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Assessment of the natural and recreational potential of the specially protected natural areas of Southern Altai

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Abstract: The assessment of the ecological and recreational potential of protected natural areas in the Southern Altai is an important area of ecological research. This article investigates the ecological condition and recreational opportunities of protected natural areas in the Southern Altai region. Using GIS technology, an electronic map of natural, historical, and cultural monuments in the area was created, and the ecological condition of protected areas and the preservation of their natural resources were evaluated. The relevance of evaluating the ecological and recreational potential of the Southern Altai's specially protected natural areas is explained by the need to preserve unique ecosystems alongside the development of tourism. The study used cartographic materials at a scale of 1:100,000, remote sensing data, and field route results (2015-2024). Firstly, the boundaries of strictly protected areas and point objects (geological, hydrological, botanical monuments) were digitized in the ArcGIS software suite, after which the entire area was divided into 80 hexagonal cells, each with a size of 5x5 km. For each cell, attribute data was collected: the number and type of monuments, the accessibility of infrastructure, and the degree of anthropogenic impact. The important results of this study include the identification of natural monuments and the areas of particular importance for their protection. The Katon-Karagay National Nature Park, the Markakol Reserve, and the geological monuments in the Kurshim district, specifically the Kiyn-Kerish and Kyzyl-Kerish stones, are considered as sites requiring ecological protection. The natural monuments and natural resources in these areas are of particular significance for ensuring ecological stability and preserving the recreational potential of the region.

Keywords: specially protected natural areas, GIS, operational territorial units, state nature reserve, state national nature park, state natural monument, recreation, tourism.

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1. Introduction

The Altai transboundary mountain region is divided into 8 physical-geographical provinces of the Altai-Sayan mountain area: the Altai and Mongolian Altai physical-geographical regions. The Altai region includes the following provinces: Charysh-Bashelak, Bukhtyrma-

Ubi, Markakol, Katyn-Terekty, Chulymshan, and Ukok-Shui; while the Mongolian Altai includes the Tabyn-Bogda-Ola-Khovda and Achitnurs-Ölgii physical-geographical provinces. In this study, the Markakol region is considered as part of the Southern Altai region. Since 1997, the former Markakol area has been integrated into the Kurshim district, which is now called the Kurshim district.

In order to evaluate the territorial-recreational system of Southern Altai, located in the transboundary area, modern complex assessment methods for the tourist-recreational potential based on geographical research are becoming increasingly relevant. Among these methods, the importance of Geographic Information Systems (GIS) is significant. GIS is a comprehensive information system that ensures the collection, storage, processing, visualization, and dissemination of geographic data in space (Longley et al., 2021).

The research work utilizes GIS technology to develop innovative methods for creating maps of the territorial-recreational potential of Southern Altai, aimed at determining the ecological condition of the area. The term "innovation" was introduced into economic sciences by American economist and sociologist J. Schumpeter. The innovative method used in this study is based on the methods proposed by A.M. Berlyant (Berlyant, 1988, 1997; Kraak et al., 2020), V.A. Chervyakov (Chervyakov, 2005, 1998; Foody et al., 2006; Gartner et al., 2018; Janelle et al., 2003; Simangan et al., 2023), and further developed by A.N. Dunec (Dunec, 2011; Zoltan et al., 2016), D.A. Dirin, E.P. Krupochkin (Dirin et al., 2014; Geneletti et al., 2013; García-Hernández et al., 2017; Nepal et al., 2002; UNEP-WCMC, 2023; Minghini et al., 2019; Sehra et al., 2017). This work introduces new approaches to the creation of tourism and recreational specialization sectors and recreational maps using GIS technology.

Since the Southern Altai is a transboundary region, the research focused on evaluating one of the factors of the tourist and recreational potential - its unique and attractive locations, or *natural monuments* (geological, hydrological, and other landmarks) preserved with their small biological diversity (such as reserves, etc.).

The assessment of the natural-recreational systems potential in the region was carried out in several stages by scientists from the Geography Faculty of Altai State University (Barnaul) (Rotanova et al., 2014).

For this purpose, cartographic and textual materials obtained from published or archival sources were used. Additionally, in the initial phase of evaluating the tourist and recreational potential, field research conducted between 2015 and 2024 played a crucial role in data collection and analysis. The use of monitoring in key areas of the Katon-Karagai, Kurchum, and Markakol natural-recreational regions in Southern Altai was suggested, and data was collected for each operational territorial unit. Thus, this information became the basis for GIS cartographic integration.

Operational Territorial Units (OTUs) refer to areas covered with a one-dimensional, trapezoidal-shaped operational grid, convenient for conducting cartometric work and transferring the obtained data onto map sheets.

