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Herbage cover heterogeneity as indicator of ecology-phytocoenotical and biotopical diversity in oak forests

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The article is devoted to the identification of biotope diversity. There were surveyed the oak forests grown on the steep ravine slope near the Severskiy Donets River (the Don basin) within the area of National Park "Homolshansky lisy" (Kharkiv region, Ukraine). Study of spatial heterogeneity of herbage cover structure allowed distinguishing statistically significantly the seven types of multi-species mosaics on the coenotical level, which are characterized by specific ecology-phytocoenotical specificity. Such types form coenotical, hygrogen-edaphogenic and climatogenic series of substitution reflected the habitat diversity of surveyed area (as markers of habitat) and were in accord with the typology units of forests in Ukraine. In this paper there were used methods of phytoindication, indirect ordination, and non-parametric correlation analysis.

Key words: *biotope, oak forest, herbage cover, coenotical mosaic, phytoindication, ordination, environmental regimes.*

Неоднородность травяного покрова как показатель эколого-фитоценотического и биотопического разнообразия дубрав

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Статья посвящена проблеме выявления биотопического разнообразия. Исследовались дубравы приречного склона р. Северский Донец (бассейн Дона) на территории НПП «Гомільшанські ліси» (Харьковская область, Украина). Изучение неоднородности пространственной структуры травяного покрова позволило на ценотическом уровне статистически достоверно выделить 7 типов многовидовых ценотических мозаик, которые характеризуются эколого-фитоценотической спецификой. Данные типы образуют ценотические, гигрогенно-эдафогенные и климатогенные ряды замещения; отражают биотопическое разнообразие исследованной территории (как маркеры биотопов) и соответствуют единицам типологии лесов Украины. В работе были использованы методы фитоиндикации, непрямой ординации, непараметрический корреляционный анализ.

Ключевые слова: *биотоп, дубрава, травяной покров, ценотическая мозаика, фитоиндикация, ординация, экологические режимы.*

Неоднорідність трав’яного покриву як показник еколого-фітоценотичного та біотопічного різноманіття дубрав

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Стаття присвячена проблемі виявлення біотопічного різноманіття. Досліджувалися дубрави прирічкового схилу р. Сіверський Донець (басейн Дона) на території НПП «Гомільшанські ліси» (Харківська область, Україна). Вивчення неоднорідності просторової структури трав’яного покриву дозволило на ценотичному рівні статистично вірогідно виділити 7 типів багатовидових ценотичних мозаїк, які характеризуються еколого-фітоценотичною специфікою. Данні типи утворюють ценотичні, гігрогенно-едафогенні та кліматогенні ряди заміщення; відображають біотопічне різноманіття досліджуваної території (як маркери біотопів); відповідають одиницям типології лісів України. В роботі були використані методи фітоіндикації, непрямої ординації, непараметричний кореляційний аналіз.

Ключові слова: *біотоп, дубрава, трав’яний покрив, ценотична мозаїка, фітоіндикація, ординація, екологічні режими.*

Introduction

Biodiversity of given site depends on the biotopical diversity. Variability of plant associations and ecological regimes within different habitats reflects diversity of ecosystems and biotopes. Classification of biotopes and ecosystems is based on the investigation of such variability. Ecosystem classification is connected with the work of European Center of Nature Protection and Biodiversity, specifically with creating database CORINE (Didukh, 2004), and working out the classification system EUNIS (Davies et al., 2004). Such classification system uses different criteria and approaches for different hierarchical levels (sometimes there were used even different foundations for separation within a single level): for some climate-geographical, for other hydrological or edaphical conditions, etc. For classification of forest phytocoenoses, the EUNIS system provides no substantial advantages (Nazarenko, Stadnyk, 2001). EUNIS, on the one side, presented the habitat classification (topography, plant or animal physiognomy, soil characteristics, climate, water quality etc.), and on the other side, provided classification of biocoenoses: of plants and animals (by virtue of species diversity analyze, dominant structure, ets.). The most reasonable for biotope classification is to use at once two classification approaches. A.L.Belgard used all three key parameters (landscape position, hydrological regime and soil features) when allocating each typological unit (Belgard, 1971). Currently, establishment of similar scheme bases on the complex application of several methodological approaches. Data on species quantity and analysis of their grouping are the basis of the first approach. The second approach is applied to groups of species already identified, taking into account the characteristics of their habitat.

