Ecological Questions 37 (2026) 2: 79–89 http://dx.doi.org/10.12775/EQ.2026.021

Representativeness of protected woody plant taxa in the Ukrainian Carpathians: a descriptive assessment based on inventory data

Serhii Popovych[1], Anatolii Tertyshnyi[2,*]

[1] Department of Landscape Architecture and Phytodesign, Education and Research Institute of Forestry and Landscape-Park Management, National University of Life and Environmental Sciences, Kyiv, Ukraine
[2] Department of Botany, Dendrology and Forest Tree Breeding, Education and Research Institute of Forestry and Landscape-Park Management, National University of Life and Environmental Sciences, Kyiv, Ukraine
* Corresponding author e-mail: tertyshnyy@nubip.edu.ua

Received: 26 September 2025 / Accepted: 16 February 2026

Abstract. The problem of biodiversity conservation is effectively solved by the mechanism of forming a geographically complete network of protected areas. Network optimization is based on the results of an analysis of its biodiversity representativeness. This area of research is relevant because the results of the analysis encourage the search and creation of new nature reserves. The aim of the study was to analyse the current state of representativeness of rare taxa of woody plants of the Ukrainian Carpathian nature reserve fund. The results of the analysis for this category of plants were conducted for the first time. It is based on the methodology of a systematic approach and differentiated assessment of the state of representativeness of the taxonomic composition. The basic principle of determining the degree of representativeness is quantitative. The greater the number of occurrences, the higher the degree of representativeness of taxa. The composition of taxa was obtained based on the results of their inventory. Fractions of the composition of taxa were distinguished by the criterion of their origin – natural, introduced. The first fraction is represented by *Pinus cembra* L., *Torminalis glaberrima* (Gand.) Sennikov & Kurtto (synonym: *Sorbus torminalis* (L.) Crantz), *Taxus baccata* L., which are most widely distributed in the nature reserve fund of the Ukrainian Carpathians. The highest indicators of the number of taxa of this fraction are characteristic of the central part of the Ukrainian Carpathians. The most representative species of the introduced and taxonomically richest fraction were *Thuja occidentalis* L., *Larix decidua* Mill. and *Picea pungens* Engelm. *Larix decidua* has the highest degree of representativeness in the categories of the nature reserve fund. The largest number of introduced taxa is concentrated in botanical gardens. The greatest concern is caused by taxa that are not found in the nature reserve fund (30 species). Or occur in one reserve locality. Therefore, identifying locations and creating new nature reserve territories is primarily necessary for these taxa. They have zero and the lowest levels of representativeness. These are mostly vulnerable, threatened, and endangered taxa.

Keywords: dendrorarities, natural species, introduced species, nature reserve fund.

1. Introduction

The level of development of the environmental protection industry is determined by the role of science in it. Modern environmental protection is characterized by a significant amount of scientific research. Most of it is focused on different types of ecosystems and species of biodiversity. In environmental science and practice, the direction of forming a geographically complete, categorically and ecosystemically balanced network of protected areas is considered

fundamental. Its development is based on the results of an analysis of the representativeness of protected biodiversity. It is the degree of representativeness that indicates the level of completeness and balance of the network. The results of the analysis of biodiversity representativeness encourage the expansion of existing, search for and creation of new protected areas. It will help to optimize their network. For example, American researchers (Aycrigg et al., 2013) evaluated the representativeness of protected area ecosystems and found that they are underrepresented at three levels of plant community organization. Therefore, it is recommended to increase the degree of representativeness of protective biosystems in the continental part of the USA from 10% to 39%. This increase is in line with the recommendations set by the Convention on Biological Diversity. This document recommends protecting 17% of terrestrial ecosystems. An optimized network will be a guarantee of reliable preservation of biodiversity, especially rare biodiversity.

Among the objects of representativeness analysis, there are still few special studies devoted to the rare arboreal diversity of nature conservation areas. The authors sought to fill this gap in knowledge. Therefore, the purpose of their research was to analyze the current state of representativeness of rare taxa of woody plants in the territories and objects of the Nature Reserve Fund (NRF) of the Ukrainian Carpathians (UK). Research on ancient forests is also relevant on this topic (O'Brien et al., 2021) and urban ecosystems (Sochacka et al., 2022).

In this area of research, fundamental botanical (florology, dendrology) and applied modern phytoconservation sciences, especially about forest conservation. It is mainly forests and other tree-morphic ecosystems of the earth's surface that form the lion's share of the phytostroma. They play a crucial role in the global functioning of the biosphere (Frankel & Soule, 1981; Global…, 1995). Preservation of arboreal diversity is impossible without the creation and support of a representative network of protected areas (Stoyanova et al., 2011; Médail et al., 2019; Hetman & Popovych, 2024). In Ukraine, such a network has had legal significance for a long time (Program…, 1994).

In the taxonomic aspect, a wide range of studies is inherent in the species level of dendrodiversity. Accordingly, the representativeness of rare natural (Medvedev & Iljenko, 2017) and exotic (Dzyba, 2021, 2022) taxa of woody plants was investigated. Also, at the species level, the issues of representative conservation of old trees are being considered quite widely (Lakićević et al., 2024; Tokarieva et al., 2024). A considerable cohort of works on the representativeness of individual rare genera of woody plants (Popovych, 2020; Tashev & Dzyba, 2023) and divisions is also reviewed, primarily the evolutionarily older and more vulnerable *Pinophyta* (Popovych & Pokotylova, 2020a; Popovych & Dzyba, 2022), to which most dendrorarities are attributed (The IUCN Red List…, 2025).

In Ukraine, systematic studies of the representativeness of rare taxa of woody plants in certain biogeographical regions are particularly important for the preservation of its dendrodiversity. Within this scientific direction, a team of researchers has analyzed different types of representativeness. The results of such analysis are presented in a series of monographs for the forest-steppe (Popovych et al., 2010; Stepanenko & Popovych, 2015), steppe (Popovych et al., 2013; Vlasenko & Popovych, 2016), mixed zone (Popovych et al., 2017; Savoskina & Popovych, 2019) and broad-leaved zone (Popovych et al., 2019; Miskevych & Popovych, 2019) of forests. An interregional comparative analysis of protected dendroflora was also carried out (Pokotylova, 2020; Popovych & Pokotylova, 2020b; Pokotylova & Popovych, 2021; Popovych et al., 2022). With this in mind, the UK region has been left out until now. Therefore, the priority of our evaluation was to determine the current state of representativeness of the two fractions of protected dendrorarities of this region.

