STUDY OF CULTURAL LANDSCAPES WITH REMOTE SENSING TECHNIQUES

Aikaterini Karagianni

Aristotle University of Thessaloniki, Faculty of Engineering, School of Civil Engineering,
Lab. of Photogrammetry – Remote Sensing, P.O. Box 465, 541 24 Thessaloniki, Greece
Email: aikateck@civil.auth.gr

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ABSTRACT: Monitoring of cultural landscapes presents a particular interest in terms of heritage maintenance and protection. The study of sites with a cultural value, as well as the road networks which provide accessibility to those landmarks and connect them with urban areas could provide valuable information on heritage sites management. Among the various methods that have been developed for this purpose, remote sensing techniques and especially processing of satellite data could contribute significantly on this direction. This paper presents the study of several landscapes in north-western Greece using open access satellite images in order to provide information regarding the detection, monitoring and mapping of areas of high cultural interest. Through the processing of Sentinel-2 satellite data using remote sensing techniques, the detection of cultural sites is done focusing in several locations. The delineation of the networks that are present is also attempted, in order to propose possible cultural routes that could promote sustainable development in the region.

1. INTRODUCTION

Preservation of cultural landscapes has become a high priority in terms of a sustainable development policy, as it could contribute to the protection and conservation of cultural heritage in order to be safeguarded and passed on to future generations (Luo et al., 2019). Searching for tools that could provide valuable information regarding the detection, monitoring and mapping of areas which present high cultural interest is closely connected to several factors, such as data availability, effectiveness of used methods, time consumed, possible cost, etc.

Among the various disciplines that could contribute towards this direction, remote sensing has shown a great potential during the last decades, making available interesting cost effective tools that could be used in heritage sites management (De Maeyer et al., 2004, Banerjee and Srivastava, 2013, Agapiou et al., 2015, Deroin et al., 2016, Luo et al., 2019). Rapid analysis of multisource datasets, dynamic monitoring of changes and open access data are among some of the benefits remote sensing offers.

This paper presents the study of cultural landscapes at the Regional Unit of Kastoria in north-western Greece using open access satellite imagery, in order to provide information useful for heritage sites management. Through the implementation of remote sensing techniques using Sentinel-2 satellite data, detection of cultural sites is achieved focusing in several locations. The delineation of the networks that are present is also attempted, in order to propose possible cultural routes that could promote the sustainable development of the region.

2. STUDY AREA AND SATELLITE DATA

2.1 Study area

Study area is located in medium-high altitude (630m) in the north western part of Greece, region of Western Macedonia (Figure 1) and it concerns Kastoria city and its surroundings. The city is located on a peninsula at the western shore of Lake Orestiada and it has a long cultural history, which is depicted in its structure (old city, newer city and urban extension) (Regional Unit of Kastoria, 2020).

Figure 1. The location of Regional Unit of Kastoria in Greece (left image) and the city of Kastoria in the red circle and Lake Orestiada (right image) (Google Maps, 2020)

Regional Unit of Kastoria is one of the most mountainous prefectures where there exist noteworthy prehistoric and byzantine monuments. Apart from its high architectural and urban value, it presents historical, geographical and archaeological value through its landscape diversity (Tsigaridas, 2012). Furthermore, rich elements of Byzantine culture (Byzantine Justinian walls and medieval churches) as well as traditional mansions of the 17th and 18th centuries, unique for their architectural design are located in the city center (Doltso and Apozari neighborhoods) (Moutsopoulos, 1989). Lake Orestiada which surrounds the city is the predominant feature of the area. It is included in the Natura 2000 network offering unique habitats for many endangered fauna and avifauna species (Ponce de León, 2015).

2.2 Cultural landscapes

Both the city of Kastoria and the surroundings are of particular interest due to the high number of cultural landmarks that adorn the area. Prehistoric settlements, dozens of byzantine and post-byzantine churches, as well as traditional mansions reveal the unique character of the area. Delineation and monitoring of those sites through remote sensing techniques could contribute to their preservation and restoration, making possible at the same time the touristic development of the region.

