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Assessment of the geo-ecological potential of the landscape districts (on the example of Sumy region, Ukraine)

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Abstract. The article is devoted to the study of the life potential support of the population, which reflects living conditions of the population in specific geosystems (on the example of the Sumy region, Ukraine). The main purpose of the article is to assess the geo-ecological potential of the regional landscape structures, namely the landscape districts of the Sumy region. The article highlights the theoretical and methodological foundations of the geo-ecological potential research, substantiates the theoretical aspects of the of "geo-ecological potential" concept, describes in detail the methodology of assessing geo-ecological potential, which is evaluated on the basis of natural geosystem potential, geosystem sustainability potential and technogenic geosystem load. The assessment of the natural potential of the Sumy region landscape districts (based on the humidity coefficient, the sum of active temperatures above 10°C, hydrothermal potential of phytomass productivity, annual precipitation, adverse natural processes such as landslides, flooding, rising groundwater levels, erosion, dry winds, hail, fogs) is conducted and the levels (low, below average, average and high) of the natural potential are defined. Three districts of the environmental sustainability of the regional landscape districts are established on the basis of component-by-component assessment of the meteorological potential of the atmosphere, surface water and soil sustainability potential, as well as biotic potential: below average, average and above average. The indicators of the population density of the region, coefficient of the territorial production concentration, economic development of lands (agricultural lands, built-up lands and open lands without vegetation), environmental pollution of the region (radiation and chemical air pollution, pollution of natural waters and soils) and the integrated indicator of technogenic load, which allows to establish the following levels of the technogenic load on the landscape districts of the region: below average, average and above average, are analyzed. Particular attention is paid to the assessment of the geo-ecological potential, which allows to establish 5 levels, of which only 3 are presented in Sumy region, based on which areas of geo-ecological potential of the landscape districts are identified: below average, average and above average and a map of the geo-ecological potential areas is created. It is established that the indicator of the geo-ecological potential of the landscape districts of the Sumy region ranges from 0.05 Psel-Vorskla landscape district (below average level) to 1.07 Esman'-Kleven' landscape district (above average level). It is established that the higher the values of the natural potential and sustainability of the natural environment and the lower the indicators of technogenic load, the higher are the values of the geo-ecological potential.

Key words: geo-ecological potential, natural potential, sustainability of natural environment, technogenic load, landscape district, Sumy region.

Оцінка геоекологічного потенціалу ландшафтних районів (на прикладі Сумської області, Україна)

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Анотація. Стаття присвячена дослідженню потенціалу життєзабезпечення населення, яке відображає умови життя населення в конкретних геосистемах (на прикладі регіону України – Сумської області). Головна мета статті полягає в оцінці геокологічного потенціалу регіональних ландшафтних структур регіону, а саме ландшафтних районів Сумської області. У статті висвітлені теоретико-методичні засади дослідження геоекологічного потенціалу, обґрунтовані теоретичні аспекти поняття «геоекологічного потенціалу», детально описана методика оцінки геоекологічного потенціалу, який оцінюється на основі природного потенціалу геосистеми, потенціалу стійкості геосистем та техногенного навантаження на геосистеми.

Здійснено оцінку природного потенціалу ландшафтних районів Сумської області та виокремлено низький, нижче середнього, середній та високий рівні природного потенціалу. Встановлено 3 ареали стійкості природного середовища ландшафтних районів регіону на основі покомпонентної оцінки метеорологічного потенціалу атмосфери, потенціалу стійкості поверхневих вод та ґрунтів, а також біотичного потенціалу: нижче середнього, середній та вище середнього. Проаналізовано показники густоти населення регіону, коефіцієнту територіальної концентрації виробництва, господарського освоєння земель, забруднення навколишнього середовища території регіону та обраховано інтегральний показник техногенного навантаження, що дозволяє встановити наступні рівні техногенного навантаження на ландшафтні райони регіону: нижче середнього, середній та вище середнього. Особлива увага приділяється оцінці геоекологічного потенціалу, що дозволяє встановити 5 рівнів, з яких лише 3 представлені для Сумської області, на основі яких виокремлено ареали геоекологічного потенціалу ландшафтних районів: нижче середнього, середній і вище середнього та створено картосхему ареалів геоекологічного потенціалу. Встановлено, що показник геоекологічного потенціалу ландшафтних районів Сумської області коливається від 0.05 Псельсько-Ворсклинський ландшафтний район (рівень нижче середнього) до 1.07 Есмань-Клевенський ландшафтний район (рівень вище середнього). Встановлено, що чим вищі значення природного потенціалу та стійкості природного середовища та нижчі показники техногенного навантаження, тим вищі значення геоекологічного потенціалу.

Ключові слова: геоекологічний потенціал, природний потенціал, стійкість природного середовища, техногенне навантаження, ландшафтний район, Сумська область

Introduction.

"Geo-ecological potential" is defined as the potential for life support of the population, which reflects conditions and quality of life of the population in specific geosystems (Olishevska, 2009). It synthesizes the natural (natural resource) potential, the level of anthropogenic impact on natural complexes and their resistance to anthropogenic loads. As a result of the interaction of nature and society in the process of nature management, a geo-ecological situation is formed, which is a kind of indicator of the quality of the natural environment of society in a specific space-time situation. The leading role in determining the living conditions of society belongs to the geo-ecological potential (GP), because the higher the natural resource potential, sustainability of the natural environment, the lower are the risks of negative impact of the technogenic load. The value of GP to some extent reflects geo-ecological living conditions of the population, so studies of this kind are extremely relevant. On the other hand, based on the natural component, GP is determined by the properties of natural-territorial complexes (landscapes). In this context, the territory of the Sumy region is no exception, so it is important to consider and assess the geo-ecological potential of the regional landscape structures, in particular landscape districts.

