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ASSESSMENT OF THE MAIN COMPONENTS OF THE NATURAL AND RECREATIONAL POTENTIAL OF THE TENIZ-KORGALZHYN DEPRESSION USING GEOINFORMATION TECHNOLOGIES AND REMOTE SENSING METHODS

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Abstract: This article presents the research results and the development of a methodology for assessing the components of the natural and recreational potential of the Teniz-Korgalzhyn depression focusing on its suitability for recreation and ecotourism development. The aim of the study is to analyze the key components of the natural environment that form the basis of the recreational potential of the Teniz-Korgalzhyn depression, utilizing geoinformation technologies and remote sensing techniques. The proposed method allows for a detailed component-by-component analysis of the region's natural and recreational resources, including relief, water resources, and vegetation. The balance method was used to calculate the potential, providing an objective assessment and comparative analysis of the territory's potential. The methodology presented in the article not only determines the priority areas of recreational activity but also allows for assessing degree of accessibility of the natural and recreational resources of the area under study. As a result of the assessment of the region's resources, territories more favorable for the development of ecotourism were identified. Analysis of landscape data obtained using NDVI and MNDWI revealed differences in the natural and recreational potential of the Teniz-Korgalzhyn Depression areas. Areas with a high NDVI value are characterized by an abundance of vegetation, which indicates their potential suitability for recreational use. On the contrary, areas with low NDVI and high MNDWI indicate insufficient vegetation, but the possible presence of water bodies, which is also important for recreational planning. These differences demonstrate a clear comparative analysis of data on the two indices and allow for reasonable distribution of recreational resources, assessment of ecosystem degradation, and identification of priority areas for restoration and protection. Key findings highlight the region's diverse natural resources, influenced by climatic variability, anthropogenic factors, and habitat diversity. Water resources, essential in the continental climate, are vital for recreation but necessitate sustainable management to avoid ecosystem degradation. The findings underline the importance of sustainable resource use to preserve the ecological balance and promote tourism in the region. The Korgalzhyn Nature Reserve emerges as the most valuable natural asset, although much of the steppe ecosystem remains unprotected and requires ecological monitoring.

Keywords: natural and recreational potential, landscapes of the Nura River basin, Teniz-Korgalzhyn depression, remote sensing methods, geoinformation technologies, Normalized Difference Vegetation Index

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INTRODUCTION

The Teniz-Korgalzhyn depression is a valuable territory with a rich landscape and recreational potential. The first information about the Teniz-Korgalzhyn depression, its geography, and bird fauna was published by Levshin in the work “Description of the Kirghiz-Cossack, or Kirghiz-Kaisakh hordes and steppes” (Levshin, 1832). The region has a rich landscape and a diversity of flora and fauna (Tolegenuly et al., 2021). In the context of growing interest in ecotourism and sustainable nature management, assessing natural resources for recreation is becoming especially relevant. This territory is characterized by a variety of natural conditions, including unique relief, water resources, and vegetation, which makes it attractive for the development of recreational and tourist destinations. However, for the effective and sustainable use of the region's recreational opportunities, a scientifically based methodology for assessing its natural resources is needed (Adekenov et al., 2020). The Teniz-Korgalzhyn depression, located in a unique natural zone of Kazakhstan, is a valuable territory with a rich landscape and recreational potential. In the context of growing interest in ecotourism and sustainable nature management, assessing natural resources for recreation is becoming especially relevant. This territory is characterized by a variety of natural conditions, including unique relief, water resources, and vegetation, which makes it attractive for the development of recreational and tourist destinations. However, for the effective and sustainable use of the region's recreational opportunities, a scientifically based methodology for assessing its natural resources is needed.

The Teniz-Korgalzhyn depression is located in the central part of Kazakhstan; most of its surface belongs to the Kazakh Upland (Figure 1). The North Kazakh Plain is located in the north of Kazakhstan, bounded in the south and southeast by the Kazakh Upland, and in the west, it smoothly passes into the Torgai tableland. Structurally, this plain belongs to the West Siberian Plate, the basement of which consists of pre-Paleozoic and Paleozoic intrusive and metamorphic rocks. The plate is complicated by faults and has a stepped structure. To the west, towards Western Siberia, the thickness of the Mesozoic and Cenozoic deposits does not exceed 300 m. At the same time, in the direction of the Irtysh syncline, the depth of the basement reaches more than 2 km (Akbar et al., 2020).

The peculiarity of the North Kazakh Plain is the combination of island forests, urban landscapes, and industrial facilities with the widespread presence of agricultural landscapes on the steppe landscapes (Makhanova & Berdenov, 2022). According to morphological features, the North Kazakh Plain is divided into the accumulative plains of the Tobol, Ishim, and Irtysh regions. The Tobol and Ishim plains, separated by the Torgai hollow, form the North Torgai, also known as the Kostanai Plain. These plains have similar morphological features and a similar history of geological development.

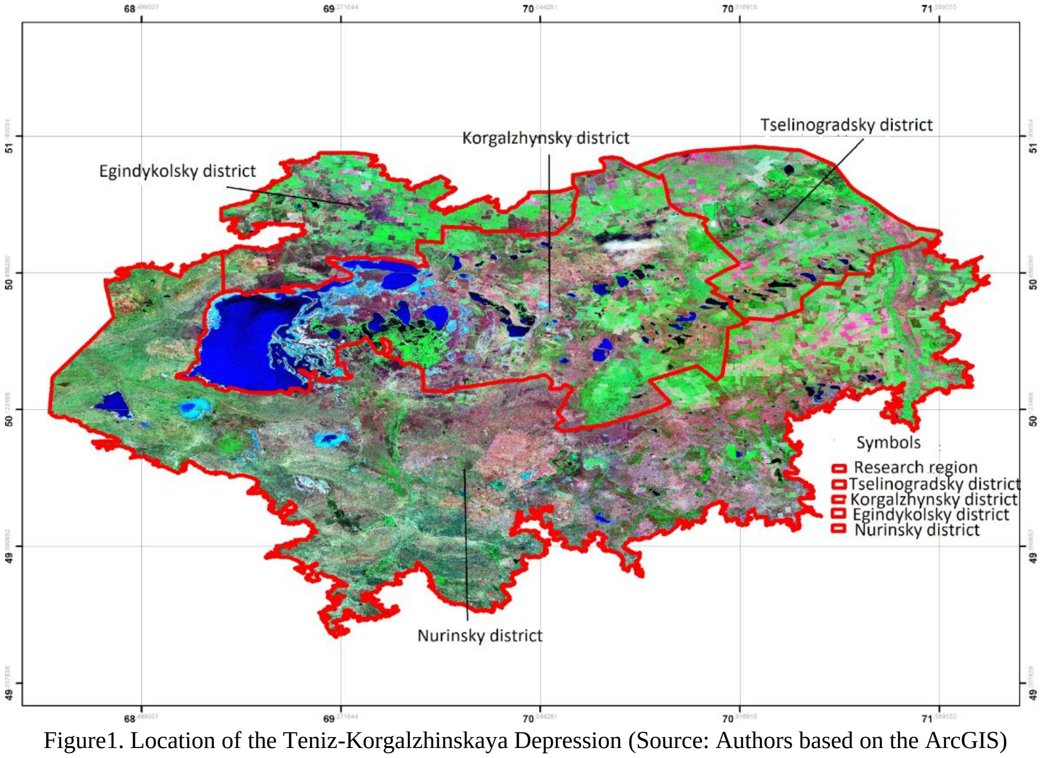

Figure1. Location of the Teniz-Korgalzhinskaya Depression (Source: Authors based on the ArcGIS)

