ANTHROPOGENIC AND NATURAL DYNAMICS OF LANDSCAPE ECOSYSTEMS OF THE SLOVECHANSKO-OVRUCHSKY RIDGE (UKRAINE)

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Abstract

The need for landscape management cannot be satisfied by static data alone. Landscape ecosystems are complex dynamic objects and the successful protection or operation of such areas depends on the quality of monitoring their dynamics and the forecasts built on its basis. Forecasting accuracy also depends on the quality of the modelling and this is why it is necessary to highlight the most universal and key characteristics of ecosystems. The Slovechansko-Ovruchsky ridge, which has a phenomenally high variety of landscapes, is well suited as an object for testing approaches to modelling. The authors singled out 11 territorial parts of the Slovechansko-Ovruchsky ridge at the level of landscapes and tracts. The differentiation of these landscapes was assessed using the synphytoindication method to determine the value of natural and anthropogenic dynamics. This made it possible to build prognostic algorithms for ecosystem changes using geobotanical data and produce prospects to create the best suitable landscape protection strategy or more effective and safe exploitation of landscapes.

Keywords: *habitats, autogenic successions, allogeneic successions, environmental monitoring, human impact*

1. INTRODUCTION

Modern natural resource management requires perfect and large-scale monitoring of ecosystems. At the same time, the requirements for monitoring are its consistency, regularity and forecasting regarding the future of the objects under study (Didukh, 2008). Fulfillment of these requirements is impossible without characterizing the dynamic processes that occur in ecosystems (Margalef, 1994). This is primarily in regards to natural and anthropogenic dynamics (Khomiak et al., 2019).

There are two fundamentally different types of dynamics: allogeneic and autogeneic successions. Autogenic successions are the process of self-organization of ecosystems without external interference. This is natural dynamics. Allogeneic successions require external influence. This is anthropogenic dynamics if the allogeneic succession is caused by human activity. In most of the cases, the anthropogenic and natural dynamics values

are inversely proportional and have opposite vectors of influence on changes in the ecosystem. Exceptions to this are the planting of aboriginal tree species and eutrophication of poor soils. Often, anthropogenic impacts hinder the self-restoration of natural landscapes and therefore require constant monitoring to manage natural resources.

Landscape-level ecosystems are complexes in which living organisms are specifically united with an abiotic environment on a conditionally homogeneous area of the earth's surface. These connections make it possible to identify some elements of the system according to the characteristics of others (Cordingley et al., 2016). According to the Monocentric Ecosystem Model, vegetation is the best indicator of environmental characteristics (Didukh, 2005). This allows us to assume that the territorial differentiation of landscapes at the level of geobotanical *tracts* will be sufficient to distinguish landscapes with different levels of natural and anthropogenic dynamics (Sochava, 1968).

The Slovechansko-Ovruchsky ridge was selected as a model region for study as it possesses a high variety of landscape ecosystems, in stark contrast to its surroundings (Khomiak, 2006). Various geological, geomorphological and pedological features and anthropogenic influences, which are at different dynamic stages of development, can be observed here on a relatively small area of landscape ecosystems (Didukh and Khomiak, 2007). Since the beginning of the twentieth century and until now, it has attracted the attention of researchers from various fields including geologists, biologists, ethnographers, linguists, historians, geographers and archaeologists (Melnyk et al., 2009; Tutkovsky, 1923; Koshik et al., 1976). Thus far a project has been launched to create an international Ukrainian-Belarusian biosphere reserve "Prypiat Polissia" with the participation of its territory and this has increased the requirements for monitoring the territory and predicting the consequences of changing human activities (Simeonova et al., 2009). According to Viktor Sochava regarding the structural-dynamic principle of landscape analysis, it is impossible to obtain a reliable forecast without the use of a cartographic method (Sochava, 1967).

The processes of anthropogenic transformation should be the central object of environmental monitoring in this area. This region has complex socio-economic problems and the cause of these is the distance from industrial centers and a poorly-developed transport infrastructure. Local communities must be guided by the principles of sustainable development to stop their social and economic degradation. As this area has a large number of natural landscapes that attract tourists, a combination of recreation and landscape-scale conservation can be an effective and promising way of business in this area. Local communities can overcome socio-economic difficulties if they control the level of anthropogenic transformation of ecosystems.

2. MATERIALS AND METHODS

The Slovechansko-Ovruchsky ridge is located in the northern part of the Zhytomyr region with a total area of $434km^2$. The surface of the ridge rises from 200m to 319m above sea level. The geomorphological basis of the ridge is the Ovruch graben and all geological

rocks belong to the Ovruch volcano-sedimentary sequence. The ridge soils (in the western part of the territory) are mainly sod-podzolic and gray forest soils. There are many small wetlands and powerful groundwater. The climate is of a warm-summer humid continental type, and natural vegetation is well preserved. The largest areas are occupied by forests (217.94km²) while the rest of the plant communities are meadow (32.96km²), swamp (9.0km²), agroecosystems (156.94km²), urban (about 8.2km²), water (3.5km²), and shrub (5.0km²) types. As of 2019, there are 1,282 species of higher vascular plants that are known. A difficult economic and social situation exists on the territory of the northern border of Ukraine and this also applies to the Slovechansko-Ovruchsky ridge. Many agricultural lands are not in use at this time. The local population works in the forest industry or in the subsistence economy and seasonal collection of wild mushrooms and berries.

Standard geobotanical field methods were used in this research (Myrkyn et al., 2001) and carried out by route-expeditionary and stationary methods in the period from 2004 to 2006. A series of 835 standard geobotanical descriptions and six ecological profiles were created. The parameters of the environmental factors were determined by the synphytoindication method (Didukh, 2012) using Simargl 1.12 software (Khomiak et al., 2018). The values of abiotic factors (soil humidity, variability of damping, acidity, salt content, nitrogen content, carbonate content, soil aeration, light degree in cenoses, climate thermic mode, humidity, continentality, criomode) are given according to the Didukh-Plyuta scale (Didukh and Plyuta, 1994); the anthropogenic factors are according to the Didukh-Khomiak scale (Didukh and Khomiak, 2007; Khomiak et al., 2018); and the value index of dynamics is based on the scale developed at the Zhytomyr Ivan Franko State University laboratory of ecosystem theory (Khomiak et al., 2019).