The purpose of the study is to assess GP of the landscape districts of the Sumy region, which is implemented through a number of tasks: to characterize the natural potential of the landscape districts of the region; to establish sustainability of their natural environment; to find out the technogenic load on the regional landscape structures; to calculate the geo-ecological potential of each landscape district, to identify the levels of geo-ecological potential and to carry out zoning of the territory of the Sumy region by the GP size.

Materials and methods of research.

In a broad sense, the term "potential" is interpreted as opportunities, available forces, stocks that can be used for anything. Scientists-geographers use the term potential to refer to the properties of natural territorial complexes that are important in terms of human economic activity, such as natural potential, natural resource potential, recreational potential, ecological potential, environmental potential, sustainability potential, and so on.

In a broad sense, GP is defined as the quality of human habitat, the ability to provide the necessary food, working and leisure conditions (recreational resources) and treatment (climate therapy, balneological resources) (Olishevska, 2009). It (potential) determines the geo-ecological living conditions of people in certain geosystems and reflects the ability of the landscape to be a favorable environment for people and a source of resources used by society.

The theoretical basis of the GP study is set out in the works of A. Isachenko (Isachenko, 1992), O. Marynych (Marynych and Shyshchenko, 2005), I. Nesterchuk (Nesterchuk, 2011), Yu. Olishevska (Olishevska, 2005), P. Shyshchenko (Shyshchenko, 1993), and others. The methodological foundations of its study are substantiated in the works of V. Baranovskyi (Baranovskyi, 2001), I. Nesterchuk (Nesterchuk, 2011), Yu. Olishevska (Olishevska, 2005).

The value of GP reflects the state of geosystems and has two components: natural-ecological and socio-economic. The natural-ecological component reflects the natural-ecological potential, which is determined on the basis of indicators of natural potential and sustainability of the natural environment, and socio-economic – the value of technogenic load on geosystems, which includes the indicators of land development and environmental pollution. The disadvantage of this approach is its certain subjectivity, but

in many cases, it is the only one possible and therefore it is the most used.

The integrated indicator of GP is determined by the formula (1):

$$GP=NP+R–TL \quad (1)$$

where GP – geo-ecological potential, NP – natural potential, R – potential of geosystems resistance to technogenic load, TL – technogenic load on the geosystems (Olishevska, 2005).

In a broad sense, natural potential is a set of available natural conditions and resources that affect economic activity and are used or can be used in the production of goods, as well as are able to meet the needs of the country or humanity (Cheremkha, 2012). By "natural potential" we mean the intrinsic natural property of NTC, which it has in relation to any function, regardless of whether it is performing it at this time or not. The integrated indicator of the natural potential is determined by the formula (2):

$$NP = P+T+C_{hum}+C_{hp} – (ANP) \quad (2)$$

where NP – natural potential, P– annual precipitation, T – sum of active temperatures above 10°C, C_{hum} – humidity coefficient, C_{hp} – hydrothermal potential of phytomass productivity, ANP – adverse natural processes.

The study and assessment of the natural potential of the regional landscape structures was carried out on the basis of the methodology proposed by Yu. Olishevska and I. Nesterchuk (Olishevska, 2005; Nesterchuk, 2011). This methodology involves several stages: analysis of the main climate indicators, namely heat and moisture of the territory, as these factors have direct ecological significance and determine the territorial differentiation of other indicators, including biological (annual precipitation, humidity coefficient, sum of active temperatures above 10°C, hydrothermal potential of phytomass productivity) (values of indicators are taken from the corresponding maps); detection and analysis of adverse natural processes and assessment of their joint manifestation (values of indicators are taken from the corresponding maps). Since these indicators have different size, they are normalized with subsequent calculation of the values of NP according to the formula (2). Based on the calculated data, a scale of natural potential levels is developed.

M. Grodzynskyi, V. Baranovskyi, P. Shyshchenko (Grodzynskyi, 1995; Baranovskyi, 2001; Shyshchenko, 1999) studied the sustainability of the natural environment. They repeatedly mentioned in their works and actively emphasized the need to study the sustainability of geosystems, as the completeness of the geo-ecological research is impossible without taking it into account. The essence of the concept of "sustainability" is revealed in the monograph of M. Grodzynskyi, where the author showed the full range of interpretations of sustainability, identified its basic forms and found out that sustainability of the geosystem is the ability of the latter, in the case of external factors, to be in one state district and return to it due to inertia and reproducibility, as well as to move due to plasticity from one district of states to others, without going beyond invariant changes during a given time interval (Grodzynskyi, 1995).

Methodological bases for determining the natural environment sustainability were developed by V. Baranovskyi and P. Shyshchenko. When determining the sustainability index, the unidirectionality of its components is taken into account, and the sustainability potential is calculated on the basis of component-by-component assessment of the meteorological potential of the atmosphere, surface water and soil sustainability potential, as well as biotic potential and is calculated by the formula (3):

$$S=A+W+S+B \quad (3)$$

where S – potential for environmental sustainability, A – meteorological potential of the atmosphere, W – surface water sustainability potential, S – soil sustainability potential, B – biotic potential.