To achieve the goal of the study, the task was to establish the degrees of occurrence of taxa in NRF categories and localities, as well as within four administrative regions of the UK. The results of the research revealed a number of plant species that are best and worst distributed, conserved, adapted and acclimatized in this region.

2. Materials and Methods

For different variants of flora analysis, the results obtained by the method of inventorying its taxa are used (Kagalo et al., 2022). The composition of taxa is used in the form of simple and annotated lists, abstracts, checklists, catalogs, identifiers (Tasenkevich, 1998; Mosyakin, 1999; Mosyakin & Fedoronchuk, 1999; Chopyk & Fedoronchuk, 2015). The methodology of the system approach and the traditional scenario of floristic analysis (Popovych et al., 2010, 2013, 2017, 2019, 2025) made it possible to obtain data for assessing the state of representativeness of rare taxa of woody plants of the NRF UK. The assessment of the composition of taxa at the level of fractions (flora subsystems) provided more objective results than the analysis of the structure of the entire Carpathian rare dendroflora. The smaller the hierarchical levels of the taxonomic system evaluated, the more detailed the evaluation results. This is the approach used in the presented assessment.

The abstracts of the fractions of rare protective dendroflora of the UK served as material for assessing the state of representativeness of taxa (Popovych et al., 2022). This publication is the result of the inventory of rare arboreal diversity (taxa and syntaxa) of the NRF of the Carpathian

region. Checklists of the fractions were compiled based on the results of 45 years of field research and a critical review of almost 95% of the specialized literature devoted to this region. The reliability of the data was confirmed by the number of reports on places of growth of rare taxa. Individual growths were specified on the ground and according to the oral reports of botanists. The entire taxonomic composition was critically revised before the synopsis was formed. About 10% of the collected taxa did not pass revision.

The work process of representativeness analysis covered several successive stages. First of all, taxa included in the red lists of international (Convention…, 1979; European Red List…, 1992; Information…, 2002; The IUCN Red List…, 2025), national (Red Data Book…, 2009), and administrative-regional (Andrienko & Peregrym, 2012) significance were selected from the abstracts. These taxa of different life forms (trees, shrubs, semi-shrubs, shrubs, semi-shrubs) were the object of research. Taxonomic nomenclature follows the Plants of the World Online database maintained by the Royal Botanic Gardens, Kew (POWO, 2025).

The second step was to clarify the status of taxa according to the criterion of their origin – natural and artificial (Popovych et al., 2010, 2013, 2017, 2019). The taxonomic composition of natural origin is exclusively indigenous to the UK. It is protected *in situ*. Introduced species represent the taxonomic composition of artificial origin. They include only those plant taxa that are protected in artificial eco-conditions (*ex situ*) by NRF UK.

The third step was to identify the frequency amplitude of the NRF plant species occurrence. For this, a list of protected localities with rare taxa was compiled. Then preventive selection of the most common taxa was carried out. Less common taxa were considered less representative (Popovych et al., 2010, 2013, 2017, 2019). Conventionally, the most widespread taxon was considered to be the one that belongs to:

1) at least four NRF categories (4 out of 11, 36%);
2) at least up to 10 protected localities (10 out of 1275 of all localities). The minimum more or less reliable level of preservation of a taxon is its presence in at least three protected localities from the selected 10 (30%);
3) two administrative regions (2 out of 4, 50%).

Why such threshold values? It has already been proven by many researchers that in conditions of large-scale degradation of ecosystems, at least 30% of natural lands and, accordingly, the composition of indigenous biodiversity should be preserved (Prendergast et al., 1999; Primask, 2002; European Commission, 2020). Undoubtedly, for reliability, it is necessary to have a higher percentage. According to the authors, the above-mentioned threshold values will ensure the minimum level of preservation of the existing rare dendrodiversity of the UK. Of course, these are conditional indicators, but they should be used in environmental protection practice.

Finally, based on three positions (categories, localities, regions), quantitative indicators of the representativeness of rare protected taxa of woody plants in the UK were derived. Undoubtedly, of these three positions, the number of protected localities plays a decisive role in obtaining values of representativeness of taxa. It is the guarantee of preservation. The more localities, the higher the guarantees of preservation. The analysis showed that usually a number of plant species simultaneously have a wide categorical amplitude (belonging to five to seven categories out of 11), but a narrow locality (present in less than 10 localities). Such plants were classified as uncommon.

The field of research was the NRF of the Zakarpattia region as a whole, as well as the Carpathian parts of the Ivano-Frankivsk, Lviv, and Chernivtsi administrative regions.

In the text, the rule of the first mention of the authors is applied in the places where taxon names are given. On the second mention, the authors of the species are not given.

3. Results and Discussion

The Ukrainian Carpathians are one of the smallest natural and geographical regions in Ukraine. Compared to large plain regions, it occupies an average position in terms of the number of rare taxa of woody plants in the NRF. These taxa are mostly restricted to foothill, low-mountain and high-mountain landscapes. The middle positions of the taxon ranking provide mesophytic types of ecosystems. Not only in the Carpathians, but also in the world, they are best represented by biodiversity due to their wide eco-amplitude. This is also facilitated by the highest percentage of regional nature reserves in Ukraine. It is natural that the best developed NRF networks (Zakarpattia and Ivano-Frankivsk regions) ensure the preservation of the largest number of rare natural taxa.

The results of inventory studies showed that the NRF UK is represented by 368 rare woody plant taxa of different geographical origins and status (Popovych et al., 2022). Comparison of this number with the results of similar regional studies showed the following rare dendrotaxonomic richness of the NRF biographical zones of Ukraine: forest-steppe 409 taxa (Popovych et al., 2010), steppe 407 (Popovych et al., 2013); mixed forests 179 (Popovych et al., 2017), broad-leaved forests 351 (Popovych et al., 2019). In this quantitative spectrum of taxa among the natural and geographical regions of Ukraine, UK occupies the third position in the ranking of rare taxa of woody plants.

Of the 368 taxa, the fraction of natural taxa of international, national and local levels of rarity is represented by 98 species

and subspecies. All of them are protected *in situ* UK. To compare this composition of taxa with similar ones for other natural and geographical regions of Ukraine, we identified the following number: forest-steppe 104 taxa (Popovych et al., 2010), steppe 145 (Popovych et al., 2013); mixed forest zones 58 (Popovych et al., 2017), broad-leaved forest zones 90 (Popovych et al., 2019). Against the background of plain regions, the UK also occupies the third position in the quantitative ranking of protected rare taxa. This indicates not only the most diverse types of ecosystems and landscapes of the UK, but also the highest (16%) percentage of regional protected areas in Ukraine (Hetman & Popovych, 2024).

