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# Study of forest plants species diversity in “Radomyshlske” forestry-hunting enterpise

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The types of plant diversity on the territory of the Radomyshl Forestry in areas with different types of forest vegetation conditions were investigated. 21 species belonging to 15 families and 18 genera have been identified. The main types of forest are determined (*Pinus sylvestris-Vaccinium vitis-idaea+V. myrtillus-Cladonia spp.+ Pleurozium; Pinus sylvestris-Calluna vulgaris-Pleurozium+ Cladonia ssp.; Pinus sylvestris-Vaccinium myrtillus-Pleurozium; Pinus sylvestris- Pteridium aquilinum-Vaccinium myrtillus-Pleurozium; Pinus sylvestris-Calamagrostis arundinacea+Convallaria majalis)* and key indices of species diversity (Simpson, Shannon-Viviver, Yvnyanyoti and Margalef). Among the types of forest, the most widespread are green moss-shrub pine forests, and it is precisely the areas with this type of forest that are characterized by the highest indicators of species diversity and richness with peak indicators of the Simpson Index – 0.89; The Shannon-Weaver index is 2.55 and the Margalef index is 3.21. The indicators of the green moss-lichen pine forest, on the contrary, indicate a rather poor species diversity, namely Simpson's index – 0.75; The Shannon-Weaver index is 1.67 and the Mar-galef index is 1.65. However, this type of forest was characterized by the maximum level of equitability – 0.9. A comparative analysis of the species composition of the studied areas was also carried out to assess beta-diversity using the Jaccard index. Shrub-green moss pine forests with a do-minance of blueberry and gorse have the greatest similarity (0.7), as well as green moss-small herbaceous and shrub-green moss pine forests with a blueberry dominance (0.6); the smallest – small-grass pine and green-moss-lichen pine (0.2)

**Key words:** types of diversity, beta-diversity, alpha-diversity, phytodiversity, Polissia of Ukraine, types of forests.

**Problem statement and analysis of recent research.** The decrease in the level of biological diversity is one of the global environmental problems. The disappearance of plant species leads to the destruction of existing ecological relationships and the degradation of natural communities, their inability to self-sustain, which will lead to their disappearance. In addition, the complexity of the interrelation-ship between ecosystems, wildlife health, and human health creates a threat to human health due to the loss of species diversity [1–3]. In particular, the biodiversity hypothesis states that contact with the natural environment enriches the human microbiome, promotes immune balance, and protects against allergies and inflammatory diseases [4].

Species diversity in general and species diversity of plants are threatened by a number of factors. The main ones are: anthropogenic load, climate change, destruction of habitats of species, introduced species [5–7].

According to the International Union for Conservation of Nature (IUCN), and according to reports from the United Nations ( UN ), by 2050 between 10 and 50 % of well-studied higher taxonomic groups are threatened with extinction, Africa will lose 50 % of its birds and mammals, and fishing in the territory of Asian countries will be completely impossible. The loss of plants and marine life will reduce the Earth's ability to absorb carbon, creating a vicious cycle. For the species diversity of the territory of Europe, this problem is even more acute. There is a significant number of species that are not yet under threat, but their number is decreasing and they can quickly find themselves on the verge of extinction. Ukraine, in

particular, belongs to the countries with very large volumes and high intensity of use of natural resources.

This is facilitated both by the presence of their considerable wealth and favorable conditions for their exploitation. Occupying about 6 % of the area of Europe, Ukraine possesses approximately 35 % of its biodiversity.

Although global extinction risk status and trends for major vertebrate groups have been accounted for and documented for decades, most plant species have no global extinction risk assessment (BGCI, 2020; IUCN, 2020). Lack of knowledge about which plants are most at risk, what is at stake, and how this changes over time limits our ability to shape conservation systems and plan actions to protect species and areas most at risk [8–11].

