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Multi-Criteria Gis-Based Modeling Of Ecotourism Potential In The Ohangaron Valley: Integrated Spatial Analysis Of Srtm-Dem, Ndvi, And Viewshed Data

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Abstract: This article provides multi-criterion GIS-based modeling of ecotourism potential in the Ohangaron Valley: SRTM-DEM, NDVI and VIEWSHED integrated spatial analysis the ohangaron Valley has been extensively researched for the further development of ecotourism with a variety of landscapes and rich resources.

Keywords: This article provides multi-criterion GIS-based modeling of ecotourism potential in the Ohangaron Valley: SRTM-DEM, NDtes.

INTRODUCTION:

When discussing the organization of travel into the embrace of nature, the term “ecotourism” is often mentioned. In essence, ecotourism is, on the one hand, a rapidly growing sector in the tourism market, and on the other hand, a system based on the positive interaction between humans and nature. Moreover, it represents an integral component of the tourism infrastructure — not merely a concept, but a distinct and tangible type of tourism. Its impact on the environment can vary, being negative, neutral, or positive, depending on how it is managed.

Ecotourism is widely applied in the modern management of protected areas and national parks. The rapid global growth of this type of tourism is driven not only by the deterioration of environmental conditions, but also by the fact that many popular recreation areas—mountain resorts, warm seashores, plains, and forest zones—are becoming increasingly developed and utilized for tourism purposes.

The Ohangaron Valley occupies the central and southeastern parts of the Tashkent region, lying between 68°50′ and 70°35′ east longitude and 40°40′ and 41°15′ north latitude. The study area extends from the source of the Ohangaron River to its mouth, with elevation decreasing from 3,716 meters to 260 meters above sea level. According to measurements conducted using GIS software tools such as ArcMap, QGIS, and ArcGIS Pro, the total area of the study region covers approximately 6,558 square kilometers (Figure 1)

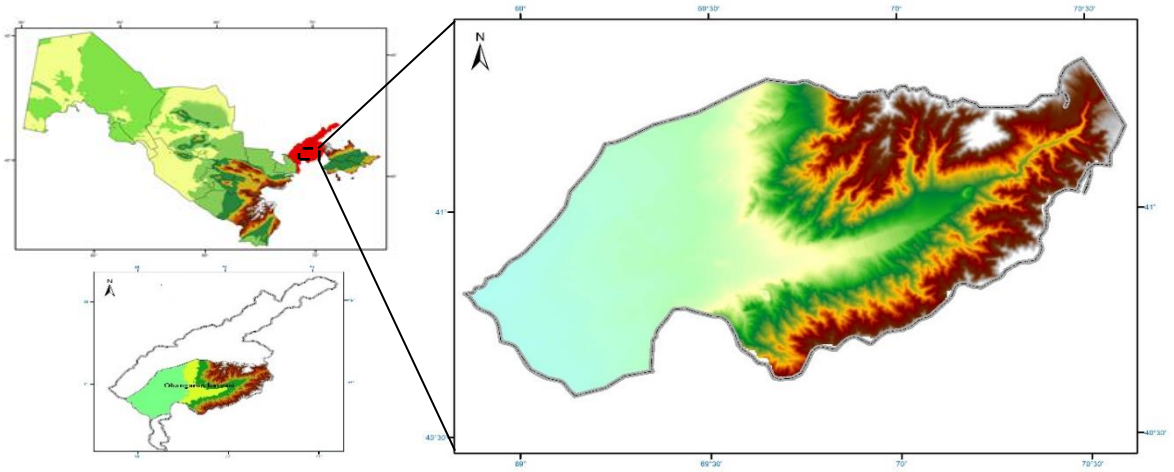

Figure 1. Geographical location of the study area.

The study area is bordered by the Kurama Mountains to the east, the Chatkal Mountains to the northeast, the Chirchiq River Basin to the north and northwest, and the Syrdarya Valley (Dalvarzin Desert) to the south. The region's snow-covered mountains, diverse landscapes, and favorable climatic conditions, along with its national parks, wildlife reserves, rich biodiversity, and ethnic as well as socio-cultural diversity, make it an attractive destination for both domestic and international tourists. Additionally, pilgrimage sites and adventure tourism opportunities further enhance the valley's appeal as a promising ecotourism region.

