Forest typological features of the α-diversity of the stand and the herb layer in the mountain forests of the Middle Urals

Natalya Ivanova[*] and *Irina* Petrova

[1]Institute Botanic Garden Ural Branch of RAS, 8 Marta Street, 202a, 620144 Yekaterinburg, Russia

Abstract. The study of the α diversity of the stand and the herb layer of all major forest types of primary pine and spruce forests in the Middle Urals was conducted. Four indices (Shannon's Diversity Index, Pielou's Evenness Index, Simpson's Diversity Index, Zhivotovsky's Diversity Index) were used to quantify α diversity. The indices were calculated based on the basal area (for the stand) and absolutely dry biomass (for the herb layer). It was shown that each forest type studied has its own characteristics of α diversity, while the relationship between the stand and the herb layer according to the dynamics of the calculated indices when changing habitats was not revealed.

1 Introduction

The problem of reducing forest biodiversity is relevant all over the world [1]. It is also relevant in the Russian Federation [2]. Information on regional, landscape and forest typological characteristics of forest biodiversity is needed to minimize this process [3]. Rapidly developing methods of remote sensing make it possible to organise a continuous flow of information on the structure of the tree layer over large areas [1, 4]. At the same time, the lower layers remain poorly studied [5, 6]. However, the contribution of the herb layer to biodiversity in boreal forests cannot be ignored. Further large-scale research is needed.

The Ural Mountains divide Europe and Asia and act as a barrier to the spread of species. In addition, the heterogeneous landscapes and soils of the Middle Urals have led to the formation, in a relatively small area, of a whole range of different forest types with their own peculiarities of vegetation structure and dynamics, performing important ecosystem functions both for the Russian Federation and for the planet as a whole. Therefore, this region is extremely interesting for research and important for nature conservation.

This paper continues a series of publications devoted to the biodiversity of the primary forests of the Ural Mountains [7, 8]. The purpose of our research is to obtain quantitative characteristics and identify forest typological features of the biodiversity of forest vegetation layers, which will serve as a benchmark for comparison when studying the transformation of forest vegetation and the success of reforestation.

[*] Corresponding author: i.n.s@bk.ru

2 Materials and methods

The research has been carried out on the eastern macro slope of the Middle Ural Mountains. The low mountain range is represented by an altitude of between 250 and 500 meters above sea level. The research is based on Genetic Forest Typology, which is widely used in the Russian Federation and recognised as a reliable basis for forestry [9-11]. We have studied 11 primary forest types (Fig. 1). The nomenclature of B.P. Kolesnikov is used for naming forest types [9]. The size of the sample plots was 0.25 hectares. Four indices (Shannon's Diversity Index, Pielou's Evenness Index, Simpson's Diversity Index, Zhivotovsky's Diversity Index) were used to quantify α diversity (Table 1). The indices were calculated based on the basal area (for the stand) and absolutely dry biomass (for the herb layer). For the determination of herb biomass, 16-20 plots (1 m^2) have been established on each sample plot. Diversity indices for the herb layer are calculated for 1 m^2 plots and average values are given.