The territory of the Teniz-Korgalzhyn depression includes the largest lake in the steppe zone – Lake Tengiz, the final water intake of the region. In rainy years, its area is 1590 km², the length of the coastline is about 470 km, the greatest depth reaches 6.7 m, and the mineralization of the water fluctuates significantly from 22 to 127 g/l (Davletbekov et al., 2018). Tengiz is an endorheic lake, fed mainly by the waters of the Nura and Kulanotpes Rivers (through the flowing Korgalzhyn lakes). Water in the lake is most often spent on evaporation. The lake consists of the main deep-water stretch and a large bay in the northeastern part (Akhmedenov et al., 2020).There are over 60 large and small islands on the lake, concentrated in the eastern part. On the southwestern side of Lake Tengiz, there are large lakes, formerly its bays - Kirey and Kypshak. In summer they dry up considerably. According to hydrochemical analyses, the mineralization of water in the reservoirs of the Tengiz-Korgalzhyn lake system increases downstream of the Nura River: in the most flowing Lake Kokai it was 1.98 g/l, in Lake Sultankeldy – 2.59 g/l. Lake Yesei (3.63 g/l) and Lake Asubalyk (4.00 g/l) are more mineralized. Lake Tengiz is distinguished by significant mineralization up to 40.8 g/l in Big Tengiz and 55.9 g/l in Small Tengiz. The desalination effect of the Nura River on the eastern sections of Big Tengiz is observed (Davletbekov et al., 2018).

The water class in all lakes remains sodium chloride group II or III types. The level of organic pollution of water bodies in all studied areas does not exceed the MAC. Water pollution with heavy metals, zinc, and mercury in reservoirs is practically at the level of background values. This problem of environmental pollution with heavy metals is one of the most acute environmental problems of our time (Satova et al., 2020). Exceeding the MAC by 1.2-5.2 times the MAC for manganese content in water was revealed in almost all reservoirs (except for Lake B. Tengiz).

According to the analysis data, the copper content in lakes Asaubalyk, Yesey, and Kokai is increased (2-4 times and above the MAC) and fluorides (1.1-2.5 times above the MAC). The phenol content does not exceed the MAC. The iron concentration significantly exceeds the MAC in all reservoirs and is 4-6 MAC, reaching a maximum in the Nura River.

The lakes of the Teniz-Korgalzhyn system are flowing and include more than 20 lake reaches. A distinctive feature of the large lakes (Korgalzhyn, Teniz) is the presence of accumulative lake terraces. The first and second terraces of Lake Teniz, coastal ridges, and the bottoms of modern lakes are made up of modern lake sediments. The Nura River flows through the large lakes, and the remaining reaches are connected by small channels. Lake Asaubalyk can be classified as a brackish lake (Sagatbayev et al., 2019a). The water balance of the Teniz-Korgalzhyn lake system consists of inflow and outflow parts. The inflow is represented by the runoff of the inflowing Nura and Kulanotpes Rivers, the runoff from the catchment area of the lakes themselves, and precipitation falling on the water surface of the lakes.

The study hypothesizes that the greatest recreational potential is possessed by territories with high natural diversity, especially at the junction of natural environments (water, forests, mountains). Unique natural objects, such as high cliffs or wooded capes jutting out into lakes, are especially attractive for tourism. Researchers concluded that the obtained results of study are of fundamental environmental and economic importance when assessing water supply and can be used as an effective tool for the assessment of the influence of water factors during socio-economic forecasting of the region’s development, especially recreational activities (Mustafayev et al., 2024).

Çadraku (2023) noted that natural and cultural values are important for current and future generations, as they serve as a medium for tourism and promote physical and mental relaxation. Tourism, as a type of economic activity, is aimed at the effective use of these resources in order to maximize their use in certain areas or countries. The aim of the study is to analyze the main components of the natural environment, which from the basis of the recreational potential of the Teniz-Korgalzhyn depression and to use geoinformation technologies and remote sensing methods.

METHODOLOGY

To assess the natural and recreational potential of the Teniz-Korgalzhyn depression, a methodology was developed that included a component-by-component analysis of the territory's natural components. The main task was to objectively assess landscapes' attractiveness, taking into account their natural, infrastructural, and environmental characteristics.

Special criteria were proposed based on research on the component-wise integrated assessment of the territory's natural and recreational potential (Gudkovskich, 2017; Popov and Gulyaeva, 2003). For the recreational and natural evaluation of landscapes, the indicators of all-natural components (relief, water bodies, vegetation cover, and specially protected natural areas) were taken into account. Images obtained as a result of the SRTM (Shuttle Radar Topography Mission) radar topography survey are grayscale images, the third coordinate of which is the height above sea level. The Shuttle Radar Topography Mission produced the Earth's most complete, highest-resolution digital elevation model (Farr et al., 2007). Such images are called a digital elevation model or DEM (Digital elevation model). The data are in the public domain and are distributed in squares measuring 1x1 degree (or 1201x1201 pixels) with a maximum available resolution of 1 second (or 30 meters). The Shuttle Radar Topography Mission produced the most complete, highest-resolution digital elevation model of the Earth. The project was a joint endeavour of NASA, the National Geospatial-Intelligence Agency, and the German and Italian Space Agencies and flew in February 2000 (Farr et al., 2007). Our methodology used three key indicators: relief, vegetation, and water resources. Each contributed to the integrated assessment of the territory's potential.

First, the relief was assessed based on the digital elevation model (DEM) obtained using Shuttle Radar Topography Mission (SRTM) data. The main parameters for the analysis were the surface slope angle and absolute height. More pronounced relief was considered attractive for active types of tourism, such as mountaineering or hiking. The values of the surface height and slope were ranked on a scale from 0 to 5 points, where the maximum score was assigned to areas with the most favorable characteristics for recreation Sagatbayev et al. (2019b). Our methodology used three key indicators: relief, vegetation, and water resources. Each of them contributed to the integral assessment of the territory’s potential.

Second, the vegetation was analyzed using the NDVI (Normalized Difference Vegetation Index) index, calculated based on Landsat satellite data. The Normalized Difference Vegetation Index (NDVI), one of the earliest remote sensing analytical products used to simplify the complexities of multi-spectral imagery, is now the most popular index used for vegetation assessment (Huang et al., 2020). This index allows one to assess the density of vegetation cover, which directly affects the ecological and aesthetic attractiveness of the territory. NDVI values were also ranked on a scale from 0 to 5 points, where high values corresponded to dense and diverse vegetation. NDVI employs the Multi-Spectral Remote Sensing data technique to find Vegetation Index, land cover classification, vegetation, water bodies, open areas, scrub areas, hilly areas, agricultural areas, thick forests, and thin forests with few band combinations of the remotely sensed data (Gandhi et al., 2015).

