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SPATIAL ANALYSIS OF CULTURAL HERITAGE TOURISM POTENTIAL IN THE SHEKI-ZAGATALA ECONOMIC REGION, AZERBAIJAN

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Abstract: This study analyzes the spatial distribution and environmental determinants of cultural heritage tourism in the Sheki-Zagatala economic region of Azerbaijan using Geographic Information Systems (GIS). Cultural heritage sites, including historical monuments, museums, and archaeological locations, were used as point data to evaluate spatial concentration patterns through Kernel Density Estimation (KDE). The analysis aimed to identify the main spatial clusters of cultural heritage tourism and to examine the influence of environmental and infrastructural factors on their distribution. In addition to KDE mapping, several spatial variables were integrated into the analysis, including elevation derived from a Digital Elevation Model (DEM), slope gradients, road accessibility buffers, and river proximity zones. Overlay analyses were conducted to quantify the relationship between KDE values and these environmental variables, while correlation analysis was applied to assess the influence of elevation and slope on heritage tourism density. The results reveal a polycentric spatial structure of cultural heritage tourism, with the most significant concentration located in the Sheki district, followed by secondary clusters in the Balakan-Zagatala and Gabala districts. The analysis indicates that the highest tourism densities occur in foothill environments between 500-1000 m elevation and within relatively accessible valley systems. Cultural heritage density gradually decreases with increasing altitude and terrain steepness, reflecting the influence of topographic constraints. Furthermore, proximity to transportation corridors and river valleys plays an important role in shaping the spatial organization of heritage tourism. These findings demonstrate that the distribution of cultural heritage tourism in the Sheki-Zagatala region is strongly influenced by the interaction of historical settlement patterns, environmental conditions, and infrastructural accessibility.

Keywords: cultural heritage tourism, GIS, kernel density analysis, spatial distribution, environmental factors, Sheki-Zagatala economic region

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INTRODUCTION

Cultural heritage tourism has emerged as one of the most dynamic components of the global tourism industry, driven by growing interest in historical monuments, archaeological sites, museums, and traditional cultural landscapes (Timothy, 2014; Zhang et al., 2023). Unlike mass tourism, cultural heritage tourism emphasises the preservation and sustainable use of tangible cultural assets, while simultaneously contributing to regional economic development and the strengthening of local cultural identity (Garrod & Fyall, 2000; Wasela, 2023). As a result, cultural heritage tourism has become an important focus of research and planning within the fields of tourism geography and regional development (Álvarez-García et al., 2019).

The intensification of socio-cultural processes and the transformation of cultural values have significantly influenced patterns of service consumption and destination choice within the tourism and recreation sector. Growing interest in cultural diversity has stimulated demand for travel experiences that enable interaction with different traditions, heritage landscapes, and historical environments. This trend has contributed to the diversification of tourism products and services offered by enterprises operating within the tourism and recreational complex. At the same time, the increasing cultural and educational awareness of the population has encouraged the adoption and adaptation of international tourism development practices, fostering the exchange of knowledge and the application of successful regional experiences in professional and planning activities (Agakishiyeva & Ismayilova, 2024).

From a spatial perspective, the development of cultural heritage tourism is closely linked to the geographical distribution of heritage resources, their accessibility, and their interaction with natural and infrastructural conditions (Zhang et al., 2024). Geographic Information Systems (GIS) provide effective tools for integrating diverse spatial datasets and for analyzing the territorial organization of cultural heritage tourism resources (Liu et al., 2024; Huang, 2024). GIS-based methods enable the identification of spatial patterns, concentration areas, and development gaps, which are essential for evidence-based tourism planning and sustainable heritage management (Šoltésová et al., 2025).

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Among geospatial techniques, kernel density analysis is widely used to assess the spatial concentration of point-based phenomena and has proven effective in tourism studies for identifying clusters of attractions and delineating core and peripheral tourism areas (Majewska & Truskolaski, 2019; Zhao & Liu, 2021).

When applied to cultural heritage tourism, kernel density analysis allows for the visualization of heritage concentration patterns and facilitates the evaluation of tourism potential across different territorial units (Lin et al., 2011). This approach supports strategic decision-making by highlighting areas with high cultural heritage value that may require improved infrastructure, protection measures, or targeted development policies.

Recent studies have increasingly applied GIS-based and spatial modelling approaches to analyze the spatial distribution and development potential of cultural heritage tourism. For example, Chen et al. (2025) demonstrated the effectiveness of integrated geospatial frameworks combining kernel density, accessibility analysis, and spatial equity assessment in identifying disparities in cultural resource distribution. Similarly, Li et al. (2023) highlighted the importance of GIS-based spatial analysis for structuring cultural heritage corridors and improving the integration of fragmented heritage assets into coherent tourism systems. More recent approaches emphasize the integration of advanced analytical techniques, including machine learning and multi-criteria evaluation, to assess tourism development patterns and their environmental and socio-economic drivers, as demonstrated by Zhou et al. (2025). In addition, recent research has expanded the focus toward experiential and cross-border cultural tourism development, emphasizing the role of spatial analysis and stakeholder engagement in identifying tourism potential and regional development opportunities (Pazari et al., 2025).