The value of anthropogenic transformation is established by the level of anthropotolerance (hemeroby index) and projective cover for a species of plants. The classes of hemeroby according to Hans-Peter Blume and Herbert Sukopp (1976) were divided into an 18-point scale: ahemerobic (1-3 points), oligohemerobic (4-6 points), mesohemerobic (7-9 points), euhemerobic (10-12 points), polyhemerobic (13-15 points), metahemerobic (16-18 points). All levels of the organization of life which are above the level of the organism have such a characteristic as anthropotolerance. It is possible to use the term hemerobic for populations, species, communities and ecosystems, e.g., an ahemerobic ecosystem, an oligohemerobic ecosystem and so on. The following formula was used to determine the magnitude of anthropogenic transformation of a particular ecosystem:

$$HE = \frac{k_1 He_1 + k_2 He_2 + \cdots + k_n He_n}{k_1 + k_2 \cdots + k_n}$$

where HE is the value of anthropogenic transformation of the ecosystem; He_1, He_2, He_n is the middle of the amplitude of anthropotolerance of species; n is the number of informative species in the description; k_1, k_2, k_n is the projective coverage of the species in points according to the new Braun-Blanquet system.

The dynamics index is set by the amount of above-ground phytomas and its age. A 21-point scale of natural dynamics was developed through observations of changes in above-ground phytomas and its age during autogenic successions. The presence of species in ecosystems with different values of the natural dynamics index was determined (Khomiak et al., 2019). A database of species tolerance amplitude relative to the value of the dynamics index was created. Standard geobotanical descriptions can be used to determine the index of natural ecosystem dynamics by the formula:

$$ST = \frac{k_1 S_{t1} + k_2 S_{t2} \cdots + k_n S_{tn}}{k_1 + k_2 \cdots + k_n}$$

where ST is the index of natural dynamics; k_1, k_2, k_n is projective coverage of the species № 1, 2, n in points according to the new Braun-Blanquet system; St_1, St_2, St_n is the middle of the tolerance range to the value of the dynamics of the species № 1, 2, n. Classification of the vegetation was made based on the Braun-Blanquet methodology of ecological-floristic criteria according to the prodromus of the vegetation of Ukraine (Khomiak et al., 2020).

3. RESULTS

The authors identified relatively homogeneous areas in terms of anthropogenic transformation. The territory was differentiated into such categories by means of a ratio of the areas of sites with certain sizes of anthropogenic transformation:
- oligohemerobic, including ahemerobic ecosystems;
- mainly (more than 75% of the area) oligohemerobic ecosystems;
- oligohemerobic and mesohemerobic ecosystems;
- euhemerobic and mesohemerobic ecosystems;
- euhemerobic and polyhemerobic ecosystems.

GPS coordinates of geobotanical descriptions and a visual analysis of satellite images of the study area were used to create the map. A cartographic analysis allowed for dividing of the ridge into two well-defined areas (Figure 1). The western part of the ridge and the northern protrusions are represented mainly by oligohemerobic ecosystems. The central part and the eastern and south-eastern outskirts of the ridge are euhemerobic and mesohemerobic ecosystems. This part of the ridge is highly mosaic and has no ahemerobic ecosystem. The western territory and the northern protrusions of the ridge are more homogeneous.

The location of ecosystems with different values of the natural dynamics index is caused by other patterns than for their anthropogenic transformation (Figure 2). Ahemerobic ecosystems do not always have high values of the natural dynamics index. These are mainly mesotrophic and oligotrophic wetlands located at a distance from settlements. They are located in the river valleys of the western part of the ridge. Large oligohemerobic forests
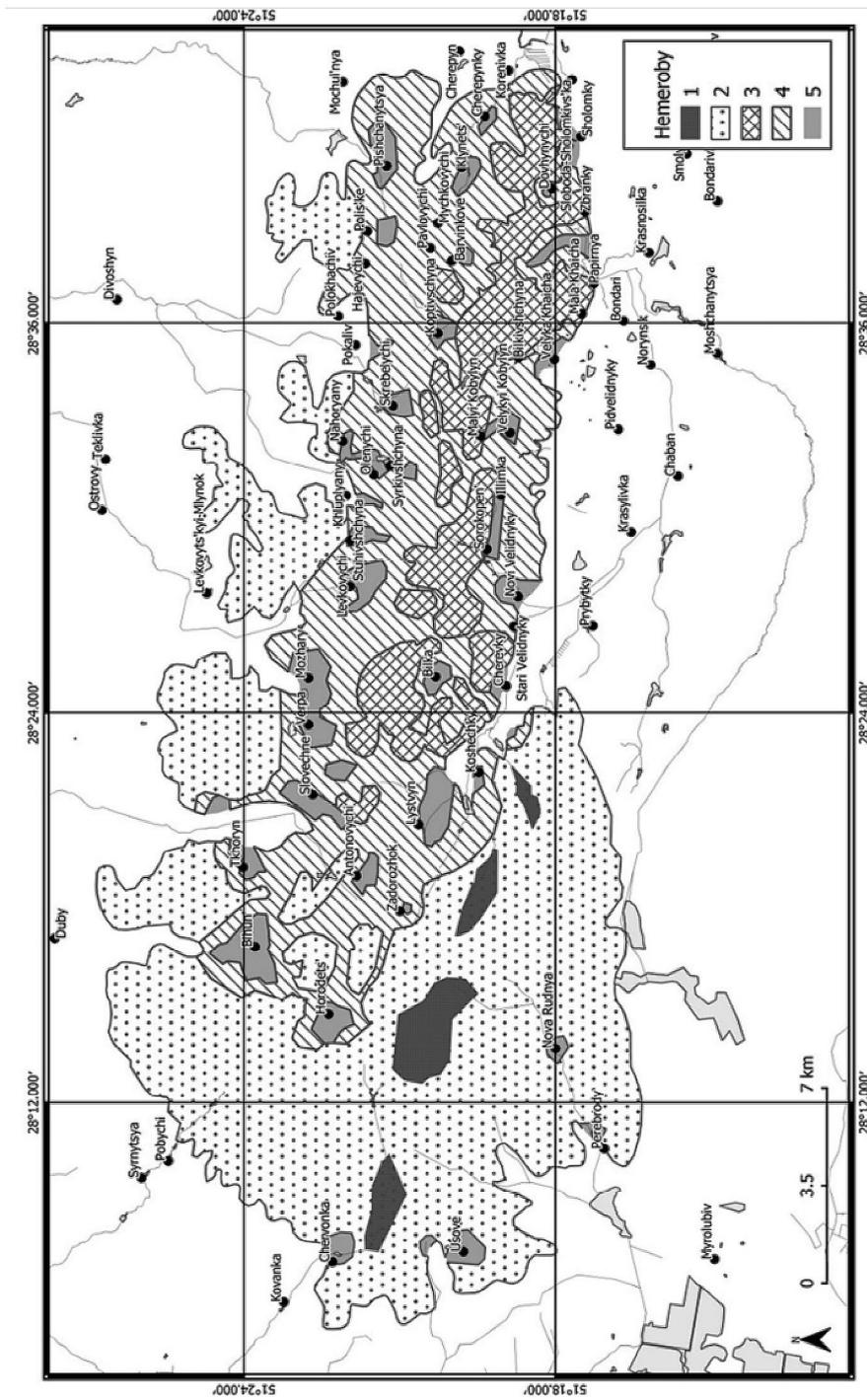
Legend: 1 – oligohemerobic, including ahemerobic ecosystems; 2 – mainly (more than 75% of the area) oligohemerobic ecosystems; 3 – oligohemerobic and mesohemerobic ecosystems; 4 – euhemerobic and mesohemerobic ecosystems; 5 – euhemerobic and polyhemerobic ecosystems

