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ASSESSMENT OF PHYSICAL CAPACITY OF THE BEACH AND RECREATIONAL AND GEOMORPHOLOGICAL POTENTIAL OF THE SOUTH-WESTERN SHORE OF ALAKOL LAKE

Abstract. In the last decade in Kazakhstan there has been an increase in the flow of domestic tourism, with poor integration of sustainable development principles into the destination management policy. As a consequence, there is an irrational use of territories and recreational resources. The study is focused at assessing the physical capacity of beaches and recreational and geomorphological potential of the south-western coast of Lake Alakol. Having analyzed the coast using remote sensing (Planet scope, Rapid Eye (Super Dove, Sentinel 2A and Landsat – 8), it was determined that the total physical capacity of beaches of the south-west coast is equal to 75 thousand recreationists per day and 3 862 thousand per season. The length of beaches and spits used for recreation reached 21 km. Score assessment of attractiveness of relief and geomorphological risks based on the criteria, determined that the recreational and geomorphological potential of beaches of the south-west coast of Lake Alakol is optimal. The quantitative parameters of the physical capacity and recreational-geomorphological potential of beaches are proposed to be used by administrative authorities for the rational development of the lake shore.

Keywords: Beach carrying capacity, geomorphologic-recreational potential, Alakol Lake

Introduction. Alakol Lake is a major developing tourist center for beach-bathing tourism during summer period. The largest number of tourists rest on the southwestern coast in the recreational areas of Akshi and Koktuma, located in the Zhetysu region (Kazakhstan) figure 1. At the present stage, the development of domestic tourism in Kazakhstan goes through stages of the use of recreational resources of the country from episodic and local to systemic mass and international. This is supported by the adopted state tourism and regional development programs [1, 2], as well as the consequences of the Covid 19 pandemic, became the reason for active development of domestic tourism.

Over the last 10 years, the transportation, hotel and recreational infrastructure on the lake shore has improved significantly. In the summer season, daily flights and trains from major cities are launched, and the construction of a new highway Almaty-Oskemen allows comfortable access to the lake by buses and cars. The measures taken have contributed to a significant increase in tourist arrivals at the lake. According to local government estimates for 2022 on the southwest coast, the total number of tourists for the season reached more than 1.5 million people [3]. This southwestern coast is the main and most popular tourist destination.



Figure 1 – Akshi and Koktuma recreational zones (Southwest coast of the Lake)

Recreationists spend most of their time on the water body on the coastal territory [4]. Tourists occupy both prepared beaches in recreational areas and beaches located on remote parts of the coast and accumulative pebble spits without standard infrastructural conditions. Sustainable recreational activities depend on the development potential and factors affecting the quality of coastal tourism. Coastal resources that meet tourist expectations are subject to rapid development of coastal areas, which increases the anthropogenic load on the coast [5]. Uncontrolled growth of popularity of local tourist destinations in the summer period goes against the principles of rational use of natural recreational resources. Beaches are the main tourism resource in coastal destinations and any impact on the quantity and quality of beaches will affect tourism [6]. The availability of beaches and the protection of coastal zones play an important role in the development of a tourism sector that ensures the economic sustainability of municipalities. It is therefore important to manage coastal areas based on the trends and conditions of coastal zones to monitor them and determine their vulnerability over time in order to promote sustainable tourism [7]. Northern Adriatic beach ecosystems suffer from high exposure to pollutants due to port activities, aquaculture, shipping, coastal agriculture and discharges into rivers. Ecosystem services including research and analysis are proposed for sustainable management of coastal recreational resources [8]. The World Tourism Organization has identified the need to strike an appropriate balance between the environmental, economic, and socio-cultural aspects of tourism development to ensure its long-term sustainability [9]. Taking into account the limited area of the shore of Alakol Lake, suitable for beach recreation, there is a need for detailed geospatial scientific studies of the physical capacity and recreational-geomorphologic potential of the beaches of the southwestern coast. The recreational potential of beaches is determined by coastal geomorphology, so by geomorphologic analysis it is possible to estimate the physical capacity of beaches. Beaches are classified according to typology, location, shape, level of urbanization and tourism [10].

Previous works have studied the component-based integrated assessment of recreational attractiveness of landscapes of the entire basin of Alakol Lake [11, 12]. Assessment of the vulnerability of the Alakol Lake coast to modern geomorphologic processes of relief formation [12, 13], and the tourist and recreational potential of the Alakol Lake basin were made [14]. Studies have been carried out to assess the tourism and recreational potential of ecotourism in Kazakhstan [15], and the impact of beach tourism on recreational areas of Lake Alakol [11]. The conducted research is a theoretical basis and is directly related to the popularization and development of beach-bathing recreation on Alakol Lake. However, in the current conditions of chaotic land use of the coast, anthropogenic pressure on the natural stability of coastal ecosystems is increasing. Unfortunately, in Kazakhstan there is a lack of knowledge and understanding of how the principles of sustainability and sustainable development should be

integrated into national tourism policy. Misunderstanding of the concept of sustainable development is a common problem among stakeholders in the tourism sector, which hinders the achievement of sustainable Development Goals [16]. The next stage of studies of the lake coast is to determine the physical capacity of different categories of beaches and assess their recreational and geomorphological potential to identify ways of rational use of recreational resources of the coast of Alakol Lake.

Physical capacity (carrying capacity) was measured by the number of visitors or users that a physical environment can serve at a given time [17]. The physical capacity of the receiving environment has a certain forward-looking nature to warn of problems arising from land occupation [18]. The concept of carrying capacity was first developed in the field of population ecology and wildlife management, where it was defined as the number of individuals of a species that can be supported within a given habitat area. This concept has also been applied to managing visitor numbers to national parks and wildlands.

