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A GIS-based method for researching the historical and architectural heritage of the mountainscapes: The case of Uludağ / Olympus Monasteries

Figen Kıvılcım Çorakbaş [*1], **Emre Mustafa Bektöre** [2]

[1]*Bursa Uludağ University, Faculty of Architecture, Department of Architecture, Bursa, Türkiye*
[2]*Eskişehir Technical University, Earth and Space Sciences Institute, Satellite and Space Sciences, Türkiye*

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Abstract

Uludağ / Mount Olympus is a mountainscape where natural and cultural values coexist. One of the under-researched cultural layers of Uludağ is the remains of the Byzantine Period monasteries, which are considered to compose one of the unique cultural landscapes of the Byzantine world. The site surveys realized by the Bursa Metropolitan Municipality Research Team proved that some remains still exist in the current Uludağ mountainscape. This study aims to understand the monasteries' cultural landscape by integrating qualitative, quantitative, historical, and current data on the Uludağ monasteries in a Geographical Information Systems (GIS) model. Various analysis tools that GIS provides are utilized in order to estimate the approximate locations of the monasteries' remains. In addition, the relationships of the monasteries with topography, city, and landscape are discussed through relevant GIS maps. As a result, it is observed that the Uludağ monasteries were located in hard-to-access locations and were well-integrated into nature. The cultural heritage of monasteries requires a multidisciplinary approach that can be managed by the utilization of GIS.

1. Introduction

1.1. Problem definition

Uludağ / Keşiş Dağı / Olympus *(the Mysian / Bythinian Olympus*) is a 2,543-meter-high mountain located south of the city of Bursa in northwestern Turkey. The earliest known beginning of the built structures in Uludağ is the monasteries located on the mountain between 600 meters and 1500 meters altitude since the 8th century AD. It is considered that these monasteries gradually lost their function in the 14th century with the transition of the administration of the historical city center of Bursa to the Ottoman authorities. According to Menthon (1935), who studied the remains of the monasteries at the beginning of the 20th century, there were about 150 monasteries on Mount Olympus during the Byzantine period. Additionally, Uludağ (1928), who researched the architectural remains on the mountain approximately 30 years after Menthon, points out that dervish lodges and dervishes replaced the monasteries and monks in the Ottoman period and supports this idea with some Ottoman legends and notes of foreign travelers. It is believed that during this period, the dervishes repaired the structures that used to be monasteries or stayed in caves to live in seclusion (Uludağ, 1928).

The fact that the rapidly-flourishing nature of the mountain quickly covers the architectural remains and makes accessibility very difficult has caused the Byzantine and Ottoman cultural fabric of the mountain to be almost completely forgotten today. As a result, there are a limited number of studies about the monastic period and the "dervishes' period," in other words, the Byzantine and Ottoman periods of Uludağ.

Within the scope of this study, it is argued that the cultural heritage values of the monasteries cannot be considered separately from their relationship with the landscape. Therefore, this study aims at analyzing and understanding the cultural values of the remains of the Uludağ Monasteries within their natural context.

This article aims to document the current cultural and natural qualities of Uludağ and to determine the cultural heritage values. As a methodology, the modeling of the multi-layered structure of Uludağ in Geographical

* **Corresponding Author**
*(figenkivilcim@uludag.edu.tr) ORCID ID 0000-0001-6932-3703
(embektore@eskisehir.edu.tr) ORCID ID 0000-0001-9697-6259

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Information Systems (GIS) is realized, and the GIS data model was created in order to obtain relevant maps from the GIS database. The determined study area covered the Menthon Map (Figure 1-2). The maps and legends were prepared according to the place's tangible and intangible characteristics. Finally, the outputs of the analysis maps were evaluated, and the qualitative and quantitative data on natural, cultural, and historical values were discussed.

Four of the forty-three monasteries within the study area boundary are located in the current city settlement of Bursa Province. Thirty-nine of them are located in rural areas. As a part of the study, the historical data obtained from the previous studies on monasteries and monastic groups were examined, and historical information on the monasteries was entered into the GIS model. For instance, the construction dates or periods and the historical narratives about the locations and views of monasteries are included in the database as textual information. A key map showing the estimated locations of the monasteries, topography map, inclination analysis map, water streams map, and current transportation map were prepared by utilizing the GIS model, and results are compared and interpreted in order to draw conclusions on the past and present conditions of the monasteries' cultural landscape.

As a result, this study contributes to the enlightenment of a new layer in Bursa's urban identity by shedding light on the unique monk life on the periphery of the city of Bursa, which stands out as an Ottoman city. This research's originality stems from the methodology based on the use of the GIS model to relate qualitative and quantitative, past and current data on the Uludağ monateries' cultural landscape.

1.2. Studying mountainscapes by GIS modeling

Although the current scholarship on the study of the cultural and natural characteristics of the mountainscapes using GIS modeling is not rich in the number of studies, some studies analyze various cultural and natural phenomena utilizing various GIS tools. According to Cillis, et al. (2021), who claim to apply historical GIS for the diachronic analysis of a Mediterranean forest scape, landscapes represent a changing element of the territory. However, in some cases, their historical, cultural, and ecological importance requires a specific and detailed approach to avoid landscape loss or excessive transformation. Therefore, it is necessary to deal with the issues in multidisciplinary and multitemporal ways (Cillis, et al., 2021). Cillis, et al. (2021) underline that GIS, although with errors, is the only way to have a spatial reference of the historical structure of the area. In addition, they emphasize that the historical GIS implementation can be a valuable tool for those involved in landscape and forest ecology because it can become the basis of a decision support system (Cillis, et al., 2021).

Considering the change in a monastic area and a settlement in a mountainscape context, Caiji *et al.* (2015) find out that a Tibetian monastery's change in land use type and landscape pattern is more stable than the change in settlement. According to their study that is based on GIS analysis of a vast area in a Tibetian mountainscape, the fragmentation index of monasteries is significantly lower than that of the settlement within the study area from 1987 to 2007. In addition, the landscape pattern of the surrounding river and lake is better than that of the surrounding settlement (Caiji *et al.*, 2015).

In their attempt to bring to light the relationship between the ancient Wari structure's locations and the mountainscape, Williams and Nash (2006) utilized GIS-based viewshed analysis to assess which points on the landscape are likely to be recognized by a large number of communities. Their methodology combined ethnohistoric and ethnographic data with topographical and spatial data, which they think can be a powerful tool for investigating the "cognitive landscapes of the past."

Concerning the development of relevant archaeological research methods in mountainscapes in Sicily, Fitzjohn (2007) emphasizes the importance of systematic field walking in landscape archeology. He states that absolute landscape archeology is possible not only by evaluating the region's physical features in the analysis but also by developing our analytical and interpretive approaches to the material. For this, he proposes unconventional humanistic uses of GIS. These uses include parameters such as interviews, and daily experiences in the region, in addition to GIS data inputs (Fitzjohn, 2007).

Investigating the tangible and the intangible aspects of the sacred landscapes in Colorado's Rocky Mountain National Park, Diggs and Brunswig (2013) applied a four-stages method, including GIS modeling, which is composed of the following steps:

1. "mining" of the ethnographic and historical records related to religious practices, belief systems, and physical manifestations of those practices and beliefs;
2. field visits of elders and members of tribes that are known to have historically occupied the region;
3. an archeological field program designed to identify sites with religious elements, including modified natural features that are associated with past ceremonial activities; and
4. using GIS software to generate and test landscape patterning and site models using the above sources.

As exemplified in the case of the Rocky Mountain National Park, cultural landscape studies necessitate combining qualitative and quantitative research methods tailored to the specificities of the case studies.

To conclude, GIS provides a convenient data model that combines spatial, historical, ethnographical, and geographical data types, making it a unique environment to analyze mountainscapes' cultural and natural characteristics integrally.