2. Materials and methods

In the Southern Altai transboundary region, the assessment of recreational potential was based on the map titled "Protected Natural Areas and Objects of the Altai Region", with a scale of 1:100,000, developed by specialists from the Water and Environmental Issues Institute (Barnaul). This map was used to evaluate tourism and recreation in the functioning and planned specially protected natural areas (SPNAs). Later, in ArcGIS software, the map was georeferenced to its primary geographical coordinates (edited by Rotanova et al., 2002).

In the next stage, an operational grid with parallel trapezoidal cells was overlaid on the primary map of the Southern Altai region. The operational grids are designed to be convenient for transferring the collected data onto map sheets.

The size and dimensions of the Operational Territorial Units (OTUs) can vary. Most often, a rectangular (trapezoidal) operational unit with latitude and longitude coordinates was used. The size

of the cells was determined based on the research tasks and scale. To optimize regional studies, the cell size was designed to range from 2x2 km to 10x10 km (Dirin et al., 2014).

To assess the accuracy and reliability of the obtained data on the geometric and topological characteristics of OTUs, numerous calculations and experiments were conducted. As a result, it was recommended to use hexagonal operational units with a size of 5 km, as they represent the accessibility of objects along pedestrian (excursion) routes within an average one-day span. During the creation of OTUs, the principle of equivalency was applied (explained in geographic terms), meaning that when determining the properties of a specific object, it was deemed optimal to define its neighboring space (Krupochkin et al., 2012).

To optimize regional spatial analysis and improve the accuracy of data interpretation, hexagonal operational territorial units (HOTUs) with a size of 5×5 km were adopted. This specific resolution was chosen after comparative tests with other grid sizes (2×2 km, 10×10 km), as recommended by Dirin et al. (2014). The 5×5 km scale strikes a balance between spatial detail and data manageability, particularly suitable for analyzing landscape-level recreational features while avoiding excessive data fragmentation.

The use of hexagonal cells instead of square or trapezoidal units was based on their mathematical and geographical advantages. Hexagons minimize edge effects, provide uniform adjacency (each cell has six equal neighbors), and offer a better approximation of natural phenomena, which tend to be more isotropic in distribution. This makes hexagons particularly effective in regions with varied topography and fragmented accessibility**,** such as the Southern Altai, as they better represent pedestrian and ecological connectivity over the landscape (Birch et al., 2007).

Furthermore, the 5 km size corresponds to the average distance covered by visitors during a one-day excursion**,** making it an ecologically and behaviorally relevant unit for recreational planning. This granularity allows for both local-level interpretation and regional synthesis, ensuring sensitivity to environmental heterogeneity while avoiding overgeneralization.

Afterward, the boundaries of the SPNAs of Southern Altai were identified, digitized, and point objects (natural, water, geological, botanical, and complex monuments) were placed. Separate layers were created for all these point objects and boundaries.

Once the digitization process was completed, the number of monuments in each cell was calculated. In this case, the number of monuments became a specific indicator that described each cell.

To assess the recreational resources of the Southern Altai region, the obtained data were converted into a five-point scale based on the formula (1) proposed by V.A. Chervyakov (1998):

$$B_i = \frac{5(x_i - x_{\min})}{x_{\max} - x_{\min}} \quad (1)$$

Thus, the B_i index played an important role in the development of various types of recreation. Therefore, for each selected type of activity, it was necessary to perform a scoring "measure". For this purpose, the B_i index was multiplied by a weight coefficient (K). In this case, the weight coefficient was given a maximum value of 1.0 (representing the presence of various natural monuments).

In the framework of this evaluation, the Bi index served as a pivotal analytical instrument in quantifying the territorial differentiation of recreational suitability for distinct types of tourism and leisure activities. For each delineated recreational typology, a weighted scoring procedure was applied, wherein the Bi index was multiplied by a corresponding weight coefficient (**K**), reflecting the relative significance of contributing landscape features. Notably, a maximum coefficient value of **K = 1.0** was attributed to sites characterized by the presence of unique and diverse natural monuments.

To ensure interpretative clarity and operational applicability, the resultant Bi values were categorized according to the following gradation of recreational potential:

- 1.0–1.9 – *Very Low Recreational Potential*: landscapes exhibiting minimal attractiveness and limited suitability for tourism development;
- 2.0–2.9 – *Low Recreational Potential*: areas with constrained opportunities, often requiring significant infrastructural intervention to support recreational use;
- 3.0–3.9 – *Moderate Recreational Potential*: territories with a balanced combination of natural and infrastructural features that permit seasonal and moderate-intensity recreational activities;
- 4.0–4.4 – *High Recreational Potential*: areas that are inherently suitable for diverse recreational uses, requiring minimal development for tourism facilitation;
- 4.5–5.0 – *Very High Recreational Potential*: ecologically and aesthetically valuable landscapes with exceptional recreational capacity, recommended for strategic planning, conservation prioritization, and sustainable visitor flow management.

