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COMMUNICATION

Assessment of the Tourism Potential of the Mountain Ecosystems of Kyrgyzstan

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ABSTRACT

The relevance of the work lies in its relation to the sustainability of mountain ecosystems of Kyrgyzstan in the context of growing tourist activity. The study area belongs to mountain ecosystems, which are highly sensitive to anthropogenic loads, and with the increase in this impact, the main tourism resources can be lost. The main objective of the work is to create a scientific basis for sustainable development of the studied region with minimal impact on the natural environment. The sustainability of the underlying surface was analyzed considering altitude, orography, climatic and seasonal changes, terrain slope, and other factors. Dominant plant species characteristic of different altitudinal levels were taken into account. An assessment of the level of degradation of the studied ecosystems was provided, based on field methods, by creating "transects," which allow the identification of different levels of sustainability under anthropogenic influences. Based on the degree of degradation, the sites were ranked into six degrees of degradation. For this purpose, plant and soil samples were collected to assess the tourist load. To determine the potential for the development of tourist flows, their one-time throughput capacity was calculated, based on the total number in a specific area. Measures were proposed to regulate the flow of vacationers throughout the mountainous region. For these purposes, the maximum number of tourists per daily flow was determined. A methodology was developed for assessing mountain tourist zones, which is important for further regulation of the flow of vacationers, and will allow for the

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sustainable development of these zones in the future.

***Keywords**:* Ecosystem; Sustainability; Mountain; Potential; Anthropogenic Factor; Tourist Flow; Terrain Slope; Climate

1. Introduction

There is a Threshold Capacity Model, which is based on the idea that ecosystems can only withstand tourism impacts up to a certain threshold. Once this threshold is exceeded, the environment deteriorates rapidly (e.g., soil erosion, loss of vegetation, loss of biodiversity). This problem has synergistic properties in mountainous conditions.

Kyrgyzstan, possessing unique natural resources and diverse ecosystems, faces serious challenges associated with climate change increasing tourist flow. At the same time, the forest territories of the country play a key role in maintaining ecological balance, but their condition is deteriorating due to increasing anthropogenic factors.

According to the State Agency for Environmental Protection and Forestry of the Kyrgyz Republic (2023), the country's forest fund includes juniper, broadleaf, and coniferous forests that occupy significant areas. However, climate change leads to a 30–40% reduction in tree growth and an increase in pest infestations (such as bark beetles) [1].

The considered territories have their own tiered vegetation zones, listed as follows:

- **Lower zone (800–1200 m)**: floodplain forests threatened by deforestation and pollution.
- **Middle zone (1200–2000 m)**: broadleaf forests, unique on a global scale.
- **Upper zone (2000–3000 m)**: juniper forests, susceptible to overgrazing and fires.
- **High mountain zone (3000–3500 m)**: coniferous forests threatened by tourism and pests.

As shown by our studies, the sustainability of the natural environment decreases with increasing altitude and anthropogenic impact. For example, the flora of the Kurshab River basin is one of the promising areas of East Alai, which, with skillful and rational use, can serve as an additional source for the pharmaceutical industry and tourism development [2].

According to data from the Border Service of the State Committee for National Security of the Kyrgyz Republic, over 8 million tourists visited Kyrgyzstan in 2024. The main countries of origin for tourists are Uzbekistan, Kazakhstan, and Russia [3]. The increase in tourist flow creates additional pressure on natural resources.

The highest influx of tourists occurs during the summer months, with most visitors coming to the Issyk-Kul region, confirming its status as the country's main tourist region [4].

2. Research Methods and Methodology

At present, various studies have been conducted to determine the recreational capacity of the territories used, but a universal methodology for this indicator has not developed, since the territories used are distinguished by their stability, and Kyrgyzstan, with its mountainous structure, is particularly sensitive to anthropogenic influences [5].

To assess, it is necessary to take into account the physical and geographical features based on the area, relief, orography, etc., some scientists supplement these parameters with social parameters, such as the behavior of tourists, their attitude to nature management, which are supplemented by environmental issues, such as the impact on flora and fauna [6]. All this is provided by the peculiarity of each object used.

The methodology for calculating recreational capacity based on the area of the recreational zone involves using the area of the territory and coefficients that account for various factors [7]:

$$RE = A \cdot K \quad (1)$$

where:

RE – recreational capacity (number of tourists),

A – area of the territory (in hectares),

K – recreational capacity coefficient (number of tourists per hectare), which depends on the type of locality, accessibility, and other factors.