Thirdly, water resources were assessed based on the MNDWI (Modified Normalized Difference Water Index). This index was used to identify and evaluate water bodies such as lakes, rivers, and reservoirs. MNDWI is more suitable for enhancing and extracting water information for a water region with a background dominated by built-up land areas because of its advantage in reducing and even removing built-up land noise over the NDWI (Xu, H. 2006). The presence of water resources increases the attractiveness of the territory, as it contributes to the development of beach, water, and health tourism. MNDWI values ranged from 0 to 5 points depending on the area and quality of water bodies.

To standardize the assessment, the territory was divided into rectangular cells measuring 1 × 1 km. Each cell was analyzed separately to calculate the total score for three indicators. The final score was determined as the sum of the scores for relief, vegetation, and water resources, taking into account transport accessibility. Transport accessibility was assessed using a coefficient that reduced the total score for areas with limited access. For example, remote areas or areas without access roads could lose up to 2 points (Sagatbaev & Dunets, 2019). The final assessment of recreational potential was calculated as the sum of points for relief, vegetation, and water resources, taking into account transport accessibility.

Based on the data obtained, the entire territory was divided into three categories:

- High potential (12-15 points): unique natural areas with high aesthetic and recreational value, such as the Korgalzhyn Reserve and Lake Karasor.
- Medium potential (6-11 points): areas with moderate natural resources and limited infrastructure, such as areas around the cities of Karaganda and Temirtau.
- Low potential (0-5 points): semi-desert areas with poor vegetation, minimal water resources, and complex relief.

To check the reliability of the results, verification was carried out by comparing them with a map of tourist infrastructure. The analysis showed that key tourist sites are concentrated in areas with a high integral score, which confirms the validity of the proposed methodology. The developed methodology allows not only to assess the natural and recreational potential of the study area but also to apply it to other regions. This enables strategic tourism planning that takes into account natural features and sustainable resource management.

RESULTS

Remote sensing data were used to study the territory of the Teniz-Korgalzhyn depression. The images were stitched together by coordinates in the ENVI software package. ENVI provides a variety of software solutions for processing and analyzing geospatial imagery. As a result of stitching, a multi-sheet raster base of the relief model was obtained. ArcGIS GIS was used to visualize the model. A fragment of the digital relief model is shown in Figure 2.

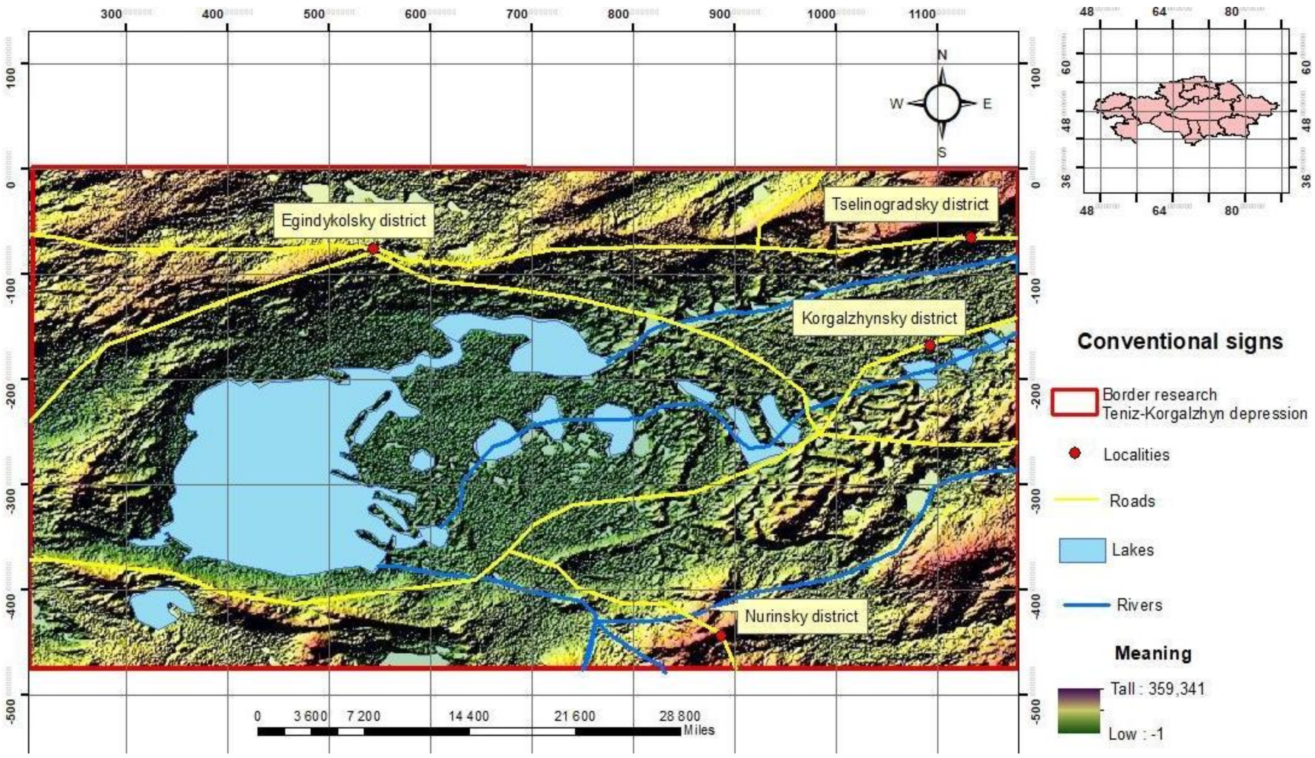

Figure 2. Visualization of the digital elevation model Shuttle Radar Topography Missionof the Teniz-Korgalzhyn Depression (Source: Authors based on the ArcGIS)

A digital elevation model (DEM) of the Teniz-Korgalzhyn Depression area, displayed in a color scale, where elevation differences are visualized through a gradient from green to red (Zengina et al., 2024). The green areas in the image indicate low-lying and flat areas, these are depressions and water bodies, in particular, Lake Tengiz, located in the center of the image. Red and orange shades indicate higher areas of the relief, which makes it easy to identify the hills and mountain ranges surrounding the depression. This method of colour coding the relief helps to highlight the main morphological structures of the region and to assess potential watercourse directions and slope processes (Figure 2). This image is useful for determining the recreational potential of the territory, thanks to which it allows you to visualize geomorphological features that affect the accessibility and attractiveness of the site for various types of tourism. Color mapping of the relief also facilitates planning for environmentally sustainable use of the territory, highlighting areas requiring additional environmental protection measures. The territory under study occupies the Teniz-Korgalzhyn depression and the plains surrounding it. The Teniz-Korgalzhyn depression is bounded by the Arganata, Shadraly, Eskenei, and other elevations. The northern sections of the depression are elevated by the Erementau Mountains and bordered by the Atbasar Plain. The boundaries of the Teniz-Korgalzhyn physical-geographical region pass through points whose absolute heights are 300 m (Figure 3).