Figure 1. *Schematic map of ecosystems location with different levels of anthropogenic transformation (Source: author's own map)*

351

Legend: 1 – ecosystem in the early stages of autogenic succession; 2 – complexes of ecosystems at the stages of formation of phanerophytes communities, derived forests, and young indigenous forests; 3 – complexes of ecosystems at the stages of derived and indigenous forests; 4 – ecosystems at the stage of formed indigenous forests with small areas of old-growth forest

Figure 2. *Schematic map of ecosystems location with different values of the natural dynamics index (Source: author's own map)*

have average values of the dynamics index. This can be explained by the lack of significant areas of old natural forests in this area. Western ravine forests, despite the lower anthropogenic pressure, do not acquire the maximum values of the dynamics due to active erosion processes. The data was generalized to build a map-scheme (Figure 2) and distribution was carried out taking into account the ratio of areas of individual groups of ecosystems:

- Territories with ecosystems at the initial stage of succession (1-4 points of the natural dynamics index);
- Territories with a complex of ecosystems at the stage of transition from grasslands to phanerophyte communities (5-8 points of the natural dynamics index) and at the stage of derived or young indigenous forests (9-12 points of the natural dynamics index);
- Territories with a complex of ecosystems at the stages of derived and indigenous forests;
- Ecosystems of formed indigenous forests (13-16 points of the natural dynamics index) with small areas of virgin forests (more than 16 points).

Ecosystems approaching the climatic climax of autogenous succession (17-21 points of the natural dynamics index) are very rare and located in small areas.

An ecological 45km long profile was laid along the 51°20′ N parallel (Figure 3). The western part of the ridge has smaller fluctuations in the values of the index than the eastern part. The increase in altitude from 200m to 300m in the west and the features of the relief have little effect on the changes of anthropogenic transformation here. The only exceptions are rivers and their coastal zone. This profile did not cross the rivers and swamps of the western part of the territory, so the effect on the decrease in the value of the dynamics index remained unnoticed here. On the eastern part of the ridge, however, the value of the dynamics index is relatively higher in the river valleys. Soils and sediment rocks of the eastern part of the territory are affected by water erosion. There are many ravines occupied by forest vegetation. Depending on the water erosion activity and the characteristics of the rocks exposed by it, a high mosaic of microlandscapes is formed here.

The main factors in the formation of landscape ecosystems are soils and underlying sedimentary rocks, soil humidity associated with microrelief, characteristics of human activity, and the stage of autogenic succession. These characteristics allow the territory to be divided into separate landscape ecosystems. Their boundaries coincide with the boundaries of areas identified by geobotanical methods.