The calculation of the permissible load on the ecosystem can be calculated by considering the impacting factors [8]:

$$DL = EC \quad (2)$$

where:

DL – permissible load (number of tourists),

C – total capacity of the ecosystem (for example, the number of individuals of a certain species or forest cover area),

E – impact coefficient (for example, the number of individuals or units of vegetation that may be lost per tourist).

The calculation of recreational capacity based on ecological factors takes into account the influence of anthropogenic factors on the sustainability of natural ecosystems [9]:

$$RE = A \cdot K_{ec} \cdot K_{soc} \cdot K_{eco} \quad (3)$$

where:

RE – recreational capacity,

A – area of the territory,

Kec – ecological sustainability coefficient (considers the condition of ecosystems),

Ksoc – social perception coefficient (considers the opinion of the local population and tourists),

Keco – economic coefficient (considers economic aspects).

The most advanced method is the use of GIS technology for spatial assessment of recreational zones.

The basic principles for assessing the impact of tourist activity on ecosystems can be described by the following formula [10]:

$$I = N \times D \quad (4)$$

where:

I – impact on the ecosystem,

N – number of tourists,

D – average impact per tourist on the ecosystem (for example, visiting a tourist zone) [11].

Below is a proposed methodology for determining the recreational potential of mountain areas (**Figure 1**).

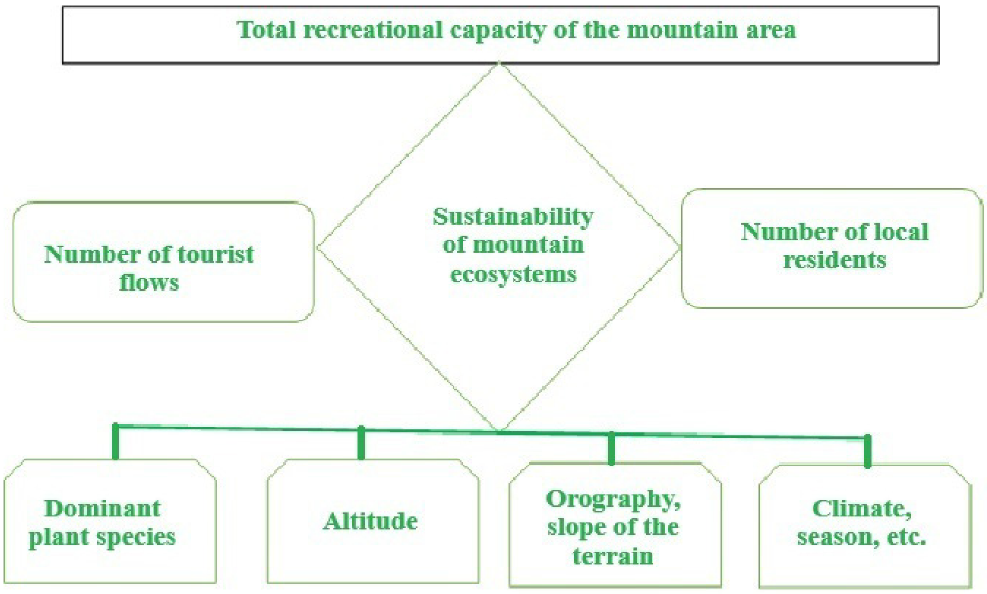

Figure 1. Methodology for assessing the sustainability of mountain ecosystems [12].

The restoration of the environment is slow, the moderate climate promotes restoration, but degradation under anthropogenic load occurs faster than natural restoration, and it takes years to be restored. In summer, the load is maximum, with trampling of the vegetation cover and kindling of fires. Restoration occurs in spring and autumn, when the least activity of the tourist flow is observed. Therefore, the assessment of the renewal of the vegetation cover was conducted at the end of the spring season to establish the reality of their sustainability.

The aim of this study is to assess the recreational potential of the territories used in Kyrgyzstan.

In this case, our tasks included determining the sustainability of the landscapes affected by the tourist flow; developing a method for calculating the recreational potential for mountain areas; and proposing ways of sustainable development of tourism in mountain regions.

The object of the study comprises the mountainous areas of Kyrgyzstan, which have recreational attractiveness for the development of tourism.

3. Materials for Discussion

The tourist potential that distinguishes Kyrgyzstan from other recreational centers is its mountain landscape, represented by forest ecosystems, occupying 5.7 % of the country's territory. These territories sometimes act as zones of anthropogenic impact, which are the most noticeable for economic development [13,14].

Taking into account, these features the attractiveness of natural components comes first for nature users, but the emphasis is on obtaining financial benefits, and possible risks of loss of these territories are left in the background. We propose to take as a basis the susceptibility of these landscapes, which should be the main criterion for determining the tourist potential (**Figure 2**).

