates comparisons. The most widely used index for assessing the dendroflora biodiversity of cities, and therefore suitable for comparison, is the Shannon diversity index.

Table 6. Correlation between diversity indices.

Values of indicators											
	S	**N**	**D_{Mn}**	**D_{Mg}**	**D_{Sm}**	**E_p**	**d**	**μ**	**h**	**H¢**	**E_{Sm}**
S	1.00	-0.01	0.45	0.85	-0.86	0.82	-0.82	0.89	0.95	0.91	0.66
N	-0.01	1.00	-0.82	-0.50	-0.42	0.49	-0.54	-0.32	0.24	0.40	0.64
D_{Mn}	0.45	-0.82	1.00	0.85	-0.14	0.07	0.00	0.78	0.15	0.10	-0.09
D_{Mg}	0.85	-0.50	0.85	1.00	-0.57	0.50	-0.46	0.97	0.65	0.58	0.30
D_{Sm}	-0.86	-0.42	-0.14	-0.57	1.00	-1.00	0.99	-0.72	-0.88	-0.97	-0.95
E_p	0.82	0.49	0.07	0.50	-1.00	1.00	-1.00	0.67	0.86	0.96	0.97
d	-0.82	-0.54	0.00	-0.46	0.99	-1.00	1.00	-0.62	-0.88	-0.97	-0.96
μ	0.89	-0.32	0.78	0.97	-0.72	0.67	-0.62	1.00	0.70	0.69	0.51
h	0.95	0.24	0.15	0.65	-0.88	0.86	-0.88	0.70	1.00	0.96	0.72
H¢	0.91	0.40	0.10	0.58	-0.97	0.96	-0.97	0.69	0.96	1.00	0.88
E_{Sm}	0.66	0.64	-0.09	0.30	-0.95	0.97	-0.96	0.51	0.72	0.88	1.00

Table 7. Diversity indices of tree species according to references.

City	Reference	Index	Value
Table 5. Species richness and biodiversity of woody plants in small towns	**Table 5.** Species richness and biodiversity of woody plants in small towns	**Table 5.** Species richness and biodiversity of woody plants in small towns	**Table 5.** Species richness and biodiversity of woody plants in small towns
		Simpson diversity	4.53–11.55
		Simpson dominance	0.09–0.22
		Share of rare species	0.19–0.39
		Shannon diversity	1.90–2.62
		Pielou evenness	0.72–0.85
		Zhivotovsky average number of species	8.15–15.89
Eight large cities in the world	Galle et al. (2021)	Shannon diversity	2.83 ± 0.46
		Simpson diversity	0.85 ± 0.09
Eight southeastern cities, USA	Blood et al. (2016)	Shannon diversity	2.3–3.2
Halifax, USA	Nitoslawski (2016)	Shannon diversity	1.26–2.66
		Simpson diversity	0.57–0.91
London, England		Shannon diversity	1.79–2.63
		Simpson diversity	0.68–0.91
Ibadan, Nigeria	Agbelade et al. (2016)	Shannon–Weiner diversity	3.35
		Pielou evenness	0.84
Melbourne, Australia	Dobbs et al. (2013)	Shannon–Weiner diversity	2.90
Streets of Aydin, Turkey	Kara (2012)	Shannon–Weiner diversity	2.05
		Simpson diversity	0.81
Streets of Grand Popo, Benin	Osseni et al. (2020)	Shannon diversity	3.61
		Pielou evenness	0.76
Parks of Bangalore, India	Nagendra, Gopal (2009)	Shannon richness	0.9–1.1
Pavlovsky Park, St. Petersburg, Russia	Kovyazin et al. (2017)	Margalef richness	2.41–3.73
Parks of Zaporozhye, Ukraine	Chongova (2013)	Shannon diversity	3.76–4.21
Sanitary protection zone of industrial enterprises in Zaporozhye, Ukraine	Sklyarenko, Bessonova (2019)	Margalef richness	1.49–3.68
		Shannon diversity	0.43–1.18
		Berger–Parker dominance	0.21–0.78
		Simpson diversity	0.08–0.53
		Jaccard similarity	0.09–0.68
		Sørensen similarity	0.16–0.81

Our Shannon diversity index values are similar to those in other cities, but on a smaller scale. In northern cities (St. Petersburg, Halifax, London) and in Aydin city, the Shannon diversity index values are slightly lower and in tropical cities (Ibadan city, central Melbourne), the values are higher.