Typical examples of cultural heritage sites were selected for this study, in order to propose possible cultural routes. Implementing remote sensing techniques in open access satellite data, the selected sites of interest are detected and connected through a proposed network. These sites concern the neolithic settlements of Dispilio and Avgi, the byzantine churches of Panagia Koumbelidiki and Agios Stefanos, the byzantine monastery of Panagia Mavriotissa, as well as Skoutaris and Tsiatsiapa mansions located in the traditional districts of Doltso and Apozari respectively. A brief description of these sites is provided below.

2.2.1 Neolithic Settlements of Dispilio: A representation of the prehistoric lake settlement of Dispilio, the first of its kind ever excavated in Greece, is located on the southern shore of the Lake Orestiada close to the lakeside village Dispilio and 7 km south of Kastoria city. The settlement consists of eight houses made of wood and clay which depict the way of life of prehistoric fishermen, farmers, stockbreeders and hunters in Neolithic era (Figure 2). Traces of this settlement were first located by Professor A. Keramopoulos of the Aristotle University of Thessaloniki in 1932. Due to various technical works that were held in the area since 1935 (including the construction of the road that connects Dispilio with Kastoria) the lake water level fell, leading to the discovery of a significant number of piles (Facorellis et al., 2014). The modern investigations started in 1992 and the current representation was gradually created. The findings of the excavation place the settlement around the sixth millennium BC, where a great civilization developed in the area (Municipality of Kastoria, 2020).

Figure 2. Representation of the Neolithic Settlement of Dispilio

2.2.2 Neolithic Settlement of Avgi: The Neolithic site of Avgi is located on a hilly terrain of clay rich deposits, very close to the modern village of Avgi circa 14 km southwest of the city. The site forms an 'extended' settlement, and the excavations which were carried out from 2002 to 2008 revealed a well-known type of the Neolithic era in the Balkans (Figure 3). The environment favored farming, grazing of domesticated animals, hunting and fishing, as well as the collection of fruits. In contrast to the modern landscape of Avgi, which is characterized by extensive land use such as farming, the Neolithic landscape was covered by forests according to the anthracological analysis (Neolithic Settlement of Avgi Kastoria, 2013).

Figure 3. The Neolithic Settlement of Avgi during the excavations in 2008
(Neolithic Settlement of Avgi Kastoria, 2013)

2.2.3 Byzantine churches of Panagia Koumbelidiki and Agios Stefanos: In the acropolis of the Byzantine castle of Kastoria, close to the wall and its two towers, rises one of the most important Byzantine monuments of the area, the church of Panagia (Virgin Mary) Koumbelidiki (Figure 4.1). The small dimensions of the church and its high dome with a variety of masonry work have made it a cultural reference point. Its name derives from the greek word 'koumpes' (which means dome) and it was established during the Ottoman rule in order to indicate the main feature of the temple, which is the only one with a dome in Kastoria city. There are different views on the dating of the monument between the middle of the 9th century and the beginning of the 11th century, based on the morphology of its masonry. The main part of the church and the inner narthex preserve decorations of very good quality depicting orthodox religious themes (dating period 1260-1280), while the external frescoes date back to 1496 with a renovation taking place in the middle of the 17th century. The church was bombed in 1940 during the Greek-Italian war and lost the greatest part of its dome, which was restored in 1949. A new cycle of restorations took place in the following years (Ministry of Culture and Sports, 2012).

The triple-aisled basilica of Agios Stefanos (Saint Stephen) is one of the oldest Byzantine temples in the city and in the Balkan Peninsula in general (Figure 4.2). Built on a hill between the two traditional districts of Kastoria (Apozari and Doltso), in the middle of the 9th century or at the latest in 900, according to its older frescoes that were preserved. It has attractive tile decoration and wall-paintings, the earliest of which date to the 9th century. These wall-paintings are of exceptional significance as an example of early painting reflecting a high level of iconographic and artistic attainment. Some scattered dedicatory or liturgical scenes in the narthex and on the lower sections of the walls in the main body of the church date to the 12th century. Scenes on the ceiling are estimated to have been painted around 1200, while some others date to the 13th and 14th centuries. Nowadays, several studies have been made regarding the restoration and preservation of the architecture of the monument, as well as the conservation of its frescoes (Ministry of Culture and Sports, 2012).