Despite these advancements, several limitations remain evident in the literature. Many studies still rely on single-factor analyses, focusing primarily on accessibility or attraction density, without incorporating a comprehensive set of environmental controls. Furthermore, kernel density estimation, although widely used, is often applied as a descriptive tool without deeper integration with topographic and hydrological variables.

Another limitation is the insufficient attention given to mountainous regions, where terrain complexity plays a critical role in shaping tourism distribution patterns. In this context, there remains a need for integrated spatial approaches that combine density analysis with environmental determinants such as elevation, slope, and proximity to infrastructure. Addressing these gaps, the present study contributes to the literature by applying a multi-factor GIS framework to assess cultural heritage tourism patterns in a complex mountainous environment.

Azerbaijan possesses a rich and diverse cultural heritage shaped by its historical position at the crossroads of major civilizations and trade routes (Agakishiyeva & Ismayilova, 2022; Jabrayilov, 2022a). The country is home to numerous historical monuments, archaeological sites, and museums that form the foundation of cultural heritage tourism development. Despite this potential, international academic research focusing on cultural heritage tourism in Azerbaijan remains limited, particularly with regard to spatially explicit, GIS-based analyses. Existing studies have often relied on descriptive assessments, lacking quantitative geospatial approaches that can support systematic tourism planning.

The Sheki-Zagatala economic region represents one of the most significant cultural heritage tourism areas in Azerbaijan (Karimov & Dargahov, 2015). The region is characterized by a high density of historical monuments, traditional architecture, and ethnographic heritage, including UNESCO World Heritage sites of international importance (UNESCO World Heritage Centre, 2019). At the same time, the mountainous relief, river networks, and uneven development of transport and tourism infrastructure influence the accessibility and spatial utilization of cultural heritage resources. These factors create both opportunities and constraints for the sustainable development of cultural heritage tourism in the region.

Previous research on tourism development in the Sheki-Zagatala region has primarily focused on qualitative descriptions or socio-economic analyses, while comprehensive GIS-based spatial assessments remain scarce. In particular, there is a noticeable lack of studies applying kernel density analysis to evaluate the concentration and spatial distribution of cultural heritage tourism resources in relation to infrastructure and natural barriers. Addressing this gap is essential for improving regional tourism planning and for promoting balanced and sustainable cultural heritage tourism development.

Therefore, the aim of this study is to analyze the spatial distribution and concentration of cultural heritage tourism resources in the Sheki-Zagatala economic region using GIS-based kernel density analysis. The study seeks to identify core and peripheral cultural heritage tourism zones, examine their relationship with transport networks, settlements, and natural barriers, and provide spatially grounded recommendations for sustainable tourism planning. By integrating geospatial techniques with regional tourism analysis, this research contributes to the international literature on cultural heritage tourism and offers practical insights applicable to other mountainous regions with rich cultural heritage.

MATERIALS AND METHODS

Study area

The study focuses on the Sheki-Zagatala economic region of Azerbaijan, located in the north-western part of the country and characterized by a complex mountainous landscape, dense river networks, and a long history of cultural and ethnographic development. The region includes a variety of cultural heritage assets such as historical monuments, archaeological sites, museums, and traditional settlements, many of which represent significant resources for cultural heritage tourism (Hasanli & Mirzeyev, 2021; Agakishiyeva & Ismayilova, 2022).

However, the spatial distribution of these resources, combined with relief complexity and uneven infrastructure development, creates notable differences in tourism accessibility and utilization across the region.

Data sources and spatial layers

The analysis was based on a set of thematic spatial datasets representing cultural heritage tourism resources, transport

infrastructure, settlements, and natural conditions. The core dataset consisted of point features of cultural heritage tourism sites, classified into three categories: historical monuments, museums, and archaeological sites (Figure 1).

Each feature included attribute information on site type and administrative location. In addition to cultural heritage data, the following spatial layers were used for contextual and interpretative analysis: road network (national and regional roads), settlements (cities and villages), tourism infrastructure (hotels and museums), natural barriers, including relief (digital elevation model) and river networks. Spatial data were obtained from official national sources and open-access geospatial databases and processed within a GIS environment.