Each geobotanical description is a system of objects within multi-dimensional space of traits. The traits, in this case are considered to be quantitative characteristics of the identified species. Multidimensional classification of vegetation identifies the object composition. The resulting accuracy depends on the number of descriptions and the number of species in descriptions. Such object composition represents a certain type of habitat conditions, and certain group of species usually growing in these conditions. Graphical presentation of multidimensional statistics results in ordination analysis allows identifying the hidden relationship between objects and their structural composition (Nazarenko, Stadnyk, 2001; Whittaker, 1967). Cluster analysis allows creating and substantiating classificatory and typological schemes. Identification of homogenic groups is based on floral similarity indexes. Distribution of objects in clusters and clusters dimension depend on the method and algorithms of clustering. Various methods and algorithms have some advantages and disadvantages. Data of other quantitative phytocoenotical methods specify and supplement the results of cluster analysis (for example, information about features of stand conditions) (Ayvazyan et al., 1974; Data analysis…, 1999; Bezrodnova, Zadorozhniy, 2001; Dyuran, Odell, 1972; Oldenderfer, Bleshfild, 1989; Smirnova et al., 2001).

Mosaic structure and complexity are two different levels of vegetation heterogeneity. A lot of scientists concerned themselves with study of such heterogeneity during typological investigation of herbage cover (Korchagin, 1976; Maslov, 1983, 1985, 1990; Nitsenko, 1969; Yaroshenko, 1958; Kershaw, 1957, 1960). Features of plant biology, specificity of and climatope and edaphotop determine the extent of mosaicity and complexity. Sometimes mosaic spot consists of several microcoenoses. Under what conditions is such heterogeneity an indicator of phytocoenosis and biotope diversity? When a certain type of multi-species coenotical mosaic (MCM) called mosaic spot is associated with certain ranges of environmental regimes, and it has specific coenotical features, than such type is a marker for plant community, habitat and biotope.

Ecology-coenotical groups of the plants are basis for type identification the ordination of MCM. All species of the ecology-coenotical group (ECG) have similar optimums by environmental factors. They have high degree of mutual proximity and occur in the particular types of habitat (Nitsenko, 1969; Didukh, 2001). ECG are widely used in phytoindication of habitat conditions (Tsyganov, 1983; Didukh, 2001), to assess the ecosystem and structural diversity (Maslov, 1990), typing associations and identifying their successional status, in prediction changes in habitat conditions (Nitsenko, 1969; Smirnova et al., 2001). ECG selection is usually conducted on the analysis of ecological scales and geobotanical descriptions, which contain information about species occurrence in different types of associations and habitats. To substantiate system of ECG of plants in the forest zone (European Russia) the expert-statistical scheme was offered. In our opinion, the most developed ECG system for the forest zone of European Russia is the grouping based on the classifications of A.A.Nitsenko (Nitsenko, 1969) and G.M. Zozulin (Zozulin, 1973). Environmental experts widely use the methods of multidimensional classification and ordination within Ukraine, for the north-steppe Dnieper region to explore plant associations and habitats diversity of Ukrainian hardwood forests (Nazarenko, 2011; Nazarenko, Stadnyk, 2001).

This paper presents the results of preliminary studies in eastern part of the forest-steppe zone. The paper is aimed to identify types of multi-species coenotical mosaics on the ground of study heterogeneity of oak forest vegetation cover. These types can be used to assess phytocoenotical and biotope diversity.

The object and approach of research

The investigations were conducted in 2011–2012. The study site is represented by National Park "Homolshansky lisy" near Biological Station of V.N.Karazin Kharkiv National University (neighborhood of Gaydary villiage, Zmiyiv district, Kharkiv region). Although the park was created only in 2004, the forest sites of this territory were investigated by prominent Ukrainian scientists since the beginning of twentieth century. In the 70th of the twentieth century researchers from Kharkiv University conducted a survey for the planned park area, and substantiated the necessity to create it (Saidakhmedova, 2006; North-Donetsk …, 1980). In the 80th the classification schemes of proposed park vegetation were made up using eco-phytocoenotical approach (Shelyag-Sosonko et al., 1990).