Preservation of species richness in forests is an extremely urgent task, because forestry is considered the second most important factor that threatens species after agriculture [12, 13]. The effect that forestry has on tree diversity is determined by the intensity of the treatment and the succession stage of the forest [14, 15]. Intensive silvicultural treatments, including commercial plantations, clearcuts, and retention (seed trees), produce low values of diversity indices. In contrast, individual selection of trees or light-intensity thinnings appear to favor diversity. A number of authors have found that tree diversity increases the productivity of stands [15–17]. Maintaining the diversity of tree species and their positive effects on the ecosystem function, at the stand level, is a challenge that forestry, as an industry, faces today [18]. The importance of having forest systems that conserve tree diversity and fulfill the objectives of forest management has prompted the need to evaluate the impact that current management practices have on the conservation of diversity and production of ecosystem services [19].

**The aim of the research.** That is why it is important to carry out qualitative monitoring of the state of vegetation that would correspond to existing threats and provide comprehensive information about the state of the ecosystem and its individual components. One of the best tools for characterizing plant species diversity and its assessment at the species level are species richness indices. Indices are not perfect, but they make it possible to capture the main trends in the state of plant associations, and to determine the direction in which some of the key components of biodiversity are moving [20, 21].

A comprehensive assessment will make it possible to more objectively solve the task of preserving biodiversity at the ecosystem level. A study that was carried out will help to evaluate further changes in biodiversity that may influence forestry-hunting enterprise decision-making and thus help to prevent biodiversity loss and forest stand productivity decrease.

**Material and methods of research.** The study was conducted in 2021 on the territory of the state enterprise "Radomyshl Forestry and Hunting Enterprise" (hereinafter – Radomyshlske FHE) located in the southeastern part of the Zhytomyr Region in the territory of the Zhytomyr Administrative District. The geographical location of the territory determines the representativeness and typicality of species and coenotic diversity, which is characteristic of most forest ecosystems of Zhytomyr Polissia.

During the research, general scientific methods of observation, comparison, analysis and synthesis were used. To determine the species diversity on the territory of the forest farm, temporary experimental plots (hereinafter – TEP) were created with typical and most common types of forest vegetation conditions (hereinafter – FVC), namely: dry and fresh forests, as well as fresh and wet pinewood. 3 plots were selected on each of the FVC, with the dominant species being Scots pine. A total of 12 plots were recorded.

The study of the above-ground cover was carried out according to the methodology of the international program ICP Forests (2008). On the territory of the TEP, 4 sites with an area of 100 m $^2$ were randomly set. The pitches were mostly square in shape. If, due to local conditions, it was impossible to sat a square-shaped study zone, then it was made rectangular. Registration sites were set as far as possible from each other within the boundaries of the TEP or its buffer zone. This is necessary so that the similarity between the accounting sites in terms of multi-year dynamics is not

due to purely spatial coincidences. Geobotanical description was carried out on the formed areas – identification of species of higher vascular plants and determination of the abundance of each identified species [22].

During the geobotanical description of the registration sites, a complete floristic list was made, taking into account the stratified structure of the vegetation. In forests, tiers are formed by plants of individual life forms (according to Serebryakov), the following tiers are distinguished: layer A – forest stand (tier of trees); layer B – understory (shrubs tier); layer C – grass (layer of herbaceous plants); layer D – moss-lichen layer [23]. The identification of the species of higher plants was carried out using the identifier of higher plants "Opredelytel vysshykh rastenyi Ukrayny" [24]. Based on the descriptions of the recording sites, each TEP was assigned to a certain type of forest.

Material for analysis floristic diversity was served by geobotanical descriptions made by author on the records TEP sites. Further analysis of species phytodiversity was carried out at the level of alpha and beta diversity.

Alpha-diversity characterizes the species richness of individual groups. The main indicators of alpha diversity are species richness – the total number of species in the community. Simultaneous accounting of species richness and species saturation allows obtaining comparable estimates of species diversity during the analysis of different groups, for example, forest types. In order to obtain formalized indicators that can characterize alpha diversity, the following indices were also determined: Shannon-Weaver, Simpson, Margalef, Evenness.

Shannon index (H) (Shannon,1948) describes both richness and evenness and is calculated as: H=∑[(pi)×ln(pi)].

Where pi is a proportion of individuals of species i in the total number of individuals presented in the area.

Simpson index (D) (Simpson, 1949) is a measure for evenness and is calculated as:

$$D = 1 - \left(\frac{1}{\sum_{i=1}^{S} Pi^2}\right)$$

where S represents the total number of species.

