

GEOGRAPHICAL BASES OF REMOTE SENSING METHODS OF RESEARCH OF THE ACCURACY OF LAKES MEASUREMENT FOR THE DEVELOPMENT OF TOURISM IN NORTHERN AND CENTRAL KAZAKHSTAN

Yerzhan SAGATBAYEV ¹, Sherim TULEGENOV ², Zhanna ADAMZHANOVA ³,
Nurkuigan AUEZOVA ⁴, Aiman KARABALAYEVA ³, Moldir AZBANTAYEVA ²,
Aigerim AMANGELDI ⁵, Aizhan ZHAMANGARA ⁴, Sergey PASHKOV ⁶

¹ L.N. Gumilyov Eurasian National University, Faculty of Architecture and Civil Engineering, Department of Geodesy and Cartography, Astana, Kazakhstan; sagatbaeve@mail.ru (Y.S.)

² L.N. Gumilyov Eurasian National University, Department of Physical and Economical Geography, Astana, Kazakhstan; sh_tulegen@mail.ru (S.T.); moldir.azbantaeva.90@mail.ru (M.A.)

³ Astana International University, Higher School of Natural Sciences, Astana, Kazakhstan, e-mail: adamzhanovazanna@gmail.com (Z.A.); karabalayeva@gmail.com (A.K.)

⁴ Astana International University, Higher School of Natural Sciences, L.N. Gumilyov Eurasian National University, Faculty of Natural Sciences, Astana, Kazakhstan; nurkuigan1971@mail.ru (N.A.); kashagankizi@mail.ru (A.Z.)

⁵ L.N. Gumilyov Eurasian National University, Tourism Department, Astana, Kazakhstan; aig.amangeldi@gmail.com (A.A.)

⁶ M. Kozybayev North Kazakhstan University, Department of Geography and Ecology, Petropavlovsk, Kazakhstan; sergp2001@mail.ru (S.P.)

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Abstract: In the context of increased interest in domestic tourism in Kazakhstan, there is a growing need for accurate and up-to-date information about natural sites, including lakes, which play an important role in developing ecotourism and recreation. This study uses remote sensing methods to analyze the morphometric characteristics of lakes in Northern and Central Kazakhstan. Sentinel-2 and Landsat satellite data, as well as geographic information systems, are used to assess the accuracy of measurements, compare them with ground data, and form recommendations for the development of tourism areas. The results obtained contribute to the scientific substantiation of spatial planning and sustainable tourism development in the region. Despite the high relevance of the problem of water resource shortage in the steppe zone, the lakes of this natural territory are currently given insufficient attention in scientific research. In the period from 2018 to 2024, studies of lakes in Northern and Central Kazakhstan were carried out thanks to the automated interpretation of space images from Landsat satellites through classification with training in the GIS geographic information system. The number of lakes and the area of their water surface were estimated using several time sections of the lake grouped by size. The analysis of the dynamics of the obtained values and data on the amount of precipitation showed that the nature of the change in the number of lakes and their area coincides with the change in the phases of water content of this territory. The variability of planned outlines of water bodies is related to seasonal fluctuations in water level. Therefore, when choosing the timing of a topographic survey, it is necessary to consider the correspondence of the phase of the water regime to the current state of water bodies. Area hydrological characteristics are one of the most important factors in terms of parameters that determine the area of river flooding and the boundary of snow cover distribution. They are extremely dynamic, so their study requires time-based aerospace photography with an accuracy of up to a day. A time series of space images covering the period from 2018 to 2024 allows monitoring the parameters of water bodies over time, as well as monitoring the emergence of new ones and assessing the condition of existing ones.

Keywords: remote sensing of the Earth, methods of filtering radar image data, accuracy of measurements from space images, change in lake areas

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INTRODUCTION

Northern and Central Kazakhstan have significant tourism potential due to the presence of numerous lakes that are of interest for recreation, water tourism, and ecosystem research, and are of significant value for the development of recreational potential, water tourism, and ecosystem research. Lakes, ponds, and wetlands are fundamental components of the terrestrial hydrological cycle in high-latitude regions (Smith et al., 2007).

However, the lack of regular monitoring of the state of these water bodies limits the possibilities for effective planning of tourist routes and infrastructure. Remote Sensing of the Earth (RS) opens up great opportunities for collecting spatial

* Corresponding author

information, revealing accurate and timely data on the size, shape, water level, and seasonal dynamics of lakes. Remote Sensing of the Earth (RS) opens up great opportunities for collecting spatial information, revealing accurate and timely data on the size, shape, water level, and seasonal dynamics of lakes (Azbantayeva et al., 2022; Kulebayev et al., 2024).

Recent research has demonstrated the effectiveness of GIS and remote sensing for assessing the natural and recreational potential of the Teniz-Korgalzhyn depression, confirming the importance of such methods for sustainable ecotourism planning in Northern and Central Kazakhstan (Sagatbayev et al., 2025). Globally, combining RS with machine learning improves lake water quality monitoring and prediction, offering insights into seasonal and long-term ecosystem dynamics (Deng et al., 2024; Wu, 2025). These approaches highlight the importance of advanced technologies for supporting sustainable tourism planning in aquatic environments. Tourist attractions play a key role in shaping the image of a destination, although they function alongside other contributing factors such as accommodation and hospitality services, entertainment, economic conditions, and socio-cultural context (Herman et al., 2019; Nigmatova et al., 2021; Wendt, 2020).

Remote methods of studying natural objects provide greater visibility, the ability to re-acquire data at certain intervals, high speed in obtaining and transmitting images, as well as the ability to apply complex analysis and assessment of the dynamics of the development of a phenomenon based on operational mapping (Sutyryna, 2013; Koshim et al., 2023; Chen, 2023; Guerrero et al., 2020). The lakes of Northern and Central Kazakhstan belong to the Irtysh natural-limnological region, and the lakes of Northern and Central Kazakhstan belong to the Central Kazakhstan region (Figure 1).

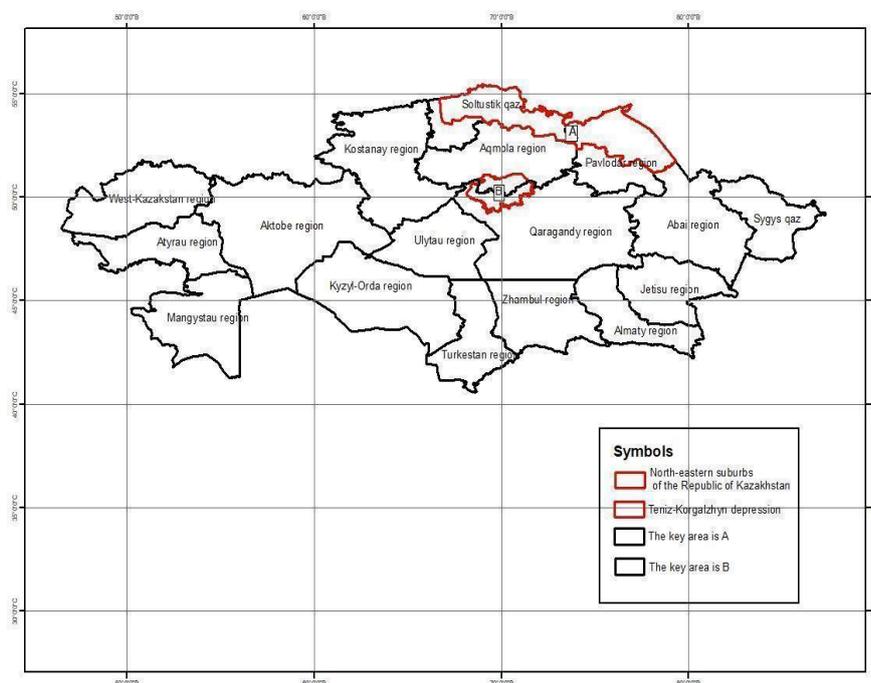


Figure 1. Geographical location of the territories of Northern and Central Kazakhstan (Source: Authors based on the ArcGIS)

In the North of Kazakhstan, there is a vast North Kazakh Plain. From the south and southeast, it borders on the Kazakh Uplands, with elevated and dissected terrain. In the west, the plain gradually turns into the Torgai tableland, giving a smooth transition from flat to more divided relief forms.