The meteorological potential of the atmosphere characterizes predominance in the atmosphere of the processes of accumulation or dispersion of chemicals and compounds. Assessment of the soil sustainability is performed according to indicators that characterize the sums of active temperatures, slope steepness, structure, resistivity, mechanical composition, humus content, type of water regime, pH reaction, afforestation, ion capacity, plowing, economic development within the natural agricultural areas of the regions of Ukraine. When determining the surface water sustainability, the days with water temperature above +16°C, water color indices and average long-term water consumption had been taken into account. Biotic potential characterizes the property of geosystems to preserve or restore biological diversity. According to the methodology of Yu. Olishevska, indicators of the resistance of the natural environment to the technogenic impact are taken from the map of V. Baranovskyi and P. Shyshchenko "Sustainability of the natural environment" (Baranovskyi and Shyshchenko, 2002). Based on the data analysis, a scale of environmental sustainability levels is developed.

The technogenic load is a degree of direct and indirect impact of people and economy on nature as a whole and its individual components. Analysis

of the technogenic impact on the environment is a complex process due to the variety of forms of human impact on it. There are different approaches to the establishment of the technogenic load on the environment, but the most successful, in our opinion, are the methods of V. Baranovskyi and I. Nesterchuk (Baranovskyi, 2001; Nesterchuk, 2011), as they are best suited for assessing the technogenic load within regional landscape structures. The indicator of the technogenic load is calculated by the formula (4):

$$TL = SEDT+EP \quad (4)$$

where TL – technogenic load, SEDT – socio-economic development of the territory, EP – environmental pollution.

The value of the technogenic load is characterized by the indicators of socio-economic development of the territory, namely: population density, territorial concentration of production and economic development of land. This indicator was calculated by the formula (5):

$$SEDT = PD+ C_{t.c.p.}+ EDL \quad (5)$$

where SEDT – socio-economic development of the territory, PD – population density, $C_{t.c.p.}$ – coefficient of the territorial concentration of production, EDL – economic development of lands.

In order to calculate the indicators of socio-economic development of the territory the data from the Main Department of Statistics in the Sumy region (Holovne upravlinnia statystyky…, 2019) and the Main Directorate of the State Geocadastre in Sumy region (Holovne upravlinnia Derzhheokadastru…, 2019) were used. The indicator of economic development of lands was calculated as the sum of shares of agricultural lands, built-up lands and open lands without vegetation.

In addition to socio-economic development of the territory, the environmental pollution, namely radiation pollution, chemical pollution of air, natural waters and soils is important for a comprehensive analysis of the technogenic load, which was calculated by the formula (6):

$$EP = P_r+P_{at}+ P_w + P_s \quad (6)$$

where EP – environmental pollution, P_r – radiation pollution of plants and soils, P_{at} – chemical pollution of the air, P_w – pollution of natural waters, P_s – chemical pollution of soils.

The analysis of the technogenic load on geosystems of the regional level needs generalized indicators. Due to the fact that for such areas it is quite difficult to collect information on specific indicators of the technogenic impact, the data are taken in terms of administrative districts and approximately calculated for landscape districts, taking into account the share of administrative districts within physical and geographical areas.

The integrated indicator of the technogenic load is calculated as the sum of normalized indicators: population density, coefficient of the territorial concentration of production, economic development of lands and environmental pollution of the landscape districts. On the basis of the received values of an indicator the levels of the technogenic load are developed.

An important stage of the study is to determine the integrated indicator of GP of the regional landscape structures, which included a number of procedures. At the first stage the normalization of the indicators of natural potential, the potential of natural environment sustainability and technogenic load of the landscape districts of the region is carried out. Next, the integrated indicator of GP is calculated, and its levels are set: low (-1…-0.60), below average (-0.59…-0.20), average (0.21–0.80), above average (0.81–1.40) and high (1.41–2.00).

These levels of GP were calculated for regional landscape structures – landscape districts that reflect the local characteristics of the hydro-functioning of the soil-plant complex and, as a consequence, form an individual landscape-morphological structure of the territory (Neshataev et al., 2005). During the study, the schemes of physical-geographical zoning developed by O. Marynych and others (Marynych et al., 2003), B. Neshataev (Neshataev, 1987; Neshataev et al., 2005) and V. Udovychenko (Udovychenko, 2003) were used.

Results and discussion. Assessment of natural potential.

The indicator of the sum of active temperatures above 10°C increases in the direction from north to south: northern, Znob-Novhorod landscape district is characterized by minimal values (2380°C), southern districts – (Transvorsklian, Lypova-Dolyna-Nedryhailiv, Lebedyn-Zinkiv – by maximal values (2650°C, 2600°C and 2640°C, respectively) (Veklych, 1995). The amount of precipitation increases in the opposite direction – from south to north. Their maximal number is received in the northern landscape districts: Znob-Novhorod and Esman'-Kleven' (600 mm per a year), and moving to the south, the amount of precipitation decreases, and in Lebedyn-Zinkiv district reaches the minimal annual amount (546 mm) (Veklych, 1995). Calculations of the humidity coefficient have established that the northern districts: Znob-Novhorod (1.2) and Shostka-Yampil'

(1.16) have excessive humidity, and the southern ones: Lypova-Dolyna-Nedryhailiv (1.0), Lebedyn-Zinkiv (1.0) – sufficient humidity. The hydrothermal potential of phytomass productivity determines the ability of the landscape to produce biomass and is estimated on the basis of the ratio of average annual productive humidity, vegetation period to average annual radiation balance (Baranovskyi, 2001). Landscape districts that have a relatively high indicator of hydrothermal potential of phytomass productivity include: Znob-Novhorod (6.0), Shostka-Yampil' (6.0), Seim (5.9) and Esman'-Kleven' (5.9), lower indicators are typical for Lebedyn-Zinkiv (5.3) and (Transvorsklian) (5.3).