Margalef index (R)(Margalef, 1958) measures the evenness, but it is highly sensitive to the sample size [25]. It is calculated in the following way:

$$R = \frac{S-1}{log\mathbf{N}}$$

where N represents the total number of individuals. This parameter does not have threshold values, and its higher values prove higher biodiversity.

The evenness of a community can be represented by Pielou's evenness index, which is calculated as:

$$J' = \frac{H'}{Hmax'}$$

Where $H'$ prime is the number derived from the Shannon diversity index and $Hmax'$ is the maximum possible value of $H' = lnS$ . Where S represents the total number of species

J' is constrained between 0 and 1. The less evenness in communities between the species (and the presence of a dominant species), the lower J' is. And vice versa.

Beta-diversity characterizes the variability of indicators of alpha-diversity in space during the transition from one type of forest to another. Beta diversity was assessed through the similarity index (Jaccard coefficient).

Jaccard index (J) (Jaccard,1901) is a measure of similarity between two sets of elements. This index is calculated as:

$$J(X,Y) = \frac{X \cap Y}{X \cup Y}$$

where X and Y are any forest stands analyzed. The intersection of two communities represents the number of species they have in common, while union represents the sum of: the number of common species, the number of species present only in the stand X and the number of species present exclu-sively in the stand Y. The PAST 4.03 software complex was used to determine the key indices of species diversity.

**Research results and discussion.** The set of vegetation layers form an ecological and coenotic series typical for the Ukrainian Polissia. Thus, areas with FVC A1 are represented by: – green moss-lichen pine forests; A2 – pine-shrub-green moss forests. Areas with FVC B2, B3 are also represented by rather typical pine forests with shrub-green mosses and small grasses dominated by various species.

TEP A1.1 – green moss-lichen pine forest *Pinus sylvestris-Vaccinium vitis-idaea+V. myrtillus-Cladonia spp.+ Pleurozium* is located on the site of a grass fire in 2011. Wooden tier (A): It consists entirely of pine (50–60 years old) with occasional admixtures of birch; Understory (B): extremely sparse, *Sorbus occurs aucuparia* L.; renewal of the pine was noted, its condition is unsatisfactory. Grass-shrub layer (C): 30–40 % coverage, dominated by shrubs – Vaccinium myrtillus and V. vitis-idaea. In this case, the dominant species is lingonberry. *Daucus carota* and *Poa angustifolia L.* are also rarely represented. Mossy-lichen layer (D): continuous, complex; from lichens of the genus *Cladonia*; from mosses there are – Pleurozium schreberi, Hylocomiun splendens.

TDD A1.2, A1.3 green moss-lichen pine forest *Pinus sylvestris-Calluna vulgaris-Pleurozium+Cladonia ssp.* Located on flat lands.

Wood layer (A): consists of *Pinus sylvestris* aged 40–60 years. Understory layer (B): not pronounced, includes single specimens of *Sorbus aucuparia*. The undergrowth consists of pine of different heights with a single admixture of *Betula pendula* and *Picea abies,* partially suppressed. Grass-shrub layer (C): coverage is low (40–50 %). Dominants are rarely found, the maximum score (according to Drude) is cor1. The most common species are: *Calluna vulgaris, Vaccinium vitis-idaea*, *Convallaria majalis*.

Moss-lichen layer (D): high coverage (60–100 %). In places, lichens (*Cladonia*) dominate. Among the mosses, *Pleurozium schreberi, Polytrichum juniperinum, and Dicranum polysetum predominate.*

