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LANDSCAPE DIVERSITY OF THE TERRITORY OF THE TOBOL RIVER BASIN WITHIN THE KOSTANAY REGION

The relevance of the study of landscape diversity has become one of the current directions of modern geographical research, allowing to obtain new scientific and practical results in the field of nature management and environmental protection. A comprehensive study and assessment of the diversity of the landscapes of the region is due to the increasing anthropogenic impact on its natural environment. The transformation of natural landscapes in the study area is associated with the raw materials orientation of its economy. As a consequence of the development, we have a wide variety of degrees and types of modifications of natural geosystems. The main results of the assessment of the landscape diversity of the territory of the Tobol river basin within the Kostanay region, performed using GIS, are presented. Landscape diversity evaluation performed using series of landscape diversity indices: uniqueness, relative wealth, landscape mosaic, landscape complexity, landscape fragmentation and the entropy measure of the complexity of landscape drawing (The Shannon index). The factors that determine the landscape diversity of the study region are considered. The results of cartographic analysis of the landscape diversity of the region are presented. A map of the landscape diversity of the territory of the Tobol River basin within the Kostanay region according to the Shannon diversity index has been compiled.

Key words: landscape, landscape diversity, Shannon diversity Index, Tobol river.

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Қостанай облысы шегіндегі Тобыл өзенінің бассейн аумағының ландшафттық әртүрлілігі

Ландшафттық әртүрлілікті зерттеудің өзектілігі табиғатты пайдалану және қоршаған ортаны қорғау саласында жаңа ғылыми, практикалық нәтижелер алуға мүмкіндік беретін заманауи географиялық зерттеулердің өзекті бағыттарының біріне айналды. Аймақтың ландшафттарының әртүрлілігін жан-жақты зерттеу және бағалау оның табиғи ортасына антропогендік әсердің артуына қатысты. Зерттелетін аумақтағы табиғи ландшафттардың өзгеруі оның экономикасының шикізаттық бағытымен байланысты. Бізде табиғи геожүйелердің модификациясының дәрежесі мен түрлері өте көп. Қостанай облысы шегінде Тобыл өзені бассейні аумағының ландшафттық әртүрлілігін бағалаудың ГАЖ көмегімен орындалған негізгі нәтижелері келтірілген. Зерттеу аймағының ландшафттық әртүрлілігін бағалау бірқатар индекстер арқылы жүзеге асырылады: бірегейлік, салыстырмалы байлық, ландшафттық мозаика, ландшафттық бөлшек, ландшафттық күрделілік, ландшафттық бытыраңқылық және ландшафт үлгісі күрделілігінің энтропиялық өлшемі (Шеннон коэффициенті). Мақалада зерттеу аймағының ландшафттық әртүрлілігін анықтайтын факторлар қарастырылады. Аймақтың ландшафттық әртүрлілігін картаға түсіру және картографиялық талдау нәтижелері ұсынылған. Шеннонның әртүрлілік индексі бойынша Қостанай облысы шегіндегі Тобыл өзені бассейні аумағының ландшафттық әртүрлілігінің картасы жасалды.

Түйін сөздер: ландшафт, ландшафттық әртүрлілік, Шеннонның әртүрлілік индексі, Тобыл өзені.

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Ландшафтное разнообразие территории бассейна реки Тобол в пределах Костанайской области

Актуальность исследования ландшафтного разнообразия стала одним из актуальных направлений современных географических исследований, позволяющих получить новые научные и практические результаты в области природопользования и охраны окружающей среды. Комплексное исследование и оценка разнообразия ландшафтов области обусловлены все возрастающим антропогенным воздействием на ее природную среду. Преобразование естественных природных ландшафтов в исследуемой территории связано с сырьевой направленностью ее экономики. Как следствие освоения мы имеем большое разнообразие степени и видов модификаций природных геосистем. Приведены основные результаты оценки ландшафтного разнообразия территории бассейна реки Тобол в пределах Костанайской области, выполненной с использованием ГИС. Оценка ландшафтного разнообразия региона исследования проведена с помощью серии индексов: уникальности, относительного богатства, ландшафтной мозаичности, ландшафтной дробности, ландшафтной сложности, ландшафтной раздробленности и энтропийной меры сложности ландшафтного рисунка (коэффициент Шеннона). Рассматриваются факторы, обуславливающие ландшафтное разнообразие региона исследования. Приводятся результаты картографирования и картографического анализа ландшафтного разнообразия региона. Составлена карта ландшафтного разнообразия территории бассейна реки Тобол в пределах Костанайской области по индексу разнообразия Шеннона.