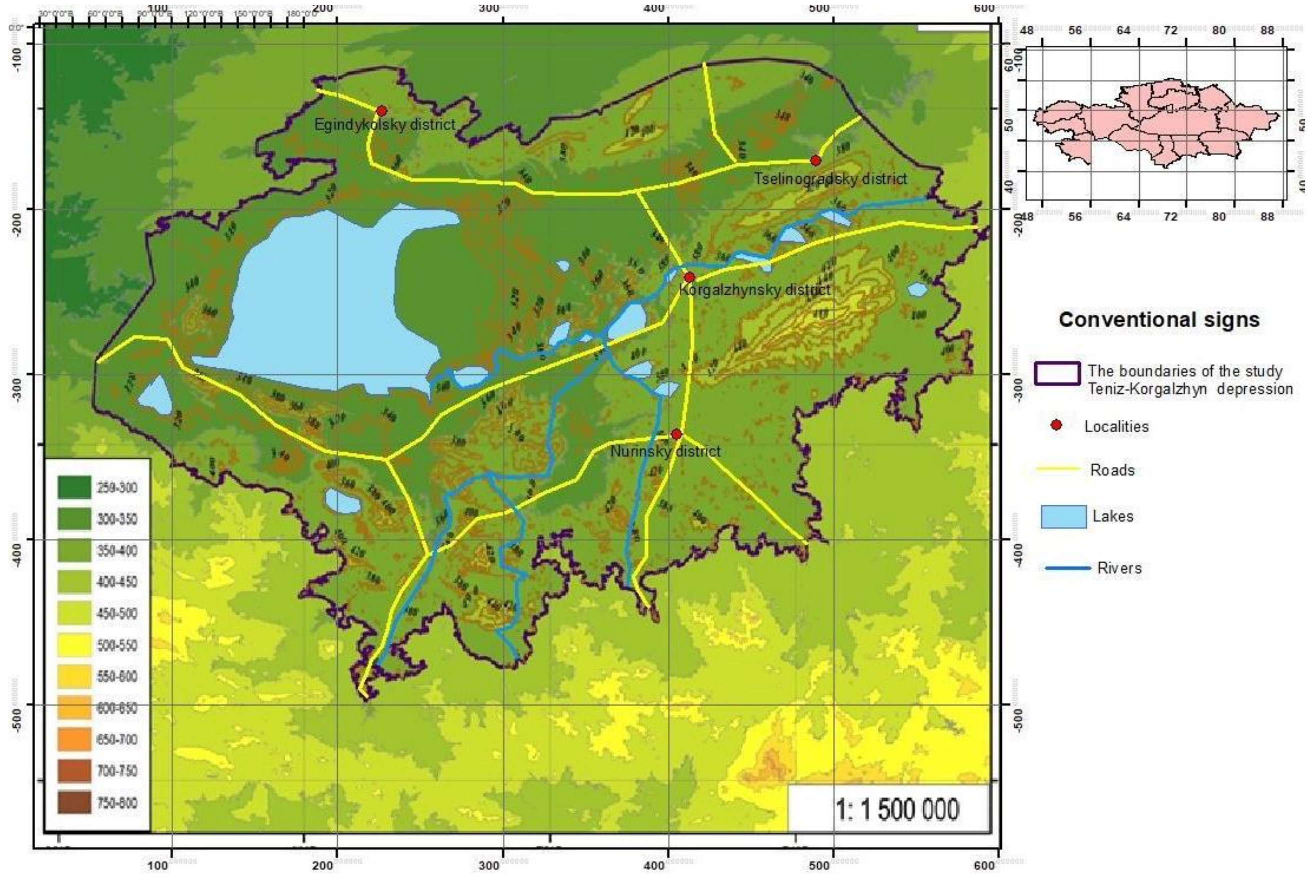

Figure 3. The elevation map of the Teniz-Korgalzhyn depression based on SRTM data (Source: Authors based on the ArcGIS)

The elevation map of the Teniz-Korgalzhyn Depression, based on SRTM (Shuttle Radar Topography Mission) data. Elevations on the map are displayed using a color scale, where different elevation ranges are indicated from light green (lowlands) to brown-red (highlands). Color gradations help to determine the territorial distribution of elevation levels: light green areas indicate low-lying areas of the depression, while yellow and red colors emphasize areas with higher elevations.The map displays the main geomorphological elements of the Teniz-Korgalzhyn Depression, including flat and hilly areas, as well as areas with elevation differences, which is important for understanding the relief structure of the region. This elevation characteristic is necessary for the analysis of natural and recreational potential and sustainable planning of the territory. The map also helps to determine which zones may be subject to erosion processes or require environmental protection measures (Karabalayeva et al., 2024). The relief of the gently rolling plain is broken by flat ravines, small hills, and knolls. The formation of the Teniz-Korgalzhyn depression dates back to the Devonian period. The sedimentary cover is represented by carbonate salt-bearing deposits. In the Neogene-Quaternary period, erosion-accumulative processes develop against the background of general neotectonic uplift in the east and relative subsidence in the west.

The vegetation map (Figure 4) of the Teniz-Korgalzhyn Depression shows various types of vegetation distributed over the area. The color gradation and legend on the map help identify different vegetation zones, distinguished according to the nature of the flora and the extent of its distribution. Water bodies (rivers and lakes) are also marked in light blue, which helps to better understand the spatial structure of the ecosystem. The map clearly demonstrates zones with different vegetation, such as steppe areas, shrub thickets, meadow areas, and marshy areas, which is important for analyzing the biological diversity of the region. The numbering and color categories on the map correspond to different types of vegetation, which are indicated in the legend, allowing you to accurately identify plant communities in each area (Tleugabulov et al., 2022). This map is necessary for assessing the natural and recreational potential of the territory because the diversity of vegetation plays a significant role in the ecological state of the region and its attractiveness for recreation.