Instead, out of 368 taxa, the fraction of rare introduced *ex situ* taxa of the NRF UK is represented by 242 species, subspecies and variations. Similar fractions were identified during the study of the plain biogeographical regions of Ukraine. The following number of introduced taxa were found in the NRF of these regions: forest-steppe 176 taxa (Popovych et al., 2010), steppe 178 (Popovych et al., 2013); mixed forest zones 105 (Popovych et al., 2017), broad-leaved forest zones 176 (Popovych et al., 2019). It is worth noting that the forest-steppe, the steppe, especially its northern part, and the broad-leaved forest zone are close to each other in terms of climatic conditions. The similarity is also confirmed by the close quantitative indicators of rare taxa of the regional fractions of the NRF. In the above-mentioned spectrum of regional fractions of the entire territory of Ukraine, the Carpathian region occupies the first position in the quantitative ranking of taxa. This indicates diverse and favorable climatic and soil conditions for the adaptation and acclimatization of alien plants. It also shows the significant interest of introducers in the world's rare dendroflora.

An analysis of the systematic, phytomorphological, ecological, geographical, phytocenotic structure and age trees of the studied taxonomic composition of the NRF UK has been published in a separate monograph (Popovych et al., 2025). The authors used the results of this floristic analysis to assess representativeness.

Representativeness of taxa in the red lists of plants of the world and Ukraine

For the field of biodiversity conservation, the degree of representativeness of the studied taxa in the red lists of different levels is of great importance (Convention…, 1979; European Red List…, 1992; Information…, 2002; Red Data Book…, 2009; Andrienko & Peregrym, 2012; The IUCN Red List…, 2025). The legal basis for protection at the national level is provided by legislation on flora and the Red Book of Ukraine. At the regional level, these are regional red lists approved by regional councils. The Red Data Book of Ukraine (Red Data Book…, 2009) lists 109 species of woody plants for the entire territory of the country. These are trees (15 taxa), shrubs (34), semi-shrubs (6), shrubs (10), semi-shrubs (44). The Carpathian region is represented by a fairly high 46% of this share. Compared to lowland regions, the UK NRF has the highest taxonomic richness. 28 natural taxa of the Red Book of Ukraine were found in the forest-steppe, 39 in the steppe, 11 in the mixed forest zone, and 26 in the broad-leaved forest zone (Popovych et al., 2010, 2013, 2017, 2019). In the composition of the rarity categories of natural taxa of Red Data Book of Ukraine (RDBU; Red Data Book…, 2009) and Regional Red List (RRL; Andrienko & Peregrym, 2012), the rare category dominates (the name is conventional and not inherent in the IUCN categorization). Also, the joint share of endemics and relicts is quite significant (Figure 1).

As the analysis showed, there are still not enough Ukrainian natural taxa in the international red lists (Table 1). This is not because they have a low degree of rarity. Organizational and technical reasons, delays in consideration are more likely. Critical analysis of taxa and submission to relevant international conservation institutions has been done for a long time (Mosyakin & Fedoronchuk, 1999).

In addition, one feature is observed: at the international level, introduced species (270 taxa) are better protected by law, while at the national and regional levels, natural taxa are better protected. In this context, it is worth noting that the IUCN Red List has not yet been ratified by Ukrainian legislators. Unlike the legal field, it is quite relevant in scientific

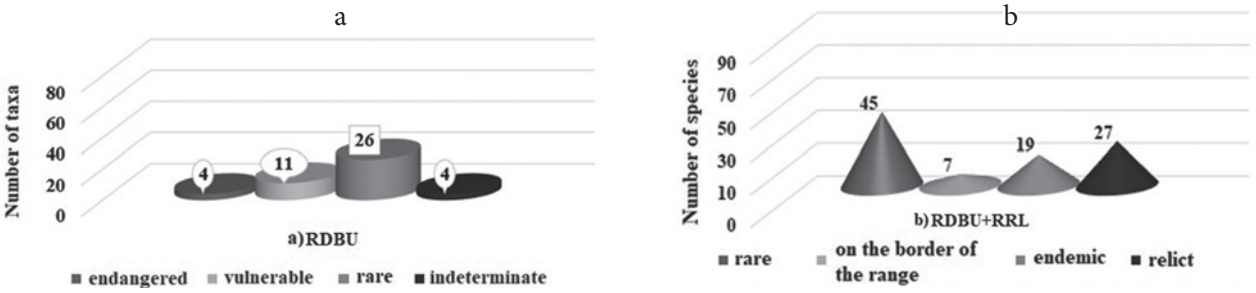

Figure 1. Quantitative distribution of natural taxa of the nature reserve fund of the Ukrainian Carpathians by belonging to rarity categories
Remark: a) RDBU, b) RDBU + RRL

Table 1. Representativeness of rare natural and introduced taxa of the Ukrainian Carpathians Nature Reserve in the Red Lists

Taxa	The number of taxa in the red lists								
	JUCN	ERL	CITES	JUCN + ERL	JUCN + CITES	ERL + RLU	JUCN + BC + RLU	RDBU	RRL
natural	28	3				4	1	45	46
introduced	242	2	2	6	2				

Remark: BC – Berne Convention, CITES – Convention CITES, ERL – European Red List, JUCN – The IUCN Red List, RDBU – Red Data Book of Ukraine, RRL – Regional Red List.

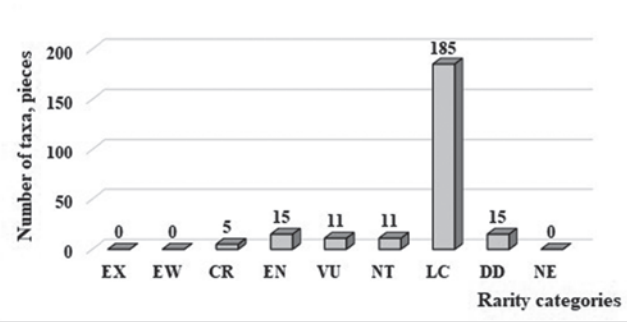

Figure 2. Quantitative distribution of introduced taxa of the nature reserve fund of the Ukrainian Carpathians by belonging to JUCN categories

publications. The affiliation of the studied introduced species to the rarity categories of this list is presented in Figure 2. It follows from it that Ukrainian scientists still do not pay enough attention to critically important categories.