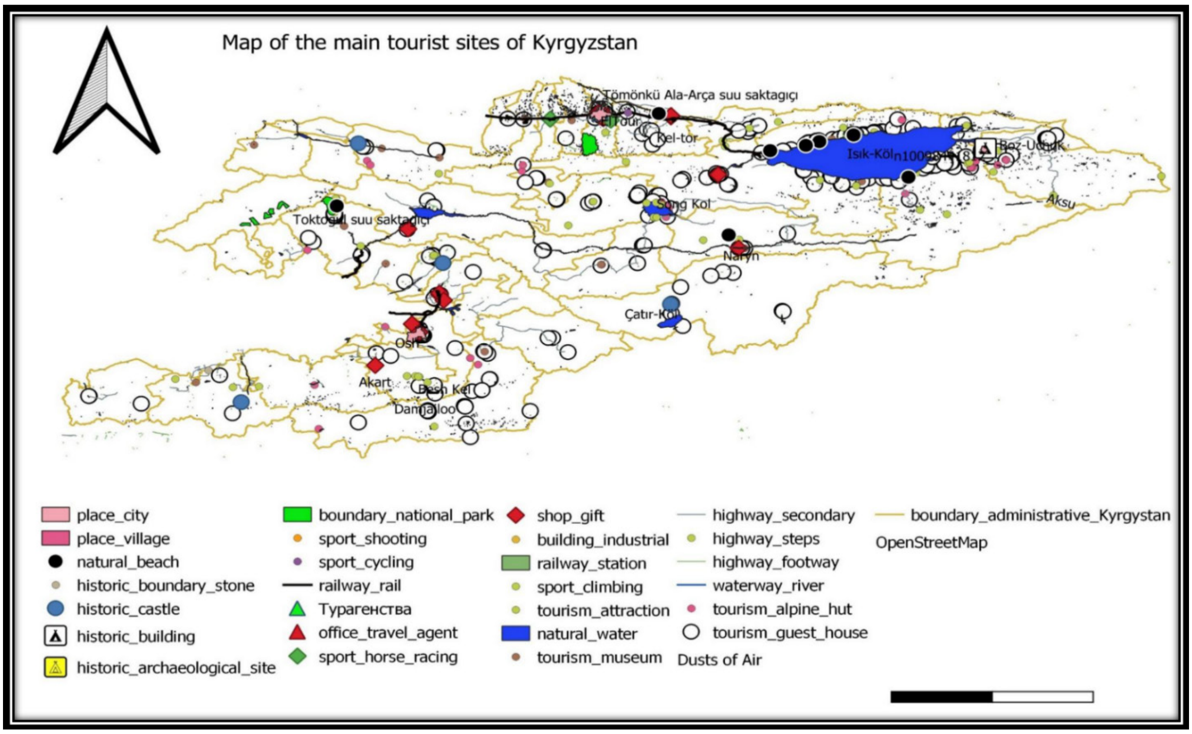

Figure 2. Map of the main tourist sites of Kyrgyzstan (compiled by the authors).

To assess the sustainability of the recreational areas used, fieldwork was carried out, providing for an analysis of the state of the vegetation cover under anthropogenic impact [15]. In this case, 45 experimental sites were identified, with different altitude zones, terrain slopes, and orographic structure.

The assessment methods were carried out using the "transect" method [16], which involved a five-stage vegetation digression. The dimensions of the "transect" were a square section of 1x1 m, and the state of vegetation depression, prevailing dominants confined to certain altitude zones, the level of area coverage by certain plant species, and other factors were analyzed (**Figure 3**).

Figure 3. The process of assessing the degradation of the study area (compiled by the authors).

We have classified six degrees of degradation to assess the sustainability of the areas used (**Figure 4**). The reliability of the results obtained was determined by the sustainability of the dominant plants in these areas.

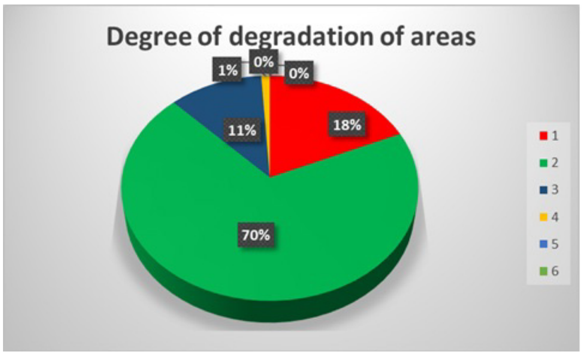

Figure 4. Results of the assessment of the stability of the studied areas.