In terms of its geographical position, the Ohangaron Valley offers favorable conditions for economic and social development. At the same time, its unique natural and geographical location deserves special attention. The valley's relief is highly diverse, consisting of plains, foothills, mountain slopes, and interconnected highlands. The Kurama and Chatkal mountain ranges create distinctive climatic and natural landscapes.

The climate of the valley is sharply continental; however, in the mountainous areas, summers are cool while winters are colder compared to the surrounding regions. Being located deep within the continent and far from seas and oceans, the valley experiences low precipitation, large temperature and humidity variations, short yet rainy springs, and long, dry summers. Various landscape types typical of Central Asia are found within the valley. For instance, the western part consists mainly of sandy, saline, and takyr desert landscapes, while the southeastern plains and foothills are dominated by agricultural (cultural) landscapes. The western fringe, adjacent to the Syrdarya Valley, features oasis-type landscapes characteristic of intensively cultivated regions.

Today, the Ohangaron Valley is considered a region with favorable natural and geographical conditions, strong economic potential, and qualified labor resources for the large-scale development of industrial and agricultural sectors. Based on these advantages, it is essential to ensure the efficient use of natural resources, increase the intensity of irrigated lands, and improve agricultural practices to enhance crop productivity. Furthermore, special attention should be given to producing high-quality, environmentally friendly, and competitive products suitable for the global market.

From a geographical perspective, the Ohangaron Valley is a unique region that encompasses sandy deserts, saline lands, oases, foothill plains, and low to medium-altitude mountains. The distinct natural conditions of the area are also reflected in the economic activities and land use patterns of the local population. The valley's diverse landscape types have served as a key factor in the development of regional specialization and natural-economic sectors. Accordingly, in the mountainous and foothill areas, activities such as animal husbandry, horticulture, beekeeping, rain-fed farming, recreation, and tourism are well developed. In contrast, the plains, consisting of both old and newly reclaimed lands, are primarily used for the cultivation of cotton and grain crops.

The favorable economic-geographical position of the Ohangaron Valley provides excellent opportunities for its socio-economic and cultural development. Its proximity to Tashkent, the most developed city in Uzbekistan, and the compact spatial structure of the area are among the key features of its advantageous location. This factor positively influences the region's economy, ensuring efficient resource utilization and convenient management of its economic activities.

The hydrographic network within the Ohangaron Valley is unevenly distributed. In the plains, rivers and streams are scarce, while in the mountainous areas, where precipitation is relatively higher, the river system is well developed. The water volume, flow

regime, and branching pattern of rivers and streams are directly influenced by the region's geographical conditions. To achieve the research objectives, both primary and secondary data sources were used, including relevant spatial and non-spatial information as well as existing maps. For analyzing topographic characteristics such as Slope and the Topographic Roughness Index (TRI), a 30-meter resolution Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) was utilized.

The assessment and prediction of ecotourism potential were carried out in three main stages:

1. Creation of a geospatial database,
2. Selection and preparation of ecotourism sites, and
3. Verification and interpretation of results (Validation criteria).

In evaluating ecotourism potential, several elements were considered, including site identification, slope, terrain roughness, vegetation cover, drainage, visibility, accessibility, proximity to settlements, altitude, climate, groundwater availability, and distance to lakes. Among these, slope plays a crucial role in determining areas suitable for ecotourism development. Lower slopes are generally preferred for constructing ecotourism facilities, as steeper gradients limit accessibility and increase development challenges. The SRTM DEM data were used to generate the slope layer based on the percentage rise method, with a 30-meter spatial resolution providing detailed topographic analysis for the study area.