1.3. The cultural layers of Mount Uludağ / Olympus

Written resources claim the existence of 150 monasteries in this area, but Menthon (1935), who studied this area in detail in the early 1900s, confirmed the existence of the remains of about 50 monasteries. Moreover, Menthon (1935) determined the names of these monasteries from historical written sources.

However, the Uludağ Cave and Monastery Research Team, established by the Bursa Metropolitan Municipality (2012), has reached the remains of only 5 or 6 of these monasteries. The site survey of the municipal team was not well integrated with the historical research, so all the names of the monastery remain were not determined.

The monastery remains are located at altitudes between 600 and 1500 meters (Figure 9). Being located in one of the highest mountains in Turkey, the area is a scene of harsh climatic conditions, and it is very much inclined (Figure 10). As mentioned above, the regional and architectural scales should be analyzed and evaluated to study the monasteries' cultural heritage.

The selected study area covers nearly 1000 square kilometers on the mountain surface (Figure 1). In order to comprehend the scale of the study area, the study area can be compared with Bursa's İnegöl District, which also extends around 1000 square kilometers. The remains of circa 50 monasteries reached by Menthon (1935) and 5 or 6 monastery remains researched by the municipal team are distributed to an area as large as the Inegol District, where 230.000 people live today. This comparison highlights that the area in question is enormous and forested.

Monastic life in a mountainous area was undoubtedly influenced by the climate cycles. One of the reasons why the monks and dervishes chose the mountain landscape for seclusion both in the Byzantine and Ottoman periods is the weather phenomena, the climate, and their reflections on nature. For instance, Lâmiî Çelebi, who wrote about the Bursa city in the 16th century, emphasizes that the valley known as Sarıalan, where important monasteries were established in the Byzantine Period, "blooms a thousand and one flowers, especially the beauty that emerges with the melting of the snow in the spring season is unique" (Uçak, 2019).

In the years following the establishment of the Republic of Turkey in 1923, Uludağ became the host of new hotels and winter tourism as the modern winter sports center of the new nation-state. As Bozdoğan (2015) pointed out, modern public spaces, especially the recreational parks and gardens in the cities, played an important role in the construction of the modern Turkish nation. Similarly, Uludağ hotels region was planned as a modern facility both for the city of Bursa and the whole country. Accordingly, in the first decades of the Republic, the mountain began to attract more attention and turned into a more accessible place than it was in the past. Mountaineers, skiers, tourism planners, bureaucrats, and other civic actors were influential in this transformation. In 1925, with the suggestion of Osman Şevki, who visited the mountain and climbed to its peak, the name "Keşiş Dağı" was changed to Uludağ. With organized trips, youth and scouting camps, and picnic activities, Uludağ became a significant source of tourism for the region in the early 1930s. Thanks to Uludağ and foreign educators who migrated to Turkey in the 1930s, skiing was promoted as a leisure activity. With the establishment of the Bursa Mountaineering Club, skiing sport began to develop in Uludağ. In 1935, Turkey's first ski house was established in Uludağ, and the accommodation facilities in the mountain were developed (İnal, 2019). Today, the ski center hosts activities such as snowboarding, bigfoot, snowmobile safari, sledding, and winter mountain climbing in addition to skiing (Adamış ve Özçoban, 2020).

Kirazlıyayla Sanatorium, designed by Leman Tomsu and Emin Onat, was opened in 1946 as the first modern accommodation and health facility in Uludağ. The building complex was designed as a lung and chest disease hospital. Accordingly, balconies were designed for each patient room to ensure that patients had fresh air. Moreover, a courtyard for sports activities was included in the design of the building. The building has architectural value due to its plan organization, natural materials used in a modern sense, and remarkable structural details. The sanatorium complex is a successful product of the period called the Second National Architecture (Türkün Dostoğlu and Erdoğdu Erkaslan, 2013). Having been used as a hotel for a while, the building changed dramatically after several renovations. In addition to the sanatorium, many hotels were built in Uludağ, and with the snow removal vehicles imported from abroad in 1949, Uludağ was made easily accessible in winter. In the 1960s, Uludağ became an alternative holiday destination for the middle and upper-income groups.

After the Second World War, new tourism opportunities were investigated in Turkey, and, as a result, leisure activities have become an important industry since the 1950s. The infrastructure investments for skiing have increased in Uludağ with the construction of new hotels and pensions and the installation of chairlifts; thus, significant changes have occurred in the mountainscape (İnal, 2019).

At the same time, since the nature of the mountain is an ecosystem famous for its biodiversity, a National Park area was created, and the plants and animals in this area were taken under protection in 1961 (Ersoy, 2012). Within the borders of the National Park, which has rich flora and fauna, there are more than 8500 endemic plants and animals, such as bears, wolves, jackals, wild pigs, partridges, and deer.

The tourism center, which has been developing and growing since the 1930s, is a limited area within the borders of the Uludağ National Park (Atasoy et al., 2008).

A significant development in 1963 was the cable car, one of the transportation methods established between Bursa and Uludağ (Figure 1). Having a horizontal length of 9 km as the longest cable car line in Turkey and being Turkey's first cable car line, it has become one of the city symbols of Bursa. This important cable car line has four stations: Teferrüç, Kadıyayla, Sarıalan, and “Oteller Bölgesi” (Hotels’ Region) respectively. Kadıyayla Station, one of these stations, constitutes an important area with much potential for Uludağ monasteries’ research. The monasteries of Saccudion, Mesolympe, Cathares, and Libiana were located in this region.

Access to the mountain became more practical by the cable car, it increased the region's attractiveness in terms of mountain and winter tourism and facilitated low-income individuals' daily visits to Uludağ (Atasoy et al., 2008).

While the number of hotels in Uludağ was five in 1961, the bed capacity increased to 1000 in 1971. Newly

opened hotels tried to attract customers to Uludağ with services such as hot water, central heating, and more comfortable spaces (İnal, 2019). For local and foreign tourists, in addition to staying at hotels and camping, there is a potential for nature tourism activities such as nature walks, mountaineering, climbing, and mountain bike tours in the plateaus (Erken et al., 2019).

On the north side of the mountain, there are Sarıalan, Kirazlı, Kadıyayla, Sobra plateaus. Kadıyayla hosts a cable car station around which important monasteries were located in the past.

Eight glacial lakes, such as Aynalı Lake, Kilimli Lake, Kara Lake, are among the main attractions of the mountain.

The modern Uludağ cultural landscape, with its hotels, provided a popular environment for the leisure activities of the Republican urban upper-middle class. In the news and columns in the local press of Bursa, especially in the 1950s, the renovation of the Uludağ road, the construction of a cable car, and various opinions on Uludağ becoming a national park were discussed. Films, literary products, news and advertisements in the local press, and postcards are essential resources for a better understanding of the importance of the modern image of Uludağ in popular culture during the Republican period. These resources have the potential to shed light on the development of the Uludağ landscape in the last century and the determination of its socio-cultural and natural values. On the other hand, the lack of monasteries or other historical constructions in the modern image of Uludağ constitutes one of the highlights in the problem definition of this study.

Similarly, it is remarkable that the mountain villages surrounding Uludağ, like a net, have not become a part of winter tourism. The examples of traditional residential architecture, monuments, and natural products in these mountain villages have significant potential for rural tourism. In contrast, the villages are not connected to tourist routes in the mountain; therefore, the villages are not a part of the recent future vision and development scenarios.

The only exception is Cumalkızık Village, which is a component of the "Bursa and Cumalıkızık: the Birth of the Ottoman Empire" UNESCO World Heritage Site (2022). Concerning this study's aims and scope, Cumalıkızık is significant since it can serve as the starting point of the monastery's cultural routes leading to the numerous monasteries in the east of the study area (Figure 1 and 2).