Such a classification not only enhances the transparency of the Bi index interpretation but also facilitates its integration into applied spatial planning contexts, including the delineation of functional recreational zones, optimization of visitor carrying capacity, and identification of areas necessitating protective measures within the regional ecological framework.

The evaluation indicators were based on the expert evaluation conducted by A.N. Dunec, D.A. Dirin, and E.P. Krupochkin (Dirin et al., 2014). The expert survey involved independent professionals recognized for their expertise in the field of recreation and tourism. Following extensive discussions, a list of 30 indicators was compiled to evaluate the region's recreational potential. These indicators were grouped into three main categories:

1. Natural factors – 19 indicators reflecting climate, geomorphology, hydrology, biodiversity, and landscape aesthetics;
2. Cultural and natural factors – 3 indicators related to the availability and accessibility of cultural heritage sites integrated into natural settings;
3. Socio-economic factors – 8 indicators reflecting tourism infrastructure, transport accessibility, population dynamics, and employment in the tourism sector.

Criteria for inclusion were based on relevance to recreational attractiveness, availability of consistent data across regions, measurability, and potential impact on tourist experience. Indicators that lacked data consistency, or whose impact on recreational value was negligible, were excluded after expert discussion.

The data sources include national and regional statistical services, open geospatial datasets (topography, land use, climate), field observations, and thematic maps. To ensure data quality, only official or peer-reviewed sources were used, and the information was cross-validated by independent experts.

To assess the relative importance and interaction of indicators, we applied the Hierarchical Analysis Method (HAM), which uses pairwise comparisons to derive weights based on expert judgment. Each indicator was rated on a standardized scale from 1 to 9, enabling the transformation of qualitative assessments into quantitative scores. The derived weights reflect both the direct and indirect contribution of each factor to the overall recreational potential.

Expert evaluations were processed using the Expert Choice software, which supports consistency checking and automated ranking. This process ensured the scientific reliability and reproducibility of the assessment results (Dunec, 2009).

The result of applying such a method is the analysis of many discussions and the identification of optimal methods. The hierarchical analysis method ensures precise and accurate determination of indicator calculations. Thanks to specially prepared questionnaires, experts identified all important indicators. The data from the questionnaire were entered into the Expert Choice program in automatic mode.

Each indicator, measured with a score (B_i), was determined using the following formula (2):

$$B_i^1 = B_i \; x \; k \qquad (2)$$

In this case, *k* is the coefficient of measurement obtained from the results of the expert questionnaire.

A final score was given for each cell based on the calculations performed.

The creation of the synthetic map of the region's tourist and recreational potential is based on the methodology proposed by B.C. Tikunov (1997) (Tikunov, 1997). According to B.C. Tikunov (1997), a synthetic map is the result of the combination of several indicators, which collectively represent natural objects on the map. In this study, the term “several indicators” refers to the natural-recreational potential, including natural monuments such as geological, hydrological, archaeological, and other types of landmarks.

To synthesize various indicators, integral characteristics were calculated, meaning the evaluation of the future of the studied region and key areas for tourism development, based on the indicators assessed. The evaluation models for creating synthetic maps should be organized in a hierarchical order, ensuring the territorial integrity of recreational regions. This algorithm allows for the acquisition of unified synthetic characteristics of territorial units based on the evaluation criteria and their assessment based on these values.

As the final phase of the study, Grid isoclines were plotted – the surface map of the natural-recreational areas of Katon-Karagai, Kurshim, and Markakol was created. As a result of this study, interesting and unique natural objects in the South Altai, as well as protected areas (EPA), were identified (Figure 1).

Field research in the South Altai natural-recreational areas identified several natural landmarks between 2015 and 2018, which enhance the region's tourism potential. Many of these sites have not been included in public information sources.

3. Results

The total number of operational territorial units in the natural-recreational areas of the South Altai was covered by 80 cells. Each of these cells had distinct features for identifying various natural monuments in the region. Among them, unique natural sites in the natural-recreational areas were highlighted (Table1).