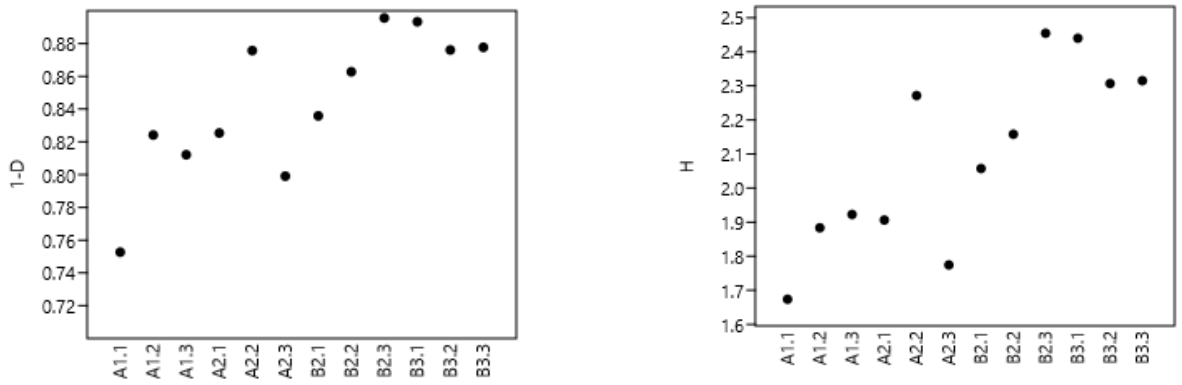
TEP A2.1, A2.2, B2.1, B2.2, B2.3 The most widespread among the studied areas is the section of pine forests, namely, shrub-green moss pine forests with the dominance of blueberries *Pinus sylvestris-Vaccinium myrtillus-Pleurozium* located on flat areas. Wood layer (A): Dominated by *Pinus sylvestris* aged 40–50 years. *Betula* is found here as an admixture pendulum. Understory layer (B): The layer of shrubs and undergrowth consists of the predominant young generation of trees *Betula pendula, B., Pinus sylvestris,* sometimes *Quercus robur L.* and associated species of shrubs, mainly *Sorbus aucuparia.* Herb-shrub tier (C): This tier is dominated by *Vaccinium myrtillus and V. vitis-idaea.* Constant species with a low cover: *Calluna vulgaris, Convallaria majalis, Campanula rotundifolia, Pteridium aquilinum,* etc.; The moss-lichen layer is well developed. Mossy-lichen layer (D): Green mosses: *Pleurozium schreberi* and species of the genus *Dicranum* predominate here. The participation of lichens is insignificant.

TEP A2.3, B3.1, B3.3 also shrub-green-moss pines, but with a predominance of eagle and blueberry *Pinus sylvestris-Pteridium aquilinum – Vaccinium myrtillus-Pleurozium*, which occupy the lowest areas of the terrain. Tree layer (A): The dominant species is *Pinus sylvestris* L. with *Quercus* admixtures *robur* L. Understory layer (B): Understory of medium density, dominated by *Frangula species alnus* Mill., *Sorbus aucuparia* L. single representatives of *Rosa occur canine* L. Grass-shrub layer (C): co-dominated by *Vaccinium myrtillus* L ., and *Pteridium aquilinum* (L.) Kuhn), also occur: *Molinia caerulea , Vaccinium vitis – idaea , Calamagrostis arundinacea* ), *Luzula pilosa*, etc.

The moss-lichen layer (D): has a projective cover of 50–98 %, it is co-dominated *by Dicranum polysetum* and *Pleurozium schreberi*, in some area *Hylocomium splendens*.

TEP B3.2 is a green-moss-small-grass pine forest dominated by *Pinus sylvestris-Calamagrostis arundinacea+Convallaria majalis* located on the gentle tops of hills. Wooden tier (A): the dominant species is pine (50–60 years old), there are minor admixtures of *Betula pendula*. Understory layer (B): thin with degree of closure 0.2–0.3; consists of *Frangula alnus, Rosa canina* L. In some places there is a *Tilia cordata*. There is undergrowth of pine (10–15 years old). Grass-shrub layer (C): well developed (60–90 % coverage). *Calamagrostis epigeios* dominates; *Convallaria majalis* is abundant in places. *Vaccinium vitis-idaea, V. myrtillus,* and *Molinia caerulea* are present in low diversity. Mossy-lichen layer (D): poorly developed and consists of individual areas of *Pleurozium schreberi, Dicranum polysetum, Polytrichum juniperinum.*

A total of 21 species belonging to 15 families and 18 genera were found. Their analysis using diversity indices is presented in fig. 1 and 2.