Within the oak forests there were allocated such forest types as pure oak, oak with maple and linden, and ash-oak. First level of such forests consists of *Fraxinus excelsior* L. and *Quercus robur* L. (sometimes *Populus tremula* L.). The second level is created with *Acer campestre* L., *Tilia cordata* Mill. (at slopes on poorer soil). As for wetting regime, the oak forests were divided into wet and mesic-wet (found fragmentarily, on small sites), dry and mesic (dominate in the park territory). Grass cover is characterized by a high degree of mosaicity, especially on the slopes of gullies and ravine slopes near watershed (Gorelova, Alekhin, 2002).

The objects of this study were the plant communities on the steep ravine slope of eastern-facing aspect (right bank of the Seversky Donets River, basin of the Don). The subjects of researches were features of herbage cover horizontal heterogeneity forming. During the field investigation, relatively undisturbed mixed oak forests, located on ravine slope were surveyed. Stands selected for sampling were relatively homogeneous vegetative units located on uniform topography and restricted to a single soil type and showed little or no evidence of recent disturbance by fire, cutting, etc. Vegetation was described using standard geobotanical methods (Andreyeva et al., 2002; Rabotnov, 1978). Four transects (a width of 0.5 m and a total length of 200 m) were located and described within these sections perpendicularly to slope from its upper part to the river bed. Transects were a set of continual discount areas (DA) measuring 0.5 to 0.2 m. At each DA it was fixed the presence all species of grass and shrubs, as well as seedlings and understory species. The obtained data reflected peculiarities of continual plant distribution along the slope. Statistical analysis of all totality of DA (in MS Excel macros) has been allocated determined quantity of structural units called coenotical mosaics (MCM). Then the resulting mosaics were analyzed as a separate description matrix. Type identification and ordination of MCM was carried out according to the scheme proposed for boreal forests of European Russia with modifications (Data analysis …, 1999), and included such stages:

1. Pre-classification according to dominants of tree layer.
2. Clustering using a Sorensen-Czekanowski (Bray-Curtis) index and cluster organization by Lance flexible beta strategy.
3. Checking the clustering (cluster homogeneity) by Multi-Response Permutation Procedures (MRPP).
4. Indirect ordination of descriptions by the method of Non-metric Multidimensional Scaling (NMS).
5. Interpretation of NMS axes by nonparametric correlation analysis (by Tau-Kendall index) using calculated scoring phytoindication parameters with the method of weight-average interval estimation on the scale of D.N.Tsyganov (Tsyganov, 1983).

Results and discussion

It is known that herbage cover has continuity as well discrecity. Mosaicity of horizontal structure within herbage cover in oak mixed forest is a reflection of such discretion, to some extent. Analysis of mosaicity features in continual distribution of plants along the slope has identified 20 discrete, repetitive elements called multi-species coenotical mosaics (MCM). Clustering of MCM allows identifying seven clusters, which are then considered as seven different types of mosaics. Identified types were characterized by high intragroup homogeneity of species composition that is confirmed statistically. Classification accuracy was confirmed by MRPP (a chance-corrected within-group agreement - 0.80).

1st type of mosaics is horsetail-greater starwort MCM. Localization is lower part of the slope. Includes 12 species of vascular plants, among which *Equisetum arvense* L. and *Stellaria holostea* L. have the highest frequency. Projective cover of these species sometimes can reach up to 25–30 %. Plant species such *Lamium maculatum* (L.) L., *Geranium robertianum* L., *Geum urbanum* L. were often encountered, but their projective cover does not exceed 3–5 %. On some sites *Aristolochia clematitis* L. and *Urtica dioica* L. developed significantly, sometimes form thickets.

2nd type of mosaics is Wood bluegrass-ground ivy MCM. They are located at the upper, sometimes at middle, parts of the slope. Includes 10 vascular plant species, among which the highest frequency is belong to *Glechoma hederacea* L. and *Poa nemoralis* L. The projective cover of these species on local sites can be 10–25 %. High occurrence is typical for *Stellaria holostea*, but it is presented considerably less than in 1st type: projective cover does not exceed 10%. Species such as *Dactylis glomerata* L., *Viola mirabilis* L. are found sporadically. Sometimes *Euonymus europaea* L. developed widely in herbage cover.