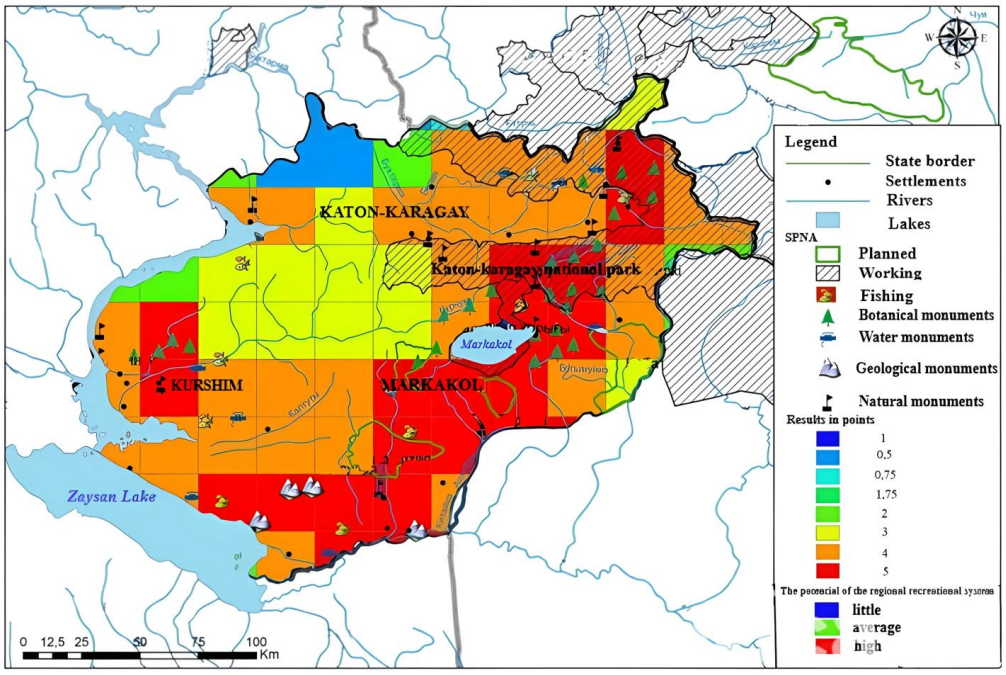

Figure 1. Map of the Assessment of the Natural-Recreational Potential of Protected Natural Areas Compiled by the author based on the studied data

In the South Altai region, the natural-recreational areas distinguished by the number of natural monuments (geological, hydrological, and other types of monuments), which stand out among protected natural areas (PNA), include the Katon-Karagai Natural National Park area, the Markakol Reserve area, and the southwestern part of the Kurshim district, where numerous natural monuments (geological monuments, such as Kiyn-Kerish, Kyzyl-Kerish No. 1, 2) are located.

Table 1. Assessment of the Natural-Recreational Potential of the South Altai Region

Studied Operational Territorial Units (OTU)	**Location Coordinates**	**Weight Coefficient (Presence of Various Natural Monuments)**	$\frac{5(x_i - x_{\min})}{x_{\max} - x_{\min}}$		**Natural Monuments (Geological, Hydrological, etc.), List of Protected Areas (PAs)**
			B_i	B_i'	
1	2	3	4	5	6
Kurchum RA					
OTU №55	85°7'56,001"E 48°32'7,933"N	1.0	$\frac{15}{5}$	3	Kalzhyr Gorge, Kalzhyr Planned Protected Area (PA)
OTU №62	84°16'42,476"E 48°16'50,351"N	1.0	$\frac{12}{3}$	4	Water Monuments: Kalguty, Confluence of Rivers Monument
OTU №39	83°33'11,49"E 48°48'21,922"N	1.0	$\frac{10}{2}$	5	Monument to Baraq Batyr, Hydrological Features, Petroglyphs, etc.
OTU №51	83°56'58,852"E. 48°30'57,614" N	1.0	$\frac{15}{3}$	5	Moynak Petroglyphs, Kurchum River, Spring of Jumakhan Kasymjanuly, etc.
OTU №72	84°36'13,879"E 48°6'18,302"N	1.0	$\frac{20}{4}$	5	Geological Monuments: Kiyn-Kerish, Kyzyl-Kerish №1, Kyzyl-Kerish №2
Katon-Karagay RA					
OTU №13	85°51'16,761"E 49°30'7,292"N	1.0	$\frac{9}{3}$	3	Yazevy Waterfall, Yazevy Lake
OTU №33	85°38'27,826"E 49°1'8,536"N	1.0	$\frac{12}{4}$	3	Katon-Karagay Nature Museum, Katon-Karagay NP Center
OTU №15	86°39'38,981"E 49°25'23,075"N	1.0	$\frac{15}{3}$	5	Kokkol Mine, Kokkol Waterfall, Katon-Karagay Natural National Park
OTU №24	86°28'5,077"E 49°19'53,446"N	1.0	$\frac{10}{2}$	5	Hydrological: Arasan Waterfall, Rakhman Springs, Rakhman Lake, etc.
OTU №34	85°56'31,352"E 48°59'27,553"N	1.0	$\frac{20}{4}$	5	Berel Mounds, Ak Berel, Katon-Karagay Natural National Park
Markakol RA					
OUT №65	85°24'58,336"E 48°16'56,614"N	1.0	$\frac{9}{3}$	3	Mynshunkyr Muddy Therapeutic Swamp, Kyzyltas Planned PA
OUT №64	84°53'48,329"E 48°21'17,621"N	1.0	$\frac{20}{5}$	4	Kyzyltas Planned PA, Kalzhyr Petroglyphs, Kalzhyr River
OTU №58	86°18'35,731"E 48°35'3,615"N	1.0	$\frac{16}{4}$	4	Kaba Planned PA, Bugimuiyz Water Monuments