This study aims to exemplify a system for the integrated documentation and conservation of the cultural and natural values of the mountain based on Geographic Information Systems (GIS). The multi-layered GIS structure consists of cultural and natural layers on the mountain, such as flora, fauna, water system, paths, and architectural remains from the Byzantine Period. Additionally, villages, roads, viewpoints, and some of the natural and cultural routes are modeled in GIS. This model is an example of a dynamic decision-making system, which can be updated, shared, and developed with the designated stakeholders. It can be a tool for conservation and site management. A wide range of qualitative and quantitative data can be entered into the system, and all data types can be analyzed and evaluated integrally.

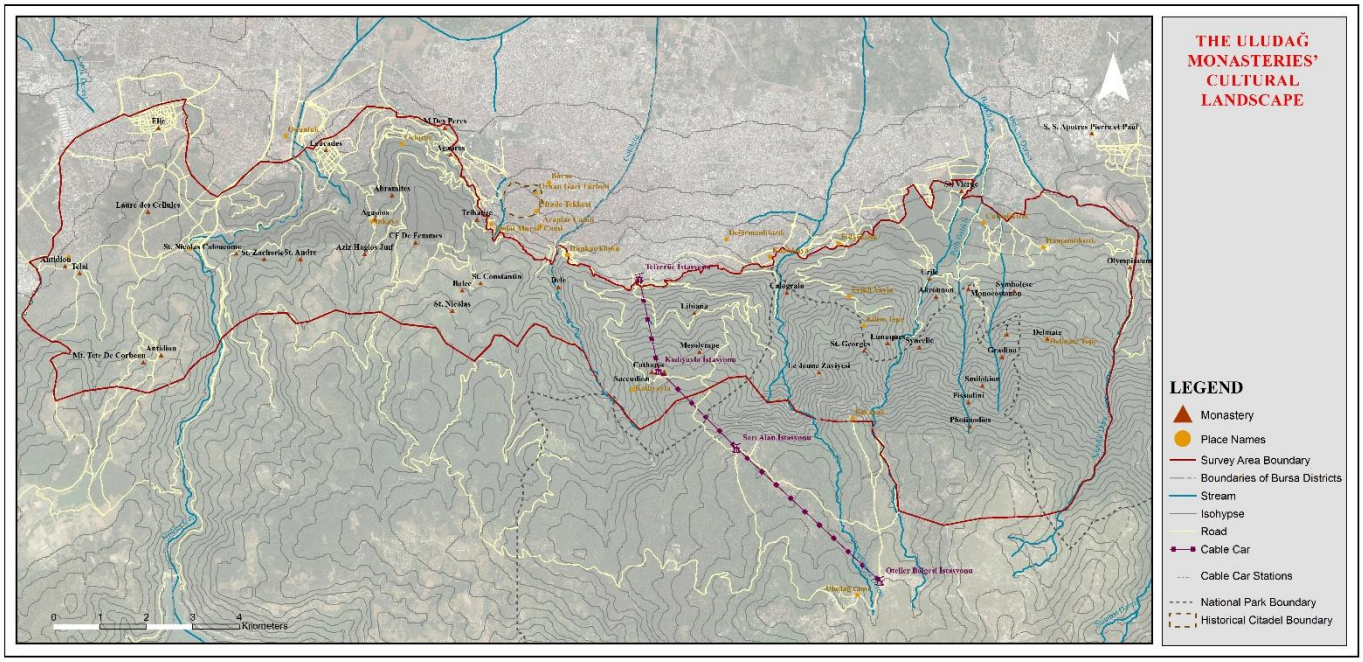

Figure 1. The key map shows the monastery's estimated locations in Mount Uludağ / Olympus

1.4. The previous studies on the monasteries of Uludağ / Olympus cultural landscape

Two of the most important studies on the Uludağ Monasteries were Bernardin Menthon, the Priest of the French Church of Bursa, in the first half of the 20th century. Menthon (1935), in his work titled "L'Olympe de Bithynie- Ses Saint, Ses Couvents, Ses Sites," evaluated the historical written resources about the monasteries in Uludağ, combined them with the results of his fieldwork

and created a sketch-map (scale: approximately 1/83.333) showing the locations of the monastery ruins (Figure 2).

In addition, Uludağ 1928, a doctor and an intellectual from Bursa, published a work titled "Bursa and Uludağ: Guide to the Travelers" and a work called "Uludağ Temples, Monks, Dervishes" in 1936. In these works, the author mentioned Uludağ / Keşiş Dağı Monasteries referring to Menthon's work and his own field studies. Like Menthon, Osman Şevki Uludağ included sketches and maps in his works (Figure 3).

After the 1930s, studies on the Uludağ Monasteries were suspended for a long time, and in 2006 and 2007, a French research team conducted church and monastic research in an area outside the area where Menthon worked, that is, on the slopes of the mountain facing west and north and in Kurşunlu (Auzépy et al., 2007 and Auzépy et al., 2009). These archaeological surveys focus on documenting the architectural fragments identified (Auzépy et al., 2006) and is shown in Figure 4. As a result, this study's originality stems from its unique approach in terms of using cultural landscape data while aiming to reveal the tangible and intangible cultural qualities of the monastery ruins. At the same time, questioning the relationship of the cultural landscape and its component monastic ruins with historical data is one of this work's original aspects.

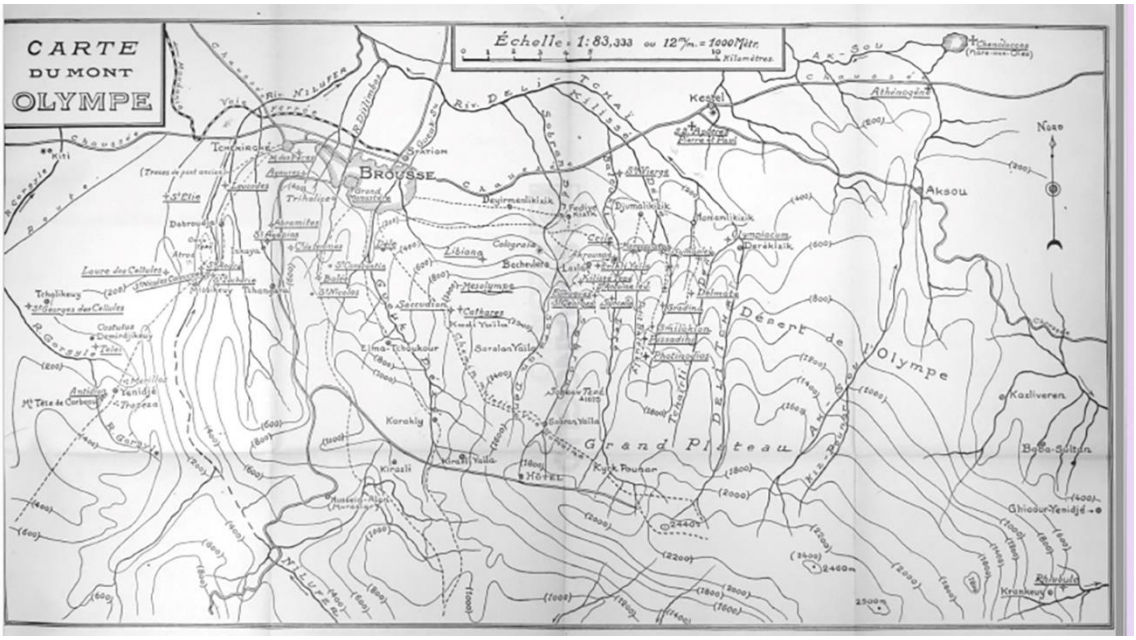

Figure 2. The Menthon Map showing the Uludağ monasteries (Menthon, 1935)