Structurally, the North Kazakh Plain belongs to the West Siberian Plate, the basement of which is composed of intrusive and metamorphic rocks of the pre-Paleozoic and Paleozoic eras, complicated by faults and characterized by a stepped structure (Beletskaya et al., 2019). Towards Western Siberia, the thickness of the Meso-Cenozoic deposits does not exceed 300 m, and in the direction of the Irtysh synecleisis, the basement is submerged to a depth of more than 2 km. According to morphological features, the plain is subdivided into the accumulative plains of the Tobol, Ishim, and Irtysh regions. The Tobol and Ishim plains are dissected by the Torgai trough and form the North Torgai or Kostanai plain. The history of their development and morphological features has only minor differences.

The Irtysh accumulative plain occupies the northeastern part of the North Kazakh Plain. The surface here is slightly inclined to the north and east, with absolute heights decreasing from 120 to 110 meters. In structural terms, the plain was formed within the Irtysh depression, the base of which gradually descended towards the West Siberian immutability. The thickness of the Mesozoic-Cenozoic deposits reaches 2000 m. The left-bank marginal parts of the plain at the junction with the Kokshetau Upland are complicated by flat-topped remnants. The object of the study is the territory of Lake Teniz, located in geographic coordinates between 68°00' to 71°41' east longitude and 48°10' to 51°43' north latitude, and founded in 1968 (Figure 2). This causes differences in the factors that form their hydrological regime. The altitude of the lakes under study also manifests itself in the uniqueness of the course of long-term changes in their characteristics. At elevations of 300-500 m above sea level the lakes of the Nura River valley (Lake Teniz) are located. On the lake-alluvial plains at an altitude of 100 to 300 m are located the largest reservoirs, surrounded by lake terraces (Bolshoi and Maly Teniz).

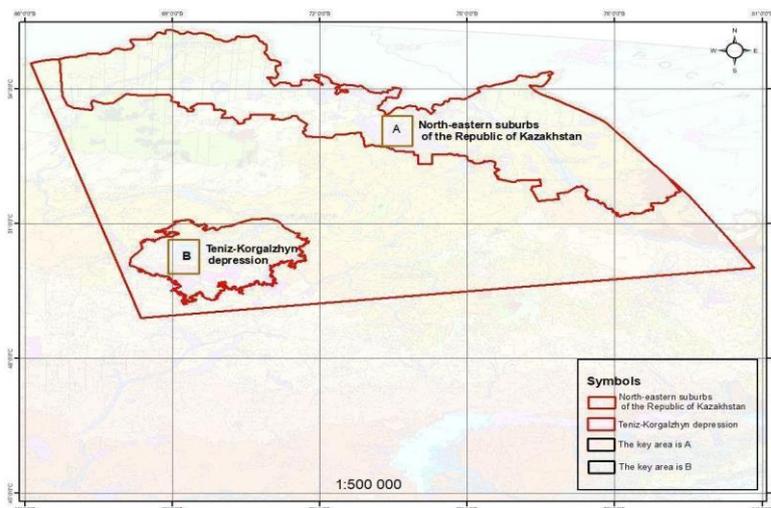


Figure 2. The border of the studied territory of Northern and Central Kazakhstan (Source: Authors based on the ArcGIS)

RECREATIONAL POTENTIAL OF LAKES

As a result of our cartometric measurements, we obtained quantitative data characterizing the sizes of the largest lakes in Northern and Central Kazakhstan. There is also other information about the sizes of individual lakes in Northern and Central Kazakhstan. As a result of the topographic and bathymetric surveys, the most reliable morphometric data were obtained, published in the relevant article by G. Muravlev (Muravlev, 1973; Muravlev, 1993) (Table 1).

Table 1. Morphometric characteristics of the study area (Source: author: Sagatbayev based on ArcGIS)

Lake	Catchment area, thousand km ²	Absolute height, m	Lake area, km ²	Length, km	Width, km	Maximum depth, m	Volume of water, km ³
Seletyteniz	23.4	64.7	777	42	21	3.2	1.5
Teniz	94.9	304	1162	74	40	8	0.6

Lake basins belong to different genetic groups, which determines the great diversity of lakes in size, shape, depth, regime, and hydrochemical features. Differences in the genesis of basins depend on both endogenous factors - the latest tectonic movements, seismicity, rock lithology, and exogenous factors - the effects of river erosion, wind, ice, karst, suffusion, and gravitational processes. Additionally, anthropogenic impact and climatic fluctuations should be considered, which also make a significant contribution to the formation and transformation of basins. The presence of terraces indicates changes in the levels and areas of lakes, which A. Shnitnikov explained within the framework of his theory of intra-century and multi-century rhythms of moisture content of the continents of the Northern Hemisphere (Shnitnikov, 1969).

According to A. Shnitnikov, the duration of individual intra-century climatic cycles ranges from 20-30 to 45-47 years. Within these intervals, periods of changes in lake levels lasting 7-11 years are distinguished. Remote sensing methods make it possible to track not only the long-term but also the seasonal dynamics of lake parameters, which makes it possible to identify patterns in the rhythm of their hydrological regime within the study area (Figure 3).

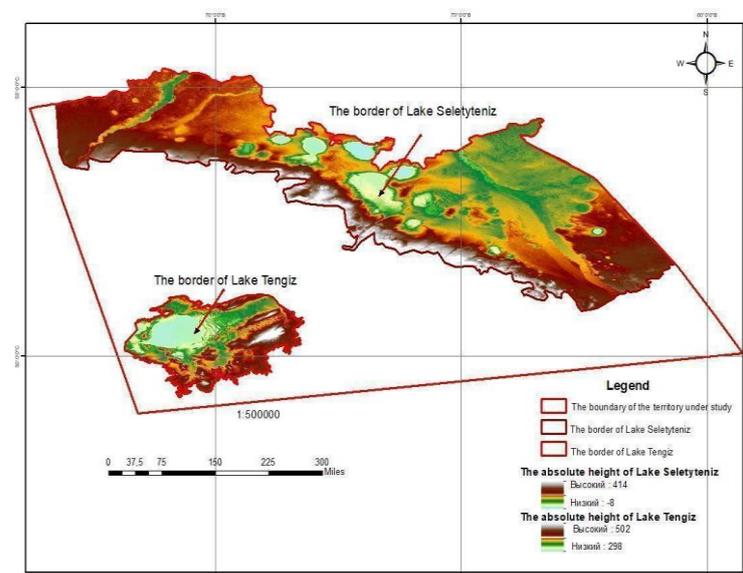


Figure 3. Digital model of the terrain of the studied area (Source: Sagatbayev based on ArcGIS)

The Irtysh natural-limnological region is characterized by a high lake content (Table 2). The largest lake is Lake Seletyteniz, located between the rivers Yessil and Ertis. Its area is 3.104 km². The Central Kazakhstan natural-limnological region is distinguished by a large number of lakes, but a smaller lake content (Table 1). The largest lake is Teniz with an area of 3.104 km², into which the Nura River flows.