According to geobotanical zoning, the territory of the ridge belongs to the Korosten-Zhytomyr district of the physical-geographical region of Zhytomyr (Central) Polissia (Andrienko et al., 1977). The territory of the ridge is divided into two regions: the Chervonsko-Horodetsky region with acidophilic sessile oak forests, and the Ovruch region with oak-hornbeam forests that fully correlate with the traditional division of the ridge into loess and rocky (quartzite) areas (Figure 4) (Yakushenko, 2005). They differ in their complex of geological, soil, cenotic, anthropological characteristics and microrelief.
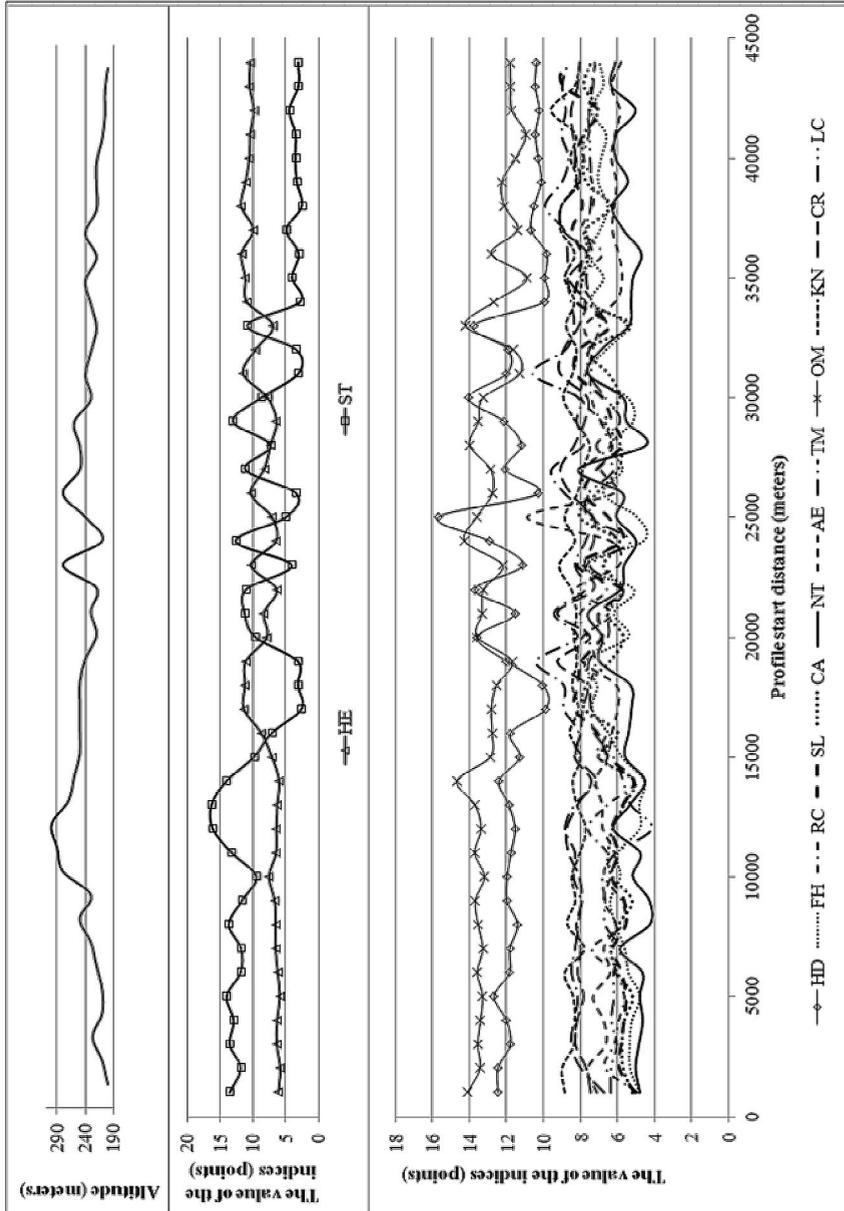
Legend: HE – value of anthropogenic transformation (in points on the Didukh-Khomiak scale), ST – index of natural dynamics (in points on the scale developed at the laboratory of ecosystem theory), HD – soil humidity, FH – variability of damping, RC – acidity, SL – salt content, NT – nitrogen content, CA – carbonate content, AR – soil aeration, LC – light degree in cenoses, TM – climate thermic mode, OM – humidity, KN – continentality, CR – criomode (in points on the Didukh-Pliuta scale)

Figure 3. *Ecological profile through the Slovechansko-Ovruchsky ridge along the 51°20' N parallel (Source: author's own diagram)*

Within the framework of the first region, poor and mainly medium-stony sod-podzolic soils are widespread. The topography is hummock-and-hollow with hills up to 319m above sea level. Human activity is mainly represented by forestry. Field cultivation is concentrated within a few small settlements. In the last several decades, the population has decreased sharply and most of the arable land lays fallow.

Within the second region, agricultural land prevails on the light gray forest soils above the loess sedimentary rocks. Human activity on the slopes of the loess hills has led to active gullying (Khomiak, 2015). Forest ecosystems have been formed in the gullies. In the west, they are predominantly of a natural type, while in the east, through the influence of plantings of invasive transformer species, they are synanthropic derivatives (Khomiak, 2006).

There are four tracts within the Chervonsko-Horodetsky district of acidophilous sessile oak forests. They are similar in many environmental factors and vegetation types. These landscapes differ in relief, the presence of mineral fragments in the soil, and the distribution of areas with different values of indices of natural and anthropogenic dynamics.

The Tkhorinsko-Pishchanytske tract is acidophilic pine-oak forests. Located in the north of the ridge, it consists of five rocky hills occupied by transformed forest lands, divided by the Slovechna, Yasenets, Zvonka, and Polokhachevka rivers. There is a difference in height from 180m above sea level in river valleys and up to 260m on individual peaks. The heights of the tops of individual rock massifs decrease from west to east from 260m to 220m. The length of the massifs is approximately 3-5km from north to south and 2-3km from west to east. Permanent rivers and streams are not common because the massifs have small areas. There are sod-podzolic soils, which have small fragments of quartzite and pyrophyllite. The landscape ecosystems are mainly oligohemerobic (4-6 points) and are at the stage of young and late indigenous forests according to the natural dynamics index (9-16 points).

The Bigunsko-Horodetske tract is acidophilic pine-oak-rhododendron forests. It is located northwest of the Bigun-Horodets line and occupied by transformed forest lands and relict groups of *Hedera helix* L. The landscape consists of two massifs between the Bigun and Pertnitsa rivers separated by the valley of the Zymukha River. The maximum heights of these massifs are 260m and 253m. Sod-podzolic soils are medium stony. Quartzite fragments with a diameter of about 10-20cm in the soil are found closer to the tops of the massifs. The ecosystems are mainly oligohemerobic and the value of the natural dynamics index is 9-16 points. In the Zymukha River valley there are mainly mesohemerobic ecosystems and the value of the natural dynamics index is 5-8 points.