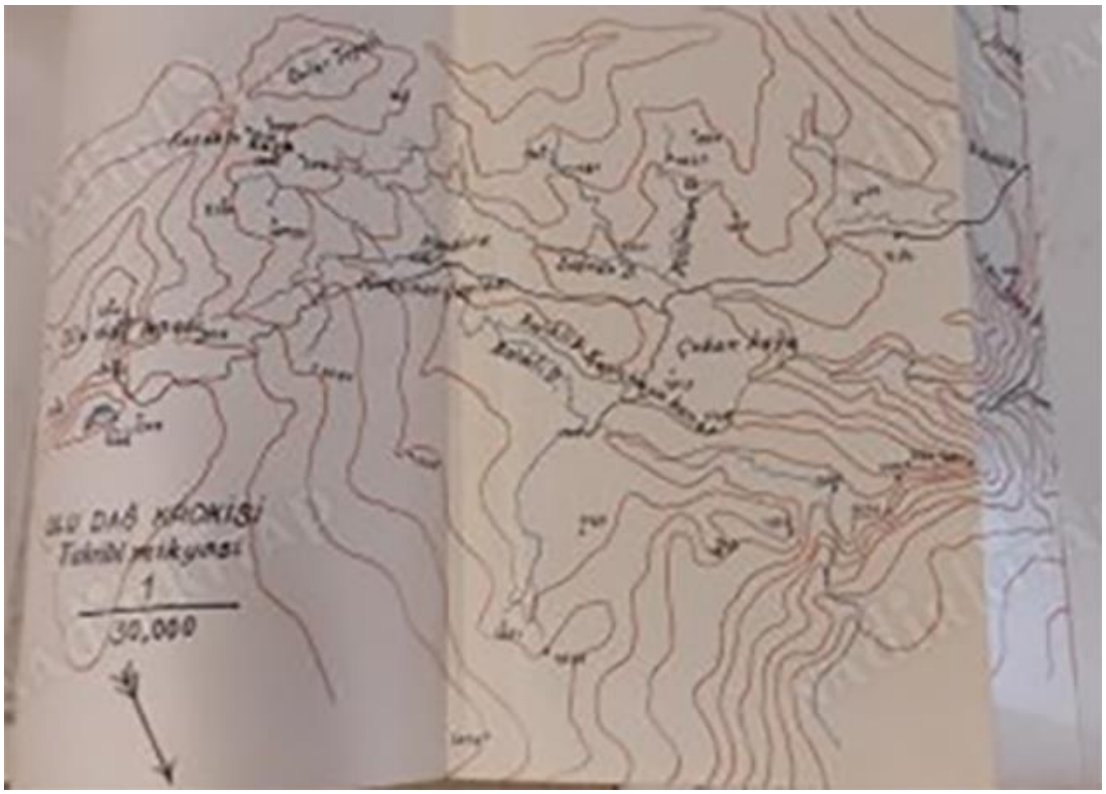

Figure 3. Uludağ sketch published by Uludağ (1928)

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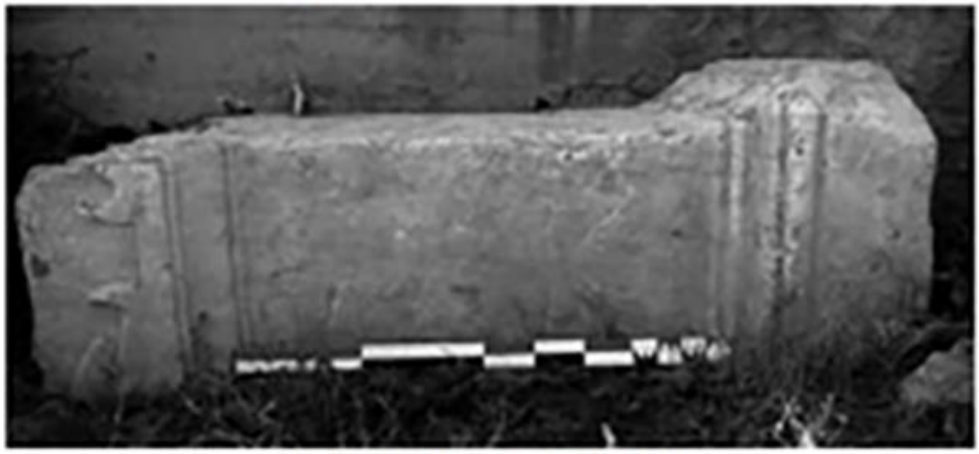

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Figure 4. An example of the ancient finds in the 2006 report (Auzépy et al.,2006).

The primary textual sources for the Olympus monasteries are the monastic saints' lives and the foundation documents. They contain information about religious subjects (e.g., organization of monastic communities) and daily life. Any monastery of Olympus does not have a complete foundation document, but the foundation document of the monastery of Stoudios in Constantinople, founded by monks from the monastery of Sakkoudion in Olympus, is indirect evidence of the monastic organization in Olympus. The document is in Greek and was translated into English (Thomas and Hero, 2000). The Life of St. Plato of Sakkoudion, written by Theodore of Stoudios, is an essential source of life in Bithynia's monasteries. The lives of St. John and St. Peter of Aatro are likewise important sources in Greek.

As a result, in this study, the original texts about monasteries and the reports and publications of the few field studies on the Uludağ monasteries are interpreted together. This study is a presurvey to discuss the advantages of utilizing GIS to understand the tangible and intangible qualities of the monastic cultural landscape. The inter-scale approach, supported by the use of GIS as a tool for analysis, proves to be an efficient and unique method to understand the cultural texture of mountains.

2. Method

The study aims to draw attention to the highly diverse and qualified cultural texture arising from the human-nature interaction of the mountain landscapes, which stand out with their natural qualities and the cultural heritage values inherent in this texture. In other words, this study aims to develop GIS-based conservation and management methods for conserving and managing complex rural systems.

Concerning the questions of determining the locations of the monasteries and the investigation of the relations they established within the cultural landscape; it should be stated that it was impossible to locate most of them. When the data obtained from the field studies carried out by Bursa Metropolitan Municipality (2012) in the recent past are evaluated, it is foreseen that the locations of at least five monasteries can be determined precisely. As a result of the interpretation of the archive documents and architectural remains related to them, important new data about these monasteries and their immediate surroundings can be reached.

The main stages of the method were as follows:

1. Preliminary site survey

2. Archival work: Compilation and examination of archival documents, historical and current maps, past and current climate data.
3. GIS database design: Creation of database structure, design of outputs.
4. Creation of GIS database: Entering land and archive data into the GIS database.
5. Analysis: Comparative analysis of all data with the opportunities offered by GIS.
6. Evaluation: Determination of natural and cultural heritage values.
7. Recommendations: Development of the GIS database as a model for site management. Proposals for the integrated conservation of natural and cultural values.

2.1. The use of GIS databases for the conservation of heritage sites

GIS is a spatial database that contains and analyzes georeferenced information. Within its broad range of applications, GIS is often used for urban management purposes, including urban and rural conservation and management. The fact that GIS has numerous spatial analysis tools that can analyze and update large amounts of data makes it a valuable tool that is well-suited for monitoring and analyzing the changing nature of the urban environment (Çabuk, et al. 2016).

GIS allows researchers working on the "cultural landscape" to analyze and evaluate physical, socio-cultural, and historical information by relating it to each other. Interactive maps based on GIS databases provide an effective environment to present the relationships between the cultural landscape and meanings. As a result, various applications carried out through GIS can be used to analyze, evaluate and present both tangible and intangible characteristics of the place. Moreover, GIS allows for the continuity of different scales; in other words, it enables "navigation" between scales. In this respect, GIS provides an ideal environment for storing and analyzing data on the historical, cultural, and physical characteristics of cultural landscapes that can be associated with specific locations, adding them to decision-making processes and monitoring the transformation of landscapes. Thus, it is possible to bring together spatial data related to different scales according to a common geographical/spatial reference system, to be monitored and queried in the same environment (Çabuk, et al. 2016).