Table 2. Irtysh natural-limnological zone (Source: Sagatbayev based on ArcGIS)

Natural limnological zones	Number of lakes			Total area lakes, km ²	Area of regions km ² as of 01.02.1967	Lakeness territories, %
	Less than 1 km ²	More than 1 km ²	Total			
Northern Kazakhstan	2 252	238	2 490	1 458	44 948	3.24
Central Kazakhstan	4 879	327	5 206	3 104	155 001	2.0
Total:	7 131	565	7 696	4 562	199 949	5.24

The number and area of lakes are given, excluding ponds, reservoirs, and pool lakes. There are 2 491 loess lakes with a total area of 49.79 km. All lakes in the study area were combined into 4 groups: very large ($A > 1000 \text{ km}^2$); large ($101 < A < 1000 \text{ km}^2$); medium ($10 < A < 100 \text{ km}^2$); small ($A < 10 \text{ km}^2$) (Filonets, & Omarov, 1974).

To study the dynamics of lakes, Earth remote sensing (ERS) methods were used. In this study, the area of lakes is understood as their size recorded at a specific point in time (at the time of space photography). Square kilometers are used as a unit of area measurement, since this unit of measurement is most often used for working with areal objects in various geographic information systems (GIS) (Figure 4). During the study, one of the assessed indicators of the state of the lakes was the area of the water surface, a spatial characteristic subject to constant changes over time. The area of the water surface is the surface area of the lake, denoted as F (in km²), excluding the area of all islands located in it.



Figure 4. Landsat-8 space image with boundaries of the study areas (Source: Sagatbayev based on ArcGIS)

The most important morphometric indicators also include the length and width of lakes, as they allow us to determine the area of the water surface, the length of the coastline, the volume of water in the reservoir, and other indicators. The length of a lake L (km) is the shortest distance between the two most distant points on the shoreline of the reservoir, measured along its surface. The average width B_{avg} (km) is the quotient of dividing the area of the reservoir surface F by its length; the maximum width B_{max} (km) is the greatest distance between the banks perpendicular to the length of the reservoir. The metric characteristics of the lakes were determined based on space images from Landsat-7, Landsat-8, ERS-2, and QuickBird, which made it possible to track both seasonal and long-term dynamics of their areas (Figure 2).

When selecting the images, the availability of a data archive for more than 30 years was considered, which made it possible to analyze the intra-century fluctuations in lake levels. An important task was to identify seasonal fluctuations in lakes (Erokhin & Kopylov, 2002). To solve this task, a series of images taken in a specific year were analyzed. To observe the rhythm of lakes in the Irtysh natural-limnological region, radar images were used (Garbuk & Gershenson, 1997), which are not affected by the cloudiness typical for the region, especially during the warm period of the year. Despite the widespread use of remote sensing, special attention was paid to the issues of assessing the accuracy of measuring the areas of lakes using optical and radar images. This is since quantitative analysis of the dynamics of the areas of salt and flowing lakes in the context of global climate change is a complex task (Kashkin & Sukhinin, 2001).

METHODOLOGY

Remote sensing (RS) and geoinformation modeling methods are used to study the dynamics of the reservoir. Comparison of multi-temporal space images Landsat-7-8 allows us to determine the boundaries of the water surface in

different seasons and years, analyze trends in altitude changes in the bottom and coastal relief based on digital elevation models (DEM), identify zones of seasonal flooding and shallowing, which is important for substantiating tourist routes.

The accuracy of remote sensing of lake areas using Landsat-7, Landsat-8, and ERS-2 images was analyzed by comparing the results of lake area measurements taken from the specified images with the area measurement data from Quick Bird images, which were considered as a standard due to their high resolution (Moiseenko, 1994). Table 3 lists the space images used in the studies of lake area measurement error. As can be seen from Table 2, images of the same year were selected for each polygon. Thus, the geosystem polygon A) Lake Seletyteniz. B) Lake Teniz, are presented in Landsat-7-8, ERS-2 and Quick Bird images of 2018-2024. Lake area measurements in space images were carried out using ENVI 4.5, ArcGIS 10.1.

Table 3. Space images selected for the study of lakes of polygons A and B (Source: Sagatbayev based on ArcGIS)

Natural limnological areas	Landfill areas	Space photos
Northern Kazakhstan	A (flat territories of the Northern outskirts of the Republic of Kazakhstan)	Quick Bird
		Landsat-7-8
Central Kazakhstan	In (suburban area of Astana)	Quick Bird
		Landsat-7-8

The study addressed the problem of filtering ERS-2 satellite radar images to reduce the impact of speckle noise, which has a significant impact on the accuracy of measuring lake areas. Speckle is high-frequency noise that occurs in radar images as a result of interference of reflected signals from many small objects within a single pixel. It appears as a grainy texture and complicates the accurate interpretation of images. To improve the accuracy of measurements, filtering methods were used to suppress speckle noise while preserving the spatial and spectral characteristics of the images.

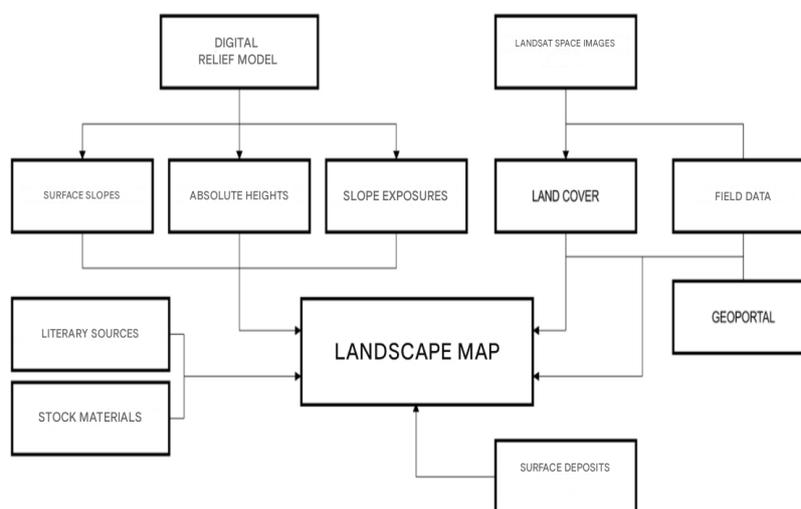


Figure 5. Generalized diagram of the landscape structure of the analysis of the accuracy of measurements of lake areas using ERS-2 radar images (Source: Sagatbayev based on the LibreOffice Draw, 2025)

Figure 5 shows a generalized diagram of the landscape structure of the analysis of the accuracy of lake area measurements, performed using ERS-2 radar images. Various filtering methods implemented in ENVI 4.5 and ArcGIS 10.1 software products were used. The accuracy of vegetation indices (NDWI, MNDWI, NDVI) in remote sensing of lake areas was assessed by comparing the results obtained from filtered radar images with measurements of the areas of the same lakes using optical images from the QuickBird satellite. Image filtering was performed using the Lee, Frost, Local Sigma and Median methods implemented in EVNI 4.5, ArcGIS 10.1 software. To identify the boundaries and classify the components of geosystems, all the original remote sensing data were transformed into mosaic coverages developed in the ENVI 4.5, ArcGIS 10.1 program. with a spatial resolution of 30 m. To collect and process the current data slice (2018-2024), remote sensing data from Sentinel series 1,2 satellites were used in the studies. In terms of their class, their capabilities correspond to Landsat-7 and 8 images. During the thematic processing of satellite images, the MNDWI and NDVI indices were calculated, and corresponding index maps were constructed covering the entire research area (Figure 6).