Ключевые слова: ландшафт, ландшафтное разнообразие, индекс разнообразия Шеннона, река Тобол.

Introduction

The term «Landscape diversity» has been increasingly found in domestic and foreign scientific works in recent years, but so far it has no generally accepted definition. One of the works notes that the idea of landscape diversity has been formed only in the last decade in connection with the problems of conservation and use of the environment (Puzachenko et al., 2002). Within the framework of landscape studies, the concept of diversity of territorial systems is much less developed, there is still no generally accepted definition of landscape diversity, understanding of the essence, and methods of studying this phenomenon as a whole and its aspects. Nevertheless, landscape diversity is recognized as the essential characteristic of territories, an integral component of the diversity of the natural environment. At the end of the twentieth century, landscape studies faced new theoretical problems caused by the acceleration of the degradation of natural complexes and ecosystems, environmental pollution, a decrease in biological and landscape diversity, and the global deterioration of the ecological situation (Ozgeldinova et al., 2021), (Ramazanova et al., 2019). A new stage in the development of landscape studies has come. The problems of accounting, assessment, and conservation of landscape diversity as a necessary condition for human life and the functioning of living organisms of the biosphere have become of paramount importance (Vitchenko, 2009), (Kerimbay et al., 2020).

A.G. Isachenko (Isachenko, 2008), N.F. Reimers (Reimers, 1994), G.V. Geldieva (Geldyeva, 2008), K.M. Dzhanaleeva (Dzhanaleeva, 2008) and others were engaged in the study of the natural properties of landscapes for the development of the proposed structure of nature management. The most famous and fundamental works in the field of landscape diversity are the works of Grodzinsky M.D. (Grodzinsky, 2015), Puzachenko Yu.G., Dyakonov K.N. (Puzachenko et al., 2002), Sokolov A. S. (Sokolov, 2014), Hansei K.S. (Hansei and Ivanov, 2012) and others. The assessment of landscape diversity considered in this paper is based on a qualitative and quantitative analysis of the landscape structure of the territory using a previously completed landscape map and various statistical coefficients. In this case, landscape diversity refers to the number and frequency of occurrence of natural territorial complexes within a region, which are a reflection of the structural and genetic heterogeneity of the territory, mainly related to the properties of the lithogenic basis.

A comprehensive study and assessment of the diversity of the landscapes of the region are due to the increasing anthropogenic impact on its natural environment. The transformation of natural land-

scapes in the study area is associated with the raw materials orientation of its economy. As a consequence of the development, we have a wide variety of degrees and types of modifications of natural geosystems. In this regard, the relevance of the study of landscape diversity has become one of the most relevant areas of modern geographical research, allowing us to obtain new scientific and practical results in the field of nature management and environmental protection (Dzhanaleeva, 1997), (Medeu et al., 2020), (Sokolov, 2014).

Materials and Methods

To assess the landscape diversity of the territory of the Tobol River basin within the Kostanay region, the operational unit of the study is the landscape. The landscape map of the Tobol River basin within the Kostanay region, previously made by us, is taken as a basis, where 12 individual landscapes are identified, which, as a result of their typological grouping, and then structural and genetic classification, are ordered into hierarchical systematics: class (plain landscapes), types (forest-steppe, steppe, semi-desert landscapes), subtypes (north-steppe and southern landscapes) (Geoportal of Kostanay region, 2021), (Abubakirova et al., 2017), (Muller and Steinhardt. 2003), (Ozgeldinova et al., 2019a).

The selected indices from a large selection of indicators of landscape diversity are presented in Table 1. All the selected indexes represent the metric characteristics of the landscape.