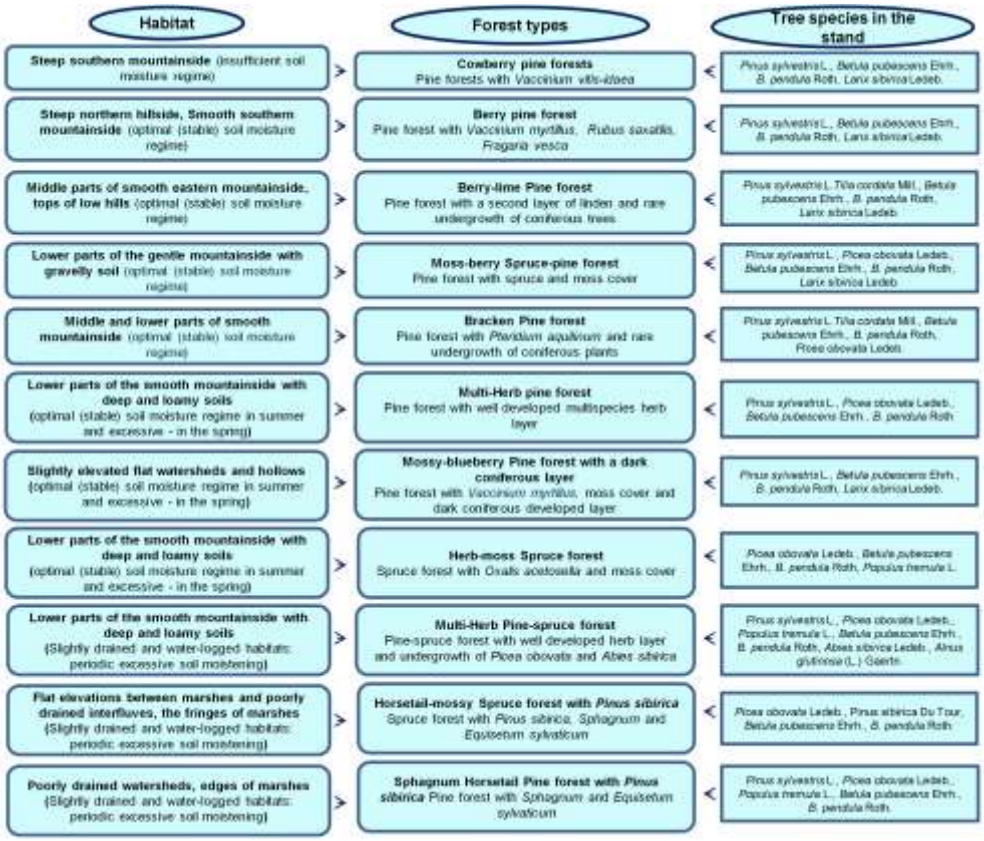

Fig. 1. Studied forest types of primary pine and spruce forests in the Middle Urals.

3 Results and Discussion

Different indices show different characteristics of forest layer biodiversity. The species diversity of the stand and the herb layer of the Cowberry Pine forest type is characterized by a large difference in the Shannon's index and smaller by Pielou's index (the biodiversity of the stand is much lower than the biodiversity of the herb layer) and the Simpson's index

(dominance is more pronounced in the stand), but differs slightly in the Zhivotovsky's index (Fig. 2).

Table 1. Diversity indices: *S* is the number of species; *pi* is the relative abundance.

Diversity Index	Formula
Shannon's Diversity Index	$H = -\sum_{i=1}^{S} p_{i*lnp_i}$
Pielou's Evenness Index	$e = \frac{H}{lnS}$
Simpson's Diversity Index	$C = \sum_{i=1}^{S} p_i^2$
Zhivotovsky's Diversity Index	$h = 1 - \frac{\mu}{S}; \ \mu = (\sum_{i=1}^{S} \sqrt{p_i})^2$

The values of the three calculated diversity indices (Shannon's Diversity Index, Simpson's Diversity Index, Zhivotovsky's Diversity Index) are similar for the Cowberry Pine forest type and the Berry Pine forest type (Fig. 3). However, differences were found between these forest types for the Pielou's Evenness Index. This index has similar values for the stand and the herb layer. Simultaneously, the values of this index are very small.

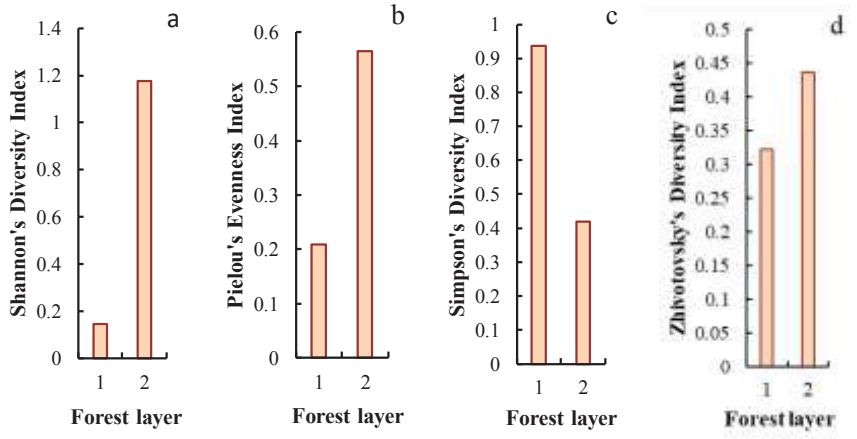

Fig. 2. Relationship between the species diversity of the stand and the herb layer in the Cowberry Pine forest type: 1 – stand, 2 - herb layer.