According to the experimental plots, the following degrees of condition were identified (**Table 1**):

1. Untouched nature – absence of anthropogenic influence, the degree of degradation is equal to zero;
2. Excellent – the vegetation is in good condition, with no degree of degradation;
3. Excellent – the condition of the vegetation is good, but there are small areas of degradation;
4. Good - the state of the vegetation has a noticeable impact, but at the same time the main dominants experience sustainable development;
5. Slightly degraded - the basic structure of the plants is preserved, but they experience some degree of degradation;
6. Degraded - the state of the main dominants confined to such altitudinal zones is to a greater extent suppressed, and disturbance processes have begun in the area under study.

In this case, the soil condition, including temperature, granulometric composition, pH, and humus content, was determined, taking into account the orographic structure and seasonal characteristics of the area.

Overall, the main fieldwork was conducted in areas ranging from 1800 to 3800 m above sea level.

The data on the stability of vegetation in terms of changes in the slope of the terrain are evident, as an increase in the angle of the underlying surface corresponds to a higher degree of degradation increases. The data for this indicator are shown in **Figure 5**.

Table 1. Results of field work based on the analysis of "transections".

Degradation Scale Number	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5	Condition 6
% degradation	18	68	11	1	0	0

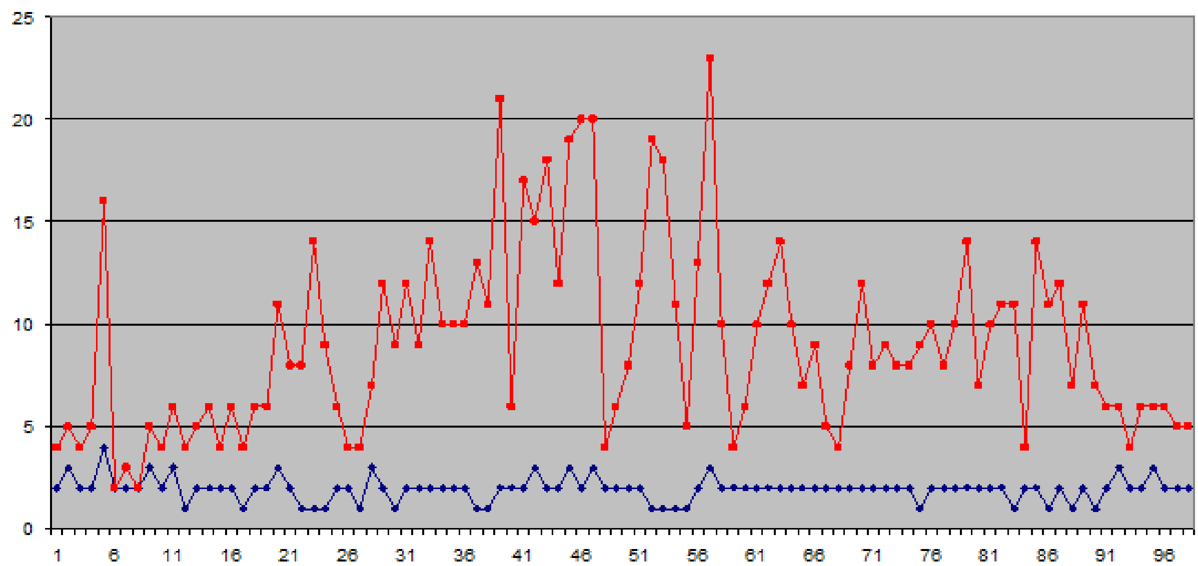

Figure 5. Stability of vegetation cover under anthropogenic impact taking into account the terrain slope: horizontal – sample number, vertical – terrain slope (compiled by the authors).

Based on this method, the load pressure was determined to be 8.76 g/cm^2 for the mixed-grass areas of the study area [17]. The average body mass of a person (Q) is 75 kg.

$$g = \frac{\frac{Q}{2}(per.)}{S_f} = \frac{\frac{75000}{2}}{184} = 203,8 gr/sm^2 \quad (2)$$

By distributing the load on two legs with an area of 184 cm^2, the load of a person at rest can be calculated [17].