$$\text{Slope (percent)} = \frac{\text{rise}}{\text{run}} \times 100.$$

The slope layer was classified into five comfortability classes: very high, high, moderate, low, and very low. These classes respectively cover 76 km², 276 km², 706 km², 1,388 km², and 4,752 km² of the study area. The suitability values were assigned according to the relative importance of each class, where steeper slopes indicate lower suitability for ecotourism development—that is, fewer opportunities for constructing ecotourism facilities—and gentler slopes represent higher suitability (Figure 2)

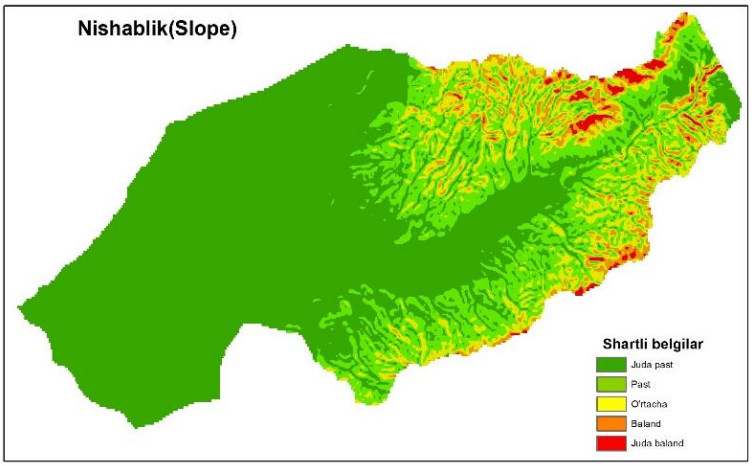

Figure 2. Slope analysis.

The Topographic Roughness Index (TRI) is used to identify and describe the terrain irregularities of the region in greater detail. This index is directly related to ecotourism development, as it plays a crucial role in assessing the ecotourism potential of an area. Areas with high terrain roughness indicate lower suitability for the development of ecotourism facilities due to construction and accessibility challenges, while low-roughness areas are generally more suitable for such development. The SRTM DEM (Digital Elevation Model) data were used to calculate the Topographic Roughness Index. TRI represents a measure of relative topographic position and surface ruggedness, and it was computed based on the SRTM DEM data using the following relationship:

$$\text{TRI} = \frac{\text{SD} - \text{MinDEM}}{\text{MaxDEM} - \text{MinDEM}},$$

Here, TRI represents the Topographic Roughness Index; SD refers to the standard deviation of a 10 × 10 pixel smoothed DEM, while max DEM and min DEM denote the maximum and minimum elevation values within a 10 × 10 pixel window, respectively. The calculated TRI values were classified into four categories: very high, high, moderate, and low. These classes respectively cover 1,029 km², 2,918 km², 2,703 km², and 854 km² of the study area. Areas with high topographic roughness are considered unsuitable for ecotourism infrastructure, whereas low-roughness zones indicate favorable conditions

for ecotourism development (Figure 3).

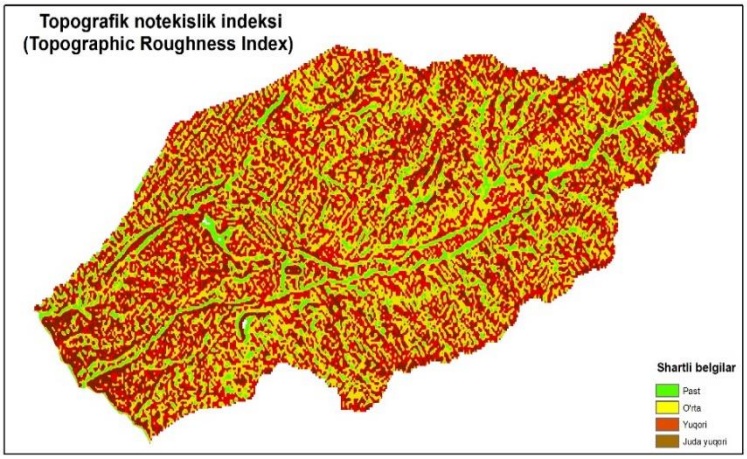

Figure 3. Topographic Roughness Index (TRI) analysis.