Adverse natural processes can be found in the Sumy region quite widely and in various forms. The most common adverse natural processes include landslides, flooding, rising groundwater level, erosion, dry winds, hail, fog, and so on. The most eroded landscape districts are: Psel-Vorskla (soil erosion reaches up to 60%), Esman'-Kleven', Lebedyn-Zinkiv and Lypova-Dolyna-Nedryhailiv (up to 40%) (Veklych, 1995). At the same time, the lowest degree of soil erosion is observed in the northern districts of the region, while in the forest-steppe part of the region the intensity of erosion processes is much higher, which is manifested in greater depth of river valleys, density of ravine-beam network, one of the reasons for which is decreasing forest area. Landslides are characteristic primarily of Psel-Vorskla (17 landslide-prone areas have been identified), Seim (16) and Lebedyn-Zinkiv (11) landscape districts (Danylchenko, 2019). Not the last among the adverse processes is flooding, which occurs during significant spring floods and rainy years. The main reason for this phenomenon is the rise in groundwater levels, associated with significant over-regulation and siltation of rivers. The largest areas affected by flooding are Seredyna-Buda (1100 ha), Krolevets (448 ha) and Yampil' (350 ha) administrative districts, in terms of basins of the main rivers of the region the first positions are occupied by the basins of the Desna, Vorskla and Seim rivers, which territorially correspond to Znob-Novhorod, Shostka-Yampil', Transvorsklian and Vyry landscape districts (Danylchenko, 2019). Manifestations of such an adverse phenomenon as hail can most often be found in Vyry, Psel-Vorskla and Transvorsklian landscape districts (3 days per year). Dry winds are most common in the south of the region, namely in Transvorsklian (10 days per year), Lebedyn-Zinkiv (9 days per year) and Psel-Vorskla (8 days per year) landscape districts, they are less common in the northern districts. The distribution of fogs is uneven throughout the Sumy region, but also has a certain pattern: it decreases from north to south. The maximal number of days with fog is in Znob-Novhorod, Shostka-Yampil', Sula, Lypova-Dolyna- Nedryhailiv and Esman'-Kleven' landscape districts (60 days per year or more), which have a sufficient and even excessive level of humidity. In the south of the region, in the Transvorsklian and Psel-Vorskla landscape districts, the number of days with fog is 57 (Veklych, 2005).

The calculated indicators of the natural potential are in the range from 0.54 to 2.68 and according to the methodology (Nesterchuk, 2011) correspond to the following levels (Table 1).

The low level of the natural potential (<0.95) is represented in 3 landscape districts: Lypova-Dolyna-Nedryhailiv ancient glacial hilly-beam area, Lebedyn-Zinkiv gently undulating terraced and Psel-

Table 1. Levels of the natural potential of the landscape districts of the Sumy region

№	Landscape district	Calculations of normalized indicators*	Level of natural potential
1.	Znob-Novhorod	3 – (2.6/8) = 2.68	High
2.	Shostka-Yampil'	2.47– (2.64/8) = 2.14	High
3.	Seim	1.4 – (3.9/8) = 0.97	Below average
4.	Sula	2.4 – (2.7/8) = 2.07	High
5.	Lypova-Dolyna-Nedryhailiv	1.06 – (2.7/8) = 0.73	Low
6.	Lebedyn-Zinkiv	0.9 – (2.9/8) = 0.54	Low
7.	Transvorsklian	1.8 – (3.95/8) = 1.31	Below average
8.	Esman'-Kleven'	2.2 – (2.85/8) = 1.85	Average
9.	Vyry	1.9 – (4.5/8) = 1.34	Below average
10.	Psel-Vorskla	1.4 – (4.9/8) = 0.79	Low

*Note: calculations of normalized indicators are carried out according to the formula: $NP = \sum_i^4 Y_s - \frac{\sum_j^8 Y_d}{8}$,

where Y_s – normalized values of indicators-stimulators of the NP (annual precipitation, sum of active temperatures above 10°C, humidity coefficient, hydrothermal potential of phytomass productivity), Y_d – normalized values of indicators-destimulants of the NP (joint manifestation of adverse natural processes: flooding, rising groundwater levels, exogenous geological processes, landslides, erosion, recurrence of dry winds, hail, fog).

Vorskla off-glacial elevated strongly dissected area. These areas are characterized by low indicators of hydrothermal potential of phytomass productivity, worse climatic conditions (minimum precipitation – 546 mm is in Lebedyn-Zinkiv landscape district). Due to the fact that adverse natural processes (such as landslides (maximum number – 17 per Psel-Vorskla landscape district), soil erosion (maximum 60 % is typical for Psel-Vorskla district, 40 % – for Lebedyn-Zinkiv and Lypova-Dolyna-Nedryhailiv) and dry winds (9 days per year dominate in the Lebedyn-Zinkiv landscape district)) are widespread in the territory (Danylchenko and Hupalo, 2017), the level of natural potential will be low.

The level below average (0.96-1.50) is also typical for 3 districts: Seim terraced weakly dissected, Transvorsklian terraced gently undulating dissected, Vyry glacial-periglacial dissected landscape districts. The normalized indicators are higher than in the areas of the previous level, especially if we take into account the climatic indicators (the maximum amount of heat receives Transvorsklian landscape district). The Seim landscape district is characterized by a high indicator of hydrothermal potential of phytomass productivity. Adverse natural processes are represented by rising groundwater levels (Vyry landscape district is the leader in terms of indicators – 13 ha), flooding (maximal value falls on Transvorsklian district), soil erosion (35 % is typical for Vyry and Seim landscape districts) and frequent hail (Vyry and Transvorsklian landscape districts suffer from it 3 days a year).