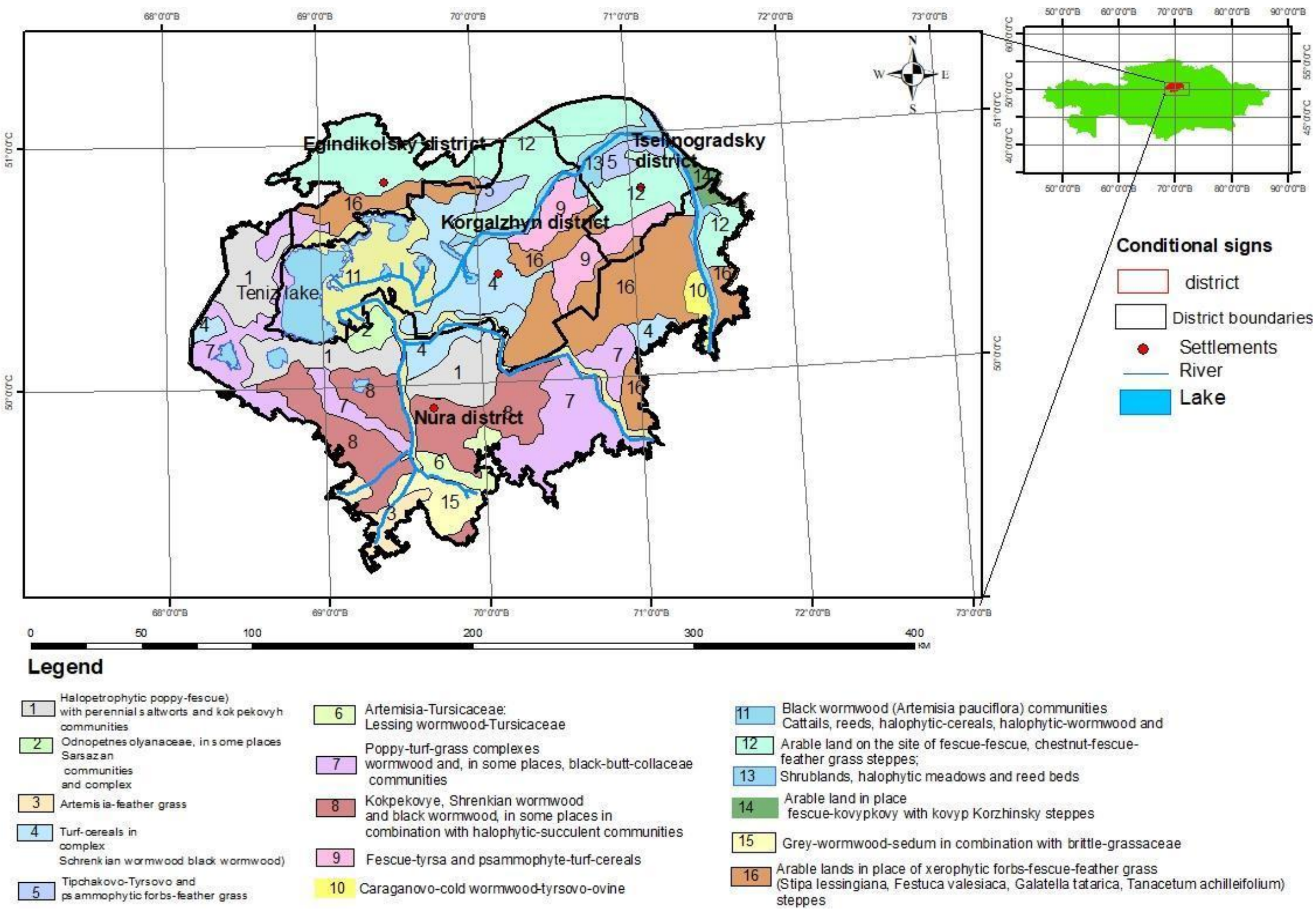

Figure 4. Vegetation map of the Teniz-Korgalzhyn depression (Source: Authors based on the ArcGIS)

Knowledge of the spatial distribution of vegetation types allows identifying areas with high conservation value and planning sustainable use of these territories. Ecological-dynamic series are adopted to reflect the vegetation cover of river floodplains and valleys. The series includes communities and soils of all ecological levels of the floodplain (reflecting the influence of alluvial) and above-floodplain (reflecting the influence of additional moistening by groundwater and the associated salinization of soils) within any section of a river valley with fairly uniform environmental conditions.

Thus, the high level of floristic diversity is facilitated by several factors:

1) the location of the territory within three subzones with different climatic features - moderately dry steppes on dark chestnut soils, dry steppes on chestnut soils, and desert steppes on light chestnut soils;

2) the diversity of plant habitats (steppe plains - clayey, gravelly, and stony; various rocks of small hills; banks of rivers, lakes, salt marshes);

3) anthropogenic activity contributing to an increase in the number of alien and weed species.

In general, 6 types of vegetation are widely represented on the territory: steppe, desert, meadow, marsh, shrub, and submerged-aquatic (Table 1).

Table 1. Characteristics of the main types of vegetation and the main formations of the Teniz-Korgalzhyn depression

Vegetation type	Vegetation subtype	Formations
1	2	3
Steppe	Bunchgrass	Feather grass, *fescue*, tyrsovaya, tyrsika, korzhinskogo stipa, eastern feather grass
Desert	Halophytic wormwood	Shrenkiano-wormwood, sintered wormwood, black wormwood
	Perennial saltwort	Kokpekovye anajuphos, *echinocaceae*
	Succulent saltwort	*Sarsazanaceae*, orach, annual saltwort
Meadow	True meadows	Wheatgrass, reed grass, field grass, foxtail, brome, bluegrass, *licorice*
	Marshy meadows	Reed, cattail, sedge
	Halophytic	*Alacritaceae*, chee, azhrekovye, barley
Marsh	Grassy	Reed, cattail
Shrub	Steppe-shrub	*Spiraeaceae*
	Floodplain-shrub	*Willow*
Submerged aquatic vegetation		Plants of the genus pondweed, floating ferns, hornwort, and duckweed.

The main types of vegetation of the Teniz-Korgalzhyn Depression are classified by dominant species and environmental conditions. The table shows the types of steppe, wormwood-feather grass, small hills, and halophytic plant communities, as well as the features of vegetation found along rivers and lakes. Each type of vegetation is described taking into account the characteristic plant species, such as fescue, feather grass, wormwood, and other species adapted to the conditions of the region, including arid and saline soils (Table 1). This cartographic material was later used to describe and geographically characterize the study area, as well as to create a landscape map of the Teniz-Korgalzhyn Depression.

Using standard tools of the ArcGis 10.2 geoinformation program, we calculated all the indicators. Previously compiled medium-scale landscape map of the Teniz-Korgalzhyn Depression (Figure 5)