The similarity with the Cowberry Pine forest type has been established for the the Berry-lime Pine forest type according to three calculated indices (Shannon's Diversity Index, Pielou's Evenness Index, Simpson's Diversity Index) (Fig. 4). At the same time, these forest types differ in the values of the Zhivotovsky's Diversity Index for the stand and the herb layer.

For the Moss-berry Spruce-pine forest type, the similarity with Berry Pine forest type has been established according to three calculated indices (Shannon's Diversity Index, Simpson's Diversity Index, Zhivotovsky's Diversity Index). At the same time, these forest types differ in large Pielou's Evenness Index values for both the stand and the herb layer (Fig. 5).

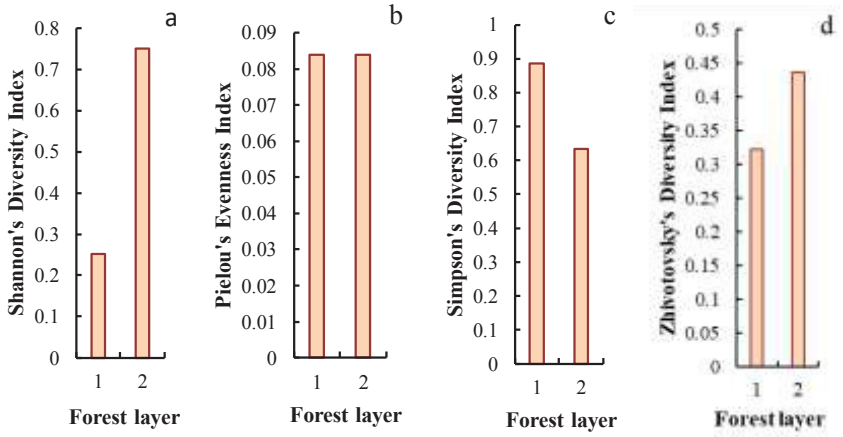

Fig. 3. Relationship between the species diversity of the stand and the herb layer in the Berry Pine forest type: 1 – stand, 2 - herb layer.

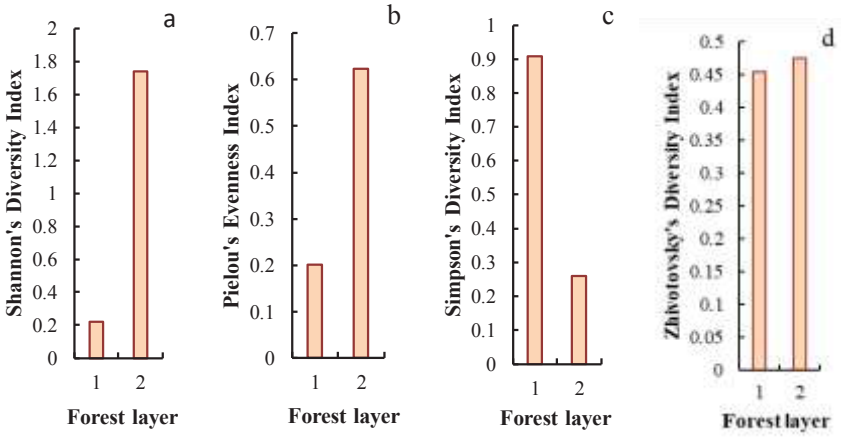

Fig. 4. Relationship between the species diversity of the stand and the herb layer in the Berry-lime Pine forest type: 1 – stand, 2 - herb layer.

The Bracken Pine forest type differs from the other forest types studied by having lower Shannon's Diversity Index and Pielou's Evenness Index values (Fig. 6).

The Multi-Herb Pine forest type with a multi-species herb layer out from the other forest types studied with the highest values of the Shannon's Diversity Index for the herb layer and the lowest values of the Simpson's Diversity Index for the same layer (Fig. 7).

The apparent similarity between in the Moss-berry Spruce-pine forest type (Fig. 5) and the Mossy-blueberry Pine forest with a dark coniferous layer (Fig. 8). At the same time, the Shannon's Diversity Index and Pielou's Evenness Index values for the Moss-berry Spruce-pine forest type are slightly higher and the Simpson's Diversity Index and Zhivotovsky's Diversity Index values for the Mossy-blueberry Pine forest with a dark coniferous layer are higher.

The Herb-moss Spruce forest type differs from the other forest types studied by the maximum Pielou's Evenness Index values for the stand and the minimum Zhivotovsky's Diversity Index values for the same layer (Fig. 9).