There is a positive correlation between ecotourism and vegetation density. Ecotourism encompasses abiotic, biotic, and cultural attractions, among which biotic features—such as biodiversity, wildlife, and natural habitats—are the most essential factors for ecotourism development.

To assess vegetation density, NASA's Landsat 8 satellite imagery was used to calculate the Normalized Difference Vegetation Index (NDVI), which serves as an important indicator for identifying vegetation health and distribution across the study area.

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{R}}{\mathrm{NIR} + \mathrm{R}},$$

Here, NIR represents the Digital Number (DN) value from the near-infrared band, while R denotes the DN value from the red band of the satellite image. The resulting NDVI values were classified into five categories, where higher NDVI values indicate areas that are more suitable for ecotourism development, reflecting denser and healthier vegetation cover (Figure 4).

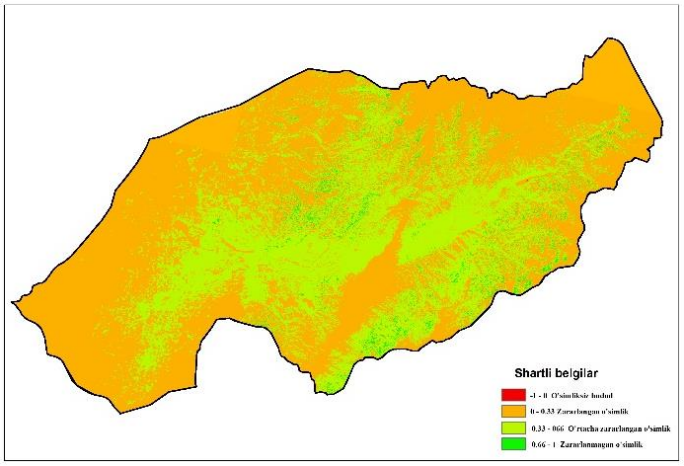

Figure 4. NDVI (vegetation) analysis.

The NDVI analysis revealed that the area was divided into four vegetation comfort classes: undisturbed vegetation, moderately disturbed vegetation, degraded vegetation, and non-vegetated areas, covering approximately 426 km², 1,836 km², 4,197 km², and 99 km², respectively. The visibility of snow-covered mountains is one of the most significant factors for ecotourism development.

The degree of visibility of snow-capped peaks influences the comfort and attractiveness of ecotourism sites, as it strongly correlates with tourist interest and visitation rates. Tourists generally prefer locations that offer scenic views of snow-covered mountains. Using visibility analysis, the spatial distribution of visible snow-capped mountain areas was determined based on the elevation and location of the peaks. The visibility results were reclassified into four suitability levels—very high, high, moderate, and low. Consequently, 32 km² of the area was classified as very high suitability, while 423 km², 157 km², and 5,946 km² corresponded to high, moderate, and low suitability zones, respectively (Figure 5).

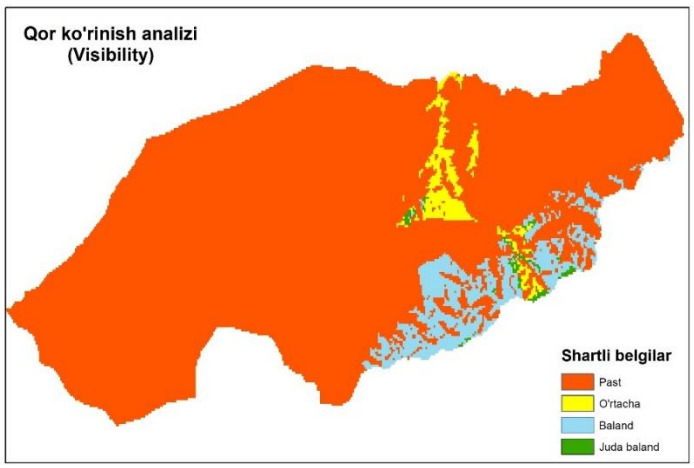

Figure 5. Snow-covered mountain visibility analysis (Visibility).