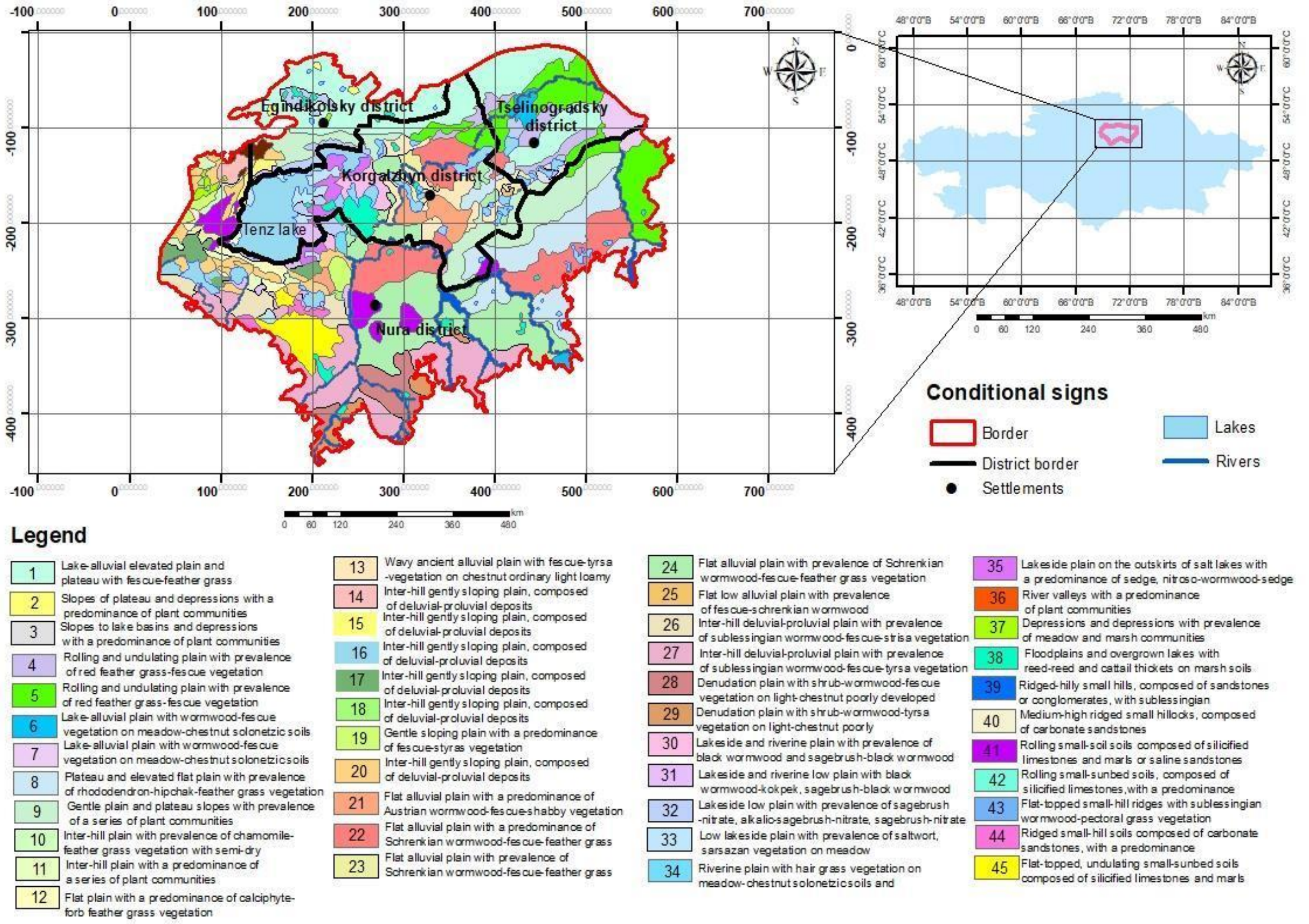

Figure 5. Landscape map of the Teniz-Korgalzhyn Depression (Source: Authors based on the ArcGIS)

The landscape map of the Teniz-Korgalzhyn Depression territory presents various landscape zones reflecting the territorial distribution of natural complexes, including steppe, forest-steppe, and lake ecosystems. By the color scale and symbols, various types of landscapes are distinguished, such as flat steppes, floodplain areas, and zones with water bodies. The boundaries of the study area are also marked. This cartographic material is important for understanding the natural diversity of the Teniz-Korgalzhyn Depression and serves as a basis for assessing the recreational potential.

The morphological structure of the landscape is a key factor in assessing the favorability of landscape components and their functional suitability for recreational purposes. Relief plays a central role in forming conditions for climatic, hydrological, and biospheric processes, which determines its high value in the framework of recreational use of the territory. The diversity of the relief creates unique conditions for recreation, including psycho physical regeneration and a favorable environment for active and passive recreation. The relief of the territory is formed under the influence of internal and external natural processes. Tectonic movements resulting from the geothermal activity of the Earth cause the formation of faults, and the uplift and subsidence of crustal blocks, affecting the formation of various geomorphological structures, which in turn affect the recreational potential of the territory.

To assess the suitability of the relief for recreational purposes, geomorphological indicators were used, where the angle of inclination and absolute height of the terrain were determined using the SRTM digital elevation model. These indicators were ranked on a scale, where the maximum values correspond to the greatest recreational suitability for active types of recreation, and the minimum values are suitable for passive and health tourism. There is a clear relationship between geomorphological indicators and recreational opportunities.

For example, areas with pronounced differences in altitude are preferable for laying tourist routes, while flatter areas are suitable for organizing health tourism (Table 2). Thus, the relief assessment scale is developed taking into account the specifics of recreational activities, allowing for a differentiated approach to the use of the landscape depending on its functional characteristics and the requirements of various types of tourism.

Table 2. Favorability assessment scale based on geomorphological indicators

	Indicators	Scale of points					
		1 p.	2 p.	3 p.	4 p.	5 p.	6p.
	Absolute height, m	<170	180	200	250	270>	310>
	Surface slope angle, degrees	1	3	5	7	9	11

Dwal (hydrological) resource by one of the factors of regional development, which has a significant impact both on tourist-recreational activities and on the development of tourism as a whole, is. The concept of “water recreational resources” can be defined as the presence (or set) of water bodies with favorable conditions for various types of recreational activity. Their recreational value is determined by a whole group of heterogeneous factors: the coastal landscape, depth, temperature of water, shape, remoteness from large cities, the bias of the coast, and the provision of access roads. Water bodies are an important recreational resource. Favorable hydrological conditions for recreation are expressed, first of all, in the existence of water flows or water surfaces of environmentally friendly, with the corresponding temperature and flow rate that make it possible to create natural beaches, swimming pools, artificial reservoirs suitable for cultivating different types of water sports. In addition, most recreational objects are located along open reservoirs, and beach-coal rest is one of the most popular among vacationers. Water can be a strong healing and healing factor.

The convenient location of reservoirs and the presence of medicinal mud and mineral springs make the territory promising for water tourism. The value of vegetation for recreation and tourism, since the vegetation cover performs many important functions, making a person’s stay in nature comfortable and useful for his body, whether it is a journey or just a rest in the fresh air. Currently, the purpose of tourist trips is increasingly becoming the knowledge of the vegetation cover of our planet, as well as the use of its useful properties in the healing of the body. If we consider the vegetation cover from the point of view of recreation, you can see that it performs a variety of functions: 1) environmental, 2) aesthetic-cognitive, 3) recreational, 4) food, and 5) therapeutic. Thus, the plant world performs very important functions, having a therapeutic effect on both the physical and mental health of a person and is a kind of shield for his body from adverse factors.

For green vegetation, reflection in the red region is always less than in the near-infrared, so NDVI values for vegetation cannot be less than 0. The larger the green phytomass, the higher the index. The value of the index is also affected by the species composition of vegetation, its closing, condition, exposure, angle of the surface, and soil color under the sparse vegetation. The index is moderately sensitive to changes in the soil background, except when the density of the vegetation cover is below 30%. The index can take values from -1 to 1. For green vegetation, the index usually takes values from 0.2 to 0.8. The assessment was carried out using NDVI and MNDWI indices, which determined the density of vegetation and the presence of water bodies. The ranking method was based on a point scale, where climatic indicators (temperature, precipitation), relief, vegetation, and accessibility of objects were taken into account.

When processing space shots in the ENVI software complex, a special calculator of vegetation indices was used.

As a result of the calculation of NDVI according to the space pictures of 1975 and 2024. Index images of the territory of the Teniz-Corgalzhinsky hollow were obtained, the fragment of which is presented in Figure 6.

Figure 6 presents the result of the NDVI index calculation (Normalized Difference Vegetation Index) according to the Landsat satellite system, received on June 5, 2024. NDVI is an important indicator for assessing the state of vegetation in the test territory since it allows you to distinguish areas with active and weak vegetation.

