LANDSCAPE ZONING OF THE GUBA DISTRICT: A CLUSTER-BASED APPROACH TO TOURISM POTENTIAL

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DOI: 10.59423/gnr.2025.77.95.006

Article history:

Received: February 05, 2025
Dispatched for revise:
April 15, 2025
Accepted: June 10, 2025

Keywords:

landscape zoning,
tourism potential,
ecotourism,
Geographic Information Systems,
cluster,
active recreation

Abstract

This article examines the landscape zoning of the Guba district of Azerbaijan with a focus on its tourism and recreational potential. Considering the abundance of natural and cultural resources in the region, the study aims to identify promising zones for the development of tourism infrastructure through the use of cluster analysis and geographic information systems (GIS). The main objective is to classify the natural landscapes of the Guba district and optimize their utilization for various types of tourism. The research results show that effective territorial planning and management can contribute to the sustainable development of the tourism sector and improve the quality of life for local residents.

1. Introduction

In recent decades, tourism has become an important factor in the socio-economic development of many regions around the world [4, 6]. However, the growing number of tourists necessitates the adoption of a special approach to planning and the rational use of natural resources in order to minimize negative environmental impacts and ensure sustainable development. One of the key tools for achieving these goals is landscape zoning, which makes it possible to identify geographically homogeneous areas for the optimal utilization of their tourism and recreational potential [2]. This study focuses on the Guba district of Azerbaijan, rich in natural and cultural resources that can serve as a basis for tourism development.

The main objective of the study is to carry out landscape zoning of the Guba district using cluster analysis in order to identify the most promising areas for the development of tourism infrastructure and the provision of tourism services. The work relies on modern methods of geographic information systems (GIS) and spatial analysis, which makes it possible to obtain more accurate and well-substantiated results.

The Guba administrative district (area 2,610 km²), located in the north of the Republic of Azerbaijan, represents a unique combination of natural and cultural resources. With its picturesque landscapes, diverse flora and fauna, and rich cultural heritage, the district possesses significant tourism and recreational potential. Effective landscape planning is a key factor in developing the tourism sector, which can contribute to regional economic growth, improve the quality of life for local residents, and preserve the environment. However, to fully realize this potential, it is necessary to implement innovative approaches to landscape planning that integrate modern technologies, sustainable development principles, and active involvement of the local community [10].

Landscape zoning is one of the key methods of spatial planning and is used to classify natural areas based on their physical and geographical characteristics [1]. The purpose of this process is to identify and describe landscapes on the basis of their internal unity and specific features, in order to enable more effective planning and use of territories for various purposes, including tourism. Zoning makes it possible to manage territories efficiently and determine their most appropriate use depending on the intended objectives [9]. In the context of tourism, zoning helps identify areas most suitable for different types of recreation,

ranging from active tourism to ecotourism [11]. For this reason, it is necessary to define and classify the natural landscapes of the Guba district in order to determine the most promising zones for tourism activities and to optimize tourist routes and recreational areas.

For the landscape zoning of the Guba district, we consider it advisable to use a cluster-based approach, which makes it possible to identify homogeneous areas with similar natural conditions and recreational opportunities. Creating clusters for zoning landscapes according to their tourism and recreational potential offers significant advantages and is theoretically well-founded. Clustering enables more effective organization and management of territorial units, taking into account their specific characteristics and potential, which is particularly relevant in the field of tourism and recreation.

The cluster approach to zoning applied in this study involves grouping landscapes based on the similarity of their natural characteristics (for example, relief, climate, vegetation). Geographic information analysis methods play an important role in this process, allowing for the creation of accurate maps and spatial models [15]. In addition, anthropogenic factors - such as the impact of tourism on the environment - are taken into account, enabling more precise planning of infrastructure development in harmony with natural conditions.

2. Methods

To conduct the landscape zoning, cluster analysis methods and geographic information systems were used. The K-means clustering algorithm was selected to classify the natural areas of the Guba district [5] based on similarities in climatic and relief conditions. The analysis considered parameters such as elevation above sea level, average annual temperature, precipitation, and vegetation cover. For visualizing the clustering results and creating maps, the ArcGIS platform was employed, which made it possible to present the data as thematic maps with clearly delineated landscape zones.