The shore in the recreational areas of Akshi and Koktuma consists of a steep coastal cliff with a height of 1 to 10 meters and a pebble beach. The cliff is a potential threat to the health and life of tourists during the beach-bathing season. On the surface of the ledge is located recreational infrastructure, due to annual abrasion, the ledge is approaching vacation homes and other facilities [19]. Given the prevailing natural and anthropogenic conditions on the coast, tools are needed to manage beaches and preserve the quality and quantity of coastal recreational resources. Therefore, the main objective of the study is to determine the physical capacity of the beach using a scientifically based method, as well as to assess the recreational and geomorphological potential of the southwestern coast.

Materials and methods. Multi-temporal Satellite data in determine of beach area of the lake. High and medium resolution space images were used to obtain the current physical characteristics of the Alakol Lake beach. Composites of Planet scope and Rapid Eye (Super Dove) space images with resolution 3 and 5 m respectively, obtained from Planet.com platform (Real-Time Satellite Monitoring with Planet), Sentinel 2A [20] with resolution 10 m, Landsat – 8 9 (United States Geological Survey) with resolution 30 m. In ArcMap 10.5, the space image composites were assigned natural RGB colors (for Planet scope bands (6,3,2,) for Sentinel bands (4,3,2) and for Landsat bands (4,3,2)) [21].

To understand the location of beach resorts, it is necessary to define the coastline and the different beach zones according to the established norms of coastal geomorphology and coastal engineering [22]. A trained image classification [23] was applied to extract the contours of the lake beach area. A beach raster was extracted from the resulting Landcover by attribute value. The beach raster was converted to vector format and spatial corrections were performed. After overlaying the vector layer of the beach area on the original Planet scope space image, the beach was zoned by location, relative to geographic objects.

ArcMap 10.5 tools were used to calculate the areas of the zoned beach areas. On the territory of the spit, which are located parallel to the beaches on the lake, a strip of land was allocated from the water's edge, which is used by tourists for recreation. According to field studies, tourists mostly use the beach from the water's edge, which is not more than 10 meters wide, rarely 15 meters. For coverage with reserve, we allocated a beach width of 20 meters as a buffer zone.

Physical Carrying Capacity Determination. The recreational physical capacity of the southwestern coast was determined based on the model proposed by Cifuentes M. This model also defines the real carrying capacity and the effective carrying capacity. In the present study, an adapted equation for estimating the physical capacity of beaches [24]. The physical capacity estimation equation is following:

$$PCC \text{ (Physical Carrying capacity)} = \frac{A}{Au} \times R_f,$$

where A – Total available beach area, Au – beach area required for one visitor; R_f – rotation factor or number of visitors per day. The determination of beach area A is described in the first paragraph of the Methods section. The beach area required for one visitor Au by different researchers ranges from 2 to 30 m² per tourist, depending on natural and socio-economic conditions.

Tentatively zoned the beach of Town of Mali Lošinj (Croatia) into 3 categories, where each was given a different Au value:

- 5 m² (2x2.5 m) within populated areas;
- for beaches outside the settlement, the Au is 8 m² (2x4 m);
- for remote beaches accessible only from the sea, the Au is 16 m² (4x4 m). Based on field studies on the beaches of Praia de Faro (Portugal) determined an optimal area of 5 to 10 m² available for each user

[25]. Most of the works repeat the average calculated value of beach area per bather, which is 5 m² [24]. In this study, this figure was taken as the normal standard design value of beach area in a recreational area per bather. Taking into account the main reason for staying on remote beaches, vacationers is the expectation of solitude, in this study it was accepted to increase the indicator of Au on the spit beach within the recreational zone to 10 m² and on remote beaches to 15 m².

Assessment of the recreational-geomorphological potential. To assess the recreational-geomorphologic potential, we used the method of calculating the attractiveness of the relief and geomorphologic risks [26, 27]. The method allows to determine the average score of attractiveness of beach-bathing recreational activity for different classes of beaches. Scoring methods based on developed criteria and their evaluation indicators are widely used in geographical studies. For example, in the evaluation of 'Coastal Scenic Evaluation System' (CSES) [28], Coastal vulnerability index [29].

Determination of the attractiveness of the relief is based on a score (numerical) assessment and includes the following principles [26]. Landscapes and culture have the highest level of motivation among tourists when visiting recreational sites [30]. In order to optimize the component evaluation of the attractiveness of the relief, evaluation criteria with scores for each parameter were developed table 1. In the study, the parameters of morphometric and intensity of coastal events [16] were supplemented with criteria reflecting the recreational natural conditions of the area. These are physical parameters beach face, skyline landforms, vistas, water color and clarity and vegetation cover. These criteria are used to evaluate Coastal Scenic proposed in studies [31].

Table 1 – Criteria for assessing the potential attractiveness of the relief of Alakol Lake coastal recreational areas

№	Site features	Physical parameters	Attractiveness		
			1 (Low)	2 (Medium)	3 (High)
1	Morphometric	Altitude	400-450	450-500	500-550
		Vertical dissection	1-2	2-6	6-10
		Slope gradient	5.5-10	1.8-5.5	0-1.8
2	Beach face	Type	Loams	Pebble/Gravel	Sand
		Width, m	Less 5	5-10	More 10
		Color	Dark	Mix (white and black) Light tan/bleached	Gold
3	Intensity of coastal events		More 5	2-5	Less 2
4	Skyline Landforms		Not visible	Flat/Undulating	Mountainous
5	Vistas		Open on two side	Open on three sides	Open on four sides
6	Water color and clarity		Milky blue/green; opaque	Green/grey blue	Clear blue/dark blue
7	Vegetation cover		Bare (< 10% vegetation only)	Scrub/grass	mature trees, bushes

Assessment criteria have been developed to assess the geomorphological risk. A risk component is identified, for each hazardous landforming process (landslide, abrasion, talus, etc.) and the degree of risk they pose to the site is established table 2. The average value is calculated by the ratio of the sum of the values of variables to the number of variables.