Table 1 – Indicators of landscape diversity assessment (compiled according to (Grodzinsky, 2015), (Puzachenko et al., 2002), (Sokolov, 2014), (Nikolaev and Ivashutina, 1971), (Jaeger, 2000)

Indicator	Formula	Description
The entropy measure the complexity of landscape drawing (Shannon coefficient)	$H = -\frac{S_i}{S} ln \frac{S_i}{S}$	N is the number of landscape genera within the administrative district;
Uniqueness Index	$I_o = \Sigma \frac{S_i}{S_i}$	N0 – the number of landscape genera in the region;
Relative Wealth Index	$I_r = \frac{N}{N_0}$	n – the number of landscape allotments within the administrative district;
Landscape Mosaic index	$I_p = 1 - \frac{N}{n}$	S – area of the administrative district (total area of landscape allotments);
Landscape Fractional Index	$I_d = 100 \cdot \frac{n}{S}$	S0 – average area of landscape allotments;
Landscape Complexity Index	$I_c = 10 \cdot \frac{n}{S_0}$	si – the total area of allotments of the I-th kind of landscape in the district;
Landscape Fragmentation Index	$I_{fr} = 1 - \frac{S_0}{S}$	Si – the total area of allotments of the I-th kind of landscape in the region.

The Shannon coefficient, transferred to landscape science from biology, measures diversity based on two components: occurrence and uniformity, i.e. the number of types of allotments in the landscape (compositional component), and their uniform distribution among the studied area (structural component). If this indicator is zero, then the entire territory contains only one type of Natural Territorial Complex (one contour). The increase in the index value is associated with a proportional increase in the number of contours or their distribution (Asocan et al., 2016), (Ozgeldinova et al., 2022).

The uniqueness index shows the degree of representation of various kinds of landscapes on the territory of the administrative district. Its value is greater the higher the proportion of the area of each kind of landscape within the district from the area of the same genera in the whole region. The relative wealth index shows the proportion of the number of landscape genera within the administrative district from the number of landscape genera in the territory of the region. The landscape mosaic index reflects the average number of allotments per genus, the resulting number is subtracted from one so that an increase in diversity is accompanied, as for other indices, by an increase in the value of the indicator. The landscape fragmentation index shows the average number of allotments per 100 km2 of the

district territory, the landscape complexity index shows the average number of allotments per 10 km2 of the territory of one kind of landscape. The landscape fragmentation index reflects the proportion of the average contour area from the area of the entire territory, this indicator does not depend on the area of the territory, but solely on the number of contours according to the formula y = 1-1/x, where x is the number of contours (Puzachenko et al., 2002), (U.S. Geological Survey, 2021).

The assessment of the landscape diversity of the territory of the Tobol River basin within the Kostanay region is carried out using a group of tools «Zonal» by ArcGIS.

Results and Discussion

As a result of the work carried out, a cartographic representation of the assessment of the landscape diversity of the study region was created (Figure 1) and the following results were obtained.

According to the Shannon index map of the territory of the Tobol River basin within the Kostanay region, 3 degrees of complexity of the landscape pattern can be distinguished as much as possible in the context of administrative districts: landscapes of maximum diversity (0.36 – 0.27); landscapes of medium diversity (0.21 – 0.10); landscapes of minimal diversity (less than 0.10) (Lundqvist et al., 1985), (Newsletter, 2007), (Varis and Kummu, 2012).

The highest values are concentrated in the south and southwest of the region (Zhitikarinsky, Naurzumsky – districts with an index of 0.36-0.27). This is primarily due to the location of this area, in particular, the Zhitikarinsky district on the territory of the Trans-Ural plateau, and the corresponding complication of the landscape pattern. Also, to preserve and restore biological and landscape diversity, and natural ecological systems, the Naurzum State Nature Reserve, included in the UNESCO World Heritage List, was created on the territory of this area (Deng and Chen, 2017), (Jai et al., 2015), (Ozgeldinova et al., 2019b).

The areas of the southeastern and central parts of the region have an average degree of diversity (index 0.21 – 0.10), the complexity of the landscape pattern was influenced by the dismemberment of logs and gullies of the slopes of the Tobol river valleys and a large number of shallow gullies and small gullies (RSE «Kazhydromet», 2021).

The northern districts of the region (Karabalyksky, Sarykolsky, Uzunkolsky, Fedorovsky) as a whole have significantly lower values (less than 0.10), this is due to the relatively small number of landscape allotments in these areas (Table 2).