Ranked representativeness of taxa in NRF categories, localities and regions

Natural taxa. According to the results of the selection of taxa, it was established that 14 species (14%) are among the most common in the UK. *Pinus cembra* leads the spectrum of NRF categories. The species is characteristic of all seven categories of natural areas of the NRF (natural protected areas) and three categories of artificial objects of the NRF (10 of 11), which we call artificial protected parks. Of the 11 subcategories of reserves, the species is specific to three: botanical, landscape and forest reserves. In the conditions of the natural habitat, *Pinus cembra* is protected in 38 nature-protected areas and 18 artificial protected parks. It is present in Ivano-Frankivsk (31 natural and 11 artificial localities), Zakarpattia (15) and Chernivtsi (10) regions. The second tier is occupied by *Torminalis glaberrima* (synonym: *Sorbus torminalis*.) The species is characteristic of nine (six natural and three artificial) NRF categories. Among the subcategories of reserves, it is noted in three: botanical, landscape and forest reserves. In native conditions, this species occurs in 24 nature-protected areas and five artificial protected parks. The largest number of protected sites of *Torminalis glaberrima* (synonym: *Sorbus torminalis*) were found in Zakarpattia (14) region, the rest in Chernivtsi (nine), Ivano-Frankivsk (five), Lviv (one) regions. The third place is occupied by *Taxus baccata*, whose protected localities occur in objects of eight categories (five natural and three artificial). The species is characteristic of three subcategories of reserves: botanical, zoological and ornithological. Its local growth is established in 27 natural protected areas and 21 artificial protected parks. The largest number of protected natural sites of *Taxus baccata* were found in Zakarpattia (23) oblasts, others in Chernivtsi (14), Ivano-Frankivsk (nine), Lviv (five) regions.

These UK data were compared with other biogeographical regions. *Magnoliophyta* plants are present in the first three taxa of the NRF categories in the forest-steppe and mixed forest zone. In the steppe, the broad-leaved forest zone and UK, *Magnoliophyta* plants with a tertiary share of *Pinophyta* prevail. Most of them are characteristic of nature reserves in all regions of Ukraine (Popovych et al., 2010, 2013, 2017, 2019, 2025).

The current state of the regional occurrence of plant species in nature-reserved territories of the UK was reflected in an ordination series of numbers. In it, the first and highest two levels of representativeness belong to *Pinus cembra* (56 protected localities) and *Taxus baccata* (51). The middle steps (range of 50-10 localities) of the ordination series are occupied by 12 (12%) species. The lowest steps of the ordination series (9-1 locality) were assigned to 50 (51%) taxa. Taxa that occur in one protected locality are of considerable concern. Such 17 taxa are mostly of local protection level. Therefore, nature conservation practitioners in the regions should develop measures to strengthen their conservation.

However, taxa not identified in NRF UK (26 species, 26%) are of greatest concern (Popovych et al., 2022). These are plants of the genera: *Salix (S. phylicifolia* L., *S. starkeana* Willd.), *Chamaecytisus (Ch. austriacus* (L.) Link., *Ch. elongatus* (Waldst. et Kit.) Tzvel., *Ch. paczoskii* (Krecz.) Klásk., *Ch. triflorus* (Lam.) Skalická, *Rosa* (*R. caesia* Pour., *R. canina* L. (synonyms: *R. heterostyla* Chrschan., *R. porrectidens* Chrshan. & Lasebna, *R. prutensis* Chrschan.), *R. corymbifera* Borkh. (synonyms: *R. frutetorum* Besser, *R. uncinella* Besser), *R. gallica* L. (synonym: *R. czackiana* Besser), *R. glauca* Pour., *R. livescens* Besser (synonym: *R. parviuscula* Chrshan. & Lasebna), *R. spinosissima* L. (synonym: *R. pimpinellifolia* L.), *Rubus* (*R. bifrons* Vest, *R. constrictus* Lefèvre & P.J.Müll., *R. gothicus* Frid. & Gelert, *R. grabowskii* Weihe ex Günther, Grab.

& Wimm., *R. haesitans* Mart. & Walsemann, *R. montanus* Lib. ex Lej., *R. praecox* Bertol., *R. saxatilis* L., *R. ulmifolius* Schott), as well as *Cotoneaster laxiflorus* J.Jacq. ex Lindl. (synonym: *C. melanocarpus* (Bunge) Fisch. ex Loudon), *Cytisus scoparius* (L.) Link (synonym: *Sarothamnus scoparius* (L.) Wimm. ex W.D.J.Koch), *Genista germanica* L., *Linum basarabicum* (Săvul. & Rayss) Klokov ex Juz. Among them, the rarest *Salix starkeana* (protected in Germany, Romania, Slovakia, the Czech Republic, Ukraine), *Chamaecytisus paczoskii*, *Rosa gallica* and *Linum besarabicum*, which are listed in the Red Data Book of Ukraine (Red Data Book…, 2009) are of particular concern. Therefore, it is necessary to immediately identify their new populations and bequeath them. The identified locations should be attributed not only to the NRF, but also to the natural cores of the Carpathian eco-network and Emerald.

Introduced taxa. According to a similar scenario to the previous fraction, an analysis of the representativeness of rare introducers was carried out. From the taxonomic composition (242) of this fraction, 32 (13%) species were selected. They are well distributed and best acclimated in NRF UK. In the integrated ordination numerical series, the first three places are occupied by *Thuja occidentalis* (70 – integrated indicator), *Larix decidua* (68), *Picea pungens* (59). *Cryptomeria japonica* (Thunb. ex L.f.) D.Don (18), *Larix sibirica* Ledeb. (17), *Juniperus chinensis* L. (16) take the last place in the list of 32 taxa.

Instead, *Larix decidua* Mill. leads only in the spectrum of representativeness of taxa in NRF categories. In the UK, this species is characteristic of 10 out of 11 categories (there are no zoos in the region). Of the 11 subcategories of reserves, the species is typical for botanical and forest reserves. It is protected in 32 nature reserve territories. In artificial conditions, the species occurs in 21 NRF objects. *Larix decidua* is introduced in all four regions of the UK. However, the largest number of protected localities (36) is in the Ivano-Frankivsk region. In total, the species has been recorded in 53 protected localities. *Pinus strobus* L., *Juglans regia* L., *Quercus rubra* L. and *Pseudotsuga menziesii* (Mirb.) Franco took second to fifth place, which are tied to seven NRF categories (four natural and three artificial). Six NRF categories (three natural and three artificial) include *Aesculus hippocastanum* L., *Chamaecyparis lawsoniana* (A.Murray bis) Oerst., *Rhus typhina* L., *Thuja occidentalis*. They are characterized by the same ratio of natural and artificial (3:3). Plants of 18 species grow on the territories of objects of five categories. There are 26 species common to four categories. 33 species of plants were noted for the three categories. 57 species are characteristic of the two categories, of which 28 species are characteristic of natural and artificial localities. Only 29 species of plants are unique to the artificial categories of the NRF. The largest share (100 taxa, 41%) is displayed for one mostly artificial NRF category.