Table 2 – Criteria for assessing the geomorphological risk of the coast of Alakol Lake

№	Hazard – a natural phenomenon that could lead to damage (various genesis)	Risk		
		1 (Low)	2 (Medium)	3 (High)
1	Earthquakes (MSK-64(K))	Less than 6	6-8	More than 8
2	Landslides, quantity on the coast	1	2	3
3	Abrasion, m per year	Less 3	3-5	More 5
4	Coastal dynamics	Low	Medium	High
5	Landfall	Low	Medium	High
6	Talus	Low	Medium	High

The criterion values are obtained from scientific literature sources, processing of SRTM digital elevation model, and field surveys.

In the context of recreational and geomorphological studies, attractiveness of relief is defined as a complex parameter consisting of specific relief properties (morphometry, diversity, aesthetic appeal, etc.). Risk is defined as the probability of adverse impacts on life, health, property or the environment. Attractiveness and risk are assessed using composite indices ranging from 1 to 3 (low, medium and high), which include individual indicators of landform features. Similar composite assessment indices have been used to assess past and future changes in the coastal geomorphology of different UK coastal types [32]. The ratio of the results of the average scores of attractiveness and risk form, according to the author's data, the value of functional suitability of the territory for recreational purposes table 3. This value is the recreational-geomorphological potential (RGP) [26]. A flowchart of the methods for this study is shown in figure 2.

Table 3 – RGP dependence on the risk-attractiveness ratio

Risks	High (2.33–3)	1	1	4	1	Insufficient
	Medium (1.67–2.33)	2	3	3	2	Medium
	Low (1–1.67)	2	3	3	3	Optimal
		Low (1–1.67)	Medium (1.67–2.33)	High (2.33–3)	4	Extreme
				Points	RGP	

Field observation. Field works and monitoring studies were conducted on the south-western shore of Alakol Lake during the summer period in 2011, 2018-2023. They included a walking route along the coast, determination of input variables for the criteria of assessment of attractiveness of relief and geomorphologic risk of the Lake coast. This is the measurement of morphometric parameters of the Lake shore; width and relative height of beaches on the shore and spits, height of the shore cliff. Visual determination of color of accumulative sediments of the beach and lake water, skyline landforms, vistas. Monitoring of shore relief processes, abrasion and accumulation. Description of Saka burial mounds destroyed by half, as a result of abrasion of the coastal cliff.

Figure 2 shows the main stages of the study of physical capacity of beaches and assessment of recreational and geomorphological potential. Using remote sensing data, the first stage was to determine the existing physical capacity of beaches on the south-western shore of the lake. The second phase is the determination of land use changes. The final stage includes assessment of recreational-geomorphological potential on the basis of developed criteria and numerical parameters of physical capacity.

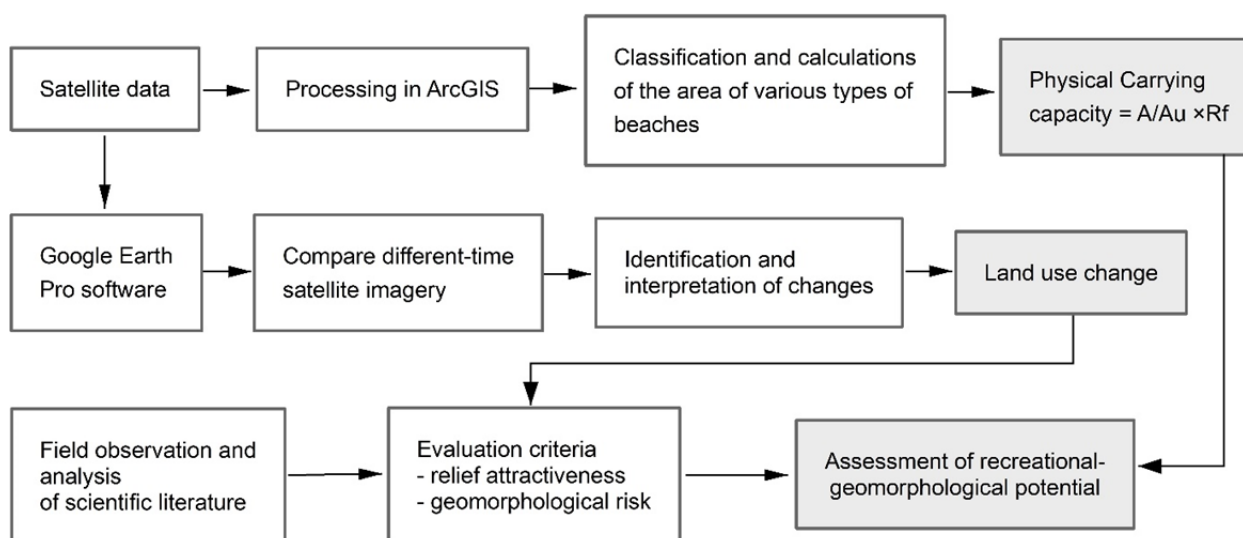


Figure 2 – Graphical scheme of the study steps

Results. Classification of beaches on the southwest shore of Alakol Lake. The total length of the beaches of the south-western coast is more than 32 km. The coastline along its entire length is characterized by varying degrees of involvement of beaches in recreational activities. The geographic location of beaches, access roads and other necessary infrastructure along the coast generally influence the degree of recreational use of beaches. Beaches located near settlements have a higher degree of recreational use, in contrast to beaches located at a distance. Based on these factors, the classification of beaches on the south-west coast of Alakol Lake was made figure 3, where 4 types of beaches are identified by location.