As a result, GIS is selected to deal with the existing diversity of resources, which is one of the problems of cultural landscape studies.

2.2. Data model in documenting cultural heritage

At the beginning of the study, the data needed for the analyses to be made in line with the aims and objectives are determined. Then, a process is started for creating thematic layers and designing the database. This process consists of logical and physical design stages.

In the logical design process, the data to be used in the study are planned, accessibility is determined, and it is decided which thematic maps will be reached as a result of which analysis with the obtained data. Planning is the stage where it is determined which data will be used and under what constraints or conditions will be stored in the database (Zeiler, 1999). At the end of this stage, a data model is put forward. This model shows all kinds of data to be used in the project, the relational structure, and storage conditions. Moreover, the thematic processes are exhibited as a whole in a single document. This model aims to ensure data consistency by preventing data repetition and ensuring that the whole project team acts in a common structure during the project process.

The physical design process consists of data generation and processing stages after the creation of the locational database in line with the data model created.

A locational database is a data model that supports storing and managing locational information in a standard relational database system.

In a locational database, data is stored in locational object tables, also defined as vector data (Figure 5). Locational object tables are components created with different geometry types to store vector data, which constitutes a layer in GIS software (Uyguçgil et al., 2017). Verbal data can be contained both in a locational database and a standard relational database. At the same time, raster data with visual content can be stored in the locational database as an attribute of an object. These features of GIS make it possible to represent and analyze the qualitative and quantitative data to be obtained in the study in the same database.

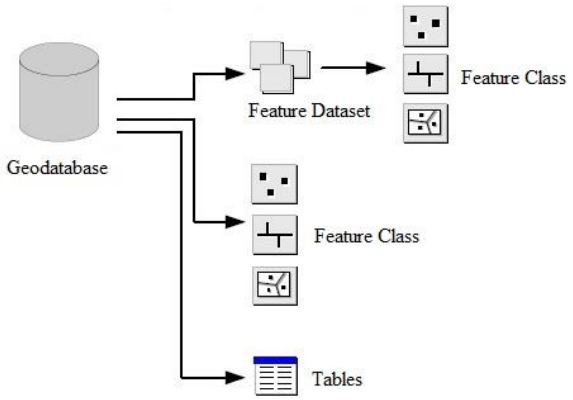

Figure 5. Locational database general data structure (Levent, 2009)

Various data sets within the database constitute conceptual models (Figure 5). These data sets form the components of a network structure that may need to be evaluated together in terms of topology relationships (Levent, 2009).

When creating a database in the documentation work, stone structures and all material cultural assets in the historical area must be documented and recorded. The sensitivity of the work to be done at this stage is of utmost significance. Performing a restoration precision study for a specific structure in the area and making an inventory of the stone structures in the area requires the formation of different data sets from each other. According to the study, geometry can be created on the database by mapping with spatial measurement, and geometries of stone structures can be created as a result of a measurement (Koçyiğit, 2020) is shown in Table 1.

Table 1. An example of data sets used in archaeological sites (Koçyiğit, 2020)

Data Sets Created for Archaeological Sites	
Administrative Boundaries (Layer usually has the largest area and contains other details like provincial border, district boundary, country boundary, etc.)	**Social Infrastructure** (The layer hosts all kinds of social infrastructure data like population density, area per capita by year, etc.)
Hydrology (The layer contains information about the water in the area, like stream flow direction, basin boundaries use, etc.)	**Land Use/Land Cover** (The layer contains information on land use in the area, such as land use purposes by year, etc.)
Weather (The layer contains the weather information in the region temporally, like minimum annual precipitation, average precipitation amounts etc.)	**Project General Information** (The layer covers general information about the project, compiled from academic articles and news about the field.)
Land Measurements (The layer contains information about measurements made by various methods in the field, such as points taken by GPS, measurement results made by photogrammetric methods, etc.)	**Geophysics and Geology** (The layer contains information about the soil structure, such as areas with earthquake risk etc.)

2.3. A GIS database prepared for the conservation of Uludağ / Olympus cultural landscape and monasteries

As mentioned above, one of the main visual resources in determining the historical and cultural texture of Uludağ is the map of Menthon. However, the lack of exact coordinates causes the map to deviate from accuracy. It is usual for a historical map to show deviations when it is overlapped with today's satellite images.

In this study, since the Menthon's Map has no accurate coordinate information that can be utilized for overlapping it with the georeferenced satellite image; villages, urban focal points, and localities whose locations can be clearly matched were used as reference points for overlapping. Since some settlements, which were small when the Menthon Map was prepared, have reached the size of neighborhoods and even districts today, the oldest buildings and squares of the settlements were selected as the reference points in the georeferencing process.

The facts that accuracy is significant in the georeferencing process and that there are many (more than 10) reference points, as well as numerous checkpoints, made the "spline" transformation in the georeferencing method work better than other methodologies. The spline function is a piecewise polynomial function that maintains continuity and uniformity between adjacent polynomials. The conversion matches the source reference points exactly to the target points, and the error rate of the pixels increases as one moves away from the reference points. This conversion is proper when reference points are accurate, and increasing the number of reference points increases the overall accuracy of the conversion (Kramer et al., 2011). In this method, at least ten reference points should be used.

In this study, in addition to historical map and written source data, the following data is used in GIS environment:

1. up-to-date stream data
2. up-to-date road data
3. DEM (Digital Elevation Model)
4. *Google Earth* maps
5. current maps (such as a map showing the National Park Area border)
6. high-resolution satellite imagery

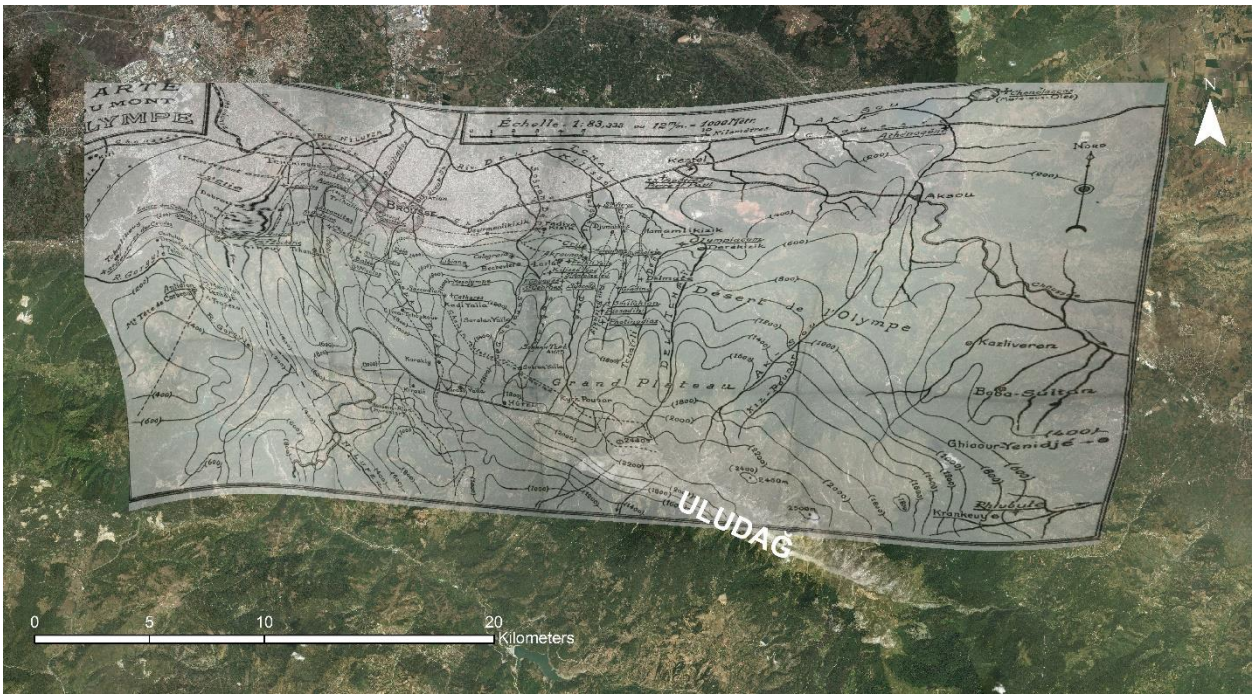

Figure 6. The georeferencing of the Menthon Map according to the reference points and the determination of the study area