An important element of the study was the examination of both anthropogenic and natural factors influencing the tourism and recreational potential of the areas. Resource assessment included an analysis of the accessibility of zones for tourists as well as potential environmental threats associated with increased tourist flows. The obtained results were divided into several clusters, each characterized by a specific potential for tourism development.

3. Analysis and Discussion.

Stages of Landscape Zoning. Given the relevance and objectives of the study, as well as the rich diversity of natural conditions in the Guba district and the need for their rational use, the implementation of landscape zoning becomes a central element of this work. This process is aimed at identifying territorial features, grouping them according to natural and anthropogenic characteristics, and developing approaches for their optimal utilization in tourism and recreational activities.

1) Analysis of landscape complexes: Using collected data (geological and climatic conditions — temperature, precipitation, relief, soil and vegetation types, anthropogenic factors, and existing recreational zones) to divide the territory into clusters, each characterized by a specific landscape type (e.g., nival zones, alpine zones, mountain-forest zones). Identification of the unique features of each cluster (for example, snow cover in nivation zones, rich biodiversity in mountain-forest zones).

2) Application of cluster analysis: Using methods such as K-means or hierarchical clustering to identify clusters. Determining the number of clusters based on natural characteristics and tourism-recreational potential. It is possible to distinguish 4–5 clusters for the Guba district.

3) Creation of cartographic models: Mapping the clusters using GIS technologies to visualize the zoning and identify areas suitable for tourism activities.

4) Analysis of the tourism and recreational potential of clusters: Evaluation of each cluster in terms of suitability for various types of tourism (ecotourism, active recreation, cultural tourism). Identification of priority zones for the development of infrastructure and tourist routes.

The Guba administrative district, with an absolute elevation range from 100 m to 4,191 m, is characterized by a diversity of natural landscapes, including nival, subnival, alpine and subalpine meadow zones, oak-hornbeam and beech-hornbeam forest zones, as well as post-forest meadow-steppe, steppe, and arid sparse forest landscape complexes (Figure 1).

- Nival landscape complexes occupy the peaks and near-peak parts of mountain ridges within the Guba administrative district and are located above 3,800 meters in elevation. They are characterized by the climate of alpine tundra, where snow cover persists year-round. The annual sunshine duration is approximately 2,200 hours, with total solar radiation and radiation balance values of about 140–145 and 20 kcal/cm²,

respectively. The average annual temperature ranges from -5 to -10°C, and summer temperatures rarely exceed 5°C. The total average annual precipitation reaches 600–900 mm, mostly in the form of snow [13, 14].

Vegetation is primarily composed of mosses and lichens, as well as rare high-altitude species adapted to harsh conditions. Soil-vegetation cover is absent due to intense weathering processes occurring here, especially frost weathering [8]. This landscape type is mostly represented by bare rocks, stone accumulations, and in some places, modern snowfields and glaciers.

• Subnival landscape complexes: Located below the nival zone within an elevation range of 3,200 to 3,800 meters, they are characterized by a reduced snow cover compared to the nival areas. The average summer temperature is about 10°C, while winter temperatures drop to -8°C. Humidity is high, around 80%, as the snow melts slowly and remains for 6 to 8 months. Vegetation is often sparse and fragmented; some alpine meadow species - flowering plants - may be present. The soil cover consists of fine earth formations that fill rock cracks and depressions [3].

• Alpine meadow high-mountain landscape complexes develop between absolute elevations of 2,800 to 3,100 (3,200) meters. These unstable and highly differentiated subtypes of high-mountain landscapes form fragmented areas of varying widths and lengths, depending on the amplitude of the current relief, slope gradient, and slope exposure. The relief of the alpine mountain-meadow belt, especially in the Gudyalchay river basin, is characterized by rockfalls, scree slopes, talus deposits, landslides, and, in places, solifluction [12]. The climate is cold, with a relatively high average annual precipitation of 800–1,000 mm, falling as rain and snow; snow cover lasts for 4–5 months. The total solar radiation is about 140 kcal/cm², and the radiation balance is 35 kcal/cm² [16].