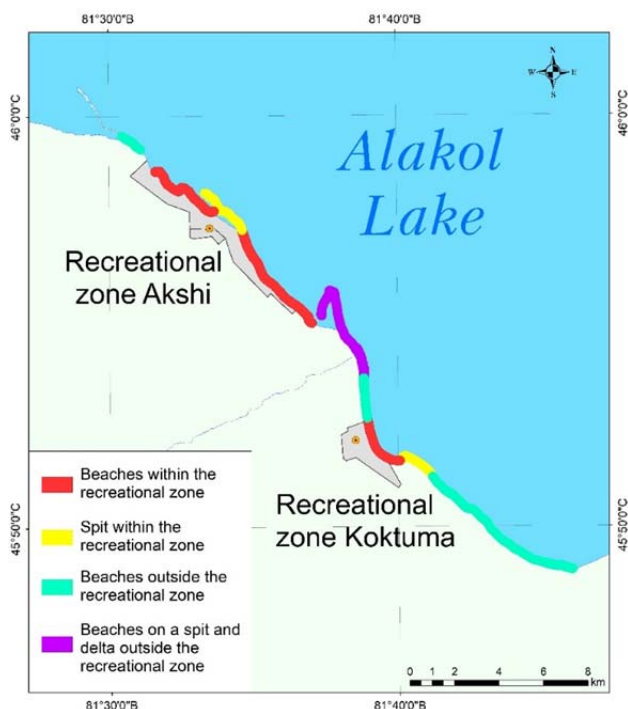


Figure 3 –
Classification of beaches
on the southwest coast of Alakol Lake

The total areas of the four beach types and the percentage of each are calculated table 4. The length of beaches within recreational zones is 11.7 km, of the total beach area they occupy 34.8 per cent of the area. The length of beaches located on spits within the recreational zones is 4.6 km, and they occupy 14.4 per cent of the beach area. The length of beaches on the shores remote from recreational zones is 11 km, with 27.9% of the total beach area. The length of the beach of the accumulative spit Kyzylagash reaches 12 km and occupies 22.9% of the total area of beaches. It is worth noting that more than 12 km of beaches (40% of the area) belong to recreational zones and are currently used for beach-bathing tourism.

Table 4 – Area and proportion of beaches by identified categories
in the recreational areas of the southwestern coast of Alakol Lake

Beach categories	Tourist recreational zone		
	Akshi	Koktuma	Σ , m ²
Beaches within the recreational zone, m ²	192.454 (58,6%)	31.289 (10%)	223.743 (34,8%)
Spit within the recreational zone, m ²	49.852 (15,2%)	42.324 (13,4%)	92.176 (14,4%)
Beaches outside the recreational zone, m ²	18.104 (5,5%)	161.312 (51,3%)	179.416 (27,9%)
Beaches on a spit and delta outside the recreational zone, m ²	67.725 (20,7%)	79.365 (25,3%)	147.090 (22,9%)
Σ , m ²	328.135	314.290	642.425

The physical capacity of the southwest coast of Alakol Lake. The coast of Alakol Lake includes abrasion and accumulative forms of relief, these are coastal abrasion cliff and beaches, spits, respectively. Abrasion shores with a beach at the base are characterized by high dynamics of coastal processing [19]. According to field studies (2018-2023) and multi-temporal satellite imagery data (2010-2023), the shapes