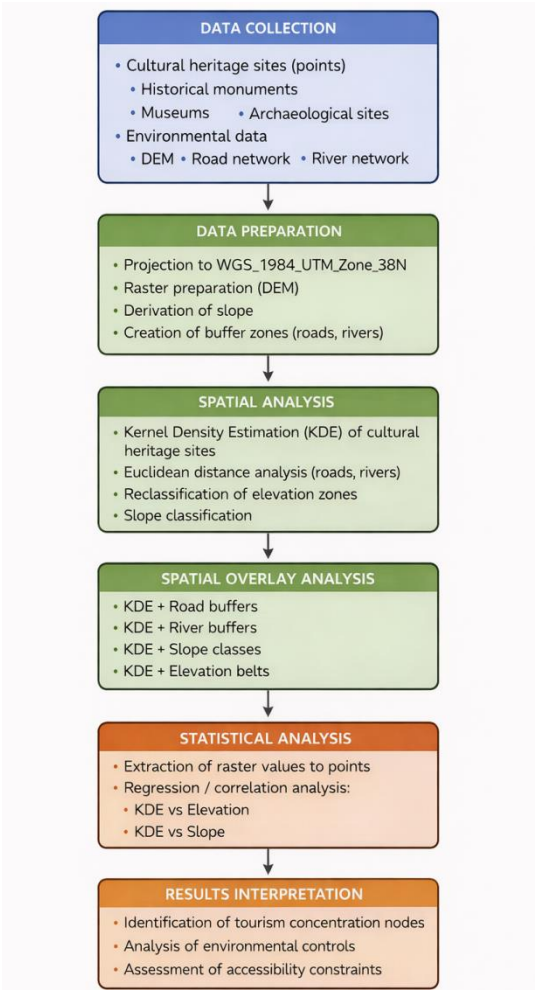


Figure 1. Methodological workflow (Source: Compiled by the authors)

Data preparation

All spatial datasets were projected into a unified coordinate reference system to ensure spatial compatibility and accurate spatial analysis. Vector layers were checked for positional accuracy, duplication, and topological consistency. Cultural heritage tourism sites were verified and categorized based on their dominant functional characteristics.

Raster-based elevation data were processed to support the interpretation of natural constraints affecting accessibility. Data preparation ensured that all input layers were suitable for kernel-based density estimation and subsequent spatial overlay analysis.

Kernel Density Estimation of cultural heritage tourism resources

To identify spatial concentration patterns of cultural heritage tourism resources, Kernel Density Estimation (KDE) was applied to the point dataset representing cultural heritage sites (Baxter et al., 1997; Wang et al., 2024; Hita et al., 2026). Kernel Density Estimation is a non-parametric spatial method that transforms discrete point features into a continuous density surface by estimating feature intensity within a defined search radius (Terrell & Scott, 1992; Chen, 2017).

In this study, KDE was used to:

- identify spatial clusters of cultural heritage tourism sites,
- delineate core and peripheral cultural heritage tourism zones,
- assess spatial heterogeneity of tourism potential across the region.

The KDE procedure was implemented using the Kernel Density tool in ArcGIS. The resulting density surface was classified into four qualitative categories - very high, high, moderate, and low density - using natural breaks to facilitate interpretation and cartographic representation. Areas with high and very high density values were interpreted as core zones of cultural heritage tourism potential, while moderate and low density areas were considered peripheral or underdeveloped zones.

Integration with infrastructure and natural conditions

To enhance the analytical value of the KDE results, the density surface was overlaid with main road networks and natural barrier layers. This integration allowed for the assessment of the relationship between cultural heritage tourism concentration and accessibility conditions. Overlay analysis made it possible to identify areas with high cultural heritage density but limited transport connectivity, as well as zones where tourism infrastructure development does not correspond to heritage concentration. Relief and river networks were used to explain terrain-related accessibility constraints and to identify environmentally sensitive areas where tourism development requires careful planning.

Methodological limitations

While Kernel Density Estimation effectively highlights spatial concentration patterns of cultural heritage tourism resources, it does not account for qualitative differences between heritage sites, such as cultural significance, visitor capacity, or conservation status. In addition, the results depend on the accuracy and completeness of the input spatial data and the selected kernel parameters. Despite these limitations, the applied GIS-based KDE approach provides a robust and transferable framework for assessing cultural heritage tourism potential and supports evidence-based regional tourism planning.

RESULTS AND DISCUSSION

The spatial distribution of cultural heritage sites within the Sheki-Zagatala economic region reflects the historical, environmental, and socio-economic evolution of the Greater Caucasus foothills. The dataset used in this study demonstrates that heritage resources are not randomly distributed, but instead exhibit a structured spatial pattern strongly associated with historical settlement cores. The Kernel Density Estimation (KDE) analysis reveals a pronounced spatial clustering pattern of cultural heritage tourism sites within the Sheki-Zagatala economic region. High and very high density zones are primarily concentrated along the central valley corridor extending from Balakan and Zagatala through Gakh to Sheki, forming a distinct northwest-southeast oriented belt (Figure 2).

The most pronounced concentration of cultural heritage sites is observed around Sheki district, which historically functioned as a major political, commercial, and cultural center in the Caucasus. The high-density cluster identified through KDE reflects the accumulation of architectural monuments, religious complexes, caravanserais, craft quarters, and museums that developed along historic trade routes, including branches of the Silk Road. In particular, the historic core of Sheki represents one of the most significant preserved urban heritage ensembles in the South Caucasus.