Figure 4.1 Byzantine church of Panagia Koumbelidiki

Figure 4.2 Byzantine church of Agios Stefanos

2.2.4 Byzantine monastery of Panagia Mavriotissa: The single-aisle church with narthex of the Panagia (Virgin Mary) Mavriotissa, is probably an 11th century building (Figure 5). Later, in the 16th century a chapel with wall-paintings dedicated to John the Theologian was erected near the main church. The monastery played an important role in all phases of the history of the region, contributing mainly to the spiritual life of the area. The paintings that have survived are confined to the sanctuary, the west wall of the main body of the church and the narthex. Characteristic of the frescoes are the eyes that have been engraved-removed from the depicted faces of Saints, as a result of the Ottoman rule. Some of these old wall-paintings were restored in the 13th century, while the exterior wall of the narthex was decorated with new ones (Macedonian Heritage, 2013).

Figure 5. Byzantine monastery of Panagia Mavriotissa

2.2.5 Skoutaris and Tsiatsiapa mansions: Kastoria has maintained two main historic districts in the city center, Doltso and Apozari, where mansions with local architecture preserve the traditional character of the area. Two representative buildings of these areas are Skoutaris mansion and Tsiatsiapa mansion respectively. Skoutaris mansion is located on the south side of the city, along the coast of the Doltso area (Figure 6.1). The ground plan has a 'Π' shape, with windows on the first floor, while the windows on the second floor stand out for their larger size. The main entrance of the building is located on the south side, between the two basements. Tsiatsiapa mansion is the oldest mansion of Kastoria and is located along the coastal road of the north side of the city, in the traditional district of Apozari (Figure 6.2). It is a brilliant example of urban architecture of the 18th century, which reflects the financial strength of the traders' caste which flourished due to the social and economic conditions prevailing at the time (Ephorate of Antiquities of Kastoria, 2017). It is the only three-story grand mansion in the city of Kastoria with a rectangular ground plan moving on a horizontal axis. The interiors are richly decorated, although in some places have suffered irreparable damage. The building opened its door to the public as a visiting monument on 30 June 2017 after restoration works conducted by the Ephorate of Antiquities of Kastoria.

Figure 6.1 Skoutaris mansion

Figure 6.2 Tsiatsiapa mansion

2.3 Satellite data

The data employed for this study concern Sentinel-2 satellite imagery covering the study area. Sentinel-2 mission consists of two polar-orbiting satellites (Sentinel-2A and Sentinel-2B) providing high-resolution optical imagery for land monitoring. The full mission specification of the twin satellites flying in the same orbit but phased at 180°, is designed to give a high revisit frequency of 5 days at the Equator (Sentinel-2, 2020). Sentinel-2A was launched on June 23, 2015 while Sentinel-2B on March 07, 2017. Both satellites are equipped with the MSI (Multispectral Imager) instrument

that offers high-resolution optical images. The optical-multispectral high resolution sensor that is provided on board covers thirteen different bands: four visible and near-infrared bands with a spatial resolution of 10 m (bands 2, 3, 4, 8), six red edge and shortwave infrared bands with a spatial resolution of 20 m (bands 5, 6, 7, 8A, 11, 12) and three atmospheric correction bands with a spatial resolution of 60 m (bands 1, 9, 10). Sentinel data products are available to all users and can be accessed free of charge (free, full and open data policy adopted for the Copernicus programme) through the Copernicus Open Access Hub (Copernicus Hub, 2020).