NDWI is an index of water content in soil and plant leaves (Xu, 2006).

To calculate the index, the spectral brightness values in the green and near infrared (NIR) ranges of the spectrum are used:

$$NDWI = (Green - NIR) / (Green + NIR), (1)$$

NDVI (Normalized Difference Vegetation Index) is an indicator of photosynthetic active biomass on the earth's surface.

$$NDVI = (NIR - Red) / (NIR + Red), (2)$$

This index is more effective than the NDWI index because it reduces the contribution of built-up areas, which are often mistakenly interpreted as water bodies in other indices. It is calculated using the green and SWIR channels.

$$MNDWI = GREEN - MIR / GREEN + MIR (3)$$

The change in the magnitude of the relative measurement (MIR) depending on the areas of lakes (S) using the Excel software system is approximated by the power function equation in the form (Azbantayeva et al., 2022).

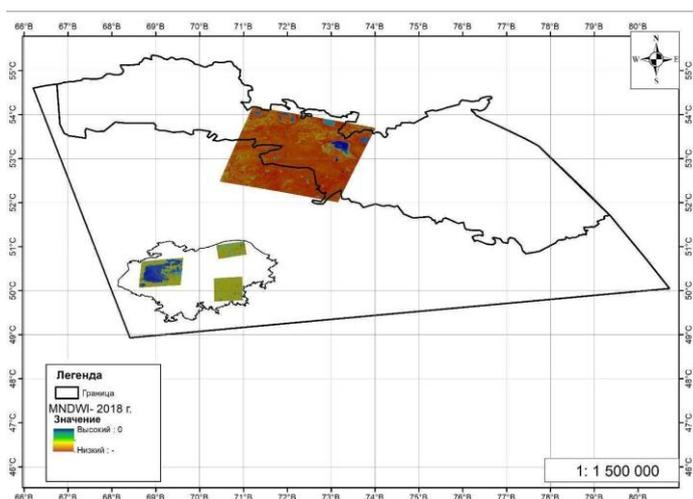


Figure 6. Thematic processing of images was applied to calculations of MNDWI indices

RESEARCH RESULTS AND DISCUSSION

During the study, the dependence of the relative measurement of the lake areas on the size of their area was established. The figures (Figures 7, 8, 9) shows the values of the relative measurement of the lake area, determined by formulas (1,2,3).

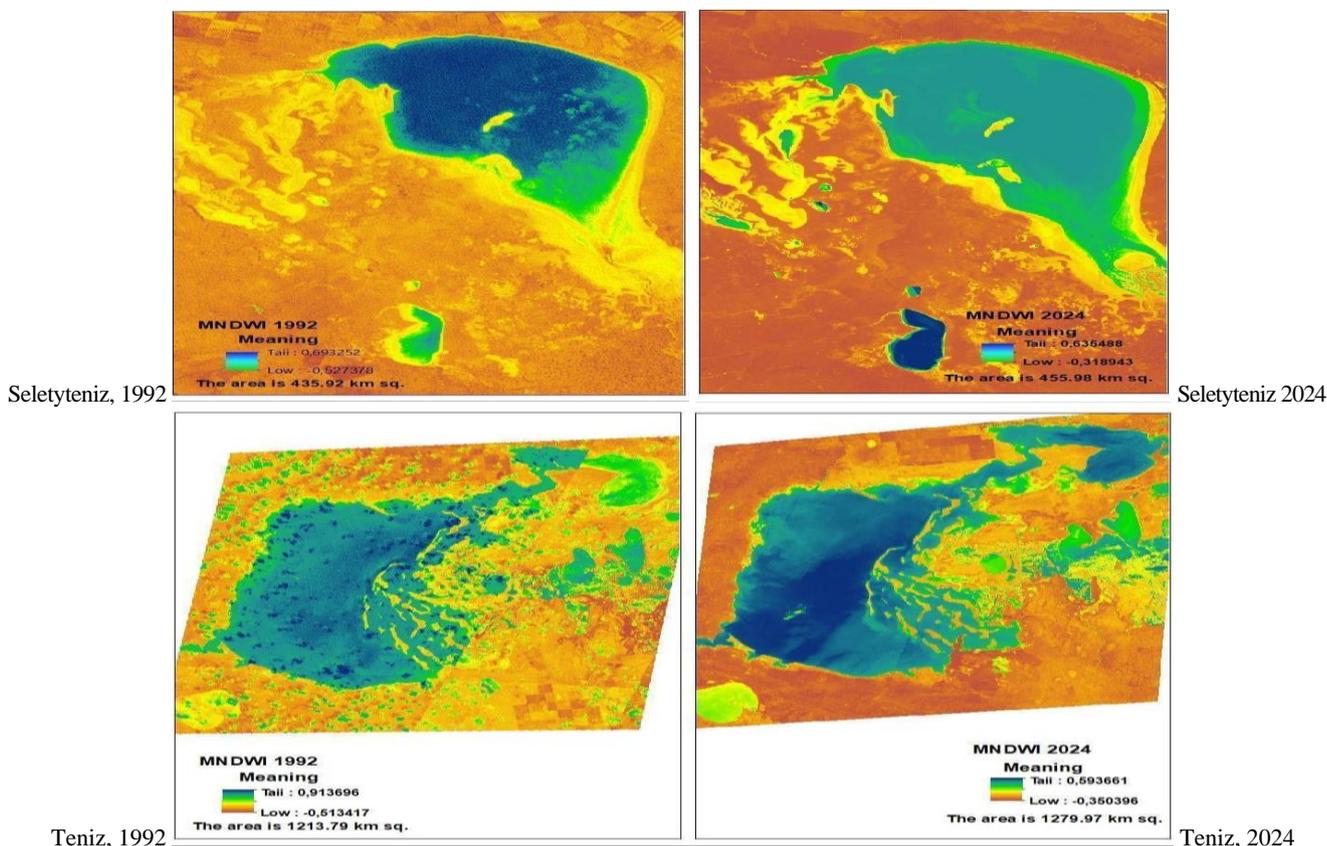


Figure 7. Figure of changes in the value of the relative vegetation indices MNDWI calculations depending on the area of the lakes Seletyteniz and Teniz 1991-2024 (Source: Authors based on the ArcGIS)

Let us consider the results of the study of measuring the areas of lakes in radar images. As can be seen from Figure 7, the relative error in measuring the areas of lakes decreases with an increase in their area. Thus, with $A - S > 4.11 \text{ km}^2$ and $B - S > 2.20 \text{ km}^2$, the average error in measuring the areas of lakes in Landsat images does not exceed 3%.