Table 2 – Entropy measure of landscape pattern complexity (Shannon index)

District	Entropy measure of landscape pattern complexity (Shannon index)
Altynsarin	0,15
Auliekol	0,04
Denisov	0,001
Zhitikarin	0,36
Kamystin	0,13
Karabalyk	0,03
Karasu	0,21
Kostanay City Administration	0,03
Kostanay	0,10
Lisakovsk	0,36
Mendykarin	0,18
Naurzum	0,27
Rudnen City Administration	0,13
Sarykol	0,05
Taranov	0,11
Uzunkol	0,04
Fedorov	0,03

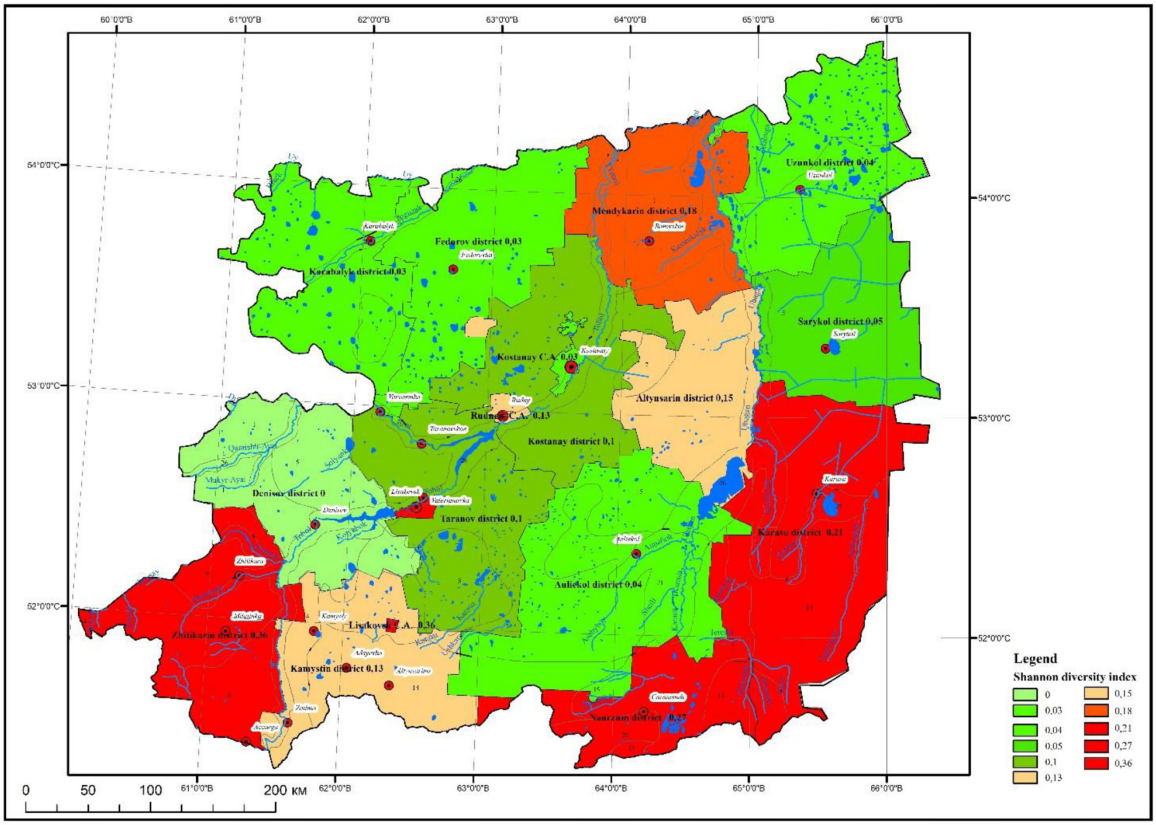

Figure 1 – Map of landscape diversity (Shannon index) of the Tobol River basin within the Kostanay region (compiled by the author)

Table 3 – Hills index of relative wealth level

District	Number of types of landscapes in the area	Total number of landscapes in the region	Relative Wealth Index
Altynsarin	2	27	0,07
Auliekol	2	27	0,07
Denisov	1	27	0,03
Zhitikarin	3	27	0,1
Kamystin	3	27	0,1
Karabalyk	2	27	0,07
Karasu	3	27	0,1
Kostanay City Administration	1	27	0,03
Kostanay	2	27	0,07
Lisakovsk	2	27	0,07
Mendykarin	2	27	0,07
Naurzum	3	27	0,1
Rudnen City Administration	2	27	0,07
Sarykol	2	27	0,07
Taranov	2	27	0,07
Uzunkol	2	27	0,07
Fedorov	2	27	0,07

According to the relative wealth index, the distribution of districts roughly corresponds to the distribution of the Shannon index. The districts with the highest values on the uniqueness index are Naurzumsky, Zhitikarinsky, Kamystinsky, and Karasu. All of them are located in the central and southern parts of the Kostanay region in the transition zones of the steppe, semi-desert. The entire northern and part of central part of the region is occupied by districts with a relatively average wealth index (0.07). Denisovsky district and the territory of the city of Kostanay turned out to have the lowest indicators of relative wealth (Table 3) (Management of the Land Cadastre, 2021).