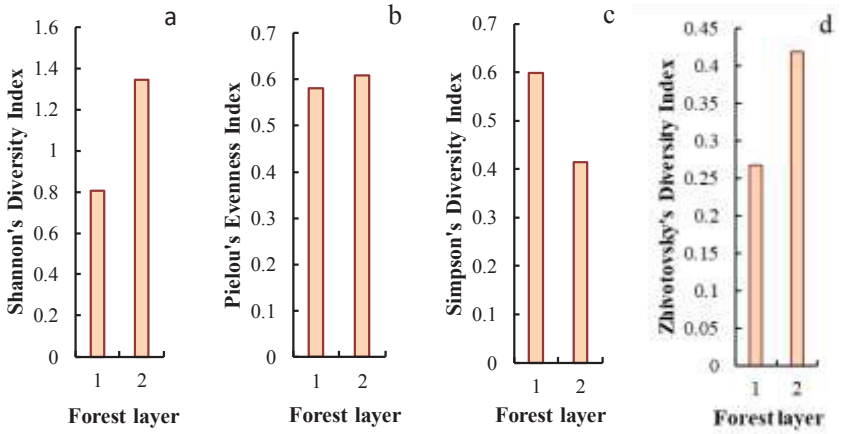

Fig. 5. Relationship between the species diversity of the stand and the herb layer in the Moss-berry Spruce-pine forest type: 1 – stand, 2 - herb layer.

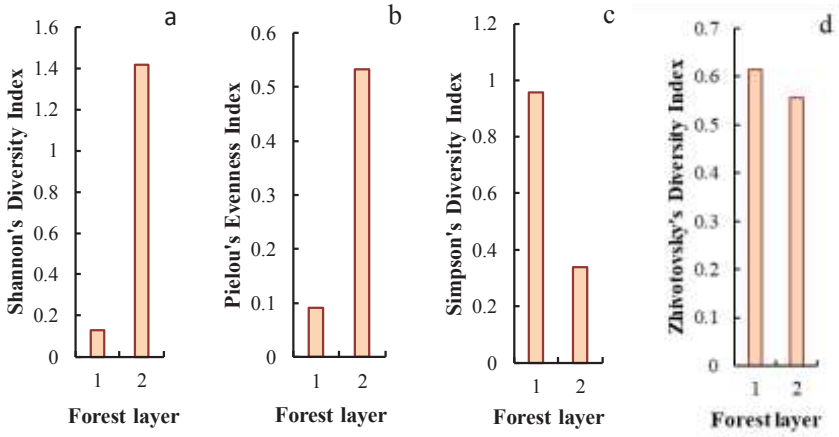

Fig. 6. Relationship between the species diversity of the stand and the herb layer in the Bracken Pine forest type: 1 – stand, 2 - herb layer.

The Multi-Herb Pine-spruce forest type differs from the other forest types studied by the maximum Shannon's Diversity Index values for the stand (Fig. 10). Note also that there are large Pielou's Evenness Index values for the stand compared to the herb layer. In general, such a ratio of stand and herb layer Pielou's Evenness Index was only found for two forest types: The Herb-moss Spruce forest type (Fig. 9) and the Multi-Herb Pine-spruce forest type (Fig. 10). It is interesting to note that the Pielou's Evenness Index is a normalised Shannon's Diversity Index. Previously, we only studied the diversity of the herb layer and concluded that the dynamics of these indices are very similar, but it is more convenient to interpret the Pielou's Evenness Index, since it varies from 0 to 1 [12]. However, this study clearly shows that with a small number of species, these indices give sharply different values and it is necessary to calculate both indices in order not to get false research results.

Based on the diversity indices, the Horsetail-mossy Spruce forest type with *Pinus sibirica* (Fig. 11) was more similar to Multi-Herb Pine forest type with a multi-species herb layer (Fig. 11) than to other spruce forests (Fig. 9, 10). At the same time, the Sphagnum Horsetail Pine forest type (Fig. 12) is more similar to spruce forests (Fig. 9, 10).