The change in the average lake area measured using the radar image relative to the Quick Bird image data depending on the size of the sliding window is shown in Figure 8. As can be seen in Figure 8, the best accuracy of remote measurement of the area of lakes when filtering ERS-2 radar images is provided by the Median method with the sizes of the "sliding window" of 3x3, 5x5 and 7x7 pixels. Thus, with $A - S > 4.09 \text{ km}^2$; $B - S > 4.49 \text{ km}^2$; the average measurement of the area of lakes in Landsat images does not exceed 2%. A comparison of the errors in measuring the areas in the original ERS-2 image (before filtering) and after filtering by the Median method with a sliding window size of 3x3 pixels is shown.

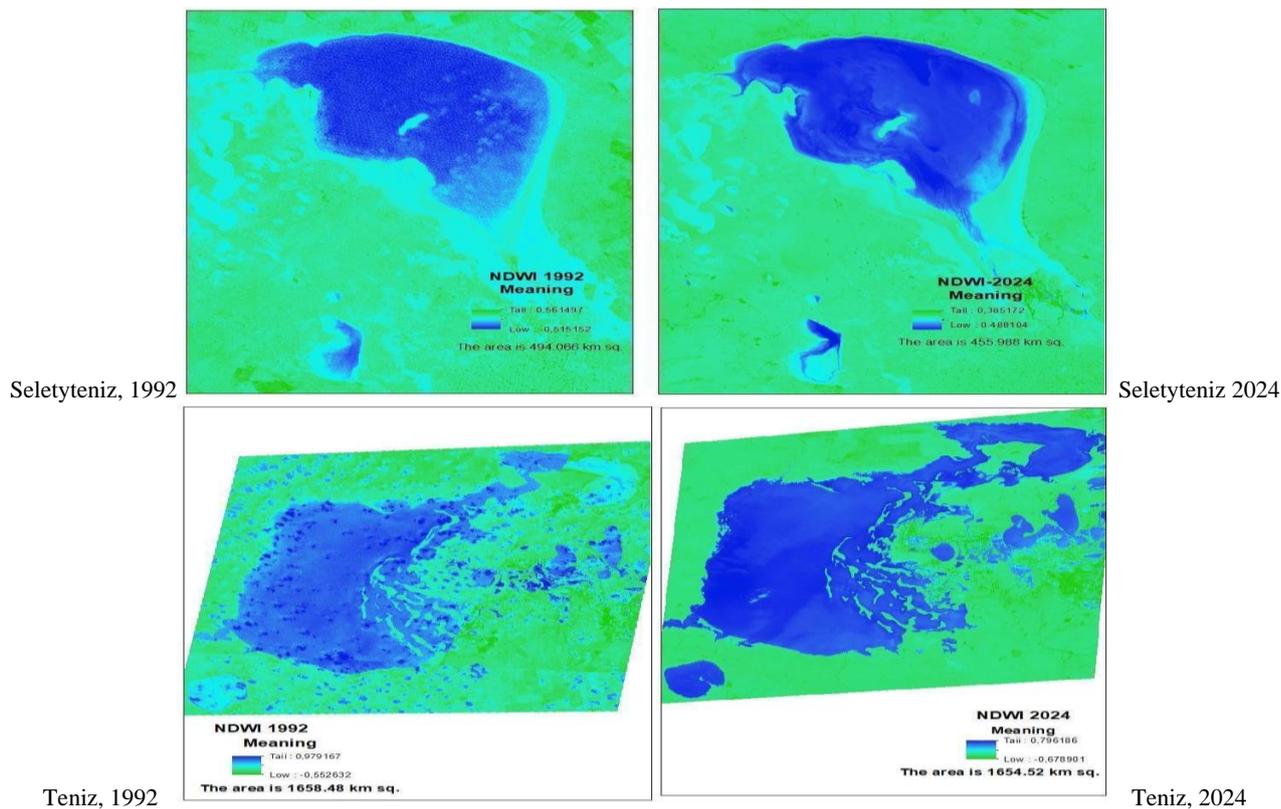


Figure 8. Figure of changes in the value of relative vegetation indices NDWI calculations depending on the area of lakes Seletyteniz and Teniz 1992-2024 (Source: Authors based on the ArcGIS)

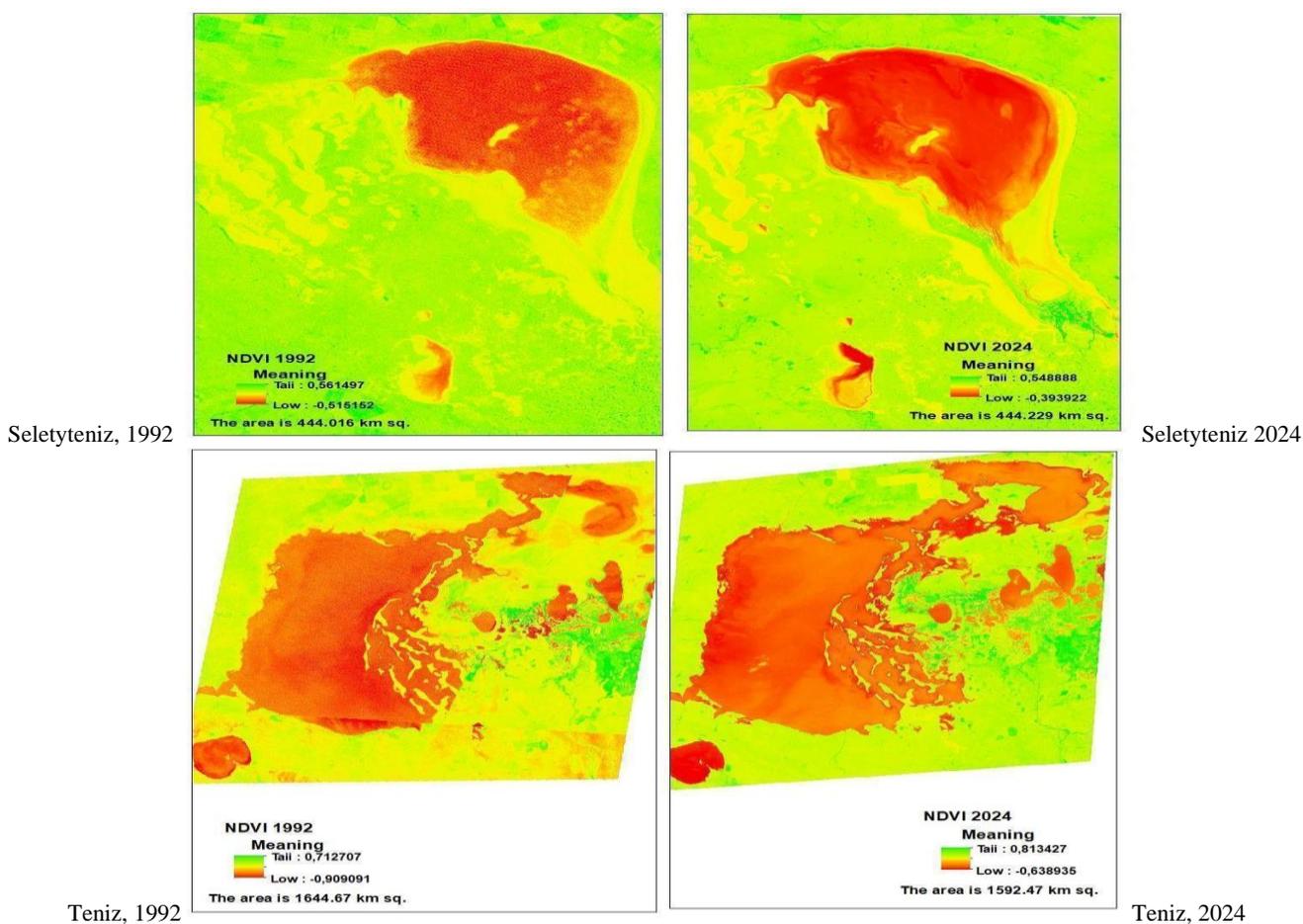


Figure 9. Figure of changes in the value of relative vegetation indices NDVI calculations depending on the area of lakes Seletyteniz and Teniz 1992-2024 (Source: Authors based on the ArcGIS)