3rd type of mosaics is Wood bluegrass-spotted deadnettle-greater starwort MCM. Occur at the middle and upper parts of the slope. It includes 15 vascular plant species, among which the highest frequency is belong to *Poa nemoralis*, *Lamium maculatum* and *Stellaria holostea*. Projective cover of these species is 3–8, 5–15 and 5–20 % respectively. Species *Pulmonaria obscura* Dumort. occurs frequently too. The projective cover of last species on some points can reach up to 15%. Species as *Geum urbanum*, *Viola mirabilis*, *Sedum ruprechtii* (Jalas) Omelcz., ets. occur sporadically.

4th type of mosaics is goutweed MCM developed widely at the middle and lower parts of the slope. It includes 21 vascular plant species, among which the highest frequency is belong to *Aegopodium podagraria* L. Projective cover of this specie is 20–70 %. Plant species such *Stellaria media* (L.) Vill., *Glechoma hederacea*, *Urtica dioica* occurred frequently. Projective cover of two last species reaches up 15%. Species as *Poa nemoralis*, *Dactylis glomerata*, *Stellaria holostea*, *Pulmonaria obscura* have a lower occurrence.

5th type of mosaics is asarabacca-goutweed MCM. Such mosaic occurs predominantly at the lower part of the slope, sometimes at middle part. Includes 9 vascular plant species, among which the highest frequency is belong to *Asarum europaeum* and *Aegopodium podagraria*. Projective cover of these species reaches up to 10–20 and 25–30 % respectively. *Stellaria holostea* occurs quite often (projective cover is 3–5 %). *Pulmonaria obscura*, *Geum urbanum*, *Dactylis glomerata*, *Glechoma hederacea* occur sporadically.

6th type of mosaics is Carex pilosa-goutweed MCM. It occurs predominantly at middle part of the slope, rarely at upper part. Includes 12 species of vascular plants, among which the highest frequency is belong to *Carex pilosa* Scop. and *Aegopodium podagraria*. Projective cover of these species is 10–15 and 10–25 % respectively. On some points *Euonymus europaea* developed extensively in the herbage cover.

7th type of mosaics is Carex pilosa MCM. It is localized at upper part of the slope, sometimes – at middle part. Includes 8 vascular plant species, among which the highest frequency is belong to *Carex pilosa* (projective cover of this specie is 15–40 %). *Glechoma hederacea*, *Stellaria holostea*, *Dactylis glomerata* have high frequency, its projective cover on the local sites reach up to 5–10, 3–8 and 3–5 % respectively. Just as in the previous type *Euonymus europaea* is developed widely in grass layer.

In this regard, the question arises: can the selected types of mosaics be used as markers of certain type of habitat conditions and reflect a specific habitat? The habitat subsystems (climatop and edaphotop) act as structural parts of every biotope. Features of climatop determined ombro-, cryo-, thermoregimes and continentality and light regime. Salt, acid, nitrogen regimes and soil wetting regime characterize the edaphotop specificity. Scoring values of nine ecological regimes were determined for each cluster group (each type of MCM) based on phytoindication values (table 1).

Comparative analysis indicates that some MCM types are quite similar in a number of parameters. The selected types of MCM have not only certain specific of their floristic composition, quantitative phytocoenotical indicators, but also demonstrate the certain environmental versatility. The selected types of MCM can be considered as markers of a particular habitat.

It was held ordination for 20 MCM within ecology-coenotical space of nonmetric multidimensional scaling axes as a number of factors (fig. 1). Such ordination demonstrates evidently MCM regimentation of seven groups, and shows the pattern of this distribution within ecology-coenotical space. The common characteristics for MCMs biotopes in the left side of Figure (groups 1, 2, 3, 6, 7) were wet forest-meadow type of wetting; soil is quite rich with respect to the mineral composition, but it is not enough with nitrogen. The habitats of the right side (groups 4, 5) have such characteristics as mesic forest-meadow type of wetting; the soil is not mineral-rich, but it is enough with nitrogen.

All MCM of top side (groups 4, 5, 6, 7) were formed in conditions of half-shade stand ecological structure, at a value of soil solution pH close to neutral. Different combinations of these features describe the habitats for three groups of MCMs in lower side. The distinctive features of the first group habitat were half-clarify ecological structure; the pH values were close to neutral. The habitats of all other groups were characterized by half-shade ecological structure; pH values were close to subacidic or neutral (groups 2 and 3, respectively). Groups formed distinct eco-coenotical series.