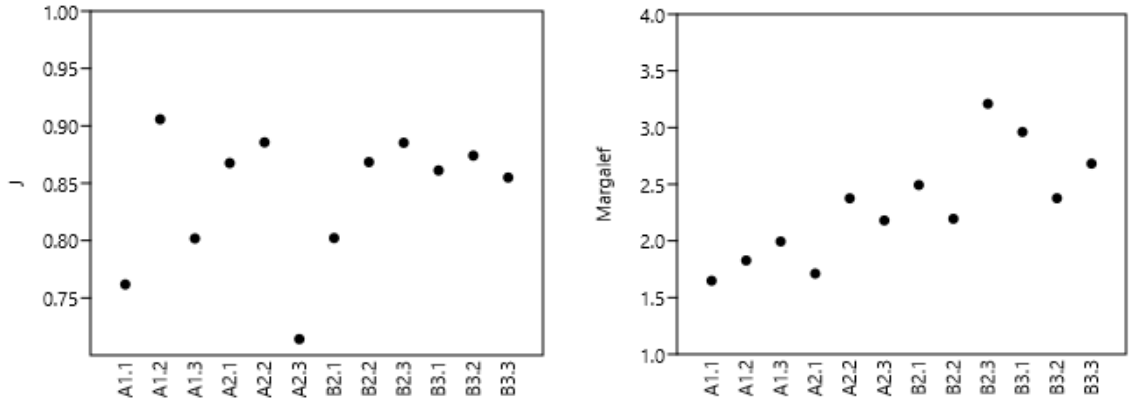

Simpson Index Shannon-Weaver index

Fig. 1. **Values of Simpson and Shannon-Weaver indices.**

Simpson's index (1-D) measures the probability that two randomly selected individuals from a sample belong to the same species. This index is a formula used to measure community diversity. It is used to measure biodiversity, that is, the variety of living things in a certain place. At the same time, the number of species present in the habitat is taken into account, as well as the number of each species.

The minimum indicator of the Simpson index for the studied areas is 0.75 for the green-moss-lichen pine area – A1.1, the peak values are for the shrub-green-moss pine areas: B2.3 and B3.1 – 0.89.

The Shannon-Weaver index is used to quantify specific biodiversity. Its values range between positive numbers, usually between 2, 3 and 4, there is no maximum value for the index. In the literature, this indicator is one of the most popular for measuring biodiversity. The index takes into account the number of species that exist in the sample and the relative number of individuals that exist for each species. Values less than 2 are interpreted as ecosystems with relatively low species diversity, while values greater than 3 are high. Among the studied territories, the following areas had a value of less than 2: A1.1, A1.2, A1.3, A2.1, A2.3. Among which the smallest indicator is 1.674 – A1.1. The maximum indicator was determined again in the section B2.3 – 2.55.




Equity J Margalef index

Fig. 2. **Values of Equitability and Margalef indices.**

Equitability index (J) characterizes the distribution of individuals among species. This index is most important in ecosystems rich in the number of species with a relatively uni-

form distribution of the number of species, in such systems it increases exponentially. All TDDs are characterized by sufficiently high levels of alignment from 0.71 for A2.3 to 0.9 for A1.2.

The Margalef index reflects species density, or species richness in a certain area. The higher the value of the index, the greater the species richness of the studied territory. This index is sensitive to the number of individuals and decreases in accuracy with an increase in the number of individuals with a relatively small number of species. The indicators of this index confirm the above-mentioned results and indicate the species poverty of green moss-lichen pine forests, A1.1 where the index is 1.65. The maximum value was again noted in the area of shrub-green moss pine forests B2.3 – 3.21.

The Jaccard similarity index was used to characterize the beta diversity and conduct a comparative analysis. The results of the analysis are presented in Table 1. When comparing groups of forest types in pairs, the values of the Jaccard similarity coefficient vary in the range from 0.2 to 0.7.

Table 1 – **The value of the Jaccard coefficient for different groups of forest types**