The Chervonsko-Horodetske tract has typical acidophilic sessile oak forests and is located in the Horodets – Chervonka – Usovo triangle. It is occupied by transformed and natural forests and wetlands. This tract is located between the Pertnytsia River and the left tributary of the Lubenets River. It consists of two hills (285m and 321m) separated by the valley of the Chervonka River. Sod-podzolic soils are very stony. Large blocks of quartzite (0.2m to 1m in diameter) appear on the day surface on some slopes. The largest areas of ahemerobic ecosystems and virgin forests with a natural dynamics index of more than 16 points can be observed here.

Figure 4. *Schematic map of the location of the landscapes and tracts of the Slovechansko-Ovruchsky ridge (Source: author's own map)*

Legend: 1 – Tkhorinsko-Pishchanytske tract of acidophilic pine-oak forests; 2 – Bigunsko-Horodetske tract of acidophilic pine-oak-rhododendron forests; 3 – Chervonsko-Horodetske tract of typical acidophilic sessile oak forests; 4 – Lystvynsko-Perebrodske tract of acidophilic pine-oak; 5 – Horodetsko-Slovechanske tract of gullies with typical deciduous forests; 6 – Bilkivske tract of gullies with a strongly transformed vegetation; 7 – Velidnytske tract of gullies with partially transformed vegetation; 8 – Ilimkivsko-Klynetske tract of gullies with strongly transformed vegetation; 9 – Levkovytsko-Korenivske tract of agricultural lands and coastal shrubs; 10 – Ubortsko-Slovechniansky district of green moss-lichen pine forests, mesotrophic and oligotrophic forests; 11 – Zherevsky district of green moss pine forests

The Lystvynsko-Perebrodske tract is acidophilic pine-oak forests. It is located between the settlements of Perebrody and Lystvyn south of the plateau with a height of 319m and heights of 250m and 261m to the north and is occupied by transformed and natural forest and wetlands. Typical sod-podzolic soils are predominant here. The soils are formed by winnow sands on the periphery of the territory of the ridge. Loams and inclusions of quartzite fragments are found closer to the tops of hills. These landscapes are primarily oligohemerobic but have lower values of the natural dynamics index (up to 14 points).

The Ovruch region of oak and hornbeam forests can be divided into five tracts. The area is divided into smaller landscape ecosystems by the level of anthropogenic transformation of ravine forest. There is a change in the origin of vegetation which is completely natural in the west and mostly introduced in the east.

The Horodetsko-Slovechanske tract is gullies with typical deciduous forests. It includes the western part of the solid woods to the Verpa-Cherevky line. This landscape ecosystem has the highest hills of this part of the ridge – up to 316m. It borders with the Chervonsko-Horodetsky district of acidophilic sessile oak forests. The soils are gray forest loam on a loess basis. The ravine forests are well preserved in their natural state. Gully outskirts are exposed to higher anthropogenic pressure. They are restored derivative forests, shrubs or forest-edge ecosystems. There is a great contrast in the index values of anthropogenic transformation between the gully outskirts and the bottom and slopes of the ravine.

The Bilkivske tract is gullies with strongly transformed vegetation. It includes areas with gullies of the Bilka River valley. This landscape ecosystem has hills with a lower height (up to 269m), smaller depth and greater width of ravines. The depth of the ravines is not more than 20m. In the Horodetsko-Slovechanske tract, the width of the ravine system is 100-200m on average, and in the Bilkivske ravine system it is 400-500m. There are exits to the day surface of bog iron ore in the valley of the Bilka River. Landscapes are mainly mesohemerobic and euhemerobic. Euhemeroby is observed only at the bottom of ravines. The value of the natural dynamics index reaches a maximum of 13 points on the upper slopes part of ravines.

The Velidnytske tract is gullies with partially transformed vegetation (includes areas with gullies on the southern slope of the ridge between the valleys of the Bilka River and the Illimka River). This landscape ecosystem has the smallest area. It is represented by the slopes of the Noryn River valley. The right bank of the valley is completely anthropized, and the left bank has fragments of natural vegetation in the ravines. This area is an example of the transition from natural ravine forests of the western part of the territory and artificial plantations of introduced species of the eastern part. There is a high mosaic of sedimentary rocks. It is dominated by loess on top of pink Ovruch quartzites, which sometimes come to the surface in monolithic blocks. Strong layers of clay are observed, and the lower part of the left bank of the Noryn River is formed by coarse-grained sands with numerous marine fauna fossils of the Jurassic period.

The Illimkivsko-Klynetske tract is gullies with strongly transformed vegetation. It includes areas with gullies on the southern slope of the ridge from the valley of the Illimka

River to the valley of the Klynets River. The depth of the ravines is maximum here and reaches 70m, despite the low heights of the hills (250m). This is due to the difference in the height of the hills and the Noryn valley and its tributaries. The Noryn River flows at an altitude of 152m, and its left tributaries, at the 180-183m and cut into the ridge. The sides of the ravines are completely occupied by man-made plantings. Introduced species have invaded the middle of the ravines and changed the vegetation of the landscapes, displacing aboriginal species and plant communities.

The Levkovytsko-Korenivske tract is agricultural land and coastal shrubs. It is located on the northern slope of the forest part of the ridge and extends east of the valley of the Yasenets River. These ecosystems are occupied on the northern slope of the loess part of the ridge. The heights of the hills reach 282m but the ravines are very small. A group of individual hills with a height of 207m to 282m are located in this part of the ridge. It is a watershed that divides the basins of the Uzh and Pripyat rivers. The system of hills of the Thoryn-Pishchanytsia landscape ecosystem rises further to the north. Most of the erosion formations in this area have the form of synanthropized and inhabited river valleys.

To the south of the village of Cherevky typical pine forests stretch along the southern slope of the ridge. The length of this strip is about 8km and the width is about 700m (from 300m to 2,200m). The vegetation and indicators of environmental factors are different from the rest of the ridge. They are similar to the neighboring Zherevsky region of green moss pine forests, adjacent to the ridge from the southeast. The belonging of this territory to the Chervonsko-Horodetsky region of acidophilic common oak and sessile oak forests is doubtful. A similar situation is observed on the northwestern edge of the ridge. This territory is adjacent to the Ubortsko-Slovechniansky geobotanical region of the Pivnichnopolisky district. Thus, on the territory of the ridge (200m above sea level with outcrops of Ovruch quartzites), the surroundings of the Ubortsko-Slovechniansky region of green moss-lichen pine forests of, mesotrophic and oligotrophic bogs and Zherevsky district of green moss pine forests.