3. Results

Since the Menthon Map covers a vast area of about 1000 square kilometers, the georeferencing was carried out on a relatively small-scale (10 m/pixel) RGB satellite image. As a result of the georeferencing process, the probable locations of the monasteries were estimated, and large-scale (high-resolution 1.2 m/pixel) RGB images, multiple spectral images, and hyper-spectral images of those regions were obtained, and the anomalies under dense vegetation were visualized for the analysis of exact locations of the monasteries. In the scope of this study, no fieldwork was carried out in places where the remains of the monasteries are thought to be present. Instead, the results of the Bursa Municipal Research Team's field surveys were compared with the probable monastery localities obtained from the georeferencing process.

As a result of obtaining the Digital Elevation Model (DEM) data of the study area and comparing the monasteries with their approximate location according to the Menthon Map, it was confirmed in Figure 9 that the monasteries in the central and right zones were generally located between 600 meters and 1500 meters (Figure 9). Similarly, when the approximate positions of the monasteries in the study area are examined according to the inclination analysis, it can be concluded that the monasteries on the east of the mountain are located on extremely inclined grounds and at difficult-to-reach points of the topography (Figure 7). The fact that the cable car line passes near one of the areas where monasteries are grouped has important potential for the research process and the development of cultural route proposals.

In the analysis of transportation and roads, it is understood that most of the monasteries are located at points that are very difficult – even impossible – to reach by motor vehicle today (Figures 8-11).

When the walking routes followed by the Bursa Metropolitan Municipality to document the ruins of the monastery are examined (Figure 12), it is observed that:

1. It is possible to create monastic routes from Cumalıkızık Village, near the Hotels District, or from the Teferrüç or Kadıyayla stations of the cable car line.
2. So far, the Bursa Municipal Research Team has reached the monastery remains at five different locations.
3. There is a considerable difference between the coordinates of the points where the remains were reached and the approximate locations of monasteries found by rectifying the Menthon Map (1935) in this study. It is calculated that the error margin is approximately 500 meters. The huge error margin leads to the conclusion that the rectification (georeferencing) of the Menthon Map for the localization of the monasteries confirms that additional methods like site surveys and remote sensing methods should be used to achieve more precise results and to discover more monastery remains at Uludağ.

As a result, the analysis and evaluation of the monasteries as part of the cultural landscape in an integrated and comparative manner with historical research, fieldwork, and geographical data reveal crucial and new information about the forgotten monastic cultural heritage of Uludag and set an important example for the preservation and presentation of mountain landscapes with their natural and cultural values.

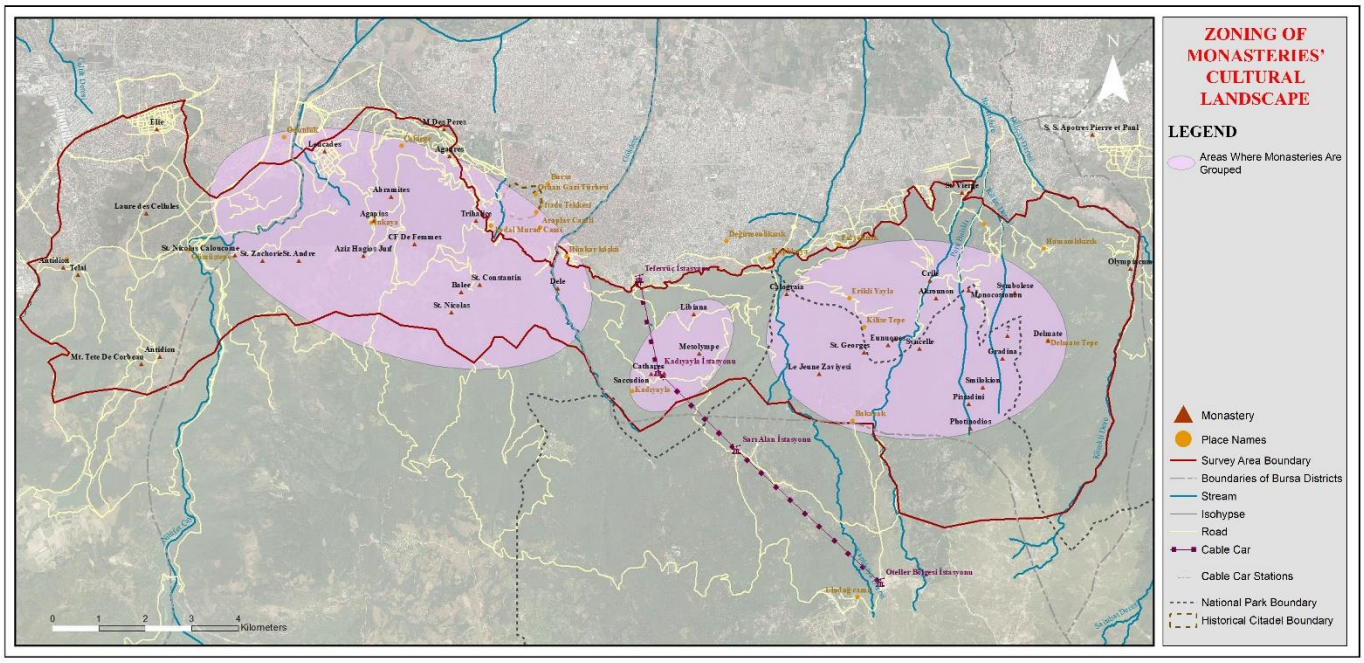

Figure 7. Identification of three areas grouped with monasteries approximately located according to the Menthon Map (1935) in the study area. The first of these areas is located in the west, the second is near the cable car line, and the third is located in the east, at the top of Cumalıkızık Village, one of the components of the World Heritage Area.