Table 1.
The ranges of ecological regimes relating to types of multi-species coenotical mosaics (MCM)

Ecological regime	**Scoring indexes of ecological regimes for each type of MCM**						
	Horsetail-greater starwort MCM	Wood bluegrass-ground ivy MCM	Wood bluegrass-spotted deadnettle-greater starwort MCM	Goutweed MCM	Asarabacca-goutweed MCM	Carex pilosa-goutweed MCM	Carex pilosa MCM
Thermoregime	7,9	8,2	8,3	8,5	8,5	8,7	8,7
Continentality	8,3	8,5	8,4	9,1	8,9	8,8	8,6
Ombroregime	8,4	7,9	7,9	8,3	8,2	7,9	7,8
Cryoregime	7,5	7,5	7,6	8,0	8,0	8,4	8,5
Hydroregime	12,8	12,7	13,0	12,2	12,4	12,5	12,6
Trophic	7,3	7,3	7,2	5,7	6,0	6,5	6,8
Acidity	7,5	7,3	7,6	7,7	7,7	7,7	7,6
Nitrogen	6,4	6,4	6,5	7,9	7,5	6,7	6,4
Light	4,1	5,2	5,1	4,6	4,8	5,2	5,2
Humus	3,2	3,5	3,7	3,8	3,7	3,4	3,3

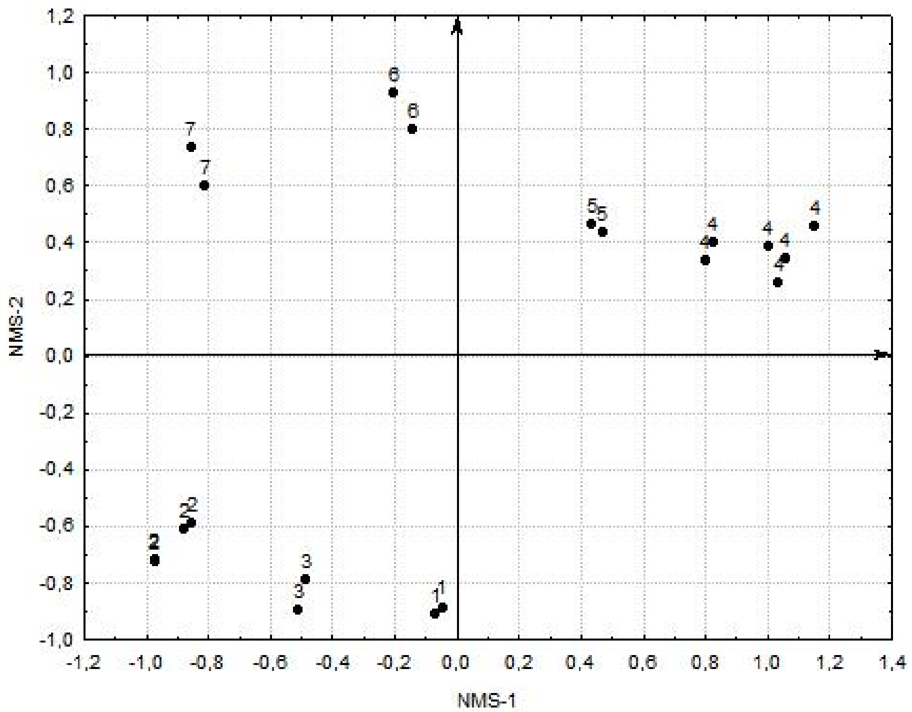

Fig. 1. Ordination of multi-species coenotical mosaics of herbage cover in oak forest in NMS axes (1–7 – types of mosaics).

Identification of NMS axes (table 2) shows a complex factor structure of coenotical series formation. Of greatest interest is the upper series of eco-coenotical ordination. These series show the different quality of habitat for soil and hydrological conditions. Positive correlation with nitrogen regime and negative correlation with salt regime and soil wetting are the most statistically significant (table 2). Difference between the minimum and maximum values for nitrogen and salt regime is more than one score (1.5 and 1.1 points, respectively).

Analysis of climatop features gave also interesting results. All biotopes belong to the continental type on regime of continentality, and to the intermediate type (from sub-arid to sub-humid) on ombroregime. Biotope of group 1 is closest in the regime of continentality and ombroregime to marine and sub-humid because direct impact of the river. Biotopes of groups 1 and 2 occupy different positions in relief (lower part of slopes in the first case, and middle and upper ones in the second case). These habitats exhibit similarity in many characteristics of edaphotop and also in climatic parameters. Regime of continentality and temperature are characterized by similar indicators. Cryoregime values are same.