The cultural diversity and traditions of the Ohangaron Valley population play a significant role in attracting responsible tourists. Ecotourists generally prefer to stay in areas where interaction with local communities and participation in authentic cultural experiences are possible. There is a positive relationship between local culture and the development of ecotourism. Distinct cultural features—such as traditional values, social customs, language, clothing styles, cuisine, and religious practices—draw visitors not only from across the country but also from abroad. At its core, ecotourism emphasizes the preservation of local community culture. Therefore, in the Ohangaron Valley, rural settlements were given priority when determining suitable locations for ecotourism infrastructure. For this analysis, five buffer zones around rural settlements were established, representing comfort, sub-comfort, discomfort, sub-discomfort, and extra-discomfort levels.

These zones cover approximately 18 km², 30 km², 36 km², 39 km², and 40 km², respectively. In selecting areas for ecotourism development, zones located closer to rural settlements are considered more suitable, while suitability decreases with increasing distance (Figure 6).

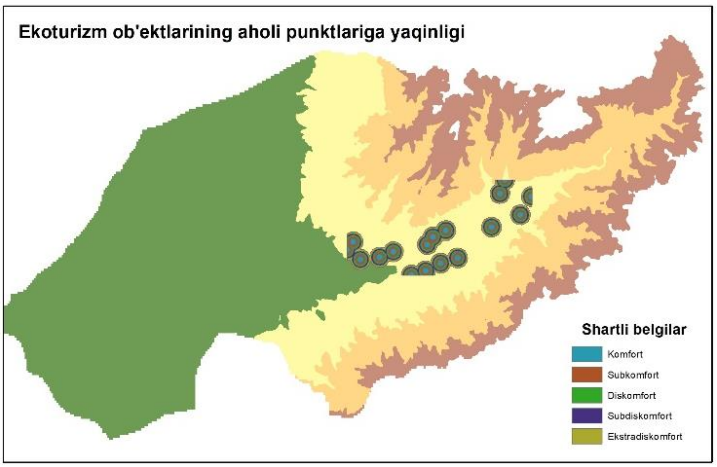

Figure 6. Proximity of ecotourism sites to settlements.

Elevation plays an important role in the development of ecotourism, as increasing altitude generally has a negative impact on accessibility and human comfort. Higher elevations are associated with lower oxygen levels and more limited living and construction conditions, while lower altitudes provide greater opportunities for establishing ecotourism facilities.

The Ohangaron Valley lies between 300 and 3,700 meters above sea level. Based on elevation, the entire region was divided into four classes:

- Very high (3,700–3,000 m),
- High (3,000–2,000 m),
- Moderate (2,000–1,000 m), and
- Low (below 1,000 m).

These classes cover areas of approximately 708 km², 1,380 km², 1,800 km², and 2,670 km², respectively. Areas at lower elevations are considered more suitable for ecotourism development, whereas higher elevations present more constraints for such activities (Figure 7).

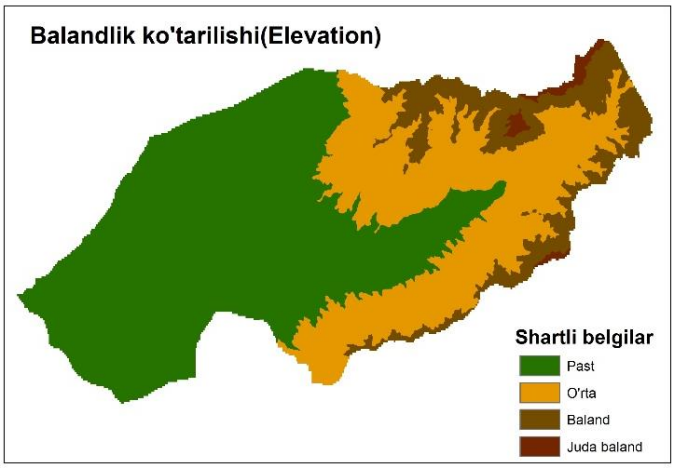

Figure 7. Elevation analysis.