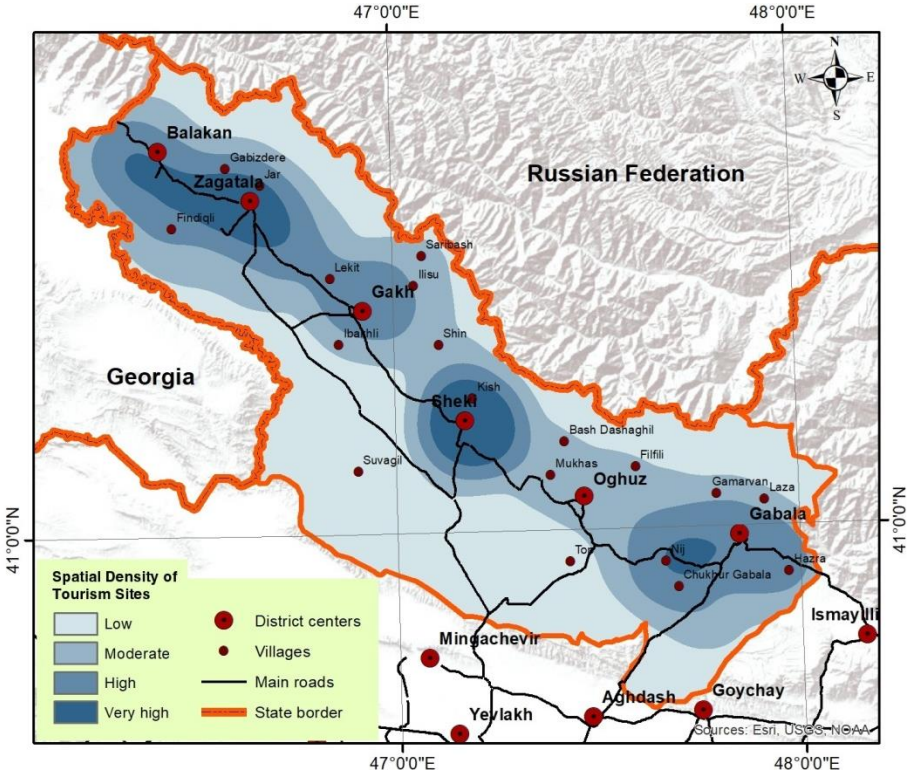


Figure 2. Spatial Density of Tourism Sites Based on Kernel Density Estimation (Source: Author's elaboration based on GIS analysis)

The city contains outstanding examples of 18th-19th century urban architecture, most notably the Palace of the Sheki Khans, a masterpiece of Azerbaijani decorative art characterized by intricate wooden lattice windows (shebeke), frescoes, and ornamental interior painting (Mammadova & Hajiyeva, 2023). The palace complex, together with the surrounding historic urban fabric, illustrates the political and cultural prominence of the Sheki Khanate period. Additionally, the presence of the Sheki Caravanserai (Upper and Lower Caravanserais) demonstrates the city's strategic importance as a commercial hub connecting Transcaucasia with Persia and Anatolia.

These structures historically accommodated merchants and facilitated long-distance trade, reinforcing Sheki's role as a Silk Road node (Alizade, 2021). The inclusion of Sheki's historic center in the UNESCO World Heritage List (UNESCO World Heritage Centre, 2025) underscores its universal value as a cultural landscape shaped by trade, craftsmanship, and environmental adaptation. The strong KDE hotspot centered on Sheki therefore reflects not only a numerical concentration of heritage sites but also the multi-layered historical significance of the city. The spatial clustering corresponds to areas where architectural monuments, museums, and archaeological remnants overlap within a compact urban environment, producing a high-intensity cultural tourism core. This confirms that Sheki functions as the principal heritage anchor within the regional tourism system of the Sheki-Zagatala economic region, structurally influencing surrounding districts and shaping the overall spatial hierarchy of tourism concentration.

Another significant concentration node identified by the KDE analysis is located in the Balakan and Zagatala districts, forming the northwestern heritage cluster of the region. This spatial concentration reflects the historical role of these districts as frontier territories, defensive zones, and culturally diverse settlement areas influenced by Caucasian Albanian, Islamic, and later Tsarist administrative systems. Unlike the compact urban concentration observed in Sheki, the Balakan-Zagatala cluster exhibits a more linear and dispersed structure aligned with river valleys and foothill settlements.

In Zagatala, cultural heritage assets include historical castles, mosques, churches, temples and ethnographically significant rural settlements that reflect the multiethnic character of the district. The region has historically been inhabited by Avars, Tsakhurs, Georgians, and Azerbaijanis, creating a layered cultural landscape visible in architectural forms and settlement morphology (Imrani & Huseynova, 2024).

Defensive structures and archaeological traces in surrounding highland zones further emphasize the strategic importance of this area as a transitional belt between mountain communities and lowland trade routes. Similarly, Balakan contributes to the observed hotspot through a combination of historical monuments, religious sites, and traditional residential architecture. The spatial proximity of heritage points in these districts indicates a pattern of valley-based settlement development, where communities historically concentrated along fertile lands and water resources while maintaining defensive oversight of mountainous approaches (Orujov, 2025).