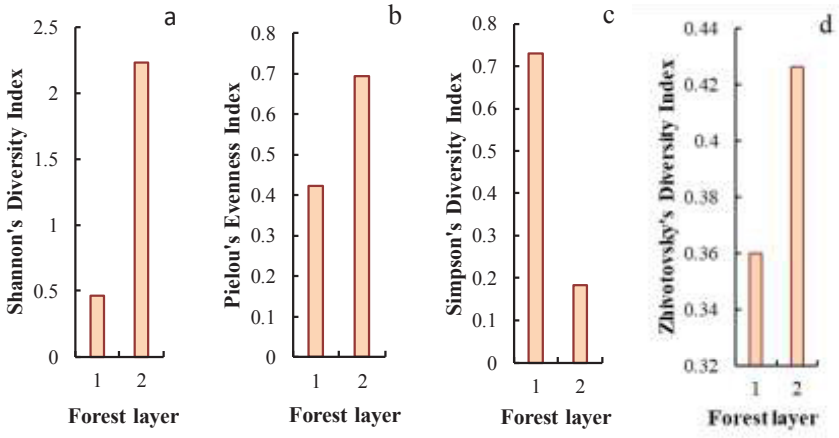

Fig. 7. Relationship between the species diversity of the stand and the herb layer in the Multi-Herb Pine forest type with a multi-species herb layer: 1 – stand, 2 - herb layer.

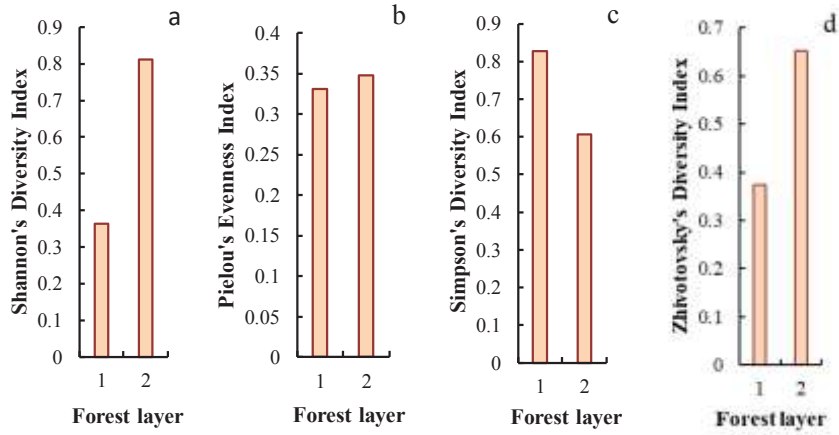

Fig. 8. Relationship between the species diversity of the stand and the herb layer in the Mossy-blueberry Pine forest with a dark coniferous layer: 1 – stand, 2 - herb layer.

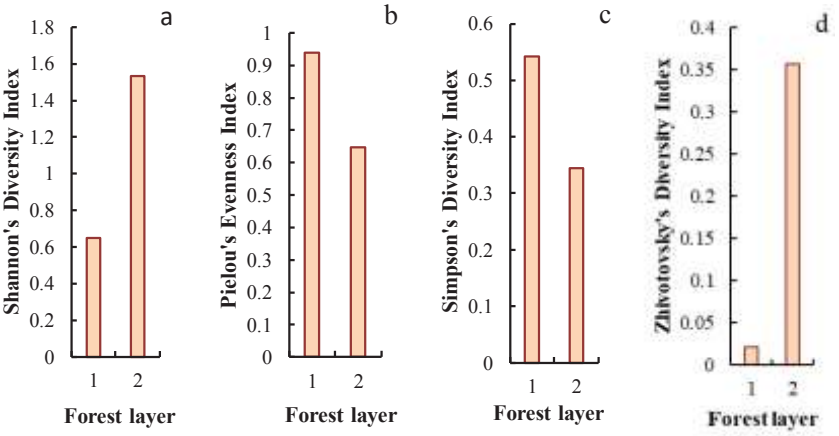

Fig. 9. Relationship between the species diversity of the stand and the herb layer in the Herb-moss Spruce forest type: 1 – stand, 2 - herb layer.