To compare the first three leading introduced taxa in the NRF UK categories, it was given data from plain regions. In the forest-steppe, the first three are *Juglans regia, Larix decidua* and *Pinus nigra* J.F.Arnold together with *Prunus armeniaca* L. (synonym: *Armeniaca vulgaris* Mill.) (Popovych et al., 2010), steppe – *Prunus armeniaca* (synonym: *Armeniaca vulgaris*), *Juglans regia, Larix decidua* together with *Thuja occidentalis* (Popovych et al., 2013), in the zone of mixed forests – *Larix decidua, Picea pungens* and *Thuja occidentalis* (Popovych et al., 2017), in the broad-leaved forest zone – *Aesculus hippocastanum*, *Juglans regia* and *Robinia pseudoacacia* L. (Popovych et al., 2019). Thus, *Juglans regia*, *Larix decidua* and *Thuja occidentalis* are the most representative in the NRF categories of Ukraine as a whole.

The next step in assessing the state of representativeness was to find out the frequency of occurrence of plant species in the localities of the NRF UK network. The first range of 60-50 protected localities is the highest level of occurrence of plant species. Each numerical step of the range has its own group of taxa. Leading the way in this range is *Thuja occidentalis*, which occurs at 60 mostly artificial NRF objects. *Larix decidua* is in second place (53 localities), *Picea pungens* is in third place (50). These three species make up only about one percent of the total composition of UK taxa. The middle levels (range 49–10) of the ordination series of occurrence frequencies are 29 species (12%). The largest share (87%) of the studied taxa occupy the lowest levels (range 9–1). The last three levels of the ordination series were distributed as follows: 26 taxa occur in three localities of the NRF, 45 in two and 81 (34%) in one.

In general, in the cultivated conditions of some nature-reserved territories of seven categories 110 (46%) species are grown receiving preservation at the same time. Accordingly, artificial objects of the NRF contain exclusively a larger share of species. This is a fairly high rate of preservation of the studied introduced taxa. It is mainly provided by artificial natural monuments and urbanized lands within the territories of national natural and regional landscape parks. This is confirmed by the fact, that only eight species (3%) are protected exclusively in the indigenous conditions of nature reserves. 129 (53%) taxa were noted in the objects of artificial NRF categories.

Representativeness of taxon composition in NRF categories (categorical representativeness)

The quantitative composition of natural and introduced taxa of this type of representativeness is presented in Table 1.

Natural taxa. Based on the analysis of obtained data, it was noted that the lowest indicator for natural taxa is the

nature reserve category. This is alarming, since it provides the strictest conservation regime. To eliminate this gap, it is worth creating at least two nature reserves in the region. Likely locations may be the least disturbed by anthropogenic activity ecosystems and biodiversity of the mountain ranges of Chyvchyn and Beskydy. For this, comprehensive studies need to be conducted. Based on their results, scientific justifications and applications for the creation of a protected area are submitted to the nature protection authorities.

Introduced taxa. The results of the assessment of the state of categorical representativeness confirm the well-known fact about the prevalence of introduced taxa in artificial protected parks.

In the network of nature reserves, the only category of the biosphere reserve has the largest number of introduced species. All of them are represented mainly in the arboretum of the Carpathian Biosphere Reserve estate. Also, in the only object of the nature reserve category ("Gorgany"), only *Larix decidua* and *Picea asperata* Mast. were found. Of the seven categories of nature reserves, the most representative was the national nature park category. Its network is represented by 12 objects and, accordingly, the largest occupied areas. These areas include cultivated landscapes – potential habitats for the introduction of rare tree species. Only *Larix decidua* was found in the network of objects of the regional landscape park category. The studied taxa occur in three subcategories of reserves (botanical, landscape, forest) and two subcategories of natural monuments (botanical and complex). Only in two artificial objects of the botanical natural monument category *Magnolia sieboldii* subsp. *sinensis* (Rehder & E.H.Wilson) Spongberg (synonym: *Magnolia sinensis* (Rehder & E.H.Wilson) Stapf) occurs.

A completely different picture is characteristic of the artificial categories of the NRF. Of the 207 taxa of the botanical garden category, 73 (30%) taxa are preserved in the collections of only two of its objects (Chernivtsi, Uzhhorod). Of the 116 taxa of category of the dendrological park, 15 (6%) taxa of gymnosperms are protected exclusively in the collections of its objects. Accordingly and naturally (compared to botanic gardens and arboretums) there are fewer taxa in the objects of the category of park-monument of landscape art. The only species *Hesperocyparis macnabiana* (A.Murray bis) Bartel (synonym: *Cupressus macnabiana* A.Murray bis) was found only in the Berehometsky park-monument of landscape art.

Tables 3 and 4 illustrate two types of representativeness (categorical, regional). These results show an uneven distribution of taxa across categories and administrative regions. This is natural. For natural taxa, the numbers depend on the degree of development of networks and the occupied areas of territories of a particular NRF category. For exotic taxa, the duration and intensity of the introduction process are important. This feature is clearly expressed for botanical gardens.

Table 3. Representativeness of rare natural and introduced taxa in the categories of the nature reserve fund of the Ukrainian Carpathians

Categories and subcategories of the nature reserve fund	Number of taxa			
	natural		introduced	
	absolute	%	absolute	%
Nature reserve territories				
Biosphere Reserve	45	46	14	6
Nature reserve	6	6	2	1
National Natural Park	44	45	100	41
Regional Landscape Park	11	11	1	1
Reserve	25	26	6	3
botanical	*18*	*72*		
landscape	*11*	*44*		
forest	*7*	*28*		
hydrological	*4*	*16*		
general zoological	*2*	*8*		
ornithological	*1*	*4*		
Natural monument	27	28	26	11
botanical	*22*	*82*		
hydrological	*5*	*19*		
complex	*4*	*15*		
Protected tract	7	7	10	4
Artificial objects of the nature reserve fund				
Botanical garden	18	18	207	86
Dendrological park	9	9	116	48
Park-monument of landscape art	13	13	93	38

Table 4. Representativeness of rare natural and introduced taxa of the nature reserve fund of the administrative regions of the Ukrainian Carpathians

Administrative regions	Number of taxa			
	natural		introduced	
	absolute	%	absolute	%
Zakarpattia	50	51	126	52
Ivano-Frankivsk*	35	36	129	53
Lviv*	14	14	40	17
Chernivtsi*	19	19	194	80

* – carpathian part of the region.