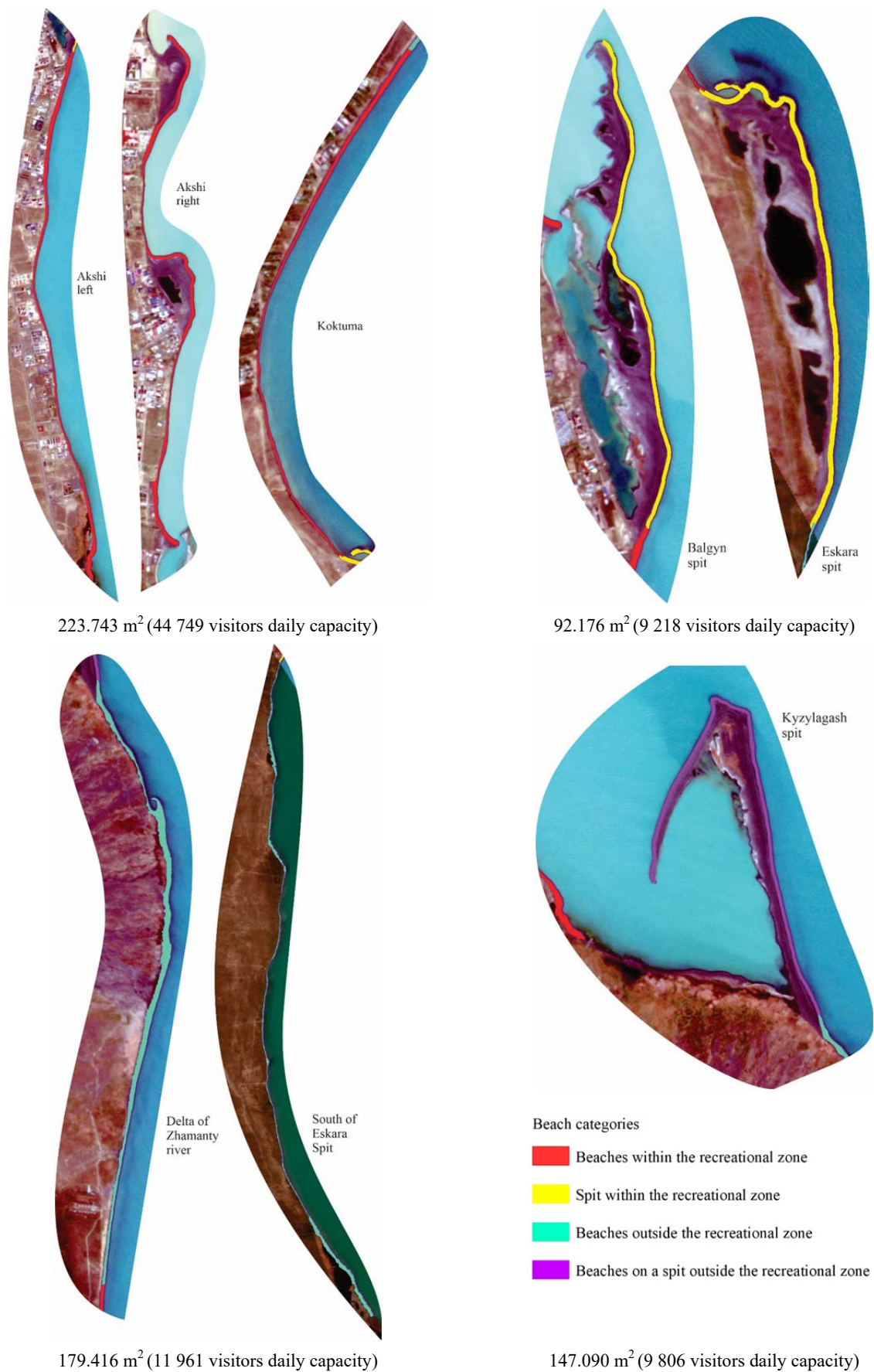


Figure 4 – Shapes and areas of beaches on the ground

of accumulative spits change significantly. Therefore, Planet scope (3 m) satellite imagery showing the terrain as of the month of May 2023 [21] was used to obtain spatial data corresponding to the present contemporary conditions. The application of the latest terrain images, allows for a reliable study of the physical carrying capacity of the southwestern shore of Lake Alakol.

Physical carrying capacity is defined as the maximum number of visits that are physically possible on a particular beach area during a given time period [17]. The results of variable (A), the total available area of all categories of beaches in the study area, are presented in table 4 and figure 4. The total area of beaches potentially suitable for beach-bathing tourism in the southwest coast is – 642425 m². Of these, *beaches within recreational zones* and located on *spits within recreational zones* account for 49.2%, and 50.8% are occupied by *beaches on the remote from recreational areas of the coast and beaches of the accumulative spit Kyzylagash*.

The indicator of beach area required per visitor (Au) was adopted separately for each of the four categories of beach on the south-east coast table 5. For each person on the beach, a separate area Au is required for each person on the beach, where satisfaction and achievement of beach comfort is an important factor. However, there is no accepted common numerical measure of the Au variable in the world. The diversity of natural conditions of different physical characteristics of beaches is the reason why scientists propose an interval of Au indicator from 2 to 30 m² per tourist.

Table 5 – Estimated physical capacity of beaches (by the number of vacationers)
by individual categories within the recreational areas of the southwestern coast of Alakol Lake

Beach categories	PCC Daily capacity (number of bathers)			PCC Seasonal capacity (number of bathers) season of 51 days		
	Akshi	Koktuma	Σ	Akshi	Koktuma	Σ
<i>Au</i> – Beaches within the recreational zone, (5 m ²)	38 491	6258	44 749	1 963 031	319 148	2 282 179
<i>Au</i> – Spit within the recreational zone, (10 m ²)	4985	4232	9218	254 245	215 852	470 098
<i>Au</i> – Beaches outside the recreational zone, (15 m ²)	1207	10 754	11 961	61 552	548 459	610 011
<i>Au</i> – Beaches on a spit and delta outside the recreational zone, (15 m ²)	4515	5291	9806	230 265	269 841	500 106
<i>PCC</i> = <i>A</i> / <i>Au</i> x <i>Rf</i> (<i>Rf</i> =1)	49 198	26 535	75 733	2 509 093	1 353 300	3 862 393

The rotation factor (Rf) is determined using the ratio of the time a beach is open for use to the average time of each beach visit [24]. Based on field observations so far, beaches are the main destination on the southwest shore of Lake Alakol. Although the spectacular North Zhetysu Alatau mountain range is located 10 kilometers away, additional developed attractive destinations and routes for tourists to visit have not yet been developed. In general, tourists come to Alakol Lake for the sake of beach-bathing recreation on the shore, so they spend all daytime on the beach. In this regard, the rotation coefficient was taken as – 1.

The results of the daily and seasonal (51 days) total physical carrying capacity of each category of beaches on the southwest coast are presented in table 5 and figure 4. Based on field observations, the main flow of tourists to the lakes coast continues from July 1 through August 20. In total, the potential physical capacity of beaches belonging to the recreational zone of Akshi is more than 49 thousand per day and for the whole season (51 days) 2509 thousand people. In the recreational zone of Koktuma more than 26 thousand per day and 1353 thousand people for the whole season (51 days) respectively.

Assessment of recreational-geomorphological potential. Component assessment of the relief attractiveness and geomorphic risk was carried out for four categories of beaches of Akshi and Koktuma recreational zones, according to the developed criteria in tables 1 and 2. The average values of the attractiveness of the Akshi and Koktuma recreational zone beaches are in the range from 2.0 to 2.18 points, and the range of the average values of the geomorphic risk is from 2.0 to 2.4 points, which corresponds to the level of Medium. Indicators of risk above the average were noted on the beaches of the recreational areas of Akshi and Koktuma, and on beaches located outside the recreational areas.