Figure 8 shows the values of relative errors in measuring lake areas using ERS-2 satellite data depending on the size of the area being measured. As can be seen in Figure 9, the accuracy of determining lake areas after filtering ERS-2 images is significantly higher compared to the original (unfiltered) data.

Thus, with the area of lakes: $A - S > 2.32 \text{ km}^2$, $A - S > 1.79 \text{ km}^2$, the average relative measurement error on Landsat images does not exceed 1%. Remote sensing data analyses conducted on the images ERS-3 and Landsat-7.8 made it possible to compile a description of the lakes, an example of which is presented in Table 4.

Table 4. Characteristics of lakes in the study area (Source: Authors based on the ArcGIS)

No.	Name	Initial data			
		Polygon A		Polygon B	
		1992	2024	1992	2024
1	Lake number according to the reference book (diagram)	2255		1539	
2	The lake and its location	Seletyteniz, 1 km west of Kyzyl-Tuz district		Teniz, 25 km W of the village of Urkendeu	
3	Inflow and outflow	located between the rivers Yesil and Ertis.		Flows into the Nura River, stream. Espesay, Mal. and Blo.-Tabylgisai and 2 dry	
4	Altitude above sea level, m	65.0		304.4	
5	Lake area, km ² .	720.00		1161.54	
6	Length, km	42.0		74.1	
7	Maximum width, km	21.0		32.2	
8	Length of coastline, km	350.0		488.0	
9	Coastline development			4.0	
10	Drying P (), non-drying H ()	P	P	P	P
11	MNDWI	4.11		2.20	
		Measurement errors - 1.9			
12	NDWI	4.09		4.49	
		Measurement errors - 0.40			
13	NDVI	2.32		1.79	
		Measurement errors - 0.53			

Analysis of remote sensing data (1992–2024) showed that between 1940 and 1982, there was a decrease in the water level and a reduction in the area of Lakes Seletyteniz and Teniz. Between 1986 and 1992, an increase in the area of these lakes was recorded. According to data for 1992–2024, in the Irtys natural-limnological region, the area of Lake Seletyteniz (Lake A) is increasing, while the area of Lake Teniz (Lake B) is decreasing (Table 5).

These changes may indicate the beginning of a new climate cycle similar to the period 1940–1982. Let us compare the error of lake area measurements on ERS-2 and Landsat-7.8 images. Table 5 shows the graphs of the dependence of the relative error of lake area measurements on the filtered ERS-2 image and on the Landsat-5.7.8 image. Relative errors of lake area measurements obtained on the filtered ERS-2 radar image and on the Landsat-7.8 image, respectively. Table 4 shows the results of lake area measurements calculated using the vegetation indices MNDWI, NDWI, NDVI (Table 5).

Table 5. Lake areas calculated using vegetation indices (Source: Authors based on the ArcGIS)

Name of vegetation indices	Name of lake area, periods			
	Area of lakes, km ²	Oz. Seletyteniz - A	Area of lakes, km ²	Lake Teniz - B
	1992	2024	1992	2024
MNDWI	761.22	763.54	1163.76	1161.97
NDWI	779.07	774.98	1158.48	1154.02
NDVI	761.72	765.83	1154.67	1152.47
Total average km ²	760.44	768.12	1162.31	1156.16
Errors in measuring km ²	3.5	19.0	0.26	1.8

Table 5 demonstrates that the accuracy of measuring the areas of lakes larger than 50 hectares on both the filtered ERS-2 radar image and the Landsat-7 image is approximately the same. However, for small lakes with areas (less than 50 hectares), there is a high accuracy of measurements according to ERS-2 data compared to Landsat-8. Thus, for lakes with an area of 10 hectares, the relative error of measuring the areas of lakes on the filtered radar image averages 3%, which is lower than on the Landsat-7,8 image, reaching 3.5%, this is due to the higher spatial resolution of ERS-3 images (12.5 m) compared to Landsat-8 (30 m). Using Landsat satellite data and geographic information systems, the accuracy of measurements is assessed, compared with ground data, and recommendations for the development of tourism areas are formed. The results obtained contribute to the scientific substantiation of spatial planning and sustainable tourism development in the region. The development of tourism in Northern and Central Kazakhstan is directly linked to the natural diversity of the region, especially water bodies, including lakes, which have high recreational potential.

Northern Kazakhstan has significant tourism, especially in terms of ecological, ethnocultural, and scientific-educational tourism potential (Mazhitova et al., 2018). The region is characterized by a variety of natural landscapes, including forest-

steppe and steppe zones, as well as the presence of unique lake ecosystems. One of such natural objects is Lake Seletyteniz, a large endorheic salt lake located in the south of the Akmola region. At the same time, it is of interest for scientific expeditions and ecotourism due to its unique geological and hydrological characteristics and rare flora and fauna. Lake Seletyteniz can also be an object of ornithological tourism, especially during periods of seasonal bird migration, which is a relevant area within the framework of sustainable tourism in the region (Ashimov & Mukasheva, 2020). For the development of tourism in these conditions, precise spatial analysis is necessary. The use of remote methods allows us to establish changes in the boundaries of water bodies, identify degradation processes, and determine zones with the greatest anthropogenic load. The use of remote sensing data facilitates environmentally sound design of tourism infrastructure, optimization of sites for the placement of facilities, planning of transport routes and allocation of restricted access areas.

This is especially important for hard-to-reach and ecologically vulnerable areas such as Seletyteniz, where it is necessary to ensure a balance between recreational use and the preservation of natural landscapes. In this context, the integration of geoinformation technologies in the development of the region's tourism potential contributes to the formation of sustainable development strategies that meet both national and international standards for nature management and environmental protection. Central Kazakhstan also has a wide range of opportunities for tourism development, especially in the direction of nature and ethnocultural tourism. The region is characterized by vast steppe and semi-desert spaces, unique geomorphological forms, sacred sites, and the presence of large lake systems. One of the most significant water bodies is Lake Teniz, the largest salt lake in Central Kazakhstan, located within the Teniz-Korgalzhyn Depression.