The average level of the natural potential (1.51-2.00) is peculiar only to 1 landscape district – Esman'-Kleven' glacial dissected district, where the most precipitation (600 mm per year) falls, the hydrothermal potential of phytomass productivity is 5.9. Due to a small number of adverse natural processes, among which it is necessary to distinguish soil erosion (up to 40 %) and frequent fogs (60 days per year), the NP of Esman'-Kleven' reaches an average level of 1.85.

The high level of the natural potential (>2.01) is is peculiar to 3 districts: Znob-Novhorod moraine-zander weakly drained, Shostka-Yampil' elevated weakly dissected and Sula elevated-dissected landscape districts. These districts have high values of annual precipitation (600 mm – Znob-Novhorod district, 598 mm – Sula), the coefficient of humidification of the territory is represented by the maximal indicators: in Znob-Novhorod landscape district is 1.2 and Shostka-Yampil' – 1.16. The hydrothermal potential of phytomass productivity reaches a maximal value equal to 6.0 in Znob-Novhorod and Shostka-Yampil' landscape districts. Among the unfavorable natural processes it is necessary to note only flooding (maximal values are typical for Znob-Novhorod and Shostka-Yampil' landscape districts) and frequent fogs (60 days per year). Due to the high values of climatic indicators and the minimal number of adverse processes, these landscape districts received maximal indicators of the NP, ranging from 2.07 to 2.68.

Table 2. Sustainability of the natural environment of the landscape districts of the Sumy region (Hupalo and Danylchenko, 2018)

№	Landscape district	Meteorological potential "A"	Potential of the surface water sustainability "W"	Potential of the soil sustainability "S"	Biotic potential "B"	Sustainability potential "S"
1.	Znob-Novhorod	A_3	W_2	S_1	B_4	-1.21 (below average)
2.	Shostka-Yampil'	A_2	W_2	S_2	B_3	-0.5 (below average)
3.	Seim	A_2	W_2	S_3	B_3	+0.5(average)
4.	Sula	A_2	W_2	S_3	B_3	+0.095 (average)
5.	Lypova-Dolyna-Nedryhailiv	A_2	W_2	S_3	B_3	+0.55 (average)
6.	Lebedyn-Zinkiv	A_2	W_2	S_3	B_3	+0.6 (average)
7.	Transvorsklian	A_2	W_2	S_3	B_3	+1.12 (above average)
8.	Esman'-Kleven'	A_2	W_2	S_2	B_3	+0.26 (average)
9.	Vyry	A_2	W_2	S_3	B_3	+0.85 (above average)
10.	Psel-Vorskla	A_2	W_2	S_3	B_3	+0.99 (above average)

Note: meteorological potential: A_3 (0.96-1.25) – below average, A_2 (0.66-0.95) – low; surface water sustainability potential: W_2 (0.006-0.1) – low; soil sustainability potential: S_1 (40 and less) – very weak, S_2 (41-50) – weak, S_3 (51-60) – medium; biotic potential: B_4 (5.6-6.5) – average, B_3 (4.6-5.5) – below average.

Assessment of the environmental sustainability.

Based on the analysis of data (indicators of meteorological potential of the atmosphere, the potential of surface water and soil sustainability, biotic potential) taken from the map (Baranovskyi and Shyshchenko, 2002), according to the methodology, 3 districts of environmental sustainability of the landscape districts of the Sumy region are outlined: below average (indicator of sustainability potential is less than -0.50); average (-0.49...+0.80) and above average (+0.81...+2.10) (Table 2).

The area of the natural environment resistance to the technogenic load below average includes 2 landscape districts: Znob-Novhorod (-1.21) and to a greater extent Shostka-Yampil' (-0.5). These districts were referred to this group due to the low value of meteorological potential A_3 (below average), low surface water sustainability potential W_2, soil sustainability potential S_1 and S_2, which are characterized as very weak and weak soils, as well as average and below average biotic potential B_4 and B_3.

The second area of environmental sustainability with an integrated average indicator includes 5 landscape districts: Seim (+0.5), Sula (+0.095), Lypova-Dolyna-Nedryhailiv (+0.55), Lebedyn-Zinkiv (+0.6) and Esman'-Kleven' (+0.26). Indicators of some components of the natural environment sustainability of this area have higher values: the potential of soil sustainability has passed into the gradation (weakly stable) S_2, and for most landscape districts is characterized by a higher indicator of soil sustainability (medium stable) S_3. The value of meteorological potential varies from below average to low A_2. The value of the surface water sustainability potential has not changed – W_2 is low. Biotic potential also changed its value and moved to a group below average – B_3.

The third area of the above average environmental sustainability includes 3 landscape districts: Transvorsklian (+1.12), Psel-Vorskla (+0.99) and Vyry (+0.85). The indicators of the meteorological potential, surface water sustainability potential and biotic potential have not changed compared to the previous area and are A_2, W_2, W_3, respectively, but the value of soil sustainability potential is only in gradation S_3 and corresponds to "medium stable". The main role in determining habitats by the degree of the natural environment sustainability is played by the soil sustainability potential.

Assessment of the technogenic load.