The alpine zone is distinguished by denser grassy vegetation because snow melts earlier here, creating favorable conditions for meadow plants to grow. These meadows are covered with a variety of grasses (such as meadow clary, fescue, and bluegrass) on weakly developed mountain-meadow peat soils, and occasionally sod soils.

• Subalpine meadow landscapes: The subalpine zone is located at elevations below the alpine zone (2,200–2,800 m) and is characterized by more favorable climatic conditions for the development of productive landscape complexes. The climate in the subalpine zone is somewhat milder. The average annual air temperature ranges from 2 to 6°C, and precipitation falls predominantly in summer (600–800 mm per year). These conditions contribute to a longer growing season and denser vegetation. The vegetation is dominated by tall meadow plants, including grasses such as bluegrass and clover. Subalpine meadow landscapes are rich in biodiversity and serve as natural pastures for local livestock.

• Mountain-forest landscape complexes occupy a significant area within the elevation range of 600–700 m to 2,200–2,300 m. The total forest area comprises approximately 30% of the entire district. This type of landscape is characterized by climates such as cold with dry winters (at elevations of 1,700–2,200 m) and moderately warm with evenly distributed precipitation in the lower mountainous areas. The annual solar radiation ranges from 120 to 135 kcal/cm². Depending on oroclimatic conditions, the forest belt exhibits considerable diversity. The most productive forest stands consist of oak-beech, hornbeam-beech, and oak forests. The mountain-forest complex of the Guba administrative district represents an important ecological and economic resource, supporting both the local population and the region's biodiversity.

• Mountain-forest-steppe and meadow-shrub landscapes develop at elevations ranging from 500–600 m to 900–1,100 m. The terrain in these landscapes is relatively gently sloping and slightly dissected. The average annual air temperature varies from 14°C at lower elevations to 6–10°C at higher elevations within this range. The average annual precipitation is 300–600 mm [14].

Within these landscapes, the soil-vegetation cover is well developed. Common soil types include residual mountain-brown post-forest soils and mountain-brown forest soils. The vegetation cover mainly consists of oak, hornbeam, ash, hawthorn, dogwood, blackberry, pear, and others, while the herbaceous layer includes feather grass, needle grass, several species of wormwood, and more.

1. Landscape zoning makes it possible to identify areas with uniform natural characteristics such as relief, climate, vegetation types, and soils. Clustering, in this context, groups such areas together to form specialized tourist zones, enabling development that takes their specific features into account. For example, mountain areas and coastal zones may attract different categories of tourists.