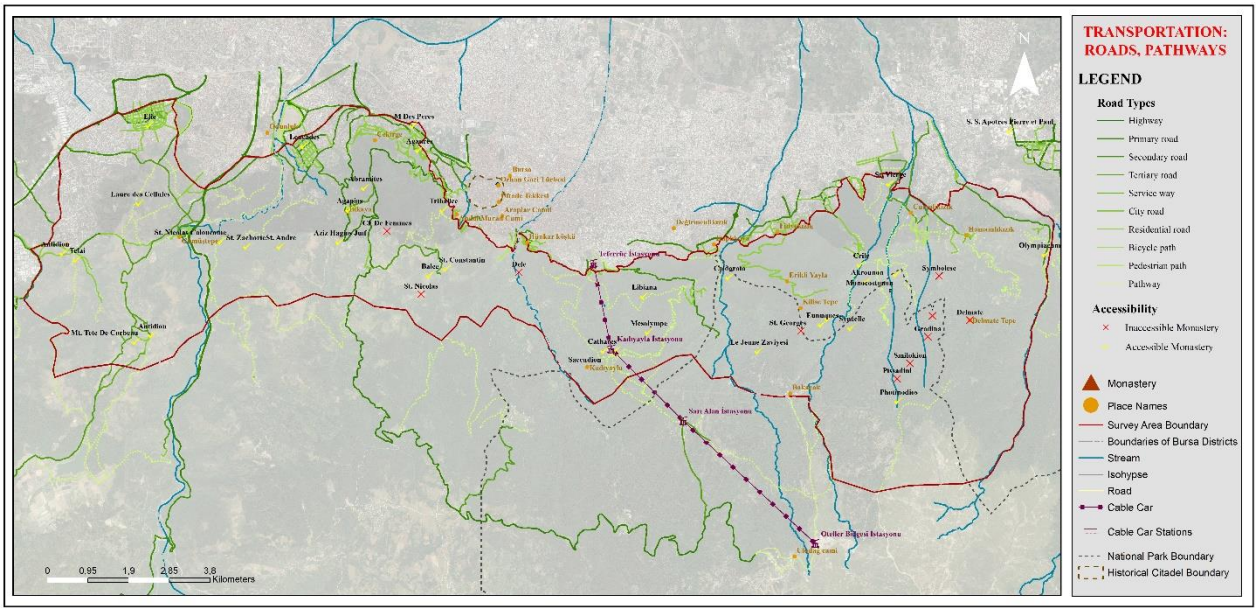

Figure 8. The current state of transportation and accessibility

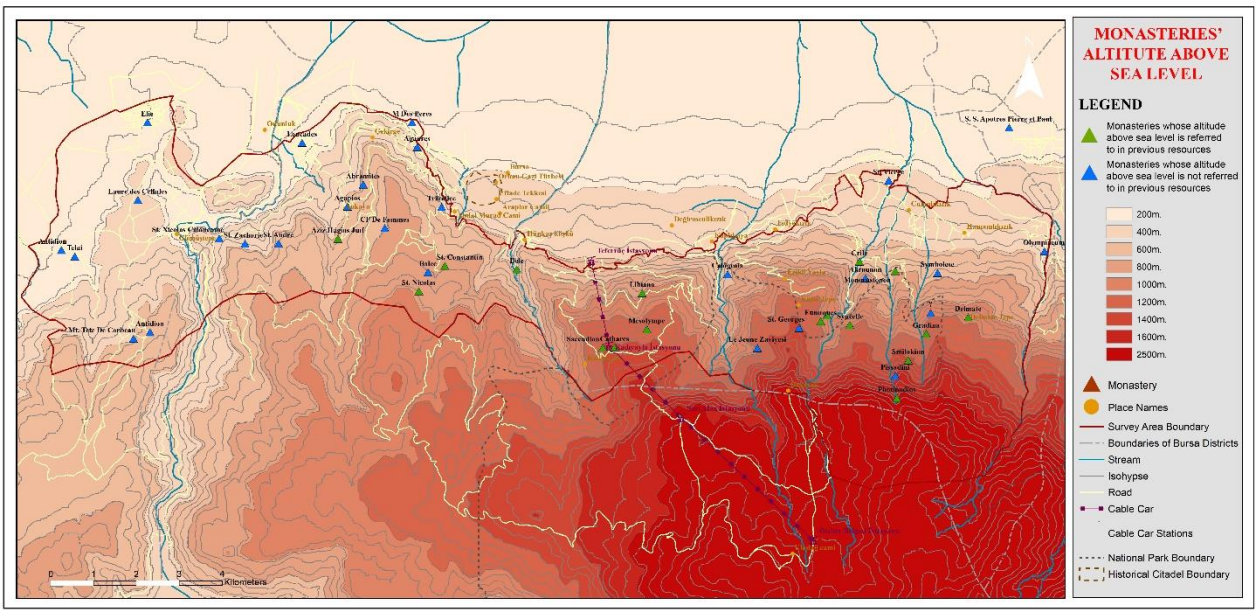

Figure 9. The analysis of the monasteries' altitude above sea level

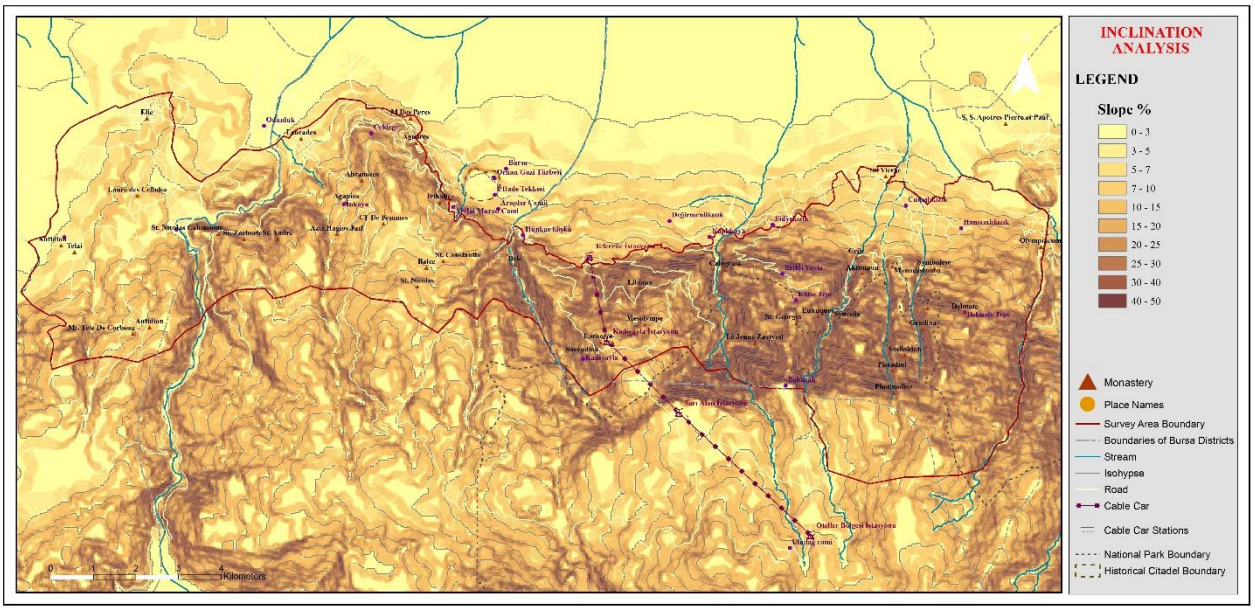

Figure 10. Inclination Analysis

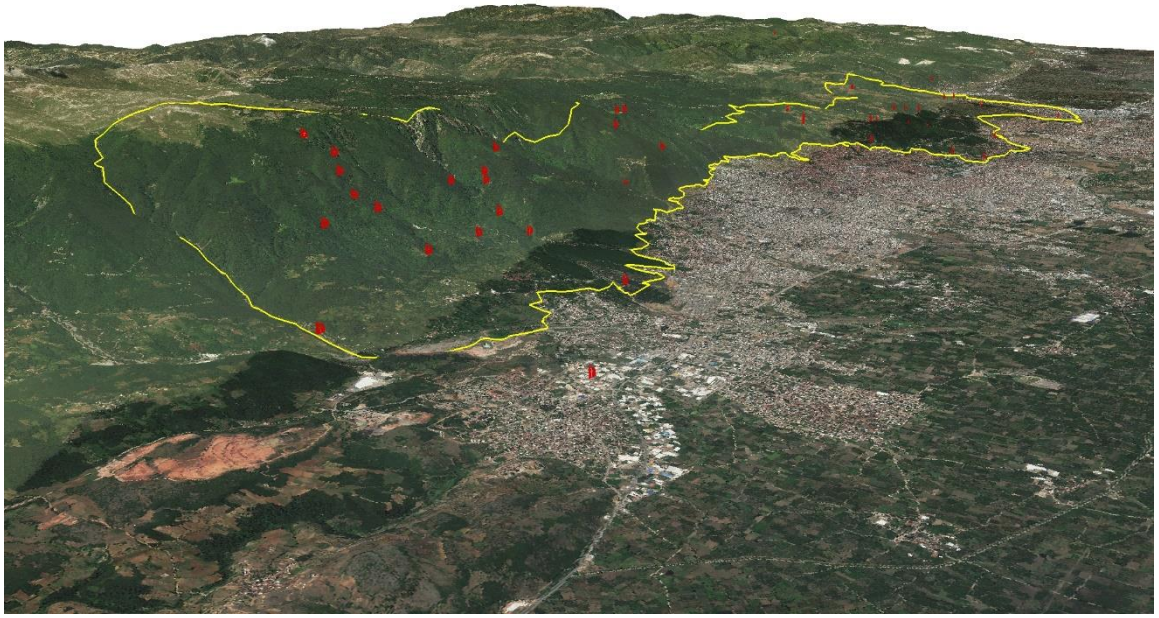

Figure 11. A 3D model showing the massive mountain and the estimated locations of the monasteries