The initial stage of the study of socio-economic development of the region is the analysis of the development of the territory. Examining the population density as a component of socio-economic development of the territory, we clearly trace the highest value (112.1 people/km^2) in the Psel-Vorskla landscape district, as it borders the regional center, and the lowest (13.0 people/km^2) in the Znob-Novhorod landscape district. The coefficient of the territorial concentration of production, as well as population density, fixed the maximum value for Psel-Vorskla landscape district (0.940), while Znob-Novhorod received the minimal value (0.009), because compared to the previous district the number of enterprises and production scale is much lower.

Economic land development (agricultural land, built-up land, open land without vegetation) is most represented in Vyry landscape district (87 %), where the largest share of developed land, and the minimal – in Znob-Novhorod landscape district (63.5 %).

A significant share in the technogenic load has environmental pollution. The Lebedyn-Zinkiv landscape district (normalized indicator 5.09) is characterized by the maximal pollution indicator, where there is an increased content of Pb and Cd in soils, chemical pollution of water and air, as well as the Psel-Vorskla landscape district (4.7), and the minimal indicator is typical for the Znob-Novhorod landscape district (2.23).

Calculations of the integrated indicator of the technogenic load allow us to identify the following levels of technogenic load (Table 3).

The level of the technogenic load *below average* (<2.40) is typical for one landscape district – Znob-Novhorod (indicator 2.23), in which there is the minimal population density, territorial concentration of production, economic development of land, and, consequently, minor environmental pollution.

The *average* level of the technogenic load is typical for 4 landscape districts – Seim (4.18), Sula (4.09), Esman'-Kleven' (2.86) and Vyry (3.78). Compared to the previous level, they have higher rates of economic development of land, population density, while the indicator of environmental pollution is not critical.

The level of the technogenic load above average is typical for 5 landscape districts: Shostka-Yampil' (4.82), Lypova-Dolyna-Nedryhailiv (4.78), Lebedyn-Zinkiv (5.62), Transvorsklian (4.71) and Psel-Vorskla (7.06). These landscape districts are characterized by high rates of the population density, territorial concentration of production, economic development of the territory, but most of them are united by high rates of environmental pollution. Psel-Vorskla landscape district stands out the most from the above-mentioned areas. It occupies a leading position in terms

Table 3. Levels of the technogenic load on the landscape districts of the Sumy region (Hupalo and Danylchenko, 2018)

№	Landscape district	Socio-economic development of the territory						Environmental pollution, integrated value	Integrated indicator of the technogenic load	Level of the technogenic load
		Population density, people/km^2	Normalized value	$C_{t.c.p.}$	Normalized value	Economic development of lands,%	Normalized value			
1.	Znob-Novhorod	13.0	0	0.009	0	63.5	0	2.23	2.23	Below average
2.	Shostka-Yampil’	47.9	0.35	0.139	0.13	67.0	0.15	4.19	4.82	Above average
3.	Seim	72.4	0.6	0.142	0.13	86.0	0.95	2.5	4.18	Average
4.	Sula	21.5	0.08	0.092	0.09	85.4	0.93	2.99	4.09	Average
5.	Lypova-Dolyna-Nedryhailiv	15.8	0.03	0.020	0.01	84.2	0.88	3.86	4.78	Above average
6.	Lebedyn-Zinkiv	35.0	0.22	0.058	0.05	69.7	0.26	5.09	5.62	Above average
7.	Transvorsklian	56.5	0.44	0.075	0.07	81.1	0.74	4.2	4.71	Above average
8.	Esman’-Kleven’	32.3	0.19	0.068	0.06	72.2	0.36	2.25	2.86	Average
9.	Vyry	31.9	0.19	0.032	0.02	87.0	1	2.57	3.78	Average
10.	Psel-Vorskla	112.1	1	0.940	1	72.1	0.36	4.7	7.06	Above average

of the population density, territorial concentration of production and environmental pollution.

Assessment of the geo-ecological potential.

Calculation of GP of the landscape districts of the Sumy region and establishment of its levels, allow to group landscape districts into certain groups by homogeneity of size of the investigated indicator and to create the map of GP areas of the region (fig. 1).

It is established that the GP indicator of the landscape districts of the Sumy region varies from 0.05 Psel-Vorskla landscape district (below average level) to 1.07 Esman’-Kleven’ landscape district (above average level) (Table 4).

The area of the *low level of the geo-ecological potential* on the territory of the Sumy region is not represented, because the state of natural resources of the region is assessed as satisfactory, and the technogenic load is not reflected as critical.

The area of the *below average level of the geo-ecological potential* unites 2 landscape districts: Lebedyn-Zinkiv and Psel-Vorskla. These are the central districts of the region, with the total area of about 4969 km^2 (21 % of the region’s territory), densely populated, economically developed, industrially developed with a technogenic load, which is 1.4 times higher than the regional average. In these districts there are low and below average levels of natural potential, due to low hydrothermal potential of phytomass productivity, unfavorable climatic indicators (Lebedyn-Zinkiv landscape district has a minimal value of precipitation and humidity),