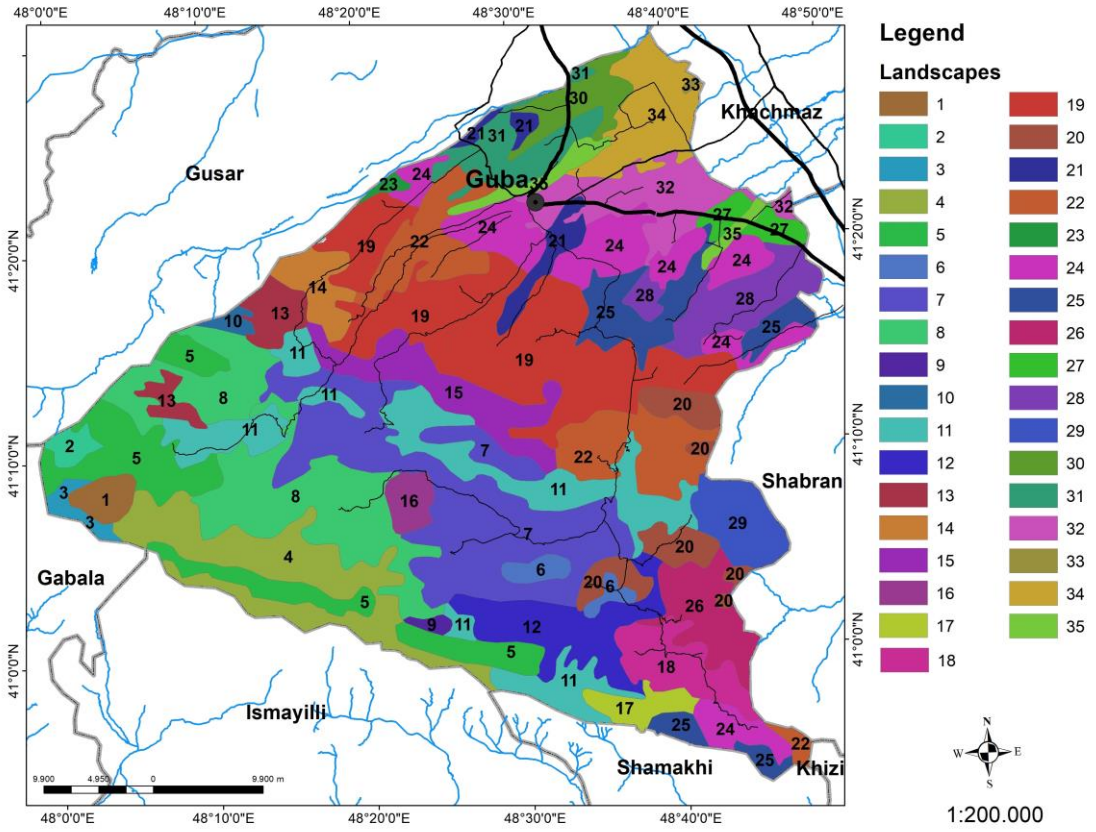

Figure 1. Landscape map of the Guba administrative district

Legend:

I. Nival landscapes

1. Moderately and partially weakly dissected steep slopes of the high mountains with rocky-nival landscapes, lacking soil and vegetation cover.

2. Intensively dissected high-mountain slopes with partial glacial cover, lacking soil and vegetation cover, with actively developing erosion-denudation processes.

II. Subnival landscapes

3. Moderately and weakly dissected, moderately inclined mountain slopes with exposed parent rocks and a disturbed soil and vegetation cover.

4. Strongly and moderately dissected rocky and talus-colluvial mountain slopes, lacking soil and vegetation cover, with patchy development of alpine meadows on rock ledges.

5. Intensively and moderately dissected steep, precipitous, rocky high-mountain slopes with subnival-rocky landscapes, lacking soil and vegetation cover.

III. Alpine meadows

6. Weakly dissected narrow watersheds and gentle mountain slopes with dense turf cover dominated by clover, chamomile, and mixed grasses.

7. Intensively dissected, very steep, sometimes precipitous mountain slopes with alfalfa and clover on eroded mountain-meadow soils.

8. Strongly dissected steep mountain slopes with alfalfa and mixed grasses on eroded mountain-meadow soils.

9. Undissected high synclinal plateaus with clover and mixed grasses on poorly developed eroded mountain-meadow soils located on rock ledges.

10. Strongly dissected rocky slopes with areas of alpine meadows on thin, severely eroded mountain-meadow soils.

1. Moderately dissected steep mountain slopes with alpine vegetation on eroded mountain-meadow soils.

IV. Subalpine meadows

13. Weakly dissected, gently sloping intramontane (basin) plains with alfalfa, savory, timothy grass, and buttercup on turf mountain-meadow soils.

14. Moderately dissected landslide slopes of mountains with alfalfa, savory, and mixed grasses on thin mountain-meadow soils.

15. Moderately dissected, moderately sloping mountain slopes with alfalfa, timothy grass, savory, and buttercup on turf-mountain-meadow soils.

16. Moderately dissected sloping, sometimes steep, stony-talus mountain slopes with subalpine meadows on mountain-meadow turf soils.

17. Moderately dissected, moderately sloping landslide-talus slopes with sparse alfalfa, savory, and grass–mixed herb vegetation on mountain-meadow turf soils.

V. Beech–hornbeam and oak–hornbeam forests of the mid-mountain zone

18. Moderately dissected, moderately sloping mountain slopes with beech-hornbeam and partially oak–hornbeam forests on brown mountain–forest soils.

19. Moderately and weakly dissected, gently sloping terraced slopes of the mid-mountain, partly low-mountain zone, with beech-hornbeam forests on brown mountain-forest and brown soils.

VI. Forests and forest-shrublands of the low-mountain zone

20. Moderately dissected, gently sloping mountain slopes with oak-hornbeam forests and forest–shrublands on mountain-brown soils

21. Weakly dissected landslide-prone river valleys with oak, hawthorn, cornelian cherry, blackberry, and sagebrush-forb vegetation on mountain-brown forest soils.