OTU №74	85°23'24,407"E 48°3'47,434"N	1.0	$\frac{20}{4}$	5	"Ashutas" Geological-Paleobotanical Natural Monument, Black Irtysh
OTU№46	86°2'51,243"E 48°53'11,208"N	1.0	$\frac{10}{2}$	5	Markakol Reserve, Markakol Nature Museum, Austrian Road, etc.

When considering the ecological condition of the natural and recreational areas of South Altai, it is crucial to maintain ecological balance in the region's specially protected natural areas and efficiently utilize its recreational potential. Each natural unit of South Altai is characterized by its unique ecological conditions. The division of the region into 80 cells allows for research that identifies the specific ecological characteristics of each natural site. The evaluation of ecological conditions in these cells reveals that natural monuments are not only significant for recreational purposes but also for their ecological importance.

The unique natural sites and monuments located in the South Altai region, including geological, hydrological, and other natural monuments, are of great ecological value. The ecological conditions of the Katon-Karagay Natural National Park and the Markakol Reserve ensure the preservation of diverse ecosystems. These areas are rich in biological diversity and serve as key centers for maintaining ecological stability. The high level of preservation of the natural wealth and ecological value of these areas depends on the correct distribution of tourist load. To prevent ecosystem changes in these natural monuments, it is essential to conduct ecological monitoring, scientific research, and continuous environmental protection measures in the protected areas.

Geological monuments located in the southwest of the Kurchum district, such as the Kyiyn-Kerish and Kyzyl-Kerish stones, are clear evidence of the region's geological history and natural geological processes. The ecological condition of these sites contributes to the preservation of the unique natural phenomena they represent. However, the impact of tourist flows and human activities on such exceptional natural monuments can lead to a disruption of ecological balance. For example, rock degradation or damage to the surrounding ecosystem could occur. Therefore, it is necessary to implement an ecological monitoring system in these areas, which should include measures for the protection of geological monuments and the monitoring of the ecological condition of plant and animal life.

Currently, the ecological condition of natural-recreational areas is largely related to the development of ecotourism. Ecotourism has both positive and negative effects: on the one hand, it can contribute to the economic development of the region and provide financial support for nature conservation activities; on the other hand, the overuse of natural resources can lead to the destruction of ecological values. In this regard, it is essential to establish a sustainable management system to preserve the ecological potential of regions during the development of ecotourism (Chlachula et al., 2021).

To preserve the ecological condition of the protected areas in South Altai, several key measures need to be implemented. Firstly, efforts should be made to raise ecological awareness and provide information, helping local communities and tourists develop an ecological culture. Secondly, it is necessary to promote scientific research and develop an ecological monitoring system for nature conservation. Thirdly, by introducing new concepts for the development of ecotourism, the possibility of maintaining the ecological balance of natural areas should be enhanced (Mammadova et al., 2022).

In conclusion, the natural and recreational potential of South Altai is closely linked to the region's ecological condition. Comprehensive ecological measures must be adopted to protect natural monuments and ecosystems. Only in this way can the region's biodiversity and natural values be preserved, ensuring the harmonious development of ecotourism and nature conservation.

4. Discussion

As a result of research conducted on the ecological and recreational potential of South Altai's specially protected natural areas, an integrated image of the interaction between natural, historical-cultural, and socio-economic factors was formed, identifying opportunities for sustainable tourism development and the preservation of unique ecosystems. Cartographic materials at a 1:100,000 scale, remote sensing satellite data, field survey results conducted between 2015-2024, and a large geodatabase based on nature reserves were created. These materials allowed for the detailed reconstruction of the boundaries of protected areas and the identification of all significant natural monuments, including geological structures, hydrological features, and areas with high botanical or historical-cultural value.

For the systematization of the area, a hexagonal grid with a cell size of 5x5 km was used, which, taking into account the terrain features, was considered suitable for covering the area corresponding to an average daily walking tour. Each cell represented a spatial unit that included quantitative and qualitative indicators: the number of identified monuments, the degree of landscape preservation, the presence of infrastructure, and the level of anthropogenic load. The obtained information was analyzed using a hierarchical method of expert analysis, which allowed for an objective distribution of weighted factors among thirty different indicators. The integral indices calculated based on the five-point scale formed the basis of the map, which clearly delineates the boundaries of areas with varying degrees of recreational attractiveness.