Another prominent high and very high cultural heritage tourism density area is located within Gabala district, forming a southeastern concentration node in the regional spatial structure. Unlike Sheki, where architectural monuments dominate the heritage landscape, the cluster in Gabala is strongly associated with archaeological and ancient urban heritage (Mammadov et al., 2018; Museyibli et al., 2023). The district contains the remains of the ancient city of Qabala (Caucasian Albania's former capital), which functioned as a major political and economic center between the 4th century BCE and the Middle Ages. Archaeological excavations have revealed fortification walls, residential quarters, craft workshops, and burial complexes, demonstrating long-term urban continuity and regional significance. The KDE hotspot in Gabala reflects the spatial accumulation of these archaeological sites alongside later historical monuments and museum complexes that interpret and preserve the region's multi-period heritage layers.

The cultural landscape here is characterized by the coexistence of ancient settlement remains, medieval structures, and traditional rural elements embedded within a valley–foothill geomorphological setting. Furthermore, Gabala's geographical position within a transitional zone between mountainous terrain and lowland plains has historically facilitated both defensive settlement and trade connectivity. The KDE results therefore indicate that Gabala functions as an archaeological–historical anchor within the southeastern part of the Sheki-Zagatala economic region, contributing to a multi-core regional heritage system. The emergence of a distinct hotspot in Gabala confirms that cultural heritage tourism density in the region is polycentric rather than monocentric. While Sheki represents the dominant architectural and urban core, Gabala strengthens the region's heritage profile through its ancient historical continuity and archaeological depth, diversifying the thematic structure of tourism resources across the economic region.

Environmental controls as explanatory variables

While the Kernel Density Estimation revealed a clear polycentric spatial structure of cultural heritage tourism in the Sheki-Zagatala economic region, the observed clustering patterns cannot be explained solely by historical and cultural factors. The spatial distribution of heritage sites is closely linked to environmental controls, particularly transportation accessibility, topographic constraints, and hydrological corridors (Figure 3).

These physical-geographic variables shape both historical settlement processes and contemporary tourism development dynamics and reflect the broader landscape sensitivity of mountainous ecosystems in Azerbaijan (Jabrayilov, 2022b), as well as variations in environmental and bioclimatic suitability influencing tourism attractiveness across different altitudinal zones (Agakishiyeva et al., 2025). To quantify their influence, spatial overlay analyses were conducted between KDE classes and road buffers, slope categories derived from DEM, and river proximity zones.

The spatial overlay between kernel density zones and ***road accessibility*** buffers indicates that 53.4% of high cultural heritage tourism density areas are located within 3 km of the primary road network. However, 46.6% of high-density zones are situated beyond 3 km, suggesting limited accessibility and potential infrastructural constraints. This distribution pattern reflects a semi-accessible heritage structure, where slightly more than half of the concentrated sites benefit from relatively close road connectivity, while a substantial proportion remain spatially peripheral.

A more detailed zonal analysis strengthens this interpretation. The spatial overlay reveals that 49.03% of high and very high cultural heritage tourism density areas are located within Zone 1 (0-1 km), while 47.68% and 43.05% are located within Zones 2 (1-3 km) and 3 (3-5 km), respectively. The progressive decrease in percentage values demonstrates a gradual distance-decay relationship between heritage concentration and the primary road network.

Although the decline is moderate, it indicates that accessibility remains a critical factor in the spatial organization of tourism intensity. This pattern is consistent with the valley-oriented settlement structure of the region, where roads typically follow river corridors and connect major district centers such as Sheki, Gabala, and Zagatala.