The recreational-geomorphological potential is calculated according to table 3, RGP dependence on the coefficient of attractiveness and risk. The insufficient recreational-geomorphological potential is defined in the category of beaches outside the recreational zones in Akshi figure 5. The remaining

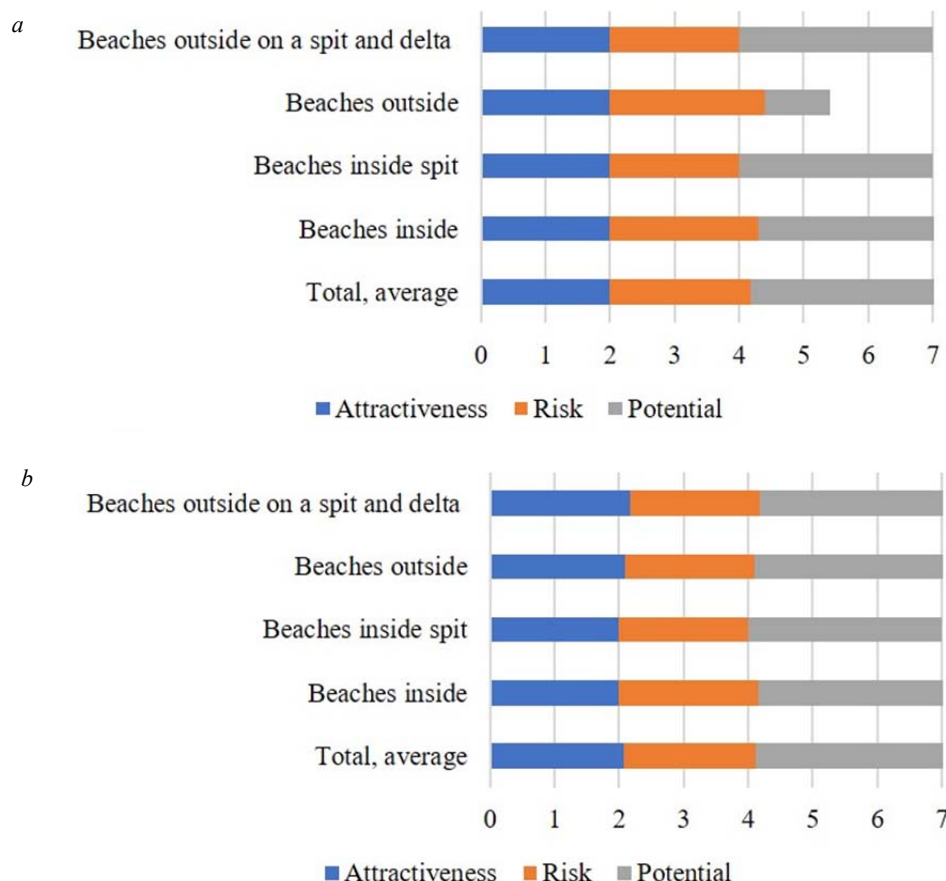


Figure 5 – Recreational-geomorphological potential of recreational zones: *a* – Akshi; *b* – Koktuma

categories of beaches on the southwest shore of Alakol Lake are defined as optimal. The category Insufficient beach in Akshi is only 5.5% of the total beach area so the total values of RGP are defined as optimal in the study area.

Discussion. Classification of beaches. Beaches in the recreational zone are most actively used by tourists, as they are close to infrastructure facilities. Within the recreational zones of Akshi and Koktuma there are accumulative pebble spits, the beaches of which are actively used in beach-bathing tourism. The advantage of the spits is their location in the depths of the water area from tens to hundreds of meters from the strip of the shore beach of the lake. In the study area the beaches on the shore areas remote from the infrastructure objects were identified. These beaches do not have any facilities, they are natural beaches of the lake. They are also very popular among tourists wishing to rest "wild" in natural conditions. The fourth class are the beaches of the Kyzylagash spit, departing from the delta of the river Zhamanty for 2 km into the lake water area. The beaches on the spit are accessible from the water area, access for ordinary motor transport is difficult due to the rugged terrain. The beaches of the spit are used by lovers of secluded recreation in natural conditions.

The result of the beach classification allowed to identify potential attractive shoreline areas for future development of beach and bathing recreation and organisation of recreational infrastructure. The total length of natural, unequipped beaches is about 20 kilometres. However, the natural conditions of such beaches, far from amenities, are popular amongst wild campers. In order to preserve nature and develop ecotourism, it is necessary to provide these beaches with basic amenities for tourists during the beach-bathing season, such as the installation of bins and toilets within walking distance of tourists.

The physical capacity. The seasonal capacity potential on the beaches of the coasts and spits within the recreational areas amounted to more than 2.7 million visitors. On the beaches remote from the settlements of Akshi and Koktuma, the potential seasonal capacity amounted to more than 1.1 million visitors. The presence of beaches near the settlements of Akshi and Koktuma, stretching for kilometers from the villages along the coast. Possessing exceptional favorable conditions in the summer season, these

are healing, mineralized lake water, pebble beaches, mountain and steppe landscapes, steppe air. They are the main resource for the development of beach and bathing recreation area on the south-western coast. As instruments of development with the support of the state for the last 10 years, highways connecting the lake with major cities have been built, railway trains and air service have been launched, communications have been brought to the coast for the construction of recreation centers near the settlements of Akshi and Koktuma. As a result, every year there is an increase in the number of visitors, at the same time there is an intensive economic development of the territory, tourism facilities are built, natural landscapes of the coast are reduced.

The calculated data of physical capacity, allow planning the rational use of recreational resources of the lake, including the coastal territory and in general adhere to the development of sustainable tourism. Sustainable recreational activity depends on the development potential and factors affecting the quality of coastal tourism [5]. On the beaches of recreational areas that meet the expectations of tourists (availability of amenities), there is rapid coastal development that increases the anthropogenic pressure on the coast.

Coastal land use change. The southwestern and eastern shores of Lake Alakol show intensive anthropogenic impacts from 2010 to 2022 (figure 6, *a* and *b*). Development of the region includes infrastructure, hotels, and beach promenades, as well as alignment of the coastal cliffs. According to the analysis of satellite images, the total development area adjacent to the lake reaches 10 km². The length of beaches and spits used for beach recreation reaches 21 km (figure 6, *a*, *b*).



Figure 6 – Change in the area of the fragment of the Aksha recreational zone: *a* – 2011; *b* – 2022

There is an annual increase in the number of tourist facilities on the coast, with both local residents and businessmen from other regions of Kazakhstan investing in the construction and provision of services. Despite a rather short favorable bathing period in the year (July, August), beach-bathing tourism on the south-western coast, has improved the socio-economic situation of the region, through the provision of seasonal employment for local residents, tax revenues to the local budget and others.