4. DISCUSSION

An analysis of the correlation between indicators of natural and anthropogenic dynamics showed a typical diagram for similar studies finding an inverse linear relationship between them (Figure 5). The Pearson correlation coefficient of this relationship is 0.6. This pattern demonstrates that human activity often slows down the processes that accompany autogenic succession. Namely, an increase in anthropogenic impact, as a rule, leads to a decrease in indicators of natural dynamics. In this case, the indicator of the dynamics was determined by the value of the above-ground phytomass and its age, which corresponds to the changes along with the autogenous succession.

Therefore, the increase in anthropogenic pressure shifts the landscape ecosystem towards the pioneer stages of succession, and its decrease shifts the landscape ecosystem towards the climax. Each of the landscape ecosystems at the tract level is differentiated

not only with the help of original geological, geophysical, or phytocenotic components, but has a different ratio of areas for settling, which, depending on different edaphic and microclimatic conditions, are at different stages of succession and are anthropogenically transformed in different ways.

This is most clearly observed at the level of landscapes of the loess and quartzite parts of the ridge. The loess part mainly consists of agricultural lands and territories of settlements with highly anthropogenically transformed ecosystems. Between them there are gullies covered by natural vegetation (Khomiak, 2014). The bottom and slopes of the gullies practically do not experience direct anthropogenic impact (Khomiak and Onyshchuk, 2018). Sometimes spontaneous illegal felling of trees occurs here, mainly windbreak and dead wood. The widest lower parts of the bottom of the gullies covered with meadow vegetation are used as hayfields and pastures. The sides of the gullies that border on agricultural landscapes are more strongly transformed (Figure 6). This is quite a fairly contrasting mosaic pattern with very different microlandscapes in terms of the level of anthropogenic transformation (Khomiak, 2015).
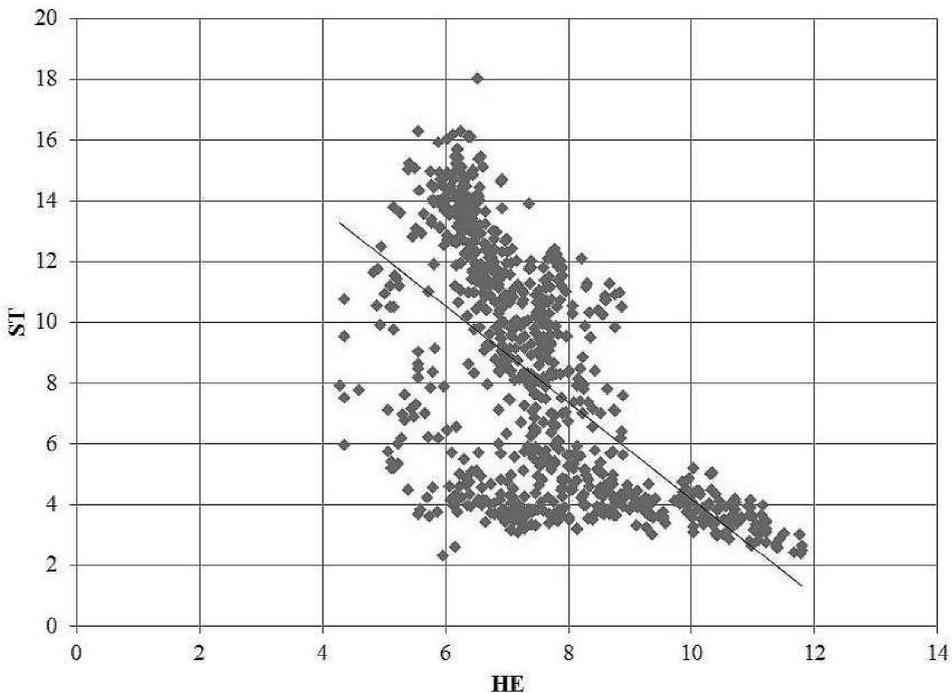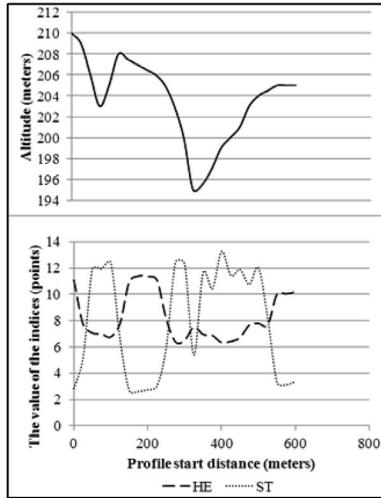

Figure 5. *Dependence between indices of anthropogenic transformation and natural dynamics on the territory of the Slovechansko-Ovruchsky ridge (Source: author's own diagram)*

Legend: HE – index of anthropogenic transformation, ST – index of natural dynamics

Figure 6. *Change in the value of indices of anthropogenic transformation and natural dynamics on the profile through loess ravines near Stari Velidnyky (Source: author's own diagram)*

For settlements, agrolandscapes and territories covered by coastal vegetation in this area, the indicators of dynamics have become in latitudinal and meridional directions. The ecosystems of gullies differ greatly in natural dynamics (Khomiak and Didukh, 2009). There is a series of recessions in the indicator of natural dynamics for the gullies of tracts of this region: Horodetsko-Slovechanske → Bilkivske → Velidnytske → Ilimkivsko-Klynetske → Levkovytsko-Korenivske (Figure 7).
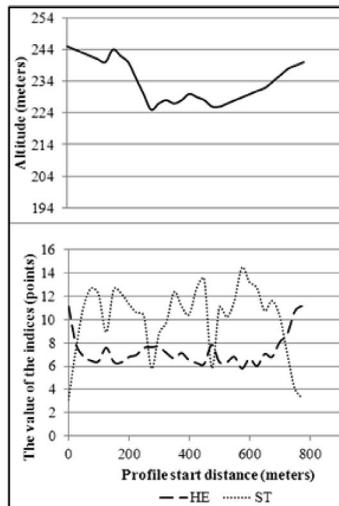
Legend: HE – index of anthropogenic transformation, ST – index of natural dynamics