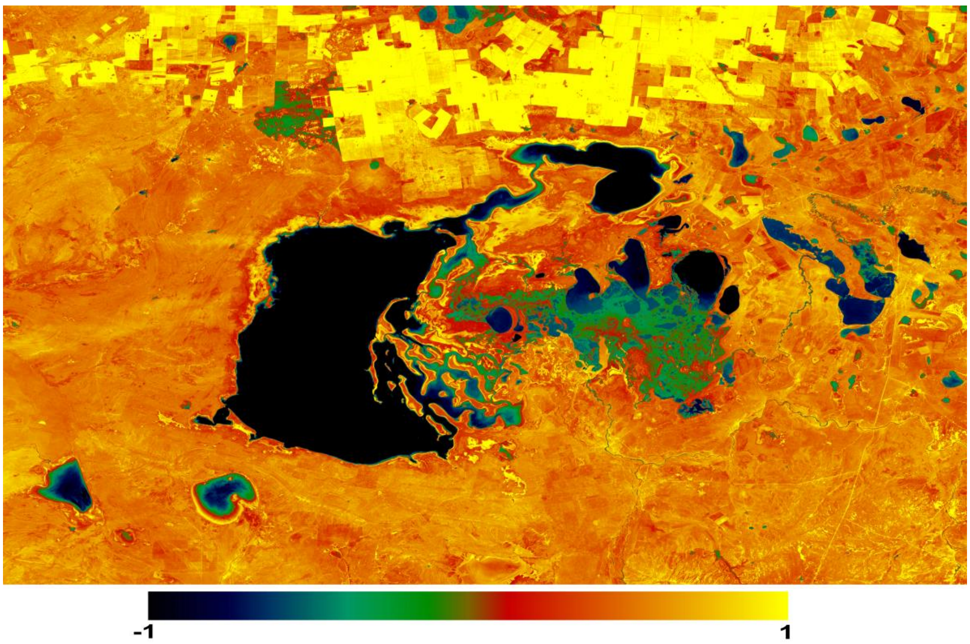

Figure 6. A fragment of the result of the NDVI index calculation by image
of the Landsat system dated 05/06/2024 (Source: Authors based on the ArcGIS)

The image shows the Teniz-Corgalzhyn cavity, where the level of growing season and vegetation varies depending on the NDVI indicator. The color scale at the bottom of the drawing varies from -1 to 1, where the values close to -1 (blue and purple shades) indicate the absence of vegetation or the presence of water bodies, while values close to 1 (green shades) indicate areas with a high activity of vegetation.

The zones with minimal NDVI values are distinguishable, representing water bodies, such as Lake Teniz, marked with black colors. The areas with moderate and high vegetation located along the periphery of the lakes are shown by green shades, this indicates the presence of thick vegetation. The lightest yellow-orange areas are indicated for weak or absent vegetation, which testifies to arid or cultivated territories. This analysis of the NDVI index is an important tool for monitoring the state of the ecosystem of the shadow-correlates cavity, allowing you to evaluate the distribution and density of the vegetation cover, as well as identify zones that require additional environmental measures or monitoring.

Table 3 presents the values of the NDVI index of the main types of objects in the image.

Table 3. NDVI index values of the main types of objects

Type of object	NDVI value
Very powerful thick vegetation	0.8-1
Powerful, thick vegetation	0.67-0.8
Scarried and discharged wood and shrub vegetation	0.4-0.5
Shrubs and pastures	0.2-0.4
Open soil	0.09-0.2
Rocks, sand, snow	-0.1-0.1
Water object	-0.42 – -0.33
Artificial materials (concrete, asphalt)	-0.55 – -0.5

NDVI has a good correlation with the biomass of vegetation. The dependence between these parameters, as a rule, is not direct and is associated with the characteristics of the studied territory, its climatic and environmental characteristics. So, for example, in this work, NDVI maps will be used to create masks of arable land in the classification of ground cover.

When processing space shots in the ENVI software complex, a special calculator of spectral channel mathematics was used. As a result of the calculation of MNDWI according to the space pictures of 1975 and 2018. Index images of the Teniz-Corgalzhyn cavity were obtained, a fragment of which is presented in Figure 7.

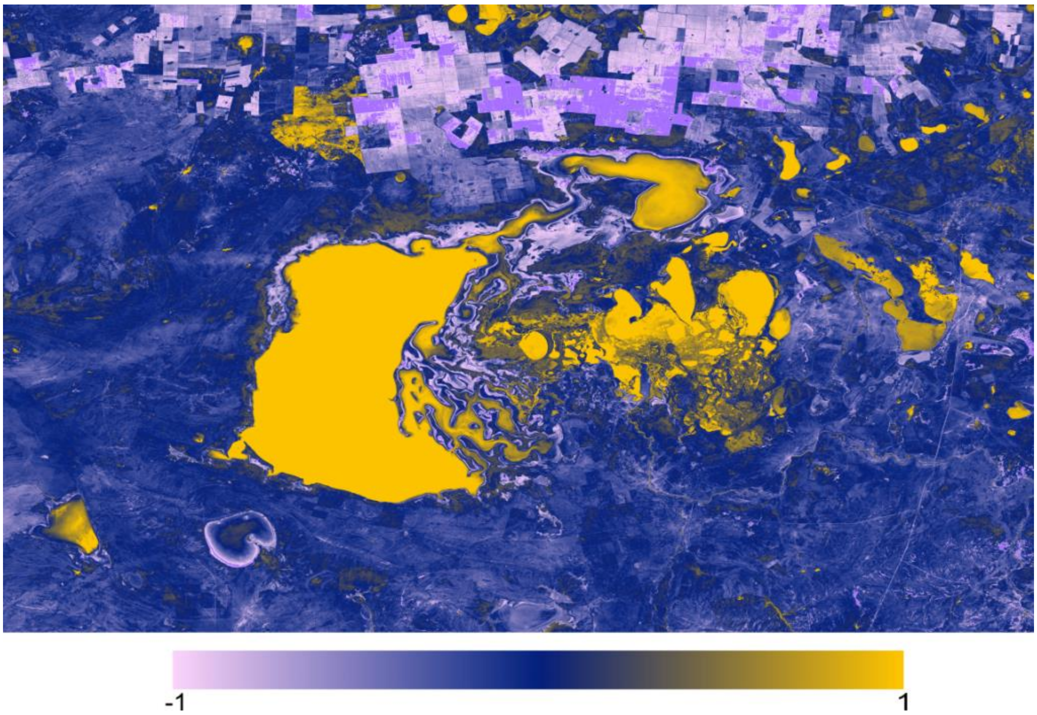

Figure 7. A fragment of the result of the MNDWI index calculation by image of the Landsat system dated 05/06/2024 (Source: Authors based on the ArcGIS)

This figure shows a fragment of the calculated MNDWI (Modified Normalized Difference Water Index) based on Landsat data from June 5, 2018. The MNDWI index is used to highlight water bodies on the surface, as it improves the distinction between water and other objects, such as vegetation or built-up areas. The color scale in the image varies from -1 to 1. Areas with high index values (shown in yellow) indicate the presence of water, which is especially noticeable in large water bodies such as Lake Teniz and other nearby water systems. Low index values, shown in dark blue and purple, correspond to dry areas not covered by water, including areas with vegetation and urban buildings.