Based on the research results, the South Altai area was divided into 80 hexagonal cells, with each cell assigned a five-point integral index calculated based on 30 indicators. Although the average index ranged between 3.6 and 3.8 points, parts of the Katon-Karagai National Park and the Markakol Reserve showed higher levels, with scores ranging from 4.4 to 4.7 points, making them the most attractive areas in terms of recreation and ecology. The geological monuments of Kiyin-Kerish and Kyzyl-Kerish scored between 4.2 and 4.5 points, placing them in the category of secondary objects in the study. These results are marked as distinctive "red" areas on the map, with an emphasis on prioritizing central monitoring and the development of ecotourism infrastructure in these zones.

The areas of the Katon-Karagai National Park and the Markakol Reserve are clearly visible on the map, with their integral indices surpassing those of other regions. This is due to the diversity of their landscapes - mountainous terrains, valleys, lakes, powerful waterfalls, healing mud springs, and an already established infrastructure capable of accommodating tourist flows. In these areas, historical and cultural values blend harmoniously with natural ones, providing visitors with a unique experience. Local residents' active involvement also plays a crucial role, as tourism becomes both an additional source of income and an opportunity for preserving traditions.

Important conclusions were drawn regarding the geological monuments of Kiyin-Kerish and Kyzyl-Kerish, which have high recreational potential and are made up of ancient crystalline rocks in the form of labyrinths, set against the backdrop of alpine meadows. These monuments are located far from main roads, and tourist traffic is correspondingly low. However, for tourism development, it is necessary to establish monitoring platforms and organize tourist routes. Conducting scientific and educational excursions with experienced guides not only promotes ecotourism but also helps prevent damage to the ecosystem.

The scientific significance of the study is as follows: the integrated approach combining traditional cartographic methods and the latest GIS technologies allows for a comprehensive understanding of the conditions for year-round tourism in mountainous regions.

The practical value is as follows: the developed map can serve as a working tool for the management bodies of reserves and national parks. It helps identify areas that require priority monitoring, as well as regions where the expansion of tourism infrastructure can take place without disrupting ecological balance.

However, the methodology used also has some limitations. Firstly, new routes and projects established after 2024 were not taken into account, so the map data must be regularly updated. Updating information through satellite monitoring and voluntary expeditions should be the next key

direction of the study. Secondly, there is insufficient data on socio-economic indicators, such as tourism revenue and the economic well-being of residents, as collecting reliable statistics proved to be challenging. In the future, sociological surveys and economic calculations are recommended in this area.

Further detailed development of infrastructure elements requires special attention. Currently, the analysis only covers major facilities, such as museums, information centers, and road junctions. For better tourist navigation and visitor comfort, aspects such as campsites, parking lots, sanitary facilities, and safe crossing points over mountain rivers should be considered. Including these parameters in the next versions of the methodology will allow for more accurate load predictions and optimization of tourist flows.

In this regard, it is important to conduct large-scale efforts to raise ecological literacy among residents and city guests. The environmental education program should include open lessons in schools, interactive lectures at information centers, and the participation of volunteer naturalists. Such activities not only foster a responsible attitude towards nature but also promote the development of project culture, which will allow the younger generation to demonstrate their initiative in preserving natural heritage in the future.

A promising direction is the digitalization of tourism services. Developing a mobile app that integrates interactive maps, routes of varying complexity, GPS navigation, guides for flora and fauna, as well as a feedback system between users and administrators, will improve service quality and allow for the collection of additional data based on the user's preferences. Having access to such data will enable more accurate forecasting of seasonal peaks and the need to introduce temporary visit restrictions.

Furthermore, the study highlights the importance of interregional and international cooperation. As the Southern Altai is a border area with Russia and Mongolia, it is rich in natural sites extending beyond national borders. Harmonizing protection standards and coordinating tourist routes can help create a transboundary eco-zone that attracts large flows of tourists while contributing to the preservation of a unified ecosystem. A pilot project to combine efforts is already being discussed in the scientific community, and the proposed results could serve as a basis for developing joint programs.

The conducted research can be said to form a reliable analytical basis for the strategic management of the protected natural areas of Southern Altai in the context of ecological tourism. The methods used have proven their effectiveness and versatility, showing that the integration of modern geospatial technologies, expert knowledge, and field observations enables a more comprehensive understanding of the complex system of relationships between humans and nature in the environment. The next step is continuous data updates, expanding the range of indicators, and deepening socio-economic analysis, which will not only preserve unique ecosystems but also ensure sustainable tourism growth that benefits all stakeholders.