Representativeness of taxon composition in NRF networks of administrative regions
(regional representativeness)

The preservation of the studied natural taxonomic composition in the Zakarpattia region is ensured by 189 protected localities. There are 133 protected localities in the Ivano-Frankivsk region, 68 in the Chernivtsi region, and 22 in the Lviv region.

The largest number of introduced rare taxa is represented by 685 protected localities of Chernivtsi region. In Zakarpattia region, the conservation of rare introduced woody plants is ensured by 378 NRF localities, in Ivano-Frankivsk region – 336, in Lviv region – 82. This distribution can be explained by the size of the areas of the Carpathian parts of the regions and, undoubtedly, by the activity of the introduction activities of local botanists.

Representativeness of taxa in NRF localities
(locality representativeness)

Natural taxa. Among the large-scale nature reserves of the main categories of the NRF, the largest number of natural taxa (more than 10 species) is identified. The Carpathian Biosphere Reserve (45 species) and the national natural parks: Carpathian (24), "Synevyr" (20), "Hutsulshchyna" (13), "Skolivskie Beskydy" (11) are among the taxonomically richest. Small-area nature reserves of other NRF categories include 12 nature reserves (9-5 species). From four to two plant species were recorded in 27 nature reserves. The studied taxa occur singly in 79 nature reserves. It is advisable to introduce population monitoring in isolated localities. No local populations of the studied species were found in 93 nature reserves, which obliges conservationists to take appropriate measures for conservation.

Protected natural plant species are still not fully represented in the artificial protected parks of the UK. Again, their largest number is in the botanical gardens of Chernivtsi (12) and Uzhhorod (11). A somewhat smaller number is typical for arboretums. Among them, the largest number of rare species of woody plants (9-5 species) is characteristic of arboretums of the Ivano-Frankivsk region. From four to two plant species were noted in 14 arboretums. One locality of species was found in four arboretums, as well as 15 parks-monuments of landscape art. No studied natural species were found in two arboretums and 40 parks-monuments of landscape art. These results should be noted by introducers and their collections should be supplemented with rare taxa that are few or absent in artificial protected parks. According to Ukrainian legislation, the preservation of rare phytodiversity of domestic and world flora by these parks is one of the key tasks.

Introduced taxa. The largest number (more than 10) of introduced species grows in large-scale nature reserves of the main NRF categories. The leading places belong to the following national natural parks: "Hutsulshchyna" (92 taxa, mostly in the arboretum), Carpathian (21), "Synevyr" (20), "Skolivskie Beskydy" (19). There are slightly fewer taxa in the Carpathian Biosphere Reserve (15 species, mostly in the arboretum) and in the regional landscape park "Hutsulshchyna" (13). Among the small-area nature reserves, within which a smaller number (range 9-5) of the studied rare species grow, there are also national nature parks. Three species of introduced plants grow in five, two species in six nature reserves. One species was recorded in the «Gorgany» nature reserve, three botanical and four forest reserves, 46 botanical natural monuments (mostly artificial), one complex natural monument, and 12 protected tracts.

There is a natural tendency for artificial protected parks to have significantly more introduced plant species than estates, cultivated landscapes, and arboretums of NRF institutions. The largest number of them is certainly in the two botanical gardens of Yuriy Fedkovych Chernivtsi National University (183 taxa) and Uzhhorod National University (107). This fact indicates that these institutions are leading centers for the introduction and acclimatization of rare taxa of woody plants of the world flora in the Carpathian region. Almost three to two times lower values of the representativeness of the taxon composition are characteristic of leading arboretums. The largest number (range 50-10) of rare exotic plant species studied is noted for seven arboretums. The remaining arboretums have identified a smaller number of species (9–1). Only one species was found in the Maloturyanskyi Arboretum. In the network of park monuments of landscape art, the largest number (range 45–10) of rare species of exotic woody plants is characteristic of 28 protected localities. In the remaining parks-monuments of landscape art, the following number of studied species were noted: nine in three protected localities, eight – four, seven – three, six – five, five – six, four – five, three – two, two – nine, one – two.

Thus, the results of the inventory are extremely important for assessing the representativeness of biodiversity. In this context, the presented analysis showed a general picture of the differentiation of the taxonomic composition of rare woody plants in the current NRF UK network. A clear distribution of taxa between NRF categories and localities was obtained. The degree of saturation of protected taxonomic structures in the administrative regions of the UK was determined. And most importantly, the data obtained from the representativeness analysis will help solve one of the most pressing applied problems of territorial nature conservation – optimizing the NRF UK network.

4. Conclusions

The presented assessment identified the highest and lowest concentrations of rare native and introduced woody plant taxa in the NRF categories and localities of the UK administrative regions. Rare natural taxa of woody plants are most widely represented in the cluster-type Carpathian Biosphere Reserve, national natural parks and natural monuments. These categories have the densest network of

objects, which are created mainly in ecosystems unique to the region. The studied taxa are underrepresented in the region's only natural reserve, regional landscape parks, protected tracts, forest and landscape reserves. This fact encourages the expansion of their object networks and their wider introduction into the NRF collection of artificial objects.

Analysis of the representativeness of rare taxa of protected woody plants revealed signs that require an appropriate response from conservationists. Of particular concern are taxa (17) that were found in only one protected locality. This may be due to their narrow ecotopic range or insufficient locality identification. To address this gap, new populations need to be sought and protected. There is also a fairly high rate (30 species, 30%) of plant species not represented in the NRF UK. Of these, the rarest *Chamaecytisus paczoskii*, *Linum besarabicum, Rosa gallica* (synonym: *Rosa czackiana*) and *Salix starkeana* are of particular concern. Priority efforts should be directed toward finding and preserving their habitats.

The studied fraction of introduced plants in Ukraine is taxonomically the richest among similar fractions of plain natural and geographical regions of Ukraine. This indicates diverse and favorable ecological conditions for the adaptation and acclimatization of alien plants. Unlike natural taxa, they are more tied to lowland and foothill landscapes with a warm climate. The highest ranking was also influenced by the significant interest of introducers of the Carpathian region in the world's rare dendroflora.