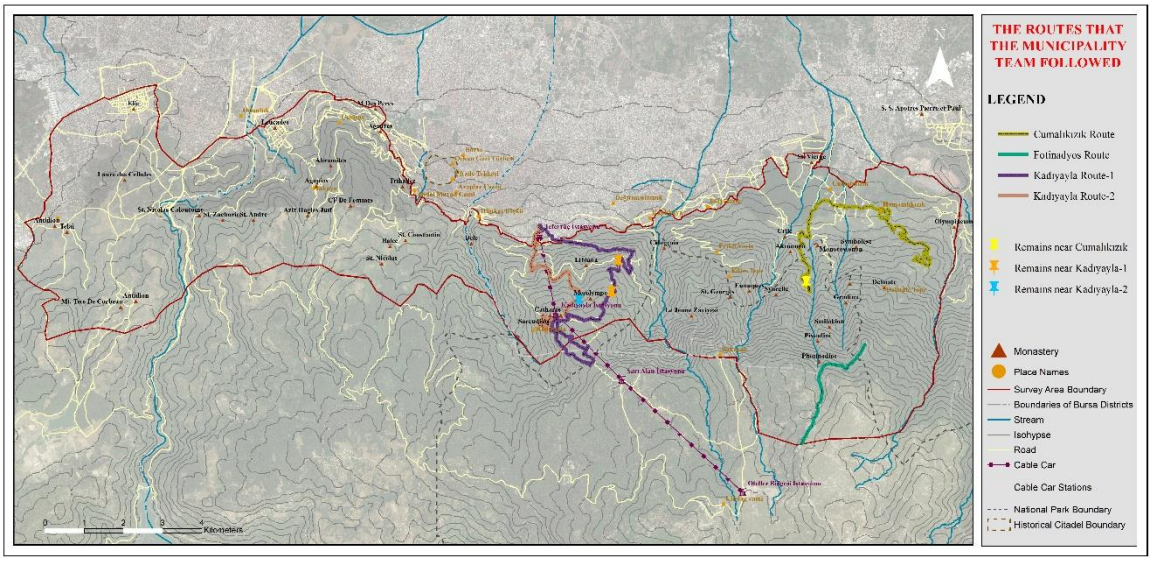

Figure 12. The discovery walks carried out by the Bursa Metropolitan Municipality (2012) in the middle and east of the study area and the approximate locations of the remains they have reached

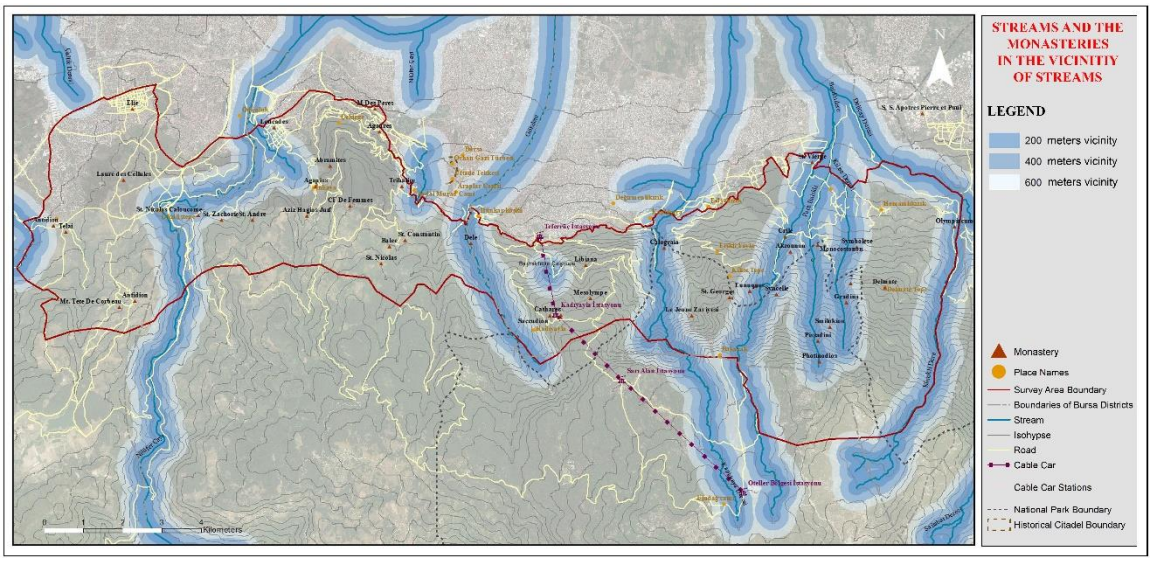

Figure 13. The water streams and the monasteries located near them

4. Conclusion

Uludağ has diversity and density in its natural and cultural resources, such as its unique mountainscape, forest, plateaus, lakes, flora, fauna, and cultural heritage. With these features, it is seen as a geographical area with nature and rural tourism potential (Erken et al., 2019). The fact that Uludağ is a destination center with a reputation increases the potential of rural tourism (Ölmez, 2021; Karadamar et al., 2018). Uludağ is a region suitable for various types of tourism thanks to its favorable climatic and geomorphological conditions. Among them are alpinism; winter tourism as a result of prolonged snowfall; ecotourism due to rich flora and fauna, and finally, rural and cultural tourism as a result of historical villages and the cultural landscape including the remains of monasteries and dervish lodges (Adamış and Özçoban, 2020).

While proposing routes to introduce the monasteries' cultural landscape, the historical and cultural attraction points in the vicinity can be entered into the GIS system in order to propose routes that enrich the identity of Uludağ by establishing relationships between the different cultural and natural layers of Uludağ and experiencing the various cultural layers and values of Uludağ. Thus, the results obtained from this study will contribute to achieving a holistic and multifaceted Uludağ identity.

To remember the monasteries in Uludağ, the monastic layer, which has been almost completely erased from the collective memory and the mountainscape, can be studied in the scope of new scientific studies by the institutions like universities and municipalities. Since it is a cultural landscape, which is characterized by both natural and built structures, GIS proves to be a compatible analysis tool for researching the values of Uludağ monasteries.

The current scholarship investigates the mountainscapes by integrating quantitative and qualitative research methods and modeling and analyzing the collected data in the GIS. Various methodologies were developed to analyze the mountainscapes' cultural and natural characteristics. In the case of Uludağ, field survey, archival research, and GIS modeling should be used in combination in order to achieve the discovery, documentation, and evaluation of the Uludağ monasteries.

With the help of GIS, it is possible to analyze and evaluate archival resources, the data obtained from site surveys, aerial photographs, maps, and DEM images. Producing a GIS-based dynamic updatable tool can also serve in site management of the monasteries' cultural landscape. The GIS database can also be a tool to support decision-making processes for the conservation and management of the area.

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Author contributions

Figen Kıvılcım Çorakbaş: Defined the problem and proposed the structure of the study. **Emre Mustafa Bektöre:** Managed the GIS database design and GIS analysis stages.

Conflicts of interest

The authors declare no conflicts of interest.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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