Teniz is a unique diverse ecosystem with an endorheic water system with a high degree of mineralization and diverse ecosystems, including marshy areas and salt marshes (Sagatbayev et al., 2019). The lake is part of the Korgalzhyn Biosphere Reserve and is included in the list of Ramsar sites and UNESCO World Heritage Sites (UNESCO, 2025). This makes it an important site for ecotourism, ornithological and scientific expedition tourism, especially due to the migration and nesting of rare bird species such as the pink flamingo. In the context of sustainable development of the region, the use of remote methods for studying the Teniz lake system allows for effective monitoring of both seasonal and long-term changes in the hydrological regime. This is critically important both for the conservation of biodiversity and for the design of tourist routes and infrastructure facilities. Geoinformation technologies and remote sensing methods facilitate accurate assessment of natural potential and risks of anthropogenic impact. Thus, an integrated approach combining geographical analysis, monitoring of water bodies, and assessment of tourism and recreational potential allows to form a sustainable model of tourism development in Northern and Central Kazakhstan. Lakes such as Teniz, Korgalzhyn, and Shalkar are unique ecosystems and important sites for ecotourism, ornithological tourism and phototourism (Yerdavletov, 2000).

Their role is enhanced by the inclusion of some of them in specially protected natural areas (SPNA), such as the Korgalzhyn State Nature Reserve, which is included in the UNESCO World Heritage List (UNESCO, 2025).

However, for effective planning of tourist routes and preservation of natural complexes, accurate spatial data on the state of lake systems are necessary. In this context, remote sensing methods, including satellite imagery analysis, are a highly effective tool for monitoring water resources, especially in hard-to-reach areas.

Remote sensing data allows tracking seasonal fluctuations in the surface area of lakes, the degree of siltation, the level of anthropogenic load and changes in the coastline. These parameters are critically important both for assessing the ecological state and for planning sustainable tourism (Liu et al., 2020).

In addition, accurate cartographic information plays a key role in the formation of tourism infrastructure, from recreation areas and routes to protected areas, while minimizing environmental damage. Thus, the integration of geographic information systems and remote sensing in the field of tourism development contributes to the rational use of the region's natural resources, ensures a sustainable balance between environmental protection and economic development.

CONCLUSIONS

For the effective use of remote sensing materials, it is important to adhere to the principle of completeness, which is achieved through the use of scanner images obtained from various satellites: Landsat-5-7-8.

The main tasks of space monitoring of large river catchments, as a single geosystem, were considered in the conditions of a deficit of ground observations of remote sensing data, the only available sources of information on the state of water bodies and their catchments. Space monitoring allows obtaining up-to-date information on the structure, dynamics of functioning depending on natural and anthropogenic features. The rationale for choosing the types of space images, spatial coverage and scale is determined by the specifics of the geosystems of basins of different ranks, their structure,

An analysis of publications on the application of remote sensing data to water resources research allowed us to identify the following water bodies and irrigation systems as objects of space photography. All lakes in the study area were combined into 4 groups. In addition, the territory under study has a wide range of opportunities for tourism development, especially in the direction of natural and ethnocultural tourism. The region has rich natural and ethnocultural heritage, predominantly steppe and semi-desert landscape, unique geomorphological forms, sacred sites and lake systems. One of the most significant water bodies is Lake Teniz, the largest salt lake in Central Kazakhstan, located within the Teniz-Korgalzhyn Depression.

Teniz is an endorheic water system with a high degree of mineralization and diverse ecosystems, including marshy areas and salt marshes. The lake is part of the Korgalzhyn Biosphere Reserve and is included in the list of Ramsar sites and UNESCO World Heritage Sites. In recent years, the water regime of the Teniz Lake basin has been significantly affected not only by the growth of water consumption, but also by the natural variability of climatic and hydrological factors. Despite this, in all reservoirs of the region, the excess of the normal backwater level (NBL) has not been recorded.

The main disadvantages that limit the widespread use of satellite information in hydrological studies are: the episodic nature of the surveys, indirect methods for assessing hydrological parameters, high errors in determining parameters, and the significant cost of high spatial resolution data. There is a pronounced dynamic of water level fluctuations in small lakes. At the same time, only for Lake Teniz over the past year a stable negative trend has been recorded - a significant decrease in the water level. In addition, an expansion of desertification areas and water mirrors with a simultaneous decrease in water intake for economic needs has been noted. Modern methods and software allow obtaining metric characteristics of lakes with high accuracy. For lakes with an area of more than 50 hectares, the accuracy of measurements using ERS-2 and Landsat-7 satellite images remains high. At the same time, for lakes with an area of less than 50 hectares, the accuracy of measurements using ERS-2 images is, on average, higher than using Landsat-8 images.

The relative error in measuring areas using images is, on average, about 3%, which is less than using Landsat-7 and 8 images (on average, 3.5%). This is due to the higher spatial resolution of ERS-3 images (12.5 m) compared to Landsat-7 (30 m).

Research into the accuracy of remote sensing of lake areas using space images makes it possible to map changes in the lake area of various objects. Calculations of the analysis of space images for the period from 1992 to 2024 showed the following trends: 1940-1982, a decrease in lake levels and a reduction in their areas in Northern and Central Kazakhstan were observed, 1986-1992 an increase in the area of lakes was recorded. 1992-2024 within the Irtysh natural-limnological region, different processes were noted, where the area of Lake Seletyteniz (A) increases, the area of Lake Teniz (B) continues to decrease. These changes may indicate the beginning of a new climatic cycle similar to the period 1940-1982.

Analysis of space images for the period from 1992 to 2024 revealed trends in changes in water bodies in Northern and Central Kazakhstan. In the period from 1940 to 1982, a decrease in lake levels and a reduction in their areas were observed. In 1986–1992, an increase in the areas of lakes was recorded. From 1992 to 2024, within the Irtysh natural-limnological region, multidirectional processes occurred: the area of Lake Seletyteniz (A) increased, while the area of Lake Teniz (B) continued to decrease. The use of remote sensing data opens up opportunities for the use of modern high-tech methods of analysis and interpretation of factual information, which significantly expands the potential for monitoring spatio-temporal changes in environmental conditions and assessing the risks of biodiversity loss.

The Teniz-Korgalzhyn Depression is a unique natural area in Central Kazakhstan with an outstanding natural and cultural heritage. Its potential in the field of ecotourism is truly enormous. The development of ecotourism activities in this region not only contributes to socio-economic growth, but also plays an important educational and scientific role. Tourists come here to get acquainted with the rich world of nature, study ecosystems, and contribute to the preservation of biodiversity.

The relatively low visitor numbers and low income of the Lake Seletyteniz buffer zone may be due to several factors, including the unorganized nature of tourism, underdeveloped infrastructure and limited diversity of tourism offerings.

The reserve development plan is being continuously developed and regularly updated with the involvement of stakeholders - the scientific community, local communities, government bodies, and environmental organizations.

Within the framework of the GEF/UNDP project, a comprehensive management plan is being formulated, encompassing strategies for the sustainable development of ecotourism, scientific monitoring of ecosystem conditions, and mechanisms for effective engagement with the public and key stakeholders.

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REFERENCES

- Ashimov, A. A., & Mukasheva, S. B. (2020). Potentsial ornitologicheskogo turizma v Akmolinskoy oblasti [The potential of ornithological tourism in the Akmola region]. *Geography and Natural Resources of Kazakhstan*, 3, 55–62 (in Russian).
- Azbantayeva, M. N., Sagynbayeva, A. B., Sagatbayev, Y. N., & Pashkov, S. V. (2022). Determination of the tourist position of lakes of Western and Central Kazakhstan by space survey. *GeoJournal of Tourism and Geosites*, 45(4spl), 1625–1632. <https://doi.org/10.30892/gtg.454spl12-983>
- Beletskaya, N. P., Nazarova, T. V., & Pashkov, S. V. (2019). Geneticheskaja klassifikacija ozernyh kotlovin Severo-Kazahstanskoj ravniny [Genetic classification of lake basins of the North Kazakhstan plain]. *Scientific Notes of the Crimean Federal University named after V.I. Vernadsky. Geography. Geocology*, 3(5), 149–159 (in Russian).