A moving person acts on 1/3 of the foot and therefore [17]:

$$g_m = \frac{\frac{Q}{2}}{\frac{1}{3}S_f} = \frac{\frac{75000}{2}}{184/3} = 611,4 rp/CM^2 \quad (3)$$

If we assume that the optimal soil resistance (g_s) is 8.86 g/cm², then the excess of the human mass over the soil resistance will be [17]:

$$\frac{g_m}{g_s} = \frac{611.4}{8.76} = 69.8 \approx 70 \ pa3 \quad (4)$$

When calculating the area required for a vacationer, it is also necessary to take into account the slope of the terrain - φ and weather conditions - p, which will undoubtedly affect the stability of the areas used. Then the final formula will look like [17]:

$$s = \varphi pn \frac{g_s}{Q} \ (gr/person) \quad (5)$$

where: φ is a coefficient that takes into account the slope of the terrain;

- for 0 < α < 3; then φ = 1.0;
- for 3 < α < 10; then φ = 1.4;
- at 10 < α < 15; φ = 1.6;
- for α > 15; φ = 1.8;
- P = 1, in clear weather;
- P = 2, in rainy weather;
- n = 70 – coefficient taking into account the excess of a person's mass over the resistance of the soil.

According to these methods, the average area per visitor calculated, which is 300 m^2.

Taking into account the peculiarities of the stability of the territories, we calculated the recreational capacity for high-mountain regions in Kyrgyzstan [18].

The territories located between 1800 m and 3200 m above sea level, considered suitable for visiting tourists, were taken as a basis. The results are presented in **Table 2**.

Table 2. Area of high mountain areas suitable for tourism.

Region	Zone Area 1800-3200 m (km^2)	Area Suitable for Tourism (km^2)
Issyk-Kul	25800	7740
Narynskaya	31500	9450
Osh	14500	4350
Jalal-Abad	16800	5040
Talasskaya	9600	2880
Chuiskaya	8000	2400
Batken	8500	2550
Total	114200	34910

According to **Table 2**, the area suitable for tourism in Kyrgyzstan is 34,910 km^2. If we take into account that 10% of the territory is favorable for tourists, then the area of use for tourism in mountainous areas is 3491 km^2.

If we take into account that the required area per tourist is 300 m^2, then the total one-time load (PE) is:

PE = 3491 × 10000000 ÷ 300 = 11636667,

that is, the mountainous territories of Kyrgyzstan can generally accommodate a given number of tourists while maintaining stability.

The regulation of the flow of tourists, which varies with the season and time of day, remains unresolved.

It is recommended that this amount be distributed over the entire period of the tourist season, while favorable in the territory of Kyrgyzstan are from June to September [19], and 70–80% of the days are favorable for walking [20], during these days you can expect 90–100 good days [21], and in certain valley areas this figure fluctuates within 100–120 days. Taking this into account, it is necessary to distribute the total one-time tourist load across individual days, in which the daily capacity of the studied territory is:

PEdn. = 11636667 ÷ 120 = 96792 people.

The above number is the limit of the number of vacationers in the mountainous territory of Kyrgyzstan, which should be regulated at the annual level, which is agreed with each region taking into account its area. There is a need to create a single online system for monitoring the number of tourists who are registered by holiday homes, boarding houses, and travel companies. This will not only enable management of the tourist impact on mountain ecosystems, but also create conditions for transparent determination of the economic efficiency of tourist zones.

4. Conclusion

Tourism plays a key role in the economy of Kyrgyzstan, but its development must be balanced with the need to preserve natural resources. Sustainable management of the tourist flow is an important step towards ensuring the environmental safety of the country.

The conducted research allowed for a comprehensive assessment of the recreational potential of the mountain ecosystems of Kyrgyzstan taking into account ecological, geographical and anthropogenic factors. The obtained data confirm that the sustainability of natural landscapes decreases with increasing altitude, slope and intensity of tourist flow. The identified areas with varying degrees of degradation of vegetation cover emphasize the need to introduce a strict system of monitoring and regulation of tourism.

The developed methods for calculating recreational capacity and analyzing the impact of seasonality allow for a well-founded approach to planning tourist loads, contributing to the conservation of natural resources during active tourism development. It is important that further development of the tourism industry aligns with sustainable development — with the participation of the state, the scientific community, and local communities. Only in this case will mountain ecosystems be able to preserve their biodiversity and serve as a source of environmental and economic benefits for future generations.

The choice of correct decisions on the definition of recreational potential can reduce the loss of utilized resources and determine the further sustainable development of the tourism potential of this region. Their consideration depends on the political will of state bodies capable of regulating the rational use of natural resources in mid-mountain zones.

Author Contributions

All authors made significant contributions to this study. B.K. developed the study concept; A.T. and N.M.k. developed the methodology; K.S. and A.B. contributed to data collection and resources; B.K. supervised the data; A.D. prepared the initial draft, and A.T. and K.S. reviewed and edited the manuscript. E.T. supervised the study. All authors read and approved the final manuscript.

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All data supporting the reported results provided within the manuscript. Additional data made available upon reasonable request.

Conflict of Interest

All the authors also declare that there is no conflict of interest in relation to the research, authorship, and publication of this study.

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