Table 2.

Identification of nonmetric multidimensional scaling axes

Ecological regime	**The axis of nonmetric multidimensional scaling ***	
	1st NMS	2nd NMS
Thermoregime	-	0,72
Continentality	0,58	0,46
Ombroregime	0,55	-
Cryoregime	-	0,68
Hydroregime	-0,64	-0,40
Trophic	-0,65	-0,37
Acidity	0,47	0,40
Nitrogen	0,73	-
Light	-0,64	-

*Note: * – statistically significant values of tau-Kendall are shown.*

The dendrite on Figure 2 shows the degree of similarity and difference between habitats within surveyed area (each biotope corresponds to a type of MCM). Dendrite is built by matrix of squared Mahalanobis distance with method of maximum correlation path. In fact, the number of investigated MCMs formed ecological series of climatogenical substitution (temperature regime and cryoregime).

MCMs of 6 and 7 groups are the closest to eu-nemoral ecological suite with regard to the general temperature regime. Boreal-nemoral ecological suite consists of groups 2, 3, 4 and 5; the Subboreal suite includes the MCMs of group 1. MCMs of groups 6 and 7 are gemicryotermal suite of mild-winters regime in relation to winter severity. MCMs of groups 4 and 5 belong to subcryotermal suite of mild-winter transitional regime. MCMs of groups 1, 2, 3 presented subcryotermal suite of mild winters.

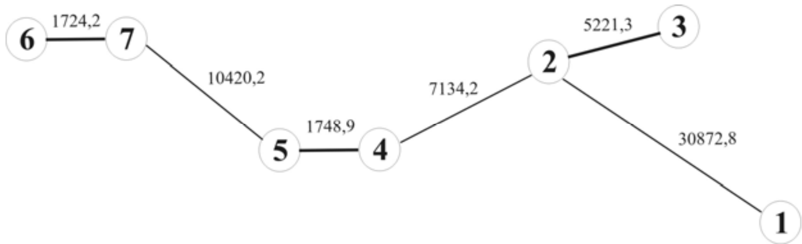

Fig. 2. Dendrogram of types of closeness in multispecies coenotical mosaics and corresponding biotopes

For each type of MCMs based on the analysis of geobotanical description were identified dominants of tree and shrub layer. Comparison of selected types of MCM with the forests typology of A.L.Belgard indicates compliance to following typological units:

1. D_3 mesic-wet horsetail-greater starwort elm-ash oak forest of half-clarify ecological structure;

2. D_3 mesic-wet wood bluegrass-ground ivy oak forest of half-shade ecological structure;

3. D_3 mesic-wet wood bluegrass-spotted deadnettle-greater starwort maple-ash oak forest of half-shade ecological structure;

4. Dcn_2 mesic salt-poor nitrophilic goutweed maple-ash oak forest with small-leaved lime of half-shade ecological structure;

5. Dn_2 mesic nitrophilic asarabacca-goutweed maple-ash oak forest dominated by small-leaved lime of half-shade ecological structure;

6. $D_{2\text{-}3}$ wet-mesic carex pilosa-goutweed maple oak forest of half-shade ecological structure;

7. $D_{2\text{-}3}$ wet-mesic carex pilosa maple-ash oak forest with field and Norway maples and European ash of half-shade ecological structure.

Conclusions

The survey shows advantages of using an integrated approach to assess the biotope diversity (on example of riverine slope oak near the Severskiy Donets River). This approach differs from the traditional research lines of habitats within National Park "Homolshansky lisy" such as investigation of geomorphology and relief features; the influence of relief forms on the formation of certain ecological types of oak forests; plant associations classification by dominants, identification of floristic diversity.

The research highlighted 7 types of multi-species coenotical mosaics. These mosaics formed coenotical, hygrogen-edaphogenical and climatogenical series of substitution, and reflected specific conditions of biotopes (as their markers), and conformed to definition units of Ukrainian forest typology.

The results of this work can be used to develop a regional inventory of forest typology in Kharkiv region, as well as to replenish the database of habitat diversity in the north-eastern part of Ukraine.

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