22. Moderately dissected, moderately sloping mountain slopes with sparse oak, hornbeam, and ash on brown mountain–forest soils.

VII. Forest-steppe, steppe, and meadow-steppe landscapes of the low- and mid-mountain zones.

23. Moderately dissected landslide-prone slopes of intermountain basins with post-forest steppes, barberry and wild rose shrubs, as well as forb vegetation (including sagebrush) on meadow-steppe soils.

24. Weakly dissected landslide-prone slopes with sparse oak–hornbeam forests, shrubs, and forbs on brown mountain–forest soils.

25. Intensively dissected steep slopes with oak-hornbeam forest-shrublands and shrubs of blackberry, wild rose, and thorn on eroded mountain-brown soils.

26. Weakly dissected gentle slopes with sagebrush-beardgrass forb vegetation, and in places oak-hornbeam forest-shrublands, on well-developed dark chestnut soils.

VIII. Arid-denudation landscapes of the low-mountain zone and intermountain basins.

27. Moderately dissected, moderately inclined slopes of the arid-denudation low-mountain zone with forest-shrublands and shrubs of oak, pear, thorn, wild rose, blackberry, and cotoneaster on dark chestnut soils.

IX. Plain arid-forest, forest-shrub, and shrub-steppe landscapes

28. Slightly dissected, gently sloping convex plains with shrubs and wormwood–feather grass steppes on post-forest brown and chestnut soils, heavily transformed into orchard-plantation agro-landscapes.
29. Slightly dissected, gently sloping alluvial-proluvial plains with wormwood-feather grass and forb-shrub dry steppes on steppe-modified brown soils, transformed into orchard-plantation agro-landscapes.

X. Post-forest steppe landscapes of denudation–accumulation plains

30. Strongly dissected elevated plains with wormwood–grass steppes and shrub thickets of blackberry and wild rose on mountain–brown soils.

31. Slightly dissected elevated plains with oak, wild rose, blackberry, and shrub thickets on mountain-brown soils.

32. Slightly dissected, gently sloping accumulative plains occupied by shrub steppes on alluvial-meadow and meadow-forest soils.

33. Slightly dissected, gently sloping accumulative plains with post-forest steppes and shrubs on alluvial-meadow and meadow-forest soils.

34. Undissected flat plains and alluvial fan surfaces with shrub and meadow-steppe vegetation on alluvial-meadow soils.

XI. Intrazonal landscapes of accumulative plains.

35. Moderately dissected river terraces with meadow–swamp vegetation on alluvial–meadow soils.

2. Defining functional zones and their intended use. Landscape zoning using a cluster-based approach simplifies the process of identifying functional zones (recreational areas, resort zones, nature parks, etc.). This is important for developing tourism products that are integrated into the natural environment without causing significant disturbance. Each cluster can be specifically adapted for a certain type of tourism, ranging from ecological to active recreation [7]. This approach enables functional zoning that takes into account both ecological and cultural features.

3. Considering resilience and load capacity of landscape complexes. The cluster-based approach in landscape zoning helps assess the ecological capacity of different areas and establish limits of use, thereby minimizing the impact of tourism on landscapes. Using clusters allows for a more accurate determination of which territories can withstand intensive use and which should be protected from mass tourism.

4. Promoting the development of landscape tourism and recreation. Landscape zoning using clusters facilitates the creation of recreational areas that incorporate diverse natural and cultural elements, providing tourists with unique experiences. For example, routes can be designed to connect different clusters, offering visitors immersion in various types of landscapes within a single trip. This approach makes it possible to provide diversity while reducing the load on any particular site.

5. Conservation and management of natural heritage. Clusters make it possible to identify and designate areas of high natural value that require a special approach to management and preservation. This is particularly relevant in regions where landscapes contain rare or unique ecosystems, landscape monuments, or important natural sites. The use of environmentally friendly technologies in the construction of hotels and tourist infrastructure can minimize environmental impact. The application of solar panels, waste recycling systems, and water-saving technologies will con-

tribute to the sustainable development of the region.