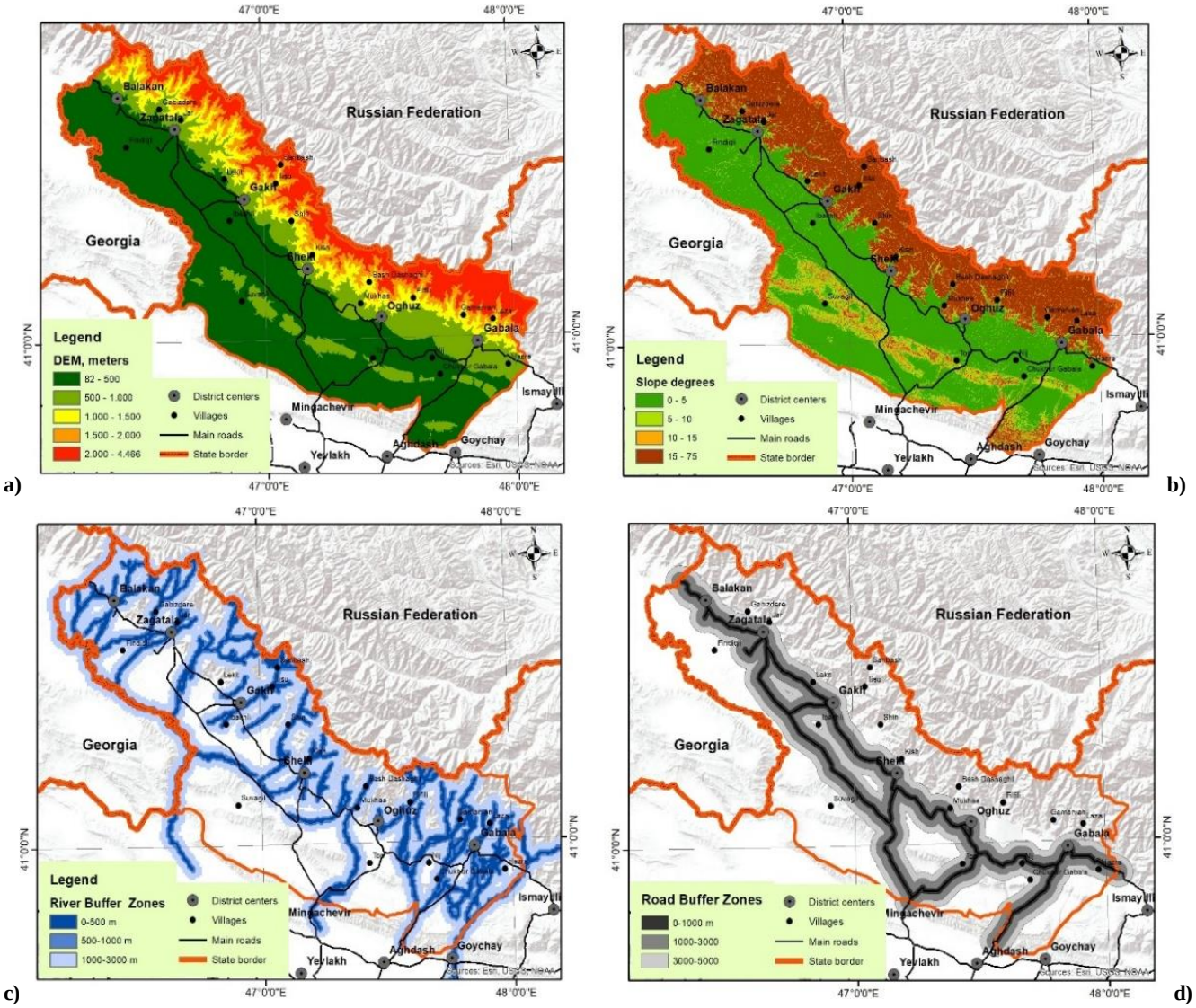


Figure 3. Spatial environmental determinants of cultural heritage tourism density in the Sheki-Zagatala Economic Region: (a) Digital Elevation Model, (b) Slope classes, (c) River proximity buffer, (d) Road accessibility buffer (Source: Author's elaboration based on SRTM DEM and OpenStreetMap (roads and river network) data)

However, the fact that nearly half of high-density heritage areas lie beyond 1 km and a significant portion beyond 3 km suggests infrastructural disparities and potential development challenges. In mountainous regions, even relatively short linear distances may translate into difficult terrain conditions, reducing functional accessibility despite spatial proximity.

Topographic conditions represent a fundamental environmental control in the Sheki-Zagatala region, characterized by sharp altitudinal gradients and complex relief structures of the Greater Caucasus system. The combined overlay analysis of kernel density estimation (KDE) classes with elevation belts and slope categories reveals a clear vertical and morphometric differentiation in the spatial organization of cultural heritage tourism sites.

The elevation overlay demonstrates that the highest concentration of high and very high cultural heritage tourism density areas (52.5%) is located within the 500-1000 m altitudinal belt (Foothill zone). This is followed by the 1000-1500 m Lower mountain belt, where 40.7% of high-density areas occur. The 0-500 m Lowland zone accounts for 32.1% of high-density areas. In contrast, heritage concentration declines markedly in the 1500-2000 m Middle mountain belt (18.5%), and becomes almost negligible above 2000 m in the high mountain zone (1.7%). This altitudinal gradient clearly indicates that foothill and lower mountain environments constitute the primary spatial core of cultural heritage accumulation. These belts historically provided favorable climatic conditions, access to water resources, fertile soils, and strategic defensive advantages, while remaining relatively accessible compared to higher mountainous terrain.

At the same time, slope analysis refines this interpretation. Overlay results show that 33.16% of high-density and 26.71% of very high-density cultural heritage tourism areas are located on slopes exceeding 15°. This demonstrates that a considerable proportion of core heritage clusters are situated within moderately steep to steep terrain. Such positioning

reflects historical settlement logic in mountainous regions, where fortifications, religious complexes, and traditional rural settlements were frequently established on elevated or defensible slopes rather than flat plains.

However, while elevation explains the broader vertical distribution pattern, slope introduces a contemporary functional constraint. Steeper terrain increases construction costs, limits transportation accessibility, raises erosion susceptibility, and restricts the availability of buildable land for tourism infrastructure. Therefore, slope operates simultaneously as:

- a historical locational determinant, shaping the original placement of cultural heritage assets, and
- a modern developmental constraint, limiting the integration of certain heritage nodes into wider tourism networks.

When considered together, elevation and slope reveal a dual topographic control mechanism. Cultural heritage tourism density is maximized within intermediate altitudinal belts (500-1500 m), yet many of these assets are embedded within morphologically complex landscapes characterized by significant terrain gradients.