Surface water visibility is an important factor positively correlated with the development of ecotourism. Areas located closer to river basins and drainage networks demonstrate a higher level of suitability for ecotourism activities, while suitability decreases with increasing distance from water sources. The proximity zones were reclassified into five comfort levels — very high, high, moderate, low, and very low. These zones cover approximately 3,266 km², 1,462 km², 982 km², 541 km², and 309 km², respectively. The closer a site is to surface water bodies, the greater its potential for ecotourism development (Figure 8).

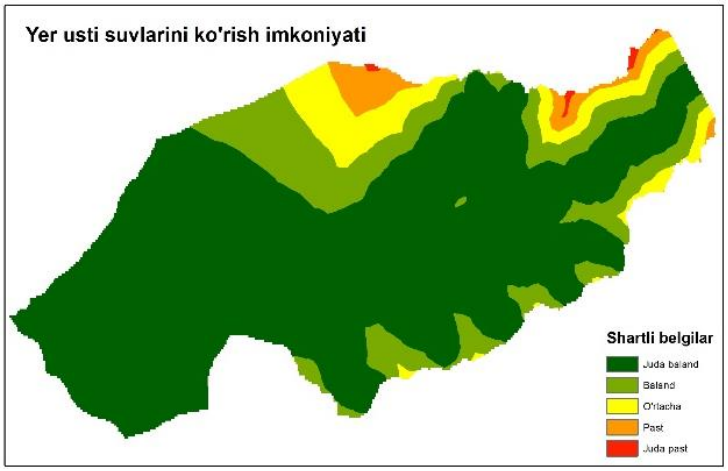

Figure 8. Surface water visibility analysis.

Proximity to lakes and reservoirs plays a significant role in the development of ecotourism, as the presence and aesthetic value of surface water bodies greatly enhance the attractiveness of potential sites. To evaluate the suitability of lake-adjacent areas, four buffer zones were created and classified as very high, high, moderate, and low suitability. These zones respectively cover 80 km², 86 km², 100 km², and 112 km² of the study area. Data on lake locations were obtained from the Diva-GIS database (Figure 9).

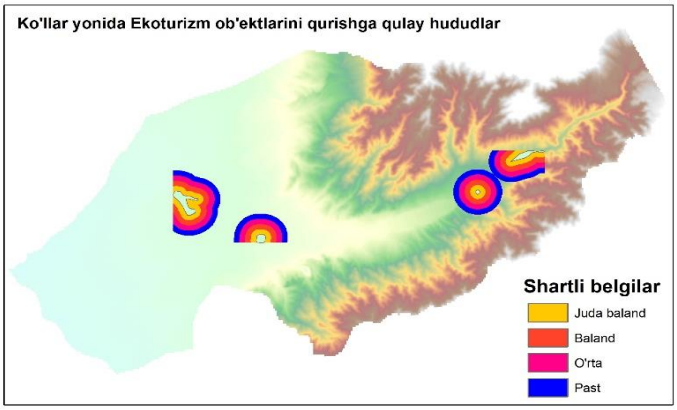

Figure 9. Suitable areas for ecotourism development near lakes and reservoirs.

Groundwater resources also play a significant role in identifying suitable areas for ecotourism development, alongside surface water availability. Based on the presence and potential of groundwater, the study area was divided into two main zones: areas well-supplied with groundwater and areas poorly supplied. Groundwater data were obtained from the National Atlas district planning maps and various thematic mapping organizations. The zones where groundwater is close to the surface cover approximately 1,270 km², while the remaining 5,288 km² are classified as poorly supplied with groundwater (Figure 10).