The cluster diagram represents a scheme reflecting the interrelationships between the main directions of landscape zoning for tourism purposes (Figure 2). Each cluster denotes a distinct thematic area, which integrates with others through shared tasks, goals, and methods aimed at the sustainable development of the region.

Criteria and methods form the foundation for both scientific and practical analysis, defining approaches to zoning territories based on their geographic, ecological, and resource characteristics. These methods are closely linked to the fundamental principles of landscape zoning, which include the objectives and theoretical basis for analyzing the natural and cultural features of areas. The theory, in turn, is supported by practical examples, enhancing its applied significance.

Mass tourism, with its impact on natural and cultural sites, creates challenges such as conflicts and climate change. Overcoming these issues requires legal regulation to ensure the sustainability of the industry. The local population plays a crucial role in this process, as their involvement in management and planning allows for more

An important aspect is anthropogenic landscapes, which demonstrate the impact of human activity on nature. These correspond with the typology of tourist landscapes, including natural, mixed, and human-altered zones, thus opening opportunities for their use in tourism.

Historical and cultural heritage holds significant value for tourism, as sites of historical and cultural importance become key attractions. This direction is closely linked to ecotourism, which promotes the conservation of natural resources and is especially relevant for areas with high biodiversity.

The successful development of tourism is impossible without high-quality infrastructure, including roads, recreational areas, and hotels. Infrastructure ensures the accessibility of territories and their comfortable use, which is an important condition for the successful implementation of tourism initiatives.

The Guba administrative district, endowed with unique natural and cultural resources, encompasses all the aforementioned aspects. This region has the potential to develop as a tourism hub, including mass, cultural, and ecological types, which underscores the importance of a comprehensive approach to its development.

Thus, all clusters are interconnected through a common goal - the creation of a sustainable tourism system that takes into account natural, cultural, and social factors, ensuring the harmonious development of the region.