Researchers have found that heterogeneity is higher in a community when there are more species and when the species are equally abundant. For both absolute and comparative estimates, the Simpson index turned out to be the most reliable (Yeom, Kim, 2011). However, no particular formula has a preeminent advantage; so, different authors have plausibly proposed different indices (Hill, 1973). Simultaneously, there is no justification for using a whole collection of indices because all of them share a similar responsiveness (Palaghianu, 2014). The most frequently measured aspect of diversity, species richness, was poorly correlated with other measures of diversity and was highly scale dependent (Chase et al., 2018). The Shannon index had a significant positive correlation with species richness and abundance and the index was not influenced by occasional species. The combination of species richness and abundance could be considered as the most important indexes for studying plant species diversity (Niu et al., 2017).

We obtained similar results. According to our data, the number of species (as opposed to the number of plants) was highly correlated with all indicators, except the Menchinik richness index. At the same time, richness indices were highly correlated (r = 0.85). According to these results, for practical purposes, among the of species richness indices, it is advisable to limit to the calculation of the Margalef richness index.

A higher correlation was found between the number of species and the Shannon diversity (0.91) and share of rare species (0.95) indices. Shannon diversity index showed the highest correlations (over 0.90) with the maximum number of indices (five). This study confirmed the numerous data obtained on this widely used biodiversity index. We believe that for the characteristic of the biodiversity of the dendroflora of a small town, it is sufficient to calculate the following indicators: the number of species, Margalef richness index, and Shannon diversity index. However, the Berger–Parker dominance index is also very convenient for the practical purposes of monitoring the quality of urban tree plantations, as it clearly demonstrates the compliance of urban tree plantations with the Santamuro rule 10–20–30. Similarly, to observe patterns, Kendal et al. (2014) showed that relative abundance of the most common taxon was a good predictor of diversity and could be a useful measure of diversity for urban forest managers.

Conclusion

The species richness and similarity of dendroflora of three small Ukrainian towns located in the mixed forests and forest-steppe zones were assessed for the first time. It was found that the similarity index values varied in a wide range: Jaccard's index from 0.26 to 0.56 and Sørensen index from 0.41 to 0.66. A high degree of similarity was obtained between the dendroflora of street plantings throughout Vyshhorod town and its center, which confirms the previous conclusions of scientists that the study of cities can to restrict by research of their centers. The lowest similarity was found with the dendroflora of Novhorod-Siverskyi town, the most distant from the capital and other studied towns. The relatively high degree of dendroflora similarity in towns is due to the large-scale planned landscaping of Ukrainian's settlements in the 60s of the last century using a limited number of tree species. As a rule, the highest indexes of species richness and diversity were obtained for Vyshhorod town, especially for its downtown. The lowest biodiversity was characteristic of Novhorod-Siverskyi town, which confirms the impact of local politics and economic capacity of communities on the state of the urban dendroflora.

We believe that indicators such as the number of species, the Margalef richness index, and the Shannon diversity index are sufficient to characterize the biodiversity of the small town's dendroflora. The Berger–Parker dominance index is also useful for the practical purposes of monitoring the quality of urban tree plantations, as it demonstrates the compliance of urban tree plantations with the Santamuro 10–20–30 rule.

We suppose that mostly, urban plantations of the studied small towns need to enrich the tree species composition, taking into account their resistance to anthropogenic impacts and climate change. Understanding the species composition in urban ecosystems can help develop strategies for sustainable green infrastructure formation. Such research in small towns can serve as a basis for policy development and balanced management of their tree plantations.

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