| Forest type | *Pinus sylvestris-Vaccinium vitis-idaea+V. myrtillus-Cladonia spp.+ Pleurozium* | *Pinus sylvestris-Calluna vulgaris-Pleurozium+ Cladonia ssp.* | *Pinus sylvestris-Vaccinium myrtillus-Pleurozium* | *Pinus sylvestris-Pteridium aquilinum-Vaccinium myrtillus-Pleurozium* | *Pinus sylvestris-Calamagrostis arundinacea+ Convallaria majalis* |
|---|---|---|---|---|---|
| *Pinus sylvestris- Vaccinium vitis-idaea+V. myrtillus- Cladonia spp.+ Pleurozium* | 1 | 0.5 | 0.5 | 0.3 | 0.2 |
| *Pinus sylvestris-Calluna vulgaris-Pleurozium+ Cladonia ssp.* | - | 1 | 0.5 | 0.4 | 0.4 |
| *Pinus sylvestris-Vaccinium myrtillus-Pleurozium* | - | - | 1 | 0.7 | 0.6 |
| *Pinus sylvestris-Pteridium aquilinum-Vaccinium myrtillus-Pleurozium* | - | - | - | 1 | 0.5 |
| *Pinus sylvestris-Calamagrostis arundinacea+Convallaria majalis* | - | - | - | - | 1 |

Shrub-green moss pine forests with a dominance of *Vaccinium vitis-idaea* and *Pteridium aquilinum* have the greatest similarity (0.7), as well as green moss-small herbaceous and shrub-green moss pine forests with a blueberry dominance (0.6); the smallest – small-grass pine and green-moss-lichen pine (0.2).

**Conclusions.** Phytodiversity of the forests of Radomyshlske FHE was conducted with the determination of the main indices of species diversity. The studied forests are classified into three main types of pine forests: green-moss-lichen, shrub-green-moss, green-moss-small grass forests. Most of the studied forests (66 %) belong to the shrub-green moss pine forests.

The main forest-forming trees forming the tree layer: *Pinus sylvestris* and *Betula pendula.* The layer of shrubs and undergrowth of trees (undergrowth) consists of the young generation of the listed trees and adult shrubs. In the grass-shrub layer there are mainly such dominant species as: *Vaccinium vitis-idaea*, *V. myrtillus, Calluna vulgaris* and *Pteridium aquilinum.* In the moss-lichen layer, lichens, green and sphagnum mosses can be combined in different ways.

Shrub-green moss forests have the greatest species richness, and the lowest indicators of species richness are characteristic of the green moss-lichen section.

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**Дослідження видового різноманіття рослин лісів ДП «Радомишльське ЛМГ»**

**Кратюк О.Л.**

Досліджено видове різноманіття рослин на території Радомишльського лісомисливського господарства на ділянках з різними типами лісорослинних умов. Ідентифіковано 21 вид, які належать до 15 родин, 18 родів. Визначено основні типи лісу (*Pinus sylvestris-Vaccinium vitis-idaea+V. myrtillus-Cladonia spp.+ Pleurozium; Pinus sylvestris-Calluna vulgaris-Pleurozium+ Cladonia ssp.; Pinus sylvestris-Vaccinium myrtillus-Pleurozium; Pinus sylvestris- Pteridium aquilinum-Vaccinium myrtillus-Pleurozium; Pinus sylvestris-Calamagrostis arundinacea+Convallaria majalis)* та головні індекси видового різноманіття (Сімпсона, Шеннона-Ввівера, Вирівняності та Маргалефа). Серед типів лісу найбільш поширеними є зеленомохово-чагарникові сосняки та саме ділянки з цим типом лісу характеризуються найбільшими показниками видового різноманіття та багатства з піко-

вими показниками індекса Сімпсона – 0,89; індекса Шеннона-Вівера – 2,55 та індекс Маргалефа – 3,21. Показники зеленомохово-лишайникового соснового лісу, навпаки, вказують на достатньо бідну видову різноманітність, а саме індекса Сімпсона – 0,75; індекса Шеннона-Вівера – 1,67 та індекс Маргалефа – 1,65. Проте, саме цей тип лісу характеризувався максимальними показниками вирівняності – 0,9. Було проведено порівняльний аналіз видового складу досліджуваних ділянок для оцінки бета-різноманіття за допомогою індекса Жаккара. Найбільшу подібність мають сосняки чагарниково-зеленомохові з домінацією чорниці та орляка (0,7), а також сосняки зеленомохово-дрібнотрав'яні та чагарниково-зеленомохові з домінацією чорниці (0.6); найменшу – сосняк дрібнотрав'яний та сосняк зеленомохово-лишайниковий (0.2).

**Ключові слова:** видове різноманіття, бета-різноманіття, альфа-різноманіття, фіторізноманіття, Полісся України, типи лісів.



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