Table 4. Geo-ecological potential of the landscape districts of the Sumy region

№	Landscape district	NP	Normalized value	S	Normalized value	TL	Normalized value	GP	Levels of the geo-ecological potential
1.	Znob-Novhorod	2.68	1	-1.21	0	2.23	0	1	Above average
2	Shostka-Yampil’	2.14	0.74	-0.5	0.3	4.82	0.53	0.51	Average
3.	Seim	0.97	0.2	+0.5	0.73	4.18	0.40	0.53	Average
4.	Sula	2.07	0.7	+0.095	0.45	4.09	0.38	0.77	Average
5.	Lypova-Dolyna-Nedryhailiv	0.73	0.08	+0.55	0.75	4.78	0.52	0.31	Average
6.	Lebedyn-Zinkiv	0.54	0	+0.6	0.77	5.62	0.7	0.07	Below average
7.	Transvorsklian	1.31	0.35	+1.12	1	4.71	0.5	0.85	Above average
8.	Esman’-Kleven’	1.85	0.6	+0.26	0.6	2.86	0.13	1.07	Above average
9.	Vyry	1.34	0.4	+0.85	0.88	3.78	0.32	0.96	Above average
10.	Psel-Vorskla	0.79	0.11	+0.99	0.94	7.06	1	0.05	Below average

and the significant impact of adverse natural soil erosion (40 % is typical for Lebedyn-Zinkiv and 60 % for Psel-Vorskla landscape districts), landslides (17 in Psel-Vorskla) and dry winds (9 days per year in Lebedyn-Zinkiv). The level of environmental sustainability of the area is defined as "average" for Lebedyn-Zinkiv and "above average" for Psel-Vorskla landscape districts, due to the low potential of the surface water sustainability (W_2) and below the average value of biotic potential (B_3). Instead, the level of the technogenic load for these landscape districts is defined as "above average", as it is aggravated by high population density, the coefficient of territorial concentration of production, which, in turn, is closely related to environmental pollution and accompanied by deteriorating air, natural waters, flora and land resources. This area is characterized by minimal values of geo-ecological potential of 0.07 for Lebedyn-Zinkiv and 0.05 for Psel-Vorskla landscape districts, which is by 10 times lower than the regional average.

The area of the *average level of the geo-ecological potential* includes 4 landscape districts: Seim, Shostka-Yampil', Sula and Lypova-Dolyna-Nedryhailiv, which, stretching from the northwest to the central part of the region, cover an area of about 10485 km^2, which is 44 % of the region. This area is characterized by a moderate population density, extensive economic development of lands, with an indicator of the technogenic load, which is almost the same as the regional average (4.4). The natural potential of the above-mentioned landscape districts, due to high climatic indicators, hydrothermal index of phytomass productivity and the minimal number of adverse natural processes is characterized by a high level, except for Lypova-Dolyna-Nedryhailiv and Seim landscape districts.

The level of environmental sustainability of most landscape districts is "average", due to the low potential of surface water resistance (W_2) and below the average value of biotic potential (B_3), only Shostka-Yampil' district belongs to the level of stability "below average" due to low meteorological potential (A_2). The level of the technogenic load "above average" is typical for Shostka-Yampil' landscape district, where there are high indicators of population density and territorial concentration of production, affecting environmental pollution, and for Lypova-Dolyna-Nedryhailiv landscape district, where this indicator is quite high due to the high value of the economic development of lands and the integrated indicator of environmental pollution and is accompanied by irrational human economic activity. The level of the technogenic load of Seim and Sula landscape districts is "average" due to the significant indicators of the population density and economic development of lands, although the integrated indicator of the environmental pollution is one of the most insignificant in the region. This district is characterized by the average value of the geo-ecological potential (0.53), including the Seim landscape district – 0.53, Sula – 0.77; Shostka-Yampil' – 0.51; Lypova-Dolyna-Nedryhailiv – 0.31, which is closed to the regional average (0.6).

The area of the *geo-ecological potential of the above average level* includes 4 landscape districts: Esman'-Kleven', Transvorsklian, Vyry and Znob-Novhorod. This area is not widespread in the Sumy region, but mainly formed in the east of the region. The total area is about 8324 km^2, which is 35 % of the region with different indicators of natural potential, with a predominance of the above average and average levels of environmental sustainability, relatively low population, extensive economic development of lands and technogenic load, which is lower than the average in the region. In these landscape districts there is: a high level of natural potential in Znob-Novhorod due to the high climatic indicators (maximal precipitation, humidity coefficient) and relatively insignificant manifestation of adverse natural processes; the average level has been achieved in Esman'-Kleven' district, due to high values of some climatic indicators (precipitation 600 mm per a year) and insignificant combined manifestation of adverse natural processes, among which we should single out soil erosion and fog; the below average level is typical for Transvorsklian and Vyry landscape districts, due to the minimal values of some climatic indicators and the widespread manifestation of adverse natural processes, including flooding, rising groundwater levels and hail. The level of environmental sustainability for Znob-Novhorod landscape district is recorded as "below average", due to the low potential of soil sustainability (S_1), for Esman'-Kleven' – as "average" due to low meteorological potential (A_2), soil sustainability potential (S_2), for Transvorsklian and Vyry landscape districts, it is defined as "above average" due to low meteorological potential (A_2) and surface water sustainability potential (W_2). The level of the technogenic load for Znob-Novhorod landscape district is "below average", due to the minimal indicators of population density, territorial concentration of production, economic development of lands, and, accordingly, environmental pollution. For Vyry and Esman'-Kleven', technogenic load is characterized by "average" level, as these landscape districts do not have a powerful industry, which, in