To maintain the relevance and practical value of the results of the assessment of the recreational potential of the region in the long term, it is necessary to ensure continuous updating of the data. The effectiveness of the Bi index and the corresponding assessment categories largely depends on the level of updating of spatial and socio-ecological data. In this regard, it is recommended to form a structured data management system that combines remote sensing technologies, seasonal field studies, and mechanisms for data exchange with local environmental and tourism institutions. Such an approach will allow for continuous improvement of the assessment model in response to changes in recreational conditions (land use, infrastructure, visitor flow).

In addition, it is necessary to consider the socio-economic consequences of tourism in the South Altai region in a broader sense. Although the development of recreational infrastructure contributes to the growth of jobs, the development of local entrepreneurship, and an increase in regional income, some of its negative effects are also observed. In particular, social tensions may arise among the local population due to the unequal distribution of income, instability of seasonal employment and an increase in the flow of tourists. Given these contradictions, it is important to

develop balanced development strategies that support economic diversification and preserve the integrity of local culture and society.

Specific policy recommendations should also be developed to reduce the negative impacts of tourism on environmentally sensitive recreational areas in the region. These include functional zoning, visitor restrictions, environmental education, and promotion of sustainable use of nature. In addition, it is necessary to introduce flexible management plans, developed with the participation of local communities, accompanied by continuous scientific monitoring. Such an integrated approach will allow for the sustainable development of tourism while preserving natural and cultural heritage.

5. Conclusion

In conclusion, the results of the integrated maps created through digital assessment with GIS demonstrate a promising future for the development of the tourism and recreation sector in the studied area. Both active (water tourism, rafting, fishing, etc.) and passive (recreation by the water) types of tourism can be developed in the region.

The practical significance of the study lies in the fact that, based on this methodology, the first electronic map of the natural monuments of the studied area was created, and an attempt was made to comprehensively assess the region’s cultural and historical potential.

The results of the assessment of the ecological and recreational potential of the protected natural areas of Southern Altai clearly demonstrate the importance of preserving the region’s natural wealth. This study identifies the need to ensure the future protection of the natural monuments and the ecological status of the 80 grid cells of the region. Using GIS technology, the structure of these areas was clarified. The features and ecological conditions of the natural sites in each grid cell were carefully studied, which in turn allows for the creation of effective strategies for the protection of natural and recreational resources (Chernykh et al., 2021).

In this study, several methodological approaches were applied to assess the natural and recreational potential of the Southern Altai region. Initially, the results of field research conducted between 2015 and 2018 were used, based on specialized cartographic and textual materials. Then, data was collected and analyzed for each operational territorial unit (OTU) using GIS technology. During this process, operational grids were applied, and digital maps of geographical coordinates and natural sites were created. For the assessment, various ecological and recreational indicators were defined based on expert opinions and converted into a five-point scale. The accuracy and reliability of the methods were verified through several experimental calculations, resulting in an effective evaluation of the region's recreational potential, considering various natural monuments (Kulikova et al., 2023).

The natural monuments in the Southern Altai region, including geological, hydrological, and other natural landmarks, are of significant ecological importance. These monuments, particularly located in protected areas such as the Katon-Karagai National Park and the Markakol Reserve, serve as key centers for biodiversity conservation. These natural monuments ensure the preservation of ecological stability, the protection of natural resources, and the effective use of their recreational potential. These areas are not only ecologically significant but also attract great interest for ecotourism and scientific research. Therefore, it is crucial to strengthen monitoring and protective measures for their ecological status (Vancura, 2016).

Overall, a comprehensive approach is necessary to preserve the ecological status of the natural and recreational areas of Southern Altai. This approach will ensure a balance between the development of ecotourism and the protection of natural resources. Measures such as ecological monitoring, scientific research, ensuring the sustainable development of ecotourism, and fostering the ecological culture of local communities will contribute to maintaining the ecological stability of the region. Additionally, considering the positive and negative impacts of ecotourism, targeted management systems and regulatory acts are required to maintain ecological safety.

In conclusion, the ecological and recreational potential of Southern Altai’s protected natural areas is extremely high. To preserve the ecological value and importance of the region’s natural monuments and ecosystems, sustainable management, scientific research, and the development of

ecotourism should be approached in a comprehensive manner. These measures will help preserve Southern Altai's natural wealth and prevent disruptions to the region's ecological balance. Only in this way can the ecological sustainability of the region be ensured.

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7. Author Contributions

Conceptualization, methodology development, supervision – N.Zh.; methodology development, software and project management – N.Zh.; methodology development, research material provision, supervision – N.R.; methodology development, research material provision, supervision – A.Ye.; text preparation and editing – N.A.; analysis – N.Zh., N.A.