Unfortunately, with intensive economic development of the coast, there are facts of non-compliance with simple principles of rational and sustainable use of natural resources of the coastal zone of the lake. These include destruction of natural conditions of the shore ledge [13], discharge of used water into the lake water area [33], lack of zoning of coastal zone use (zones for bathing, areas for the use of watercraft, etc.), construction of recreational facilities near the coastal escarpment, without taking into account the processes of abrasion, etc.). In general, the increase in anthropogenic development of the south-western coast obviously leads to an increase in the unfavorable anthropogenic impact on the natural conditions of the coast.

In many papers, the research focuses only directly on beaches: assessing beach carrying capacity for planning sustainable tourist destinations [34], determining beach capacity for their wise use and management [25], the success of a resort depends on having an “attractive” beach [22], sustainable tourism development requires assessment and study of the main resource to be “exploited” – the beach [6]. However, the results of this study revealed the impact of beaches and their potential physical capacity on anthropogenic alteration of coastal landscapes. Speaking about the value of beaches, in general, conducting studies, it is necessary to include all elements of the coast in the assessment. In the case of the shores of Akshi and Koktuma villages, these are the beach, the coastal escarpment and the surface above the coastal escarpment. Based on the potential of the physical capacity of the beach, there will be a direct

dependence of anthropogenic changes on all elements of the shore. And as practice shows significant loads from anthropogenic impact are experienced by the land area up to the beach, but at the same time visitors spend the main time on the beach.

One example of irrational land use of the coast is the destruction of the coastal escarpment and the mounds located on them - archaeological monuments, for the construction of recreational infrastructure. An archaeological site of the era of early nomads (the 1st millennium BC) was located on the south-western coast, representing a group of more than 30 mounds of various sizes (figure 7, *a*, *c*, *d*, *e*). Currently, the mounds are almost completely leveled with the ground surface. The territory with the mounds is allocated for infrastructural development, as well as for beach tourism development.

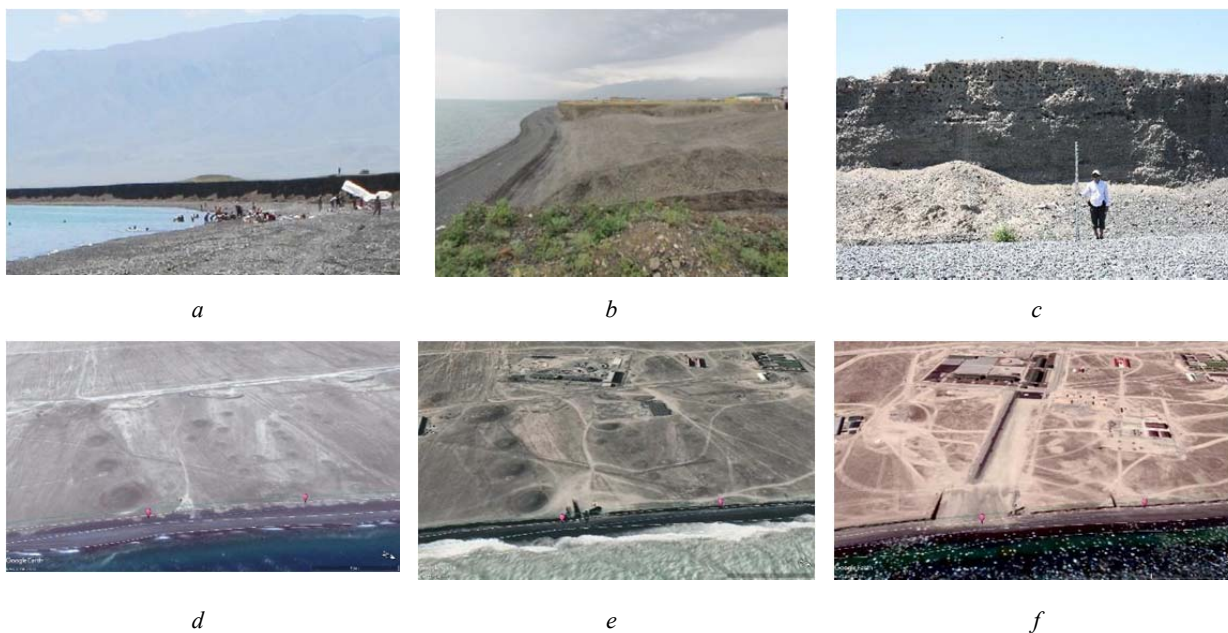


Figure 7 – Negative anthropogenic impact on archeological sites (the 1st millennium BC) – mounds located in the territory of a recreational zone of the Akshi village (south-west coast, 45°56'30" N, 81°35'20" E):

- a* – a mound with a diameter of 25 m in the study area the picture was taken in 10.07 2011;
- b* – an artificially flattened coastal ledge on which there was a mound, a picture of 6.06 2018;
- c* – a mound cut off by the abrasion process, 10.07 2011; man-made alteration of the coastal land on which there was a group of mounds; *d* – 2011; *e* – 2015; *f* – 2017 (Google Earth Pro)

With the rational use of recreational resources of the coast, it was possible to preserve an archaeological monument of Iron Age history. This site could claim to be a historical landmark and become a part of the development of sustainable tourism on the southwest coast of Lake Alakol. The limitations of the study are the active dynamics of relief formation of the coastal area. The shapes of beaches and their areas under the influence of various natural processes are in constant change. There is a decrease in beach area and length of spits, as well as an increase in beach width and size of spits. Therefore, the relevant data in the study are the results of beach areas as of 2022. In the future, the beach areas are likely to change, so the physical capacity values should be adjusted based on the current beach parameters. At the same time, the results are of great importance as a useful tool for planning the infrastructural development of the coast, preventing the negative impact of tourism on the environment and rational use of coastal resources.