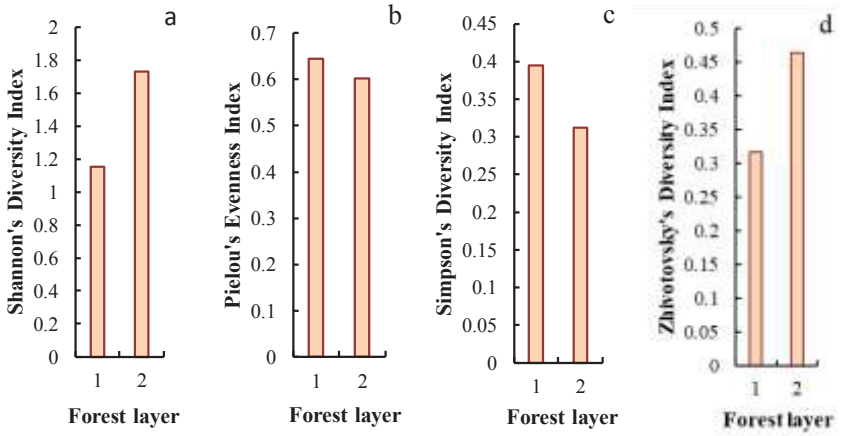

Fig. 10. Relationship between the species diversity of the stand and the herb layer in the Multi-Herb Pine-spruce forest type: 1 – stand, 2 - herb layer.

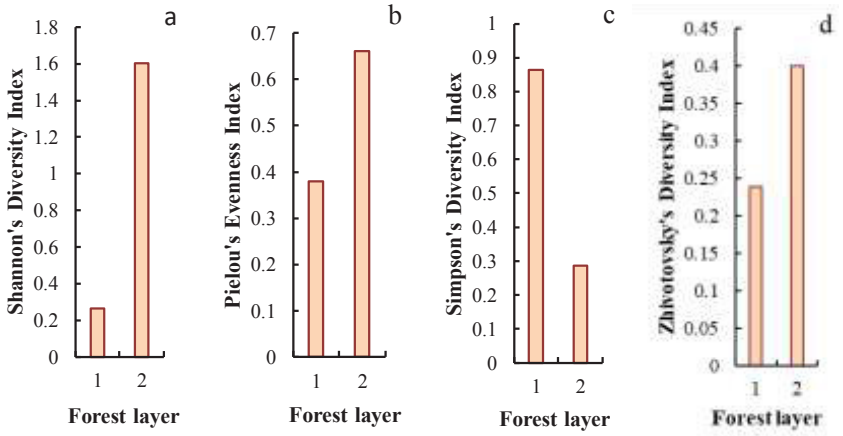

Fig. 11. Relationship between the species diversity of the stand and the herb layer in the Horsetail-mossy Spruce forest type with *Pinus sibirica*: 1 – stand, 2 - herb layer.

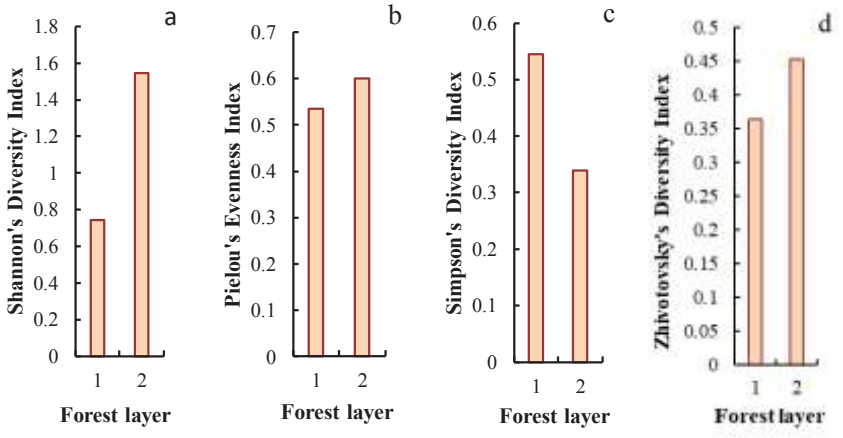

Fig. 12. Relationship between the species diversity of the stand and the herb layer in the Sphagnum Horsetail Pine forest type: 1 – stand, 2 - herb layer.

3 Conclusion

Thus, the relationship between the stand and the herb layer according to the dynamics of the calculated indices when changing habitats was not revealed, while each forest type studied has its own characteristics of species diversity. Also, when changing habitats, each of the calculated indices has its own dynamics specific to the forest layer. Therefore, for an accurate and comprehensive assessment of the species diversity of forest layer, it is necessary to use a set of indices of diversity, evenness, dominance and indices for assessing the contribution of rare species. Unfortunately, the research results have shown that based on the assessment of the species diversity of the stand, we cannot judge the species diversity of the subordinate layers. Therefore, the results of assessments of forest species biodiversity based on GIS technologies, when only the stand is taken into account, cannot be extended to the entire biocenosis, since this in most cases will lead to false conclusions.

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