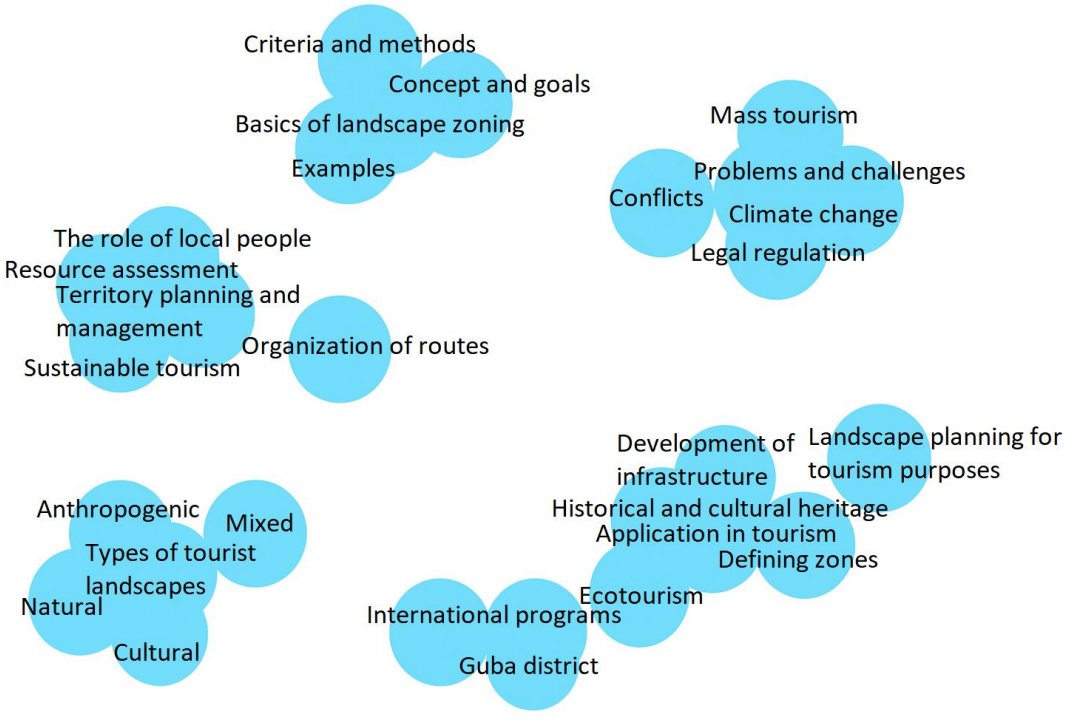

Figure 2. Cluster-based landscape zoning for tourism purposes

Table 1

Classification of zones of the Guba district by tourism potential

Cluster	Altitude above sea level (m)	Average annual temperature (°C)	Precipitation (mm)	Vegetation type	Tourism and recreational potential
1	200-500	10-15	300-400	Floodplain meadow-steppe	Water tourism, hiking
2	500-1000	10-15	400-600	Forest-steppe	Ecotourism, cycling routes
3	600 (800)-1800 (2200)	2-10	600-800	Forests and shrubs	Active tourism (trekking)
4	1800-3000	-5-0	600-1000	Subalpine and alpine meadows	Ecotourism, mountaineering, skiing
5	3000+	-10-5	600-900	Subnival–nival zones	Extreme tourism (ski touring

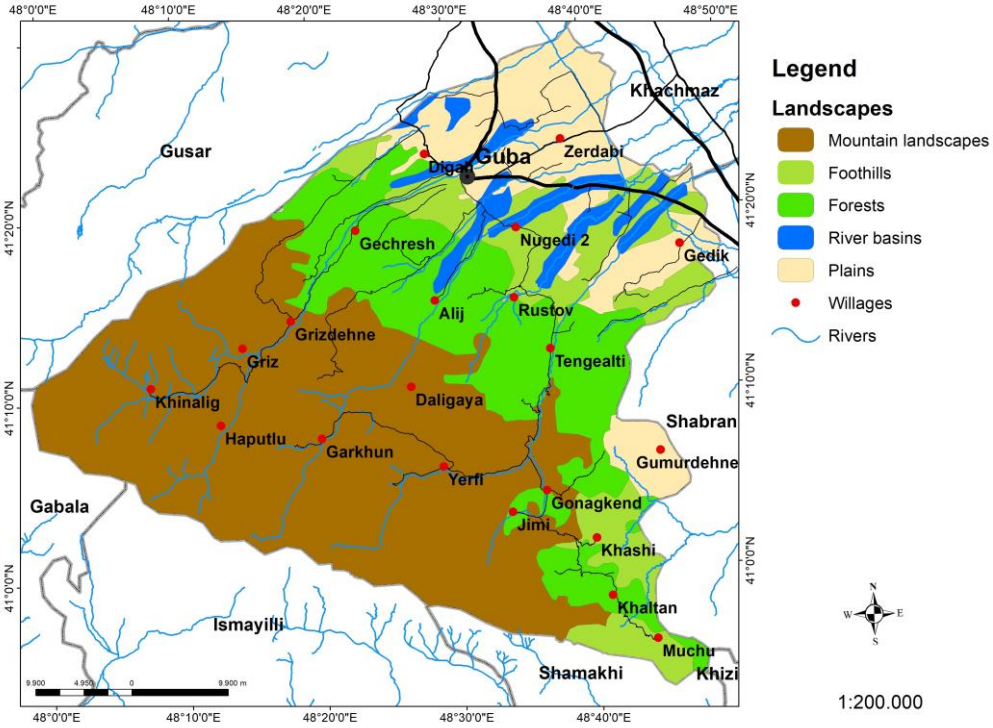

Figure 3. Map-scheme of landscape and tourism zoning

Landscape zoning is a key tool for identifying the potential of territories and ensuring the sustainable development of tourism. This approach makes it possible not only to determine the most promising directions for tourism but also to minimize possible negative impacts on ecosystems. It contributes to the effective planning of natural resource use and the development of infrastructure that fits harmoniously into the natural environment while meeting the needs of tourists. Based on landscape zoning, a map of the Guba district was created, assessing the tourism potential of various areas. This map (Figure 3) clearly illustrates zones with diverse tourism opportunities and the necessary measures for their sustainable development.

1. Mountain landscapes with ecotourism potential

High-mountain areas featuring alpine and subalpine meadows, rocky peaks, and steep gorges. Suitable for ecotourism, hiking, rock climbing, mountain ascents, and wildlife observation.