This confirms that the spatial structure of heritage tourism in the Sheki-Zagatala region is not random but strongly conditioned by vertical zonation and relief morphology.

The regression analysis between kernel density estimation (KDE) values and elevation reveals a weak but noticeable negative relationship between cultural heritage tourism density and altitude (Figure 4a). As elevation increases, KDE values gradually decline, indicating that the spatial concentration of cultural heritage sites becomes lower in higher mountainous environments. The scatter distribution demonstrates that the majority of high KDE values are clustered within lower and intermediate elevation ranges, generally below 1500 m. This pattern confirms the earlier spatial overlay results, which showed that foothill and lower mountain belts represent the principal zones of cultural heritage concentration in the Sheki-Zagatala economic region. The decreasing trend at higher elevations reflects historical settlement limitations related to harsh climatic conditions, difficult terrain, and reduced accessibility in high mountain landscapes.

A similar pattern is observed in the relationship between KDE values and slope gradients (Figure 4b). The regression trend line indicates a weak negative correlation, suggesting that cultural heritage tourism density tends to decrease as terrain steepness increases. Although a number of heritage sites occur on moderate slopes due to historical defensive or strategic considerations, very steep slopes generally show lower KDE values. The dispersion of points across the graph indicates that slope alone does not fully determine heritage distribution; however, it still functions as an important geomorphological constraint influencing the spatial pattern of cultural heritage resources.

Together with elevation, slope contributes to shaping the environmental framework within which historical settlements, monuments, and archaeological sites were established and preserved in the region.

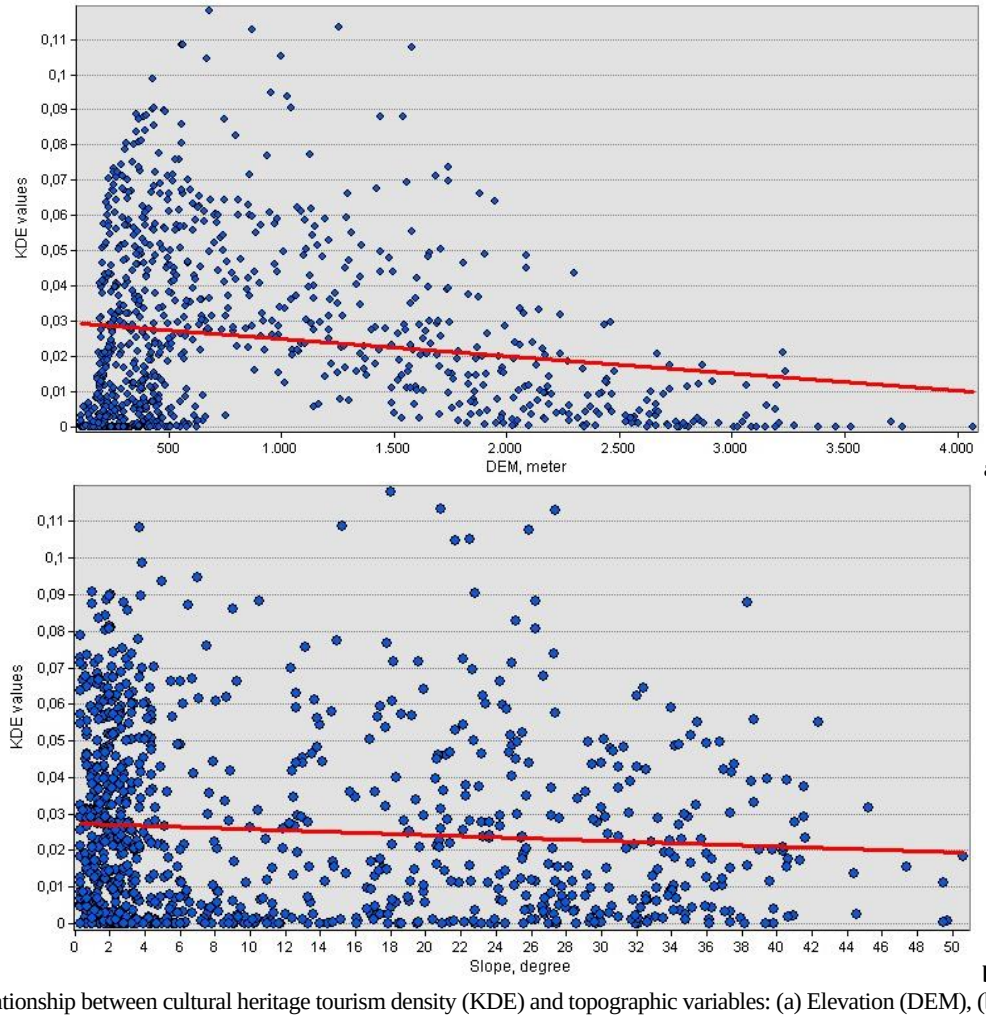


Figure 4. Relationship between cultural heritage tourism density (KDE) and topographic variables: (a) Elevation (DEM), (b) Slope gradient

Hydrological networks also exert a significant influence on the spatial concentration of cultural heritage tourism. The zonal overlay analysis reveals that 41.04% of high and very high tourism density areas are located within 500 m of river networks. This proportion decreases to 38.02% within 1000 m and 37.56% within 3000 m. The gradual decline indicates a distance-decay effect, confirming that river corridors significantly influence the spatial concentration of heritage tourism.