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Оңтүстік Алтайдың ерекше қорғауға алынған табиғи аумақтарының табиғи-рекреациялық әлеуетін бағалау

Назгуль Женсикбаева, Нургуль Рамазанова, Айгуль Егинбаева, Назерке Амангелды

Аңдатпа. Оңтүстік Алтайдың ерекше қорғауға алынған табиғи аумақтарының экологиялық-рекреациялық әлеуетін бағалау экологиялық зерттеулер үшін маңызды бағыт болып табылады. Бұл мақалада Оңтүстік Алтай аумағындағы қорғалатын табиғи аудандардың экологиялық жағдайы мен рекреациялық мүмкіндіктері зерттелген. ГАЖ технологиясының көмегімен аймақта кездесетін табиғи, тарихи және мәдени ескерткіштердің электронды картасы құрастырылып, қорғалатын аумақтардың экологиялық жағдайы мен табиғи ресурстарының сақталуына баға берілді. Оңтүстік Алтайдың ерекше қорғалатын табиғи аумақтарының экологиялық және рекреациялық әлеуетін бағалаудың өзектілігі туризмді дамытумен қатар бірегей экожүйелерді сақтау қажеттілігімен түсіндіріледі. Зерттеуде 1:100 000 масштабтағы картографиялық материалдар, жерсеріктік қашықтықтан зондтау деректері, далалық маршруттардың нәтижелері (2015-2024 жж.) қолданылды. Біріншіден, ArcGIS бағдарламалық кешенінде қатаң қорғалатын аймақтар мен нүктелік нысандардың шекаралары (геологиялық, гидрологиялық, ботаникалық ескерткіштер) цифрландырылды, содан кейін бүкіл аумақ 5х5 км өлшемді 80 алтыбұрышты ұяшықтарға бөлінді. Әрбір ұяшық үшін атрибуттар бойынша деректер жиналды: ескерткіштердің саны мен түрі, инфрақұрылымның қолжетімділігі, антропогендік әсер ету дәрежесі. Бұл зерттеудің маңызды нәтижесі ретінде, табиғи ескерткіштерді анықтау және оларды қорғау мақсатында ерекше мәні бар аудандар көрсетілді. Катон-Қарағай табиғи ұлттық саябағы, Марқакөл қорығы және Күршім ауданындағы геологиялық ескерткіштер, атап айтқанда Қиын-Керіш және Қызыл-Керіш тастар, экологиялық тұрғыдан қорғауды қажет ететін нысандар ретінде қарастырылады. Бұл аудандардағы табиғи ескерткіштер мен табиғи ресурстар экологиялық тұрақтылықты қамтамасыз ету және аймақтың рекреациялық әлеуетін сақтау үшін ерекше маңызға ие.

Түйін сөздер: ерекше қорғалатын табиғи аумақ, ГАЖ, операциялық аумақтық бірліктер, мемлекеттік табиғи қорық, мемлекеттік ұлттық табиғи парк, мемлекеттік табиғи қаумал, рекреация, туризм.

Оценка природно-рекреационного потенциала особо охраняемых природных территорий Южного Алтая

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Аннотация. Оценка экологического и рекреационного потенциала особо охраняемых природных территорий Южного Алтая является важным направлением экологических исследований. В данной статье исследуется экологическое состояние и рекреационные возможности охраняемых природных территорий Южного Алтая. С помощью ГИС-технологии была составлена электронная карта природных, исторических и культурных памятников, встречающихся в регионе, дана оценка экологического состояния охраняемых территорий и сохранности природных ресурсов. Актуальность оценки экологического и рекреационного потенциала особо охраняемых природных территорий Южного Алтая объясняется необходимостью сохранения уникальных экосистем наряду с развитием туризма. В исследовании представлены картографические материалы в масштабе 1: 100 000, данные спутникового дистанционного зондирования, результаты полевых маршрутов (2015-2024 гг.). Для начала в ArcGIS были оцифрованы границы строго охраняемых зон и точечных объектов (геологические, гидрологические, ботанические памятники), а затем вся территория была разделена на 80 шестиугольных ячеек размером 5х5 км. Для каждой ячейки были собраны данные по атрибутам: количеству и типу памятников, доступности инфраструктуры, степени антропогенного воздействия. Как важный результат данного исследования были выделены районы, имеющие особое значение, с целью выявления памятников природы и их защиты. Катон-Карагайский природный национальный парк, Маркакольский заповедник и геологические памятники Курчумского района, в частности, Кийн-Кериш и Кызыл-Кериш рассматриваются как объекты, требующие экологической защиты. Природные памятники и природные ресурсы в данных районах имеют особое значение для обеспечения экологической устойчивости и сохранения рекреационного потенциала региона.

Ключевые слова: охраняемая природная территория, ГИС, операционные территориальные единицы, государственный природный заповедник, государственный национальный природный парк, государственный природный заказник, рекреация, туризм.