Figure 7. *Change in the value of indices of anthropogenic transformation and natural dynamics on the profile through loess ravines near Bilka (Source: author's own diagram)*

Their differences are not subject to edaphic or orographic characteristics, but due to anthropogenic impact. The only exception is the last tract (Levkovytsko-Korenivske), where, behind relatively gentle slopes, there is an insignificant number of gullies of the required depth and area (Figure 8).
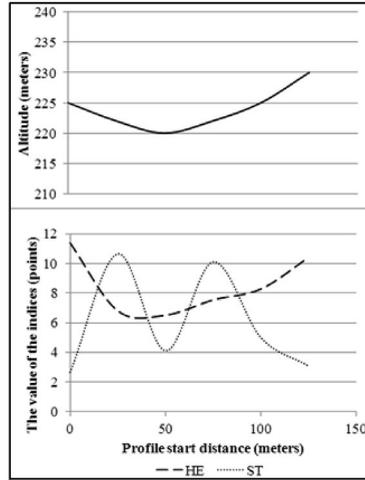
Legend: HE – index of anthropogenic transformation, ST – index of natural dynamics

Figure 8. *Change in the value of indices of anthropogenic transformation and natural dynamics on the profile through loess ravines near Syrkivshchyna (Source: author's own diagram)*
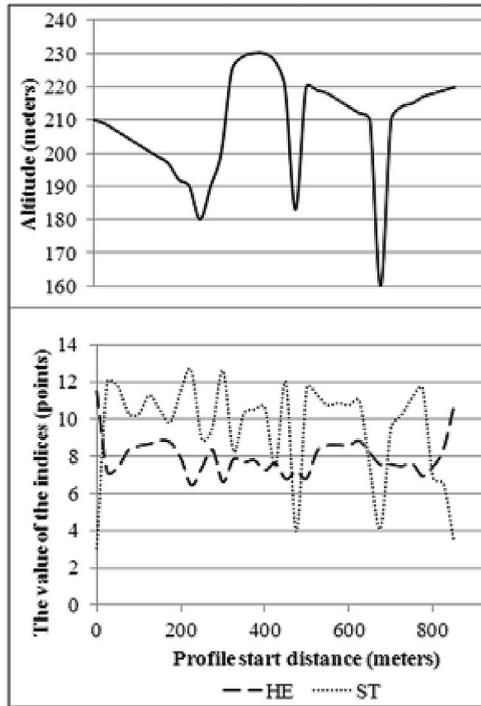
In the gullies of the Horodetsko-Slovechanske tract there are the maximum values of the indicator of natural dynamics (Figure 9).
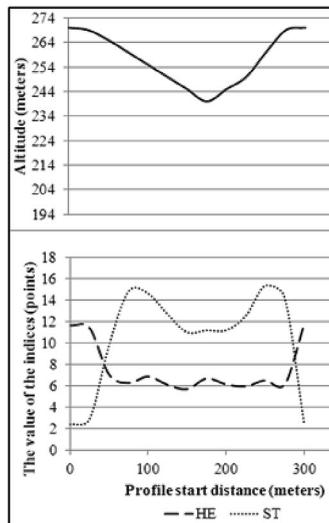
Legend: HE – index of anthropogenic transformation, ST – index of natural dynamics

Figure 9. *Change in the value of indices of anthropogenic transformation and natural dynamics on the profile through loess ravines near Horodets (Source: author's own diagram)*

361

In some cases, the indicators reached 15-18 points. This indicator is 9-12 points on average in the Ilimkivsko-Klynetske tract, and it is decreased to 6-9 points in the Levkovytsko-Korenivske tract (Figure 10).

Legend: HE – index of anthropogenic transformation, ST – index of natural dynamics

Figure 10. *Change in the value of indices of anthropogenic transformation and natural dynamics on the profile through loess ravines near Zbranky (Source: author's own diagram)*

The levels of the anthropogenic transformation changes with the opposite tendency can be observed in the gullies of the Horodetsko-Slovechanske tract which range from 5 to 7 points, and it varies from 5 to 9 points on the Didukh-Khomiak scale in the Ilimkivsko-Klynetske and Levkovytsko-Korenivske tracts.

Edaphic and dynamic characteristics of landscape ecosystems allow for them to be divided into separate tracts according to the size of the natural dynamics index and anthropogenic transformation index. For the rocky part, the closest ones in terms of these indicators are the Chervonsko-Horodetske and Lystvynsko-Perebrodske tracts. Nowadays, roughly the same anthropogenic pressure is observed here. However, there are historical differences. On the territory of the first tract, due to the presence of significant solid woods of *Quercus petraea* (Matt.) Liebl., a number of reserves were created in the 1980s. On the territory of the Lystvynsko-Perebrodske tract, a large reserve "Slovechansko-Ovruchsky Ridge" was created only in the late 1990s. Thus, in recent decades, the anthropogenic pressure in both tracts is approximately the same, but in the first, the indicators of natural dynamics are slightly higher (Khomiak et al., 2019). The

Tkhorynsko-Pishchanitske and Bigunsko-Horodetske tracts differ from the rest by the presence of massive sandy deposits in their northern outskirts. Under such edaphic conditions, the rate of autogenous succession decreases. There is the possibility to observe a high patchiness of landscapes with their dynamics. For the Tkhorynsko-Pishchanitske tract, it is strengthened by the river valleys of the Prypiat basin, which emerge from the northern slopes of the ridge. The valleys of these rivers with their more fertile meadow soils are used as arable land, hayfields, and pastures. This contributes to an increase in the level of anthropogenic transformation in such places up to 8-11 points.