- Chen, W. (2023). Developing a sustainable business model of ecotourism in ethnic-minority regions guided by the green economy concept. *Sustainability*, 15(2), 1400. <https://doi.org/10.3390/su15021400>
- Deng, Y., Zhang, Y., Pan, D., Yang, S. X., & Gharabaghi, B. (2024). Review of recent advances in remote sensing and machine learning methods for lake water quality management. *Remote Sensing*, 16(22), 4196. <https://doi.org/10.3390/rs16224196>
- Erokhin, G. N., & Kopylov, V. N. (2002). Ispol'zovanie dannyh NOAA/AVHRR dlja operativnogo kosmicheskogo monitoringa okruzhajushhej srede Sibiri [Using NOAA/AVHRR data for operational space monitoring of the Siberian environment]. In *Proceedings of the International Symposium "NOAA Image of Siberia"* 85–91. Novosibirsk, Russia (in Russian).
- Filonets, P. P., & Omarov, T. R. (1974). Ozera Severnogo, Zapadnogo i Vostochnogo Kazakhstana [Lakes of Northern, Western, and Eastern Kazakhstan]. Leningrad: Gidrometeoizdat Publ. (in Russian).
- Garbuk, S. V., & Gershenson, V. E. (1997). Kosmicheskie sistemy distancionnogo zondirovaniya Zemli [Space systems for remote sensing of the Earth]. Moscow: A&B Publishing House, 154–163 (in Russian).
- Guerrero, J. V. R., Gomes, A. A. T., de Lollo, J. A., & Moschini, L. E. (2020). Mapping potential zones for ecotourism ecosystem services as a tool to promote landscape resilience and development in a Brazilian municipality. *Sustainability*, 12(24), 10345. <https://doi.org/10.3390/su122410345>
- Herman, G. V., Wendt, J. A., Dumbravă, R., & Gozner, M. (2019). The role and importance of promotion centers in creating the image of tourist destinations – Romania. *Geographia Polonica*, 92(4), 443–454. <https://doi.org/10.7163/GPol.0158>
- Kashkin, V. B., & Sukhinin, A. I. (2001). Distancionnoe zondirovanie Zemli iz kosmosa [Remote sensing of the Earth from space]. Moscow: Logos Publ. (in Russian).
- Koshim, A., Sergeeva, A., Kakimzhanov, Y., Aktymbayeva, A., Sakypbek, M., & Sapiyeva, A. (2023). Sustainable development of ecotourism in "Altynemel" National Park, Kazakhstan: Assessment through the perception of residents. *Sustainability*, 15(11), 8496. <https://doi.org/10.3390/su15118496>
- Kulebayev, K. M., Alimkulov, S. K., Tursunova, A. A., Makhmudova, L. K., Talipova, E. K., Saparova, A. A., Rodrigo-Clavero, M. E., & Rodrigo-Ilarri, J. (2024). Assessing the vulnerability of lakes in Western Kazakhstan to climate change and anthropogenic stressors. *Water*, 16(24), 3709. <https://doi.org/10.3390/w16243709>
- Liu, X., Shi, Z., Huang, G., Bo, Y., & Chen, G. (2020). Time series remote sensing data-based identification of the dominant factor for inland lake surface area change: Anthropogenic activities or natural events? *Remote Sensing*, 12(4), 612. <https://doi.org/10.3390/rs12040612>
- Mazhitova, G. Z., Pashkov, S. V., & Wendt, J. A. (2018). Assessment of landscape-recreational capacity of North Kazakhstan region. *GeoJournal of Tourism and Geosites*, 23(3), 731–737. <https://doi.org/10.30892/gtg.23309-323>
- Moiseenko, A. E. (1994). Sovremennoe sostojanie i perspektivy ispol'zovanija sredstv distancionnogo zondirovaniya Zemli iz kosmosa v celjah izuchenija prirodnyh resursov i jekologii [The current state and prospects of using remote sensing of the Earth from space for the study of natural resources and ecology]. Moscow: Nauka Publ. (in Russian).
- Muravlev, G. G. (1973). Malye ozera Kazakhstana [Small lakes of Kazakhstan: Resources and use in agricultural production]. Alma-Ata: Kainar Publ. (in Russian).
- Muravlev, G. G. (1993). Ozera Kazakhstana i chto ih zhdet [Lakes of Kazakhstan and what awaits them]. Almaty: Kainar Publ. (in Russian).
- Nigmatova, S., Zhamangara, A., Bayshashov, B., Abubakirova, N., Akmagambet, S., & Berdenov, Zh. (2021). Canyons of the Charyn River (South-East Kazakhstan): Geological history and geotourism. *GeoJournal of Tourism and Geosites*, 34(1), 102–111. <https://doi.org/10.30892/gtg.34114-625>
- Sagatbayev, Y. N., Pashkov, S. V., Dunets, A. N., & Mazbayev, O. B. (2019). Landscapes of the Teniz-Korgalzhyn depression in the Republic of Kazakhstan: Evaluation of ecosystem functions and opportunities for tourism. *GeoJournal of Tourism and Geosites*, 26(3), 1046–1056. <https://doi.org/10.30892/gtg.26328-416>
- Sagatbayev, Y., Tursynova, T., Dunets, A., Mazbayev, O., Jaxylykova, A., Abilova, S., Karabalayeva, A., Amangeldi, A., & Pashkov, S. (2025). Assessment of the main components of the natural and recreational potential of the Teniz-Korgalzhyn depression using geoinformation technologies and remote sensing methods. *GeoJournal of Tourism and Geosites*, 59(2), 638–649. <https://doi.org/10.30892/gtg.59211-1443>
- Shnitnikov, A. V. (1969). Vnutrivenkovaja izmenchivost' komponentov obshchej vlazhnosti [Intrasecular variability of total humidity components]. Leningrad: Nauka Publ. (in Russian).
- Smith, L. C., Sheng, Y., & MacDonald, G. M. (2007). A first pan-Arctic assessment of the influence of glaciation, permafrost, topography and peatlands on Northern Hemisphere Lake distribution. *Permafrost and Periglacial Processes*, 18(2), 201–208. <https://doi.org/10.1002/ppp.581>
- Sutyryna, E. N. (2013). Distancionnoe zondirovanie Zemli: uchebnoe posobie [Remote sensing of the Earth: A textbook]. Irkutsk: Irkutsk State University Publ. (in Russian).
- Wendt, J. A. (2020). Directions and area of tourism research in Kazakhstan. *GeoJournal of Tourism and Geosites*, 32(4), 1418–1424. <https://doi.org/10.30892/gtg.32433-589>
- Wu (2025). Remote sensing inversion of lake water quality and its seasonal dynamics. *Journal of Water and Climate Change*, 16(7), 2277. <https://doi.org/10.2166/wcc.2025.108508>
- Yerdavletov S.R. (2000). *Geografiya turizma: istoriya, teoriya, metody, praktika [Geography of Tourism: History, Theory, Methods, Practice]*. Textbook. Almaty, 336 p. (in Russian).