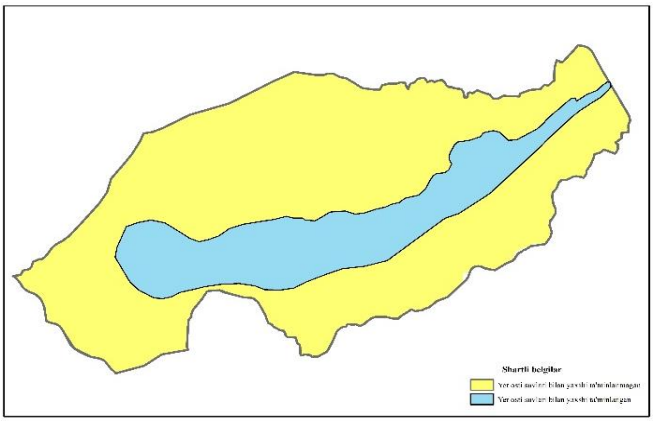

Figure 10. Groundwater availability and proximity to the surface.

To verify the results of assessing the tourism potential of natural components and complexes within the Uzbek part of the Ohangaron Valley, spatial analyses were conducted in ArcGIS. Based on these analyses, tourist routes were identified and mapped using GIS tools. The field research was carried out along these routes and observation stations, providing practical validation of the GIS-based findings (Figure 11).

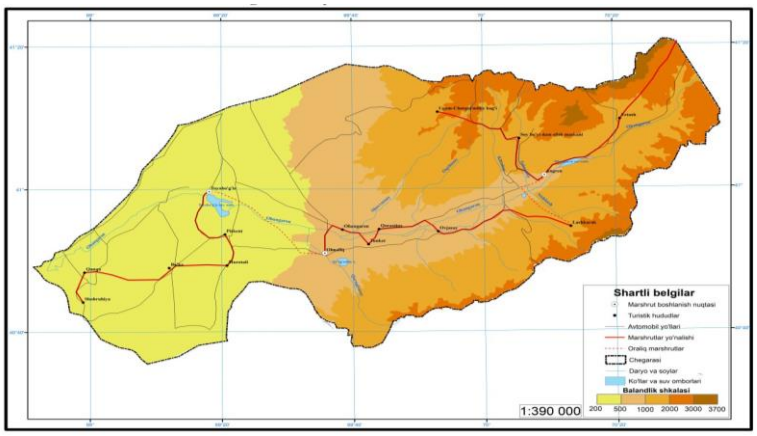

Figure 11. Tourist route map of the Ohangaron Valley.

Based on the above analyses and identified routes, several potential areas within the Ohangaron Valley were determined as alternative zones suitable for the construction of ecotourism facilities and for attracting tourists (Figure 12).

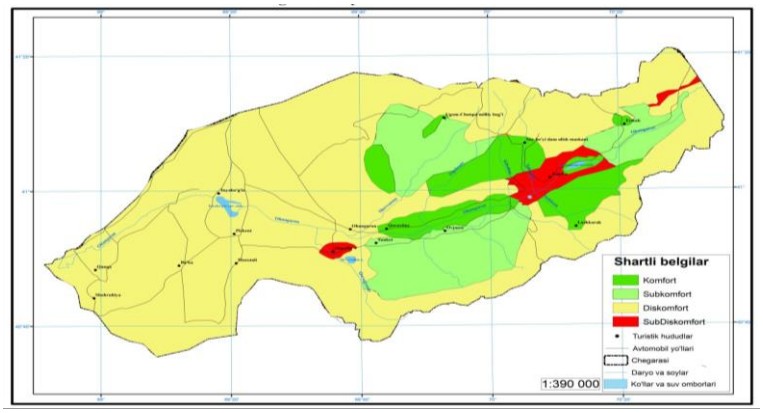

Figure 12. Map of ecotourism zones in the Ohangaron Valley.

In the Ohangaron Valley, the comfort levels for ecotourism development were determined based on six main criteria: Slope, Visibility, Topographic Roughness Index, NDVI, Hillshade, and NDSI. The analysis revealed that approximately 26% of the area possesses high natural suitability for constructing ecotourism facilities, while an additional 35% of the territory contains primary tourism factors that can also be utilized for tourism purposes. The regions classified within the high comfort zones are characterized by low anthropogenic impact and the presence of well-preserved natural landscapes, making them highly favorable for ecotourism development. Moreover, the area offers ample potential not only for ecotourism, but also for the integrated development of gastronomic, adventure, cultural, and historical tourism.

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