Each of the landscape ecosystems has its own balance between allogeneic (mainly direct and indirect anthropogenic) and autogenous influences. As a result of this, over time the position of the ordination field of the ecosystems is shifted within the edapho-dynamic model. There are three complexly organized processes here: the predominance of autogenous succession, which leads to the formation of forest landscapes with primeval forests; the balance between opposite processes that stops dynamic changes in landscapes; and the predominance of allogeneic processes that leads to the temporary degradation of the vegetation cover (Khomiak, 2014). German researchers obtained similar results for the territory of Germany (Walz and Stein, 2014). They observed changes in the hemeroby index during the expansion of lignite mining and agricultural industrialization (Steinhardt et al., 1999). The vegetation is a good indicator of these processes. This indicator can thus be used to determine the dynamics of landscapes under the influence of natural processes and anthropogenic pressure. Mark Oliver Hill, David Brian Roy and Ken Thompson point to several ways of using plants as indicators of hemerobia (Hill et al., 2002), such as individual characteristics of species, their origin, belonging to a certain class of phytocenoses and others. The authors draw attention to the difficulties of using this approach. Our method of determining hemerobia avoids a number of these problems.

5. CONCLUSION

Anthropogenic impact slows down or reverses the processes of natural dynamics in most cases. The dynamic equilibrium is shifting towards pioneer ecosystems under the influence of human activity. Anthropogenically transformed ecosystems of the eastern part of the Slovechansko-Ovruchsky ridge are at the earlier stages of autogenic succession than the natural ecosystems of the western part in similar conditions.

The level of anthropogenic transformation is directly dependent on soil conditions and microrelief for areas located nearby and with the same history of human activity. The level of anthropogenic transformation is higher for the territory where the conditions of agriculture are better. That is why forests are more common in the areas with sod-podzolic soils and agricultural landscapes in the areas with gray forest soils.

Deviation of the moisture level from the optimum for terrestrial ecosystems leads to a decrease of the natural dynamics index in weakly anthropogenic ecosystems (western part of the Slovechansko-Ovruchsky ridge) and to an increase in strongly anthropogenic ecosystems (eastern part of the Slovechansko-Ovruchsky ridge).

Forest planting slows down or stops autogenic succession if the planted species belong to alien invasive species of transformers. Plantations of these species have displaced natural vegetation and changed the direction of ecosystem dynamics in the east of the Slovechansko-Ovruchsky ridge.

The landscapes and tracts identified by vegetation are well correlated with indicators of environmental factors, the level of anthropogenic transformation and the value of the natural dynamics index.

The information obtained can be used for a strategic planning of the use of natural resources and protection of natural habitats. The western part of the Slovechansko-Ovruchsky ridge is most suitable for the creation of a national nature park.

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DINAMIKA ANTROPOGENIH I PRIRODNIH KRAJOBRAZNIH EKOSUSTAVA SLOVEČANSKO-OVRUŠKOG GREBENA U UKRAJINI

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Sažetak

Upravljanje krajobrazima ne može se temeljiti isključivo na statičnim podacima. Krajobrazni ekosustavi složeni su dinamični objekti pa uspješna zaštita i upravljanje takvim područjima ovisi o kvaliteti praćenja njihove dinamike te prognozama koje se na temelju toga oblikuju. Točnost prognoza ovisi i o kvaliteti modeliranja zbog čega je važno odabirati najuniverzalnija i ključna obilježja ekosustava. Zbog toga je Slovečansko-Ovruški greben kojeg obilježava iznimno bogata krajobrazna raznolikost prikladan kao objekt za ispitivanje različitih pristupa modeliranju. Autori su izdvojili 11 teritorijalnih dijelova Slovečansko-Ovruškog grebena na razini krajobraza i trakta. Diferencijacija krajobraza procijenjena je metodom sinfitoindikacije kako bi se utvrdila vrijednost njihove prirodne i antropogene dinamike. Zatim su izrađeni prognostički algoritmi za promjene u ekosustavima koristeći geobotaničke podatke, što omogućuje oblikovanje prikladnijih strategija zaštite krajobraza te njihova učinkovitijeg i sigurnijeg iskorištavanja.

Ključne riječi: *staništa, autogene sukcesije, alogene sukcesije, monitoring okoliša, ljudski utjecaj*

DYNAMIK DER ANTHROPOGENEN UND NATÜRLICHEN LANDSCHAFTSÖKOSYSTEME DES SLOVETSCHAN-OVRUSCH-GRATES IN DER UKRAINE

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Zusammenfassung

Das Landschaftsmanagement kann nicht ausschließlich auf statistischen Angaben beruhen. Landschaftsökosysteme sind komplexe und dynamische Objekte und ein erfolgreicher Schutz und Verwaltung solcher Gebiete hängt von der Qualität der Überwachung, deren Dynamik und der darauf beruhenden Prognosen ab. Die Richtigkeit der Prognosen hängt von der Qualität der Modellierung ab, deshalb ist es wichtig, die universalsten und wichtigsten Merkmale des Ökosystems auszuwählen. Aus diesem Grund ist der Slovetschan-Ovrusch-Grat mit einer Vielfalt der Landschaften dazu geeignet, den Modellieransatz zu testen. Die Differenziertheit der Landschaften wurde mit Hilfe der Synphytoindikationsmethode geschätzt, damit der Wert der natürlichen und anthropogenen Dynamik festgestellt werden kann. Dann wurden prognostische Algorithmen für Änderungen in den Ökosystemen unter Anwendung von gebotanischen Daten erstellt. Dadurch wird ermöglicht, eine besser geeignete Strategie zum Landschaftsschutz zu bilden und die Landschaft auf eine effizientere und sicherere Art und Weise zu nutzen.

Schlüsselwörter: *Habitate, autogene Sukzession, allogene Sukzession, Landschaftsüberwachung, Einfluss des Menschen*