This analysis is an important tool for monitoring the state of water resources in the Teniz-Korgalzhyn Depression, as it allows one to estimate the area and distribution of water bodies, as well as to identify changes in them that may be caused by seasonal or anthropogenic factors. Taking into account the landscape structure, as well as the presence of lands of various categories, it is possible to calculate the level of anthropogenic transformation of the territory. According to the proposed methodology, in the case of extensive development of the territory, the analysis of the land use structure is carried out within administrative boundaries. To determine the degree of anthropogenic load on lands, expert point assessments are introduced. Each type of land receives a corresponding point.

The territory under study can be most successfully used for the development of ecotourism. Of interest is the diversity of vegetation and landscapes combined with the opportunity to observe animals and birds. The highest ratings of recreational components are characteristic of hilly landscapes, as well as near water bodies on the Nura River, lakes Sholak, Zharsuat and Shubasor. Eco-routes for tourists can operate from May and end in October.

DISCUSSION

Based on the collected data, we developed a map of the landscape's natural and recreational potential of the Nura River, which reflects the distribution of different levels of recreational suitability of the territory.

Areas with low natural and recreational potential are mainly represented by hilly-dome-shaped landscapes composed of granite, dolomites, sandstones, and siltstones. These landscapes are characterized by steppe plant communities, where feather grass, wormwood, and fescue prevail, as well as shrub species growing on light chestnut, poorly developed, and saline soils. Semi-desert landscapes of the Nura River have limited recreational opportunities due to the lack of natural resources that can significantly increase their attractiveness, such as therapeutic mud or mineral springs. This reduces interest in these areas for recreational and tourist use.

Landscapes with an average degree of natural and recreational potential include the area around the city of Karaganda. The average annual precipitation here is 220 mm, the duration of sunshine reaches 2100 hours per year, and the average annual wind speed is 3 m / sec. This territory is part of the desert region of Betpak-Dala. Natural conditions turned out to be favorable for moderate recreational loads, and this allowed for the development of tourism and health activities within these territories. The highest natural and recreational potential is possessed by landscapes, the following areas with unique natural objects: Korgalzhyn State Nature Reserve and the therapeutic mud of Lake Karasor, located 45 km north of Karkaralinsk. These territories are characterized by high levels of precipitation (average annual amount is 320 mm) and a significant height of snow cover (25-27 cm), which helps maintain unique ecosystems and their biodiversity.

The Korgalzhyn State Nature Reserve "Pearl of the Region" is included in the UNESCO World Heritage List and performs an important function in preserving and developing the natural habitat, as well as maintaining biological diversity. The reserve is home to 123 large and small lakes, including Tengiz and Korgalzhyn, and has 347 bird species, 41 of which are listed in the Red Book of Kazakhstan, and 26 species are in the International Red Book. The reserve also has 443 species of flowering plants, in connection with which its significance as a natural site of global significance is noted. The Karkaraly State National Nature Park also belongs to the territory with high natural and recreational potential. This park contains important historical and cultural sites: the Kyzyl-Kensh Palace, an archaeological site of the Kent forestry, and the Forester's House in the Komissarovka tract, built in 1914. The list of specially protected areas of national significance includes the following objects: Mount Zhirensakal, the Three Caves Grotto, Kalmyk Val, the Bolshaya Palata Stone Grotto, the Bassein and Shaitankol Lakes, and the Sphagnum Bog. These objects have not only aesthetic, but also scientific, cultural, and ecological value, contributing to an increase in the tourist attractiveness of the region.

Thus, the research revealed a significant contrast in the natural and recreational potential of various landscape zones of the region. Landscapes with low potential require significant efforts to improve their recreational attractiveness, while areas with medium and high potential can already be used to develop tourism, health, and cultural events.

Analysis of landscape data obtained using NDVI and MNDWI revealed differences in the natural and recreational potential of the Teniz-Korgalzhyn Depression areas. Areas with a high NDVI value are characterized by an abundance of vegetation, which indicates their potential suitability for recreational use. On the contrary, areas with low NDVI and high MNDWI indicate insufficient vegetation, but the possible presence of water bodies, which is also important for recreational planning. These differences demonstrate a clear comparative analysis of data on the two indices and allow for reasonable distribution of recreational resources, assessment of ecosystem degradation, and identification of priority areas for restoration and protection. The recreational potential of the region was ranked. Areas with high potential are presented in unique zones (Korgalzhyn Reserve). Areas with low potential are concentrated in semi-desert areas.

The high potential of the Korgalzhyn Reserve is explained by its unique natural resources and inclusion in the UNESCO list. The low potential of desert zones is due to the lack of infrastructure and climatic limitations.

CONCLUSION

The study of the Teniz-Korgalzhyn Depression area allowed us to identify the key characteristics of its natural and recreational potential, as well as to determine the main advantages and disadvantages in terms of recreation and ecotourism development. The data obtained demonstrate the importance of this region for the sustainable use of natural resources.The Teniz Depression is located in the west of the Kazakh Uplands. Soils vary from dark to light chestnut.

This is due to climate change from moderately dry in the north to desert in the south. The vegetation cover is diverse due to the climate, anthropogenic impact, and habitat. The most valuable natural heritage site is the Korgalzhyn Nature

Reserve, included in the UNESCO list. However, a significant part of the steppe ecosystems remains unprotected, which requires increased monitoring of their condition to maintain the ecological balance.

The assessment of the main components that make up the natural and recreational potential allowed us to divide the territory into zones with high, medium, and low attractiveness for recreation. Low-potential landscapes located in semi-desert areas are characterized by a limited amount of natural resources and low attractiveness for tourism.

The average potential is found in areas with more favorable climatic conditions, especially around large settlements such as Karaganda and Temirtau. High potential is recorded in unique natural areas, including the Korgalzhyn Nature Reserve and Lake Karasor, which makes them promising for the development of ecological and health tourism.

Water resources. Particular attention is paid to the region's water bodies, which play an important role in the conditions of a sharply continental climate. Small lakes and reservoirs are key elements of recreation but require careful use to prevent pollution and degradation of ecosystems.

Recommendations

The following measures are proposed for the effective management of natural resources of the Teniz-Korgalzhyn Depression:

− Identification of priority areas for ecotourism with minimization of anthropogenic impact.
− Regular monitoring of the state of water bodies and vegetation using satellite data.
− Introduction of environmentally sustainable practices in tourism activities, which will preserve unique natural resources and increase the environmental awareness of the population.
− Development of programs for the restoration of degraded lands and reduction of anthropogenic load, especially in agricultural areas.

Scientific results

The spatial and temporal dynamics of land covers were assessed using multi-spectral remote sensing data (NDVI and MNDWI). It was found that in most areas the changes are stable, but in some natural zones, the amplitude of changes reaches 40%. The landscape map constructed based on these data allowed us to assess in detail the dynamics of ecosystems for the period from 1975 to 2024. These results provide valuable information for natural resource management and environmental planning. Ecological and economic status. The analysis showed that extensive farming has led to environmental problems, including soil erosion, pasture degradation, and decreased fertility.

Against the background of these processes, a decrease in the area of arable land is observed. It is necessary to switch to intensive land use with the introduction of innovative technologies to eliminate the negative consequences.

Thus, the results of the study are of practical importance for strategic planning and sustainable development of the region. They will not only help preserve the natural resources of the Teniz-Korgalzhyn Depression, but also increase its tourist attractiveness, promoting the harmonization of the interests of society, the economy, and the environment.

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