Among introduced species, most of the leading positions according to the results of the representativeness assessment belong to *Pinophyta*. *Larix decidua* (massively introduced into forest crops) has the highest degree of categorical representativeness, and *Thuja occidentalis* (the leading species in landscaping) has the highest degree of local representativeness. This can be explained by the wide adaptive amplitude of most *Pinophyta* species in the ecological conditions of the UK. The trend is natural and not only in Ukraine, when there are more introduced plant species in artificial protected parks than in estates, cultivated landscapes and arboretums of nature reserves.

The largest number of rare introduced species is characteristic of the oldest botanical garden of the Yuriy Fedkovych Chernivtsi National University (183 taxa). This is because it has its own historical conservation traditions and is a leading center for the introduction and acclimatization of rare taxa of woody plants of the world's flora in the Carpathian region.

The obtained research results have scientific and applied significance. They will improve the inventory direction of development of dendrology, florology, and taxonomy of woody plants, protection of dendrodiversity, and nature reserves. The results of the analysis will be useful for preparing the National Report on the State of Biodiversity in Ukraine and reporting on the state's implementation of the requirements of international conventions. The factual material obtained can form the basis for organizing dendrotaxonomic monitoring at NRF UK.

Acknowledgements
None.

Conflict of Interest
None.

References

Andrienko T.L., & Peregrym M.M., 2012, Official lists of regional rare plants of administrative territories of Ukraine (reference book). Kyiv: Alterpress, 148 p. [in Ukrainian].

Aycrigg, J.L., Davidson, A., Svancara, L.K, Gergely K.J., McKerrow A., & Scott, J.M., 2013, Representation of ecological systems within the protected areas network of the Continental United States. PLoS One 8(1), e54689. DOI: https://doi.org/10.1371/journal.pone.0054689

Chopyk, V.I., & Fedoronchuk, M.M., 2015, Flora of the Ukrainian Carpathians. Ternopil: Terno-graf, 712 p. [in Ukrainian].

Convention on the Conservation of European Wildlife and Natural Habitats, 1979, Appendix 1: Strictly protected flora species, Bern, 24 p. https://rm.coe.int/168097eb56

Dzyba A., 2021, *Pinus strobus* L. on protected areas of Ukrainian Polissya. Forestry ideas 27: 1(61), 156–168.

Dzyba A., 2022, *Pseudotsuga menziesii* (Mirb.) Franco on protected areas of Ukrainian Polissya. Ukrainian Journal of Forest and Wood Science 11(2): 40–52. DOI: https://doi.org/10.31548/forest.13(2).2022.7-15

European Commission, 2020, EU Biodiversity Strategy for 2030: Bringing nature back into our lives. COM (2020) 380 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52020DC0380

European Red List of Globally Threatened Animals and Plants, 1992, United Nations: European Economic Commission, New York.

Frankel, O.H., & Soule, M.E., 1981, Conservation and evolution. Cambridge, 327 p. https://unesdoc.unesco.org/ark:/48223/pf0000048016

Global Biodiversity Assessment, 1995, Ed. Heywood, V.H., & Watson, R.T. United Nations Environment Programme. Cambridge: Cambridge University Press, 1140 p. https://archive.org/details/GlobalBIO_201905/page/n3/mode/2up

Hetman, V., & Popovych S., 2024, Geographical representativeness of the network of reserves and national natural

parks of Ukraine. Visnyk of V.N. Karazin Kharkiv National University, series "Geology. Geography. Ecology" 60: 188–198. DOI: https://doi.org/10.26565/2410-7360-2024-60-13 [in Ukrainian].

Information materials on the implementation of the CITES Convention in Ukraine, 2002, Kyiv: Ministry of Ecology and Natural Resources of Ukraine, Ministry of Agrarian Policy of Ukraine. https://zakon.rada.gov.ua/laws/show/z0496-02#Text [in Ukrainian].

Kagalo, O.O., Prots, B.G., Kruglov, I.S., Danylyk, I.M., Kish, R.Ya., Chorney, I.I., Resler, I.Ya., Omelchuk, O.S., Sychak, N.M., Andreeva, O.O., & Sosnovska, S.V., 2022, Methodology for identification, inventory and visualization of habitat diversity. Second edition, Ed. O.O. Kagalo, & B.G. Prots. Lviv: Prostir M, 110 p. [in Ukrainian].

Lakićević, M., Đoković, A., & Kaloz, O., 2024, Comparative floristic analysis (2004 and 2022) of the Natural Monument "Stari park" in Temerin, Serbia, Contemporary Agriculture, 73(1–2): 60-68. DOI: https://doi.org/10.2478/contagri-2024-0008

Médail, F., Monnet, AC., Pavon, D., & Nicolić, D., 2019, What is a tree in the Mediterranean Basin hotspot? A critical analysis, Forest Ecosystems 6(17): 1–19. DOI: https://doi.org/10.1186/s40663-019-0170-6

Medvedev, V.A. & Iljenko, A.A., 2017, The representation of species of the Red Book of Ukraine and the list of rare plants of Chernigiv Region in the flora of dendropark Trostjanets of the NAS of Ukraine, Introduction Plant 3: 32–40. [in Ukrainian].

Miskevych, L.V. & Popovych, S.Yu., 2019, Protected dendrosozoexotics of the broad-leaved forest zone of Ukraine: Monograph, Kyiv: CP Komprint, 109 p. [in Ukrainian].

Mosyakin S.L., 1999, Plants of Ukraine in the World Red List. Ukrainian Botanical Journal 56 (1): 79–88. http://botany.kiev.ua/doc/mosykin12.pdf [in Ukrainian].

Mosyakin S.L. & Fedoronchuk M.M., 1999, Vascular plants of Ukraine: A nomenclatural checklist, Kiev: M.G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine, 346 p. DOI: https://doi.org/10.13140/2.1.2985.0409

O'Brien, L., Schuck, A., Fraccaroli, C., Pötzelsberger, E., Winkel, G., & Lindner, M., 2021, Protecting old-growth forests in Europe – a review of scientific evidence to inform policy implementation, Final report. European Forest Institute. DOI: https://doi.org/10.36333/rs1

Pokotylova K.G., & Popovych, S.Yu., 2021, Artificial reserve parks of Rivne region: dendrofloristic aspect: Monograph, Kyiv: CP Komprint, 124 p. [in Ukrainian].