Infrastructure: Accessibility may be limited; development of trails, campsites, and informational signage is required.

2. Foothill zones with recreational opportunities

Mid-altitude landscapes combining forests, meadows, and hills, with gentler slopes and mod-

erate climatic conditions. Suitable for family recreation, picnics, camping, cycling tours, and photo tours.

Infrastructure: Requires camping areas, recreational zones, designated picnic sites, and cycling routes.

3. Forest zones for wellness and educational tourism

Dense deciduous forests of oak and beech-hornbeam trees, rich in flora and fauna, with a mild climate. Suitable for wellness retreats, ecological excursions, forest hikes, and berry and mushroom picking.

Infrastructure: Development of eco-trails, signage, small observation decks, and areas for meditation or yoga is needed.

4. Floodplain zones for water-based and rural tourism

Areas along rivers featuring floodplain meadows, lakes, and small water bodies, with fertile soils and marshy sections. Suitable for water recreation, fishing, rural tourism, and bird-watching.

Infrastructure: Requires camping facilities, boat rentals, birdwatching platforms, and farm zones for visitors.

5. Valley zones for agritourism and cultural recreation

Valleys between foothills and mountains featuring agricultural lands with orchards, vineyards, and fields. Suitable for agritourism (visiting farms), excursion tourism (harvest festivals), and ethnotourism.

Infrastructure: Requires the development of agritour routes, tasting areas, ethno-cultural centers, and signage.

This zoning allows for the identification of key areas for tourism development based on the natural and landscape features of the Guba district. However, to achieve sustainable development of tourism potential, it is essential to consider ecological and economic aspects of the tourism sector. Protecting ecosystems is necessary to maintain the natural balance and preserve biodiversity. The design of tourism infrastructure must take ecosystem sustainability into account. For example, in high-mountain areas, it is important to minimize the impact on soil and vegetation by using methods such as building trails with natural materials and creating restricted access zones to allow ecosystem recovery.

4. Conclusion

Landscape zoning of the Guba district using a cluster-based approach enables the identification of zones homogeneous in natural characteristics and the creation of effective tourist routes based on them. This approach fosters a deeper understanding of the region's natural diversity and allows for the development of strategies aimed at sustainable tourism development, focused on minimizing ecological risks and preserving biological diversity.

The results of the conducted study confirm the high importance of landscape zoning for optimizing the tourism resources of the Guba administrative district. The identified landscape clusters provide opportunities for targeted development of tourism infrastructure, including ecotourism and active recreation, which can significantly enhance the region's attractiveness to tourists. However, realizing this potential requires the implementation of innovative approaches in planning and natural resource management, including the active involvement of the local population in the tourism development process. Sustainable use of natural resources, based on scientific methods and modern technologies, will ensure not only economic growth but also the preservation of the unique natural and cultural heritage of the Guba district.

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QUBA RAYONUNUN LANDŞAFT RAYONLAŞDIRILMASI: TURİZM POTENSİALINA KLASTER ƏSASLI YANAŞMASI

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Xülasə. Təqdim olunan məqalədə Azərbaycanın Quba rayonu ərazisində turizm-rekreasiya potensialının landşaft rayonlaşdırılması araşdırılır. Ərazinin təbii və mədəni sərvətlərinin zənginliyi nəzərə alınaraq, tədqiqat işində klaster yanaşması və Coğrafi İnformasiya Sistemlərindən (CİS) istifadə edilməklə turizm infrastrukturunun inkişafı üçün perspektivli sahələr müəyyən edilmişdir. Bu zaman, əsas məqsəd kimi Quba rayonunun təbii landşaftları təsnif edilərək onların müxtəlif turizm növlərinin inkişafı üçün istifadəsinin optimallaşdırması yolları verilir. Tədqiqatın nəticəsi göstərir ki, ərazilərin səmərəli planlaşdırılması və idarə olunması turizmin davamlı inkişafına, eləcə də yerli sakinlərin həyat keyfiyyətinin yaxşılaşdırılmasına töhfə verə bilər.

Açar sözlər: landşaft rayonlaşdırılması, turizm-rekreasiya potensialı, ekoturizm, Coğrafi İnformasiya Sistemləri, klaster, aktiv istirahət.