Table 4 – Landscape Complexity Index

District	Number of landscape allotments in the area	Average landscape area (km^2)	Landscape Complexity Index
Altynsarin	2	3684	0,005
Auliekol	6	3684	0,01
Denisov	1	3684	0,002
Zhitikarin	3	3684	0,008
Kamystin	9	3684	0,02
Karabalyk	2	3684	0,005
Karasu	5	3684	0,01
Kostanay City Administration	1	3684	0,002
Kostanay	3	3684	0,008
Lisakovsk	2	3684	0,005
Mendykarin	3	3684	0,008
Naurzum	11	3684	0,02
Rudnen City Administration	2	3684	0,005
Sarykol	2	3684	0,005
Taranov	4	3684	0,01
Uzunkol	3	3684	0,008
Fedorov	2	3684	0,005

The index of landscape complexity (Table 4) in the study area ranges from 0.002 to 0.02. The most difficult is the Naurzum (0.02) and Kamystinsky (0.02) districts. Further down the Auliekolsky, Karasusky, Taranovsky. The indexes of all other districts are not more than (0.01). The lowest indicator is identical to the areas of relative wealth (White, 1963).

Table 5 – Landscape Mosaic index

District	Number of types of landscapes in the area	Number of landscape allotments	Landscape Mosaic index
1	2	3	4
Altynsarin	2	2	0
Auliekol	2	6	0,66
Denisov	1	1	0
Zhitikarin	3	3	0
Kamystin	3	9	0,66
Karabalyk	2	2	0
Karasu	3	5	0,4
Kostanay City Administration	1	1	0
Kostanay	2	3	0,33
Lisakovsk	2	2	0

1	2	3	4
Mendykarin	2	3	0,33
Naurzum	3	11	0,72
Rudnen City Administration	2	2	0
Sarykol	2	2	0
Taranov	2	4	0,5
Uzunkol	2	3	0,33
Fedorov	2	2	0

Landscape mosaic (Table 5) is determined by the separation of allotments of one type of landscape on the territory of the district, that is, the more allotments correspond to one type of landscape, the higher the index will be. According to this indicator, the largest figures are in the Naurzum district (index 0.72, 11 allotments with 3 types of landscape). Further down, Auliekolsky, Kamystinsky (index 0.66), Taranovsky (index 0.5), Karasu 0.4, Kostanay and Uzunkolsky 0.33.

At the same time, almost half of the districts of the Kostanay region have an index of zero (Fedorovsky, Sarykolsky, Altynsarinsky, Denisovsky, Zhitikarinsky, Karabalyksky districts, and in the main cities of the region Kostanay, Rudny, Lisakovsk), which means that each type of landscape has one allocation in these areas (Aghazamani and Hunt, 2017), (Medvedev, 2017).

Conclusion

Thus, investigating the problems of the diversity of natural landscapes, we assessed the landscape diversity of the territory of the Tobol River basin within the Kostanay region using 5 different indices proposed by different authors. The experiment showed that using different methods, in some cases, we get similar results. It is established that high indices of diversity are characteristic of the Zhitikarinsky, Naurzumsky, and Kamystinsky districts, which are associated with their location on the borders of physical and geographical areas. In these regions, about half of the natural-territorial complex used for recreation is characterized by the maximum degree of diversity. The degree of sustainability, features of economic use, biodiversity, environmental potential and a number of other important properties also affect. The least diverse are the northern districts of the Kostanay region – Denisovsky, Fedorovsky, and Karabalyk districts.

The assessment of landscape diversity made it possible to identify areas with different diversity potentials. The results obtained make it possible to identify spaces of monofunctional and diverse uses, including finding specific places for the organization of protected and recreational areas (Mukayev, et al., 2020).

The results of the assessment of landscape diversity are of leading importance in the justification of economic activity and are a necessary component of the design of modern environmental management.

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