Pokotylova K.H., 2020, Representativity of Rivne Region Artificial Protected Parks Dendroflora, Ukrainian Journal of Forest and Wood Science 11(1): 98–107. DOI: https://doi.org/10.31548/forest2020.01.098

Popovych, S., & Dzyba, A., 2022, Geography of conservation *ex situ* of rare taxa of ancient exotic trees *Pinophyta* in Ukraine, AgroLife Scientific Journal 11(1): 176–185. DOI: https://doi.org/10.17930/AGL2022121

Popovych, S., & Pokotylova, K., 2020a, Subtropical coniferous dendrorarity acclimatization trends *ex situ* in Ukraine, AgroLife Scientific Journal 9(2): 250–262. https://agrolifejournal.usamv.ro/index.php/agrolife/article/view/277

Popovych, S. & Pokotylova, K., 2020b, Comparative analysis of regional parks dendrofloras of Ukraine in the zonal aspects, AgroLife Scientific Journal 9(1): 273–280. https://www.agrolifejournal.usamv.ro/index.php/agrolife/article/view/589

Popovych, S.Yu., Dzyba, A.A., Pokotylova K.H., Tomych M.V., & Tertyshnyi A.P., 2025, Reserve dendrosozoflora of Ukrainian Carpathians: Monograph, Ed. S.Yu. Popovych. Kyiv: Lira-K, 266 p. [in Ukrainian].

Popovych, S.Yu., Savoskina, A.M., Sherstyuk, M.Yu., Mykhailovych, N.V., & Dzyba, A.A., 2017, Reserve dendrosozoflora of Ukrainian Polissya: Monograph, Ed. S.Yu. Popovych, Kyiv, Central Publishing House Comprint, 188 pp. [in Ukrainian].

Popovych, S.Yu., Sherstyuk, M.Yu., Pokotylova, K.G., Mykhailovych, N.V., & Miskevych, L.V., 2019, Reserve dendrosozoflora of the broad-leaved forest zone of Ukraine: Monograph, Ed. S.Yu. Popovych. Kyiv: FOP Yamchynskyi O.V., 147 p. [in Ukrainian].

Popovych, S.Yu., Stepanenko, N.P., Dyachenko, Ya.M., Dzyba, A.A., Vasylyk, O.V., Korinko, O.M., Ustymenko, P.M., Kushnir, A.I., Vintonyak, I.Yu., Syplyva, N.O., & Krupkina, L.I., 2010, Reserve dendrozoflora of the Forest-Steppe of Ukraine, Ed. S.Yu. Popovych. Kyiv: Agrar Media Group LLC, 262 p. [in Ukrainian].

Popovych, S.Yu., Ustymenko, P.M., & Pokotylova, K.G., 2022, Dendrosozological catalog of the nature reserve fund of the Ukrainian Carpathians: Monograph, Ed. S.Yu. Popovych. Kyiv: Lira-K, 1026 p [in Ukrainian].

Popovych, S.Yu., Vlasenko, A.S., Berehuta, E.I., Korinko, O.M., Dyachenko, Ya.M., Dzyba, A.A., Mykhailovych, N.V., & Hotska M.V., 2013, Reserve dendrosozoflora of the steppe of Ukraine: Monograph, Ed. S.Yu. Popovych. Kyiv: Central Publishing House Comprint, 260 p. [in Ukrainian].

Popovych, S., Yakubenko, B., & Tsybulia, M., 2022, Chorology of rare dendroflora of the National Nature Park "Male Polissya" (Ukraine) in zonal comparison. Ecological Questions 33(3): 19–28. DOI: https://doi.org/10.12775/EQ.2022.022

Popovych, S.Yu., 2020, Geography of dendrorarities Conservation of the genus *Spiraea* L. in Ukraine. Ukrainian Journal of Forest and Wood Science 11(2): 40–52. DOI: https://doi.org/10.31548/forest2020.02.040 [in Ukrainian].

POWO, 2025, Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. https://powo.science.kew.org

Prendergast J.R., Quinn, R.M., & Lawton, J.H., 1999, The Gaps between Theory and Practice in Selecting Nature Reserves. Conservation Biology 13(3): 484–492. https://conbio.onlinelibrary.wiley.com/doi/epdf/10.1046/j.1523-1739.1999.97428.x

Program of perspective development of protected areas in Ukraine ("Reserves"), 1994, Bulletin of the Verkhovna Rada, No. 48, Art. 430 [in Ukrainian].

Red Data Book of Ukraine. Plant World, 2009, Ed. Ya.P. Didukh. Kyiv: Globalconsulting, 912 p. [in Ukrainian].

Savoskina A.M. & Popovych, S.Yu., 2019, Protected dendrosozoexotics of the Ukrainian Polissya: Monograph. Kyiv: CP Komprint, 110 p. [in Ukrainian].

Sochacka, E., Rzeszotarska-Pałka, M., & Nowak, G., 2022, Representative versus Natural Values of Public Open Spaces – A Landscape Approach (Szczecin Case Study), Sustainability 14(24): 16664. DOI: https://doi.org/10.3390/su142416664

Stepanenko N.P., & Popovych S.Yu., 2015, Protected Dendrosozoexotic Plants of the Forest-Steppe of Ukraine: Monograph. Kyiv: Central Publishing House Comprint, 131 p. [in Ukrainian].

Stoyanova, N., Dimitrov, D., Georgiev, G.P., & Delkov, A., 2011, Biosphere Reserves in Bulgaria and ther Forest genetic resources, Silva Balcanica 12(1): 13–24. https://silvabalcanica.wordpress.com/wp-content/uploads/2012/11/nstojanova_dimdim.pdf

Tasenkevich, L., 1998, Flora of the Carpathians, Checklist of the native vascular plant species. Lviv: State Museum of Natural History NASU, 623 p.

Tashev, A. & Dzyba A., 2023, Representation on the genus *Larix* Mill. in the protected areas of Ukrainian Polissya. Ukrainian Journal of Forest and Wood Science 14(4): 8–25, DOI: https://doi.org/10.31548/forest/4.2023.08

The IUCN Red List of Threatened Species Online, 2025, online version at: http://www.iucnredlist.org/ [Accessed: 7 April 2025].

Tokarieva, O., Kushnir, A., Sendonin, S., Yavnyi, M., & Kurylo, O., 2024, Monumental trees of Ukraine and public awareness of them. Ukrainian Journal of Forest and Wood Science 15(2): 153–169. DOI: https://doi.org/10.31548/forest/2.2024.153

Vlasenko A.S., & Popovych S.Yu., 2016, Protected Dendrosozoexotic Plants of the Steppe of Ukraine: Monograph. Kyiv: Central Publishing House Comprint, 128 p. [in Ukrainian].