Conclusions. The article is devoted to the assessment of the physical capacity of beaches and recreational-geomorphological potential of the south-western coast of Alakol Lake. This topic has high relevance in the light of sustainable tourism development in Kazakhstan and rational use of natural resources. The study, based on remote sensing methods and quantitative assessments of recreational potential, contributes to the scientific discussion on recreational pressure on natural areas.

Despite the high tourist and recreational potential, the beaches of the southwestern coast have limits of physical capacity. The territory of beaches is limited by the area suitable for recreation. At the same time, the assessment of the recreational-geomorphological potential of the territory showed an optimal

level. Therefore, the obtained quantitative data on the physical capacity of the beach and evaluation of the recreational and geomorphological potential on the basis of scientific research, are tools for the effective management and development of beach and swimming tourism on the southwest coast of Alakol Lake.

Calculated results of the seasonal physical capacity of beaches and spits allowed us to define the free capacity of recreationists in the number of more than 1 200 thousand people for the whole season or 24 thousand people per day within the limits of Akshi and Koktuma recreation zones. This confirms the significant recreational potential of the beaches of the south-west coast, given the involvement of remote beaches and spits in recreational activities. However, the factor of increasing the capacity of transport infrastructure on the south-west coast should be taken into account. These measures will contribute to a significant increase in the number of tourists on the lake. Therefore, it is necessary to carry out parallel development of recreational infrastructure on the lake shore based on the principles of sustainable development to meet the needs of the annually increasing flow of tourists. Preventive recreational infrastructure measures will allow rational use of the coast of Alakol Lake.

The relief of the coast significantly affects the tourist and recreational potential. The study confirms the relevance of studying the relationship between tourism development and relief. Subsequent studies of recreational capacity of the south-west coast of Alakol Lake should cover the parameters of real and effective capacity, as well as the definition of norms and standards of recreational capacity of beaches of the south-west coast of Alakol Lake. The results of the study of physical capacity and assessment of recreational-geomorphological potential are of scientific and applied interest for the implementation of sustainable development approaches and rational land use in the development of beach-bathing tourism.

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АЛАКӨЛ КӨЛІНІҢ ОҢТҮСТІК-БАТЫС ЖАҒАЛАУЫНЫҢ ФИЗИКАЛЫҚ СЫЙЫМДЫЛЫҒЫН ЖӘНЕ РЕКРЕАЦИЯЛЫҚ-ГЕОМОРФОЛОГИЯЛЫҚ ЖАҒАЖАЙДЫҢ ӘЛЕУЕТІН БАҒАЛАУ

Аннотация. Соңғы онжылдықта Қазақстанда дестинацияларды басқару саясатына орнықты даму қағидаттарының әлсіз ықпалдасуымен ішкі туризм ағымының ұлғаюы байқалады. Нәтижесінде аумақтар мен рекреациялық ресурстарды ұтымсыз пайдалану орын алады. Зерттеу Алакөл көлінің оңтүстік-батыс жағажайлардың физикалық сыйымдылығын және жағалауының рекреациялық-геоморфологиялық әлеуетін бағалауға бағытталған. Қолдану арқылы жағалауды талдағаннан кейін қашықтықтан зондау деректері (Planet scope, Rapid Eye (Super Dove, Sentinel 2A and Landsat – 8), оңтүстік-батыс жағалауындағы жағажайлардың жалпы физикалық сыйымдылығы тәулігіне 75 мың рекреантқа және бір маусымда 3862 мыңға тең екендігі анықталды. Критерийлер негізінде рельефтің тартымдылығы мен геоморфологиялық тәуекелдердің балдық бағасы Алакөл көлінің оңтүстік-батыс жағалауындағы жағажайлардың рекреациялық-геоморфологиялық әлеуеті оңтайлы екенін анықтады. Әкімшіліктің көл жағалауын ұтымды игеру үшін жағажайлардың физикалық сыйымдылығы мен рекреациялық-геоморфологиялық әлеуетінің сандық параметрлерін пайдалану ұсынылады.

Түйін сөздер: жағажайдың рекреациялық сыйымдылығы, геоморфологиялық-рекреациялық әлеуеті, Алакөл көлі

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ОЦЕНКА ФИЗИЧЕСКОЙ ЕМКОСТИ ПЛЯЖА И РЕКРЕАЦИОННО-ГЕОМОРФОЛОГИЧЕСКОГО ПОТЕНЦИАЛА ЮГО-ЗАПАДНОГО БЕРЕГА ОЗЕРА АЛАКОЛЬ

Аннотация. В последнее десятилетие в Казахстане происходит увеличение потока внутреннего туризма при слабой интеграции принципов устойчивого развития в политику управления дестинациями. Это является причиной нерационального использования территорий и рекреационных ресурсов. Исследование направлено на оценку физической емкости пляжей и рекреационно-геоморфологического потенциала юго-западного побережья озера Алаколь. Проанализировав использование побережья с применением ДДЗ (Planet scope, Rapid Eye (Super Dove, Sentinel 2A and Landsat – 8), мы определили, что общая физическая емкость пляжей юго-западного побережья равняется 75 тыс. рекреантов в сутки и 3862 тыс. за сезон. Протяженность пляжей и кос, используемых в рекреации, достигла 21 км. Балльная оценка аттрактивности рельефа и геоморфологических рисков выявила, что рекреационно-геоморфологический потенциал пляжей юго-западного побережья озера Алаколь является оптимальным. Количественные параметры физической емкости и рекреационно-геоморфологического потенциала пляжей предлагается использовать для рационального освоения побережья озера.

Ключевые слова: рекреационная емкость пляжа, геоморфолого-рекреационный потенциал, озеро Алаколь.