The strongest clustering occurs in immediate proximity to river valleys, reflecting their historical role as primary settlement corridors, agricultural zones, and trade routes. In mountainous regions such as Sheki-Zagatala, valleys provided favorable microclimatic conditions, fertile soils, and natural transportation pathways. Consequently, urban centers, caravanserais, and religious structures historically emerged along fluvial corridors. The KDE analysis quantitatively confirms this relationship, demonstrating that cultural landscape formation in the region is strongly valley-oriented.

Taken together, these findings demonstrate that cultural heritage tourism density in the Sheki-Zagatala economic region is shaped by an interaction between historical–cultural processes and environmental controls.

Road accessibility influences contemporary tourism integration, slope conditions reflect geomorphological constraints, and river proximity corresponds to long-term settlement patterns. The spatial structure that emerges is neither purely accessibility-driven nor entirely environmentally determined; rather, it represents a historically conditioned landscape system where physical geography and human activity have co-evolved.

This integrated perspective supports the interpretation of the region as a structured cultural landscape in which environmental factors continue to influence tourism potential and spatial development trajectories.

CONCLUSION

This study examined the spatial distribution and environmental determinants of cultural heritage tourism in the Sheki-Zagatala economic region of Azerbaijan using Geographic Information Systems (GIS) and Kernel Density Estimation (KDE). The analysis incorporated multiple spatial variables, including elevation, slope, road accessibility, and river proximity, in order to identify the key physical and infrastructural factors influencing the spatial concentration of cultural heritage sites. The KDE results revealed a clear polycentric structure of cultural heritage tourism distribution, with the most pronounced concentration occurring in the Sheki district, followed by secondary clusters in the Balakan-Zagatala corridor and the Gabala district.

These clusters reflect the historical significance of the region as an important settlement and trade zone influenced by Silk Road routes, administrative centers, and long-term cultural development. The study demonstrates that environmental and infrastructural conditions play a significant role in shaping the spatial structure of cultural heritage tourism. Accessibility analysis showed that more than half of high-density heritage areas are located within 3 km of the primary road network, confirming the importance of transportation corridors in facilitating tourism development.

At the same time, a considerable proportion of heritage clusters remain located in relatively remote areas, indicating potential infrastructural constraints that may limit tourism accessibility. The influence of hydrological systems was also evident, as a large share of high-density heritage sites were concentrated within close proximity to river valleys, reflecting the historical role of fluvial corridors as settlement axes and economic routes. Topographic analysis further highlighted the importance of vertical landscape differentiation in determining heritage distribution.

The highest concentration of cultural heritage tourism density was observed within the 500-1000 m foothill belt, followed by the lower mountain zone between 1000-1500 m. In contrast, heritage density declined significantly in higher mountain environments above 1500 m. Slope analysis supported these findings, indicating that while a portion of heritage sites occur on moderately steep terrain due to historical defensive and settlement considerations, increasing slope gradients generally reduce the spatial concentration of tourism resources. Regression analysis between KDE values and elevation and slope confirmed a weak but consistent negative correlation, indicating that cultural heritage tourism density decreases with increasing altitude and terrain steepness.

Overall, the results confirm that the spatial organization of cultural heritage tourism in the Sheki-Zagatala region is shaped by the interaction of historical settlement processes, accessibility conditions, and physical geographic constraints. The concentration of heritage sites in foothill valleys and along transportation corridors reflects both environmental suitability and long-term cultural landscape evolution. These findings provide a spatially grounded understanding of tourism resource distribution and highlight areas where improved infrastructure, accessibility, and sustainable tourism planning could enhance the utilization of cultural heritage assets.The methodological approach applied in this study demonstrates the effectiveness of GIS-based spatial analysis for identifying tourism development patterns and environmental constraints in mountainous regions. By integrating kernel density modelling with terrain and accessibility variables, the research contributes to the broader field of tourism geography and cultural landscape studies. The results may support regional planning initiatives aimed at promoting sustainable cultural heritage tourism while preserving the historical and environmental integrity of the Sheki-Zagatala economic region.

Despite these contributions, the study has several limitations. The analysis is based on available spatial datasets of cultural heritage sites, which may not fully capture all existing heritage resources in the region. In addition, the use of KDE provides a generalized representation of spatial concentration patterns and may be influenced by parameter selection, such as bandwidth and cell size. The environmental variables considered in this study were limited to elevation, slope, road accessibility, and river proximity, while other potentially important factors, such as tourism infrastructure quality and socio-economic conditions, were not included due to data limitations.

Future research should incorporate higher-resolution datasets, additional variables, and more advanced spatial modelling techniques to provide a more comprehensive assessment of cultural heritage tourism dynamics.

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