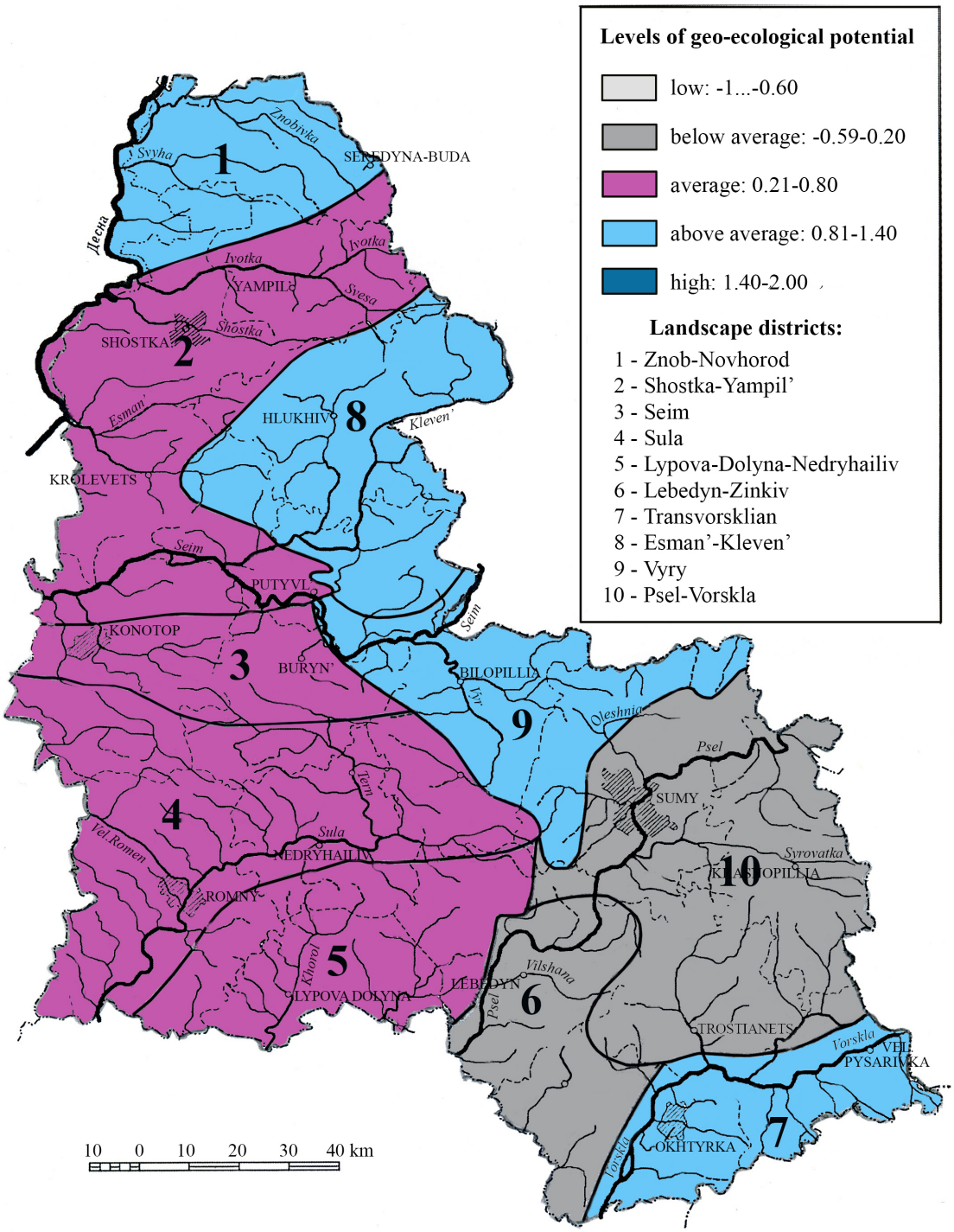

Fig. 1. Geo-ecological potential of the landscape districts of the Sumy region

turn, reduces the demographic and, consequently, technogenic impact on the natural environment of the region. This area is characterized by the maximal values of the GP (average – 0.97), namely: 1.07 for Esman'-Kleven', 1 for Znob-Novhorod, 0.96 for Vyry and 0.85 for Transvorsklian landscape districts, which 1.6 times higher than the regional average. With all the diversity of the natural potential levels, environmental sustainability and technogenic load, it was possible to establish a certain peculiarity: the main role in high indicators of the geo-ecological potential is played by low indicators of the technogenic load.

The area of the *geo-ecological potential of the high level* is characterized by comfortable living conditions of the population with minimal impact of the technogenic load. In the course of the study, this area of GP was not identified.

Conclusions.

Geo-ecological potential is the potential of life support of the population, which reflects the living conditions of the population in specific geosystems.

The value of the geo-ecological potential is estimated on the basis of natural potential of geosystems, potential of geosystems resistance to the technogenic load and technogenic load on geosystems. The natural potential of the landscape districts of the Sumy region is determined, and the low, below average, average and high levels of natural potential are distinguished. The analysis of the natural environment sustainability of the landscape districts of the Sumy region is calculated on the basis of indicators of geosystems resistance to the technogenic impact.

In the course of the study 3 areas of environmental sustainability of the landscape districts of the Sumy region were identified: below average, average and above average. The integrated indicator of the technogenic load allows to establish the following levels of the technogenic load: below average, average and above average. The assessment of the geo-ecological potential allows to establish the levels on the basis of which the areas of the geo-ecological potential of landscape districts are determined. 5 levels of the geo-ecological potential have been identified, and only 3 of which are presented for Sumy region and a map of the areas of the geo-ecological potential has been created. It is found out that the higher the values of the natural potential and sustainability of the natural environment and the lower the indicators of the technogenic load, the higher are the values of the geo-ecological potential, with the decisive role of the minimal anthropogenic impact. The results of the study provide an opportunity to assess the internal regional capabilities of the landscape districts, as well as to identify areas for the most/least favorable living conditions.

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