The image data that have been used in this study derive from Sentinel-2A (S2A_MSIL2A) and were acquired at 2019-09-29 with level processing 2A. Figure 7 presents the Sentinel-2 subset of the study area along with the general locations of the cultural sites mentioned in Section 2.2 (coloured dots). The Level-2A products provide Bottom of Atmosphere (BOA) reflectance images derived from the associated Level-1C products. Each Level-2A product is composed of 100x100 km2 tiles in cartographic geometry (UTM/WGS84 projection). Combining multispectral bands 4-3-2 for RGB respectively, urban features appear in white and grey shades (or red in areas covered by houses with tile roofs), while the water body (Orestiada lake) is visible in the center with darker shades. Vegetation and crops appear in green tones, while bare soil has different shades of brown.

Additionally, refined open access data from OpenStreetMap were used as base vector layers in order to delineate the existing networks and to further propose possible cultural routes as part of a sustainable development strategy (OpenStreetMap, 2020).

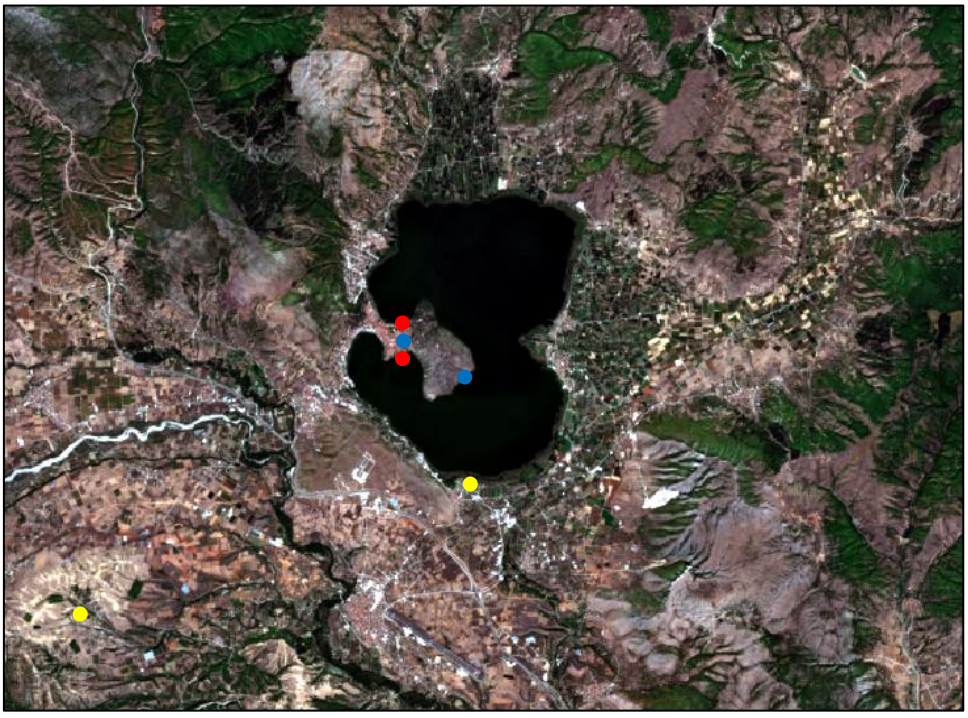

Figure 7. Sentinel-2 subset of the study area in Natural Color Composite (RGB: 4-3-2)
Locations of: Neolithic Settlements of Avgi & Dispilio (yellow dots), Panagia Koumbelidiki-Agios Stefanos & Panagia Mavriotissa churches (blue dots), Skoutaris & Tsiatsiapa mansions (red dots)

3. DIGITAL IMAGE PROCESSING AND CULTURAL ROUTES

Digital processing of Sentinel-2A data includes resembling at 10 m, layerstacking of the downloaded data, subsetting of the scene focusing on the study area, and implementation of image enhancement techniques in order to delineate the areas of interest.

Edge and line detection is an important enhancement technique in digital image processing, especially when studying the delineation of urban features or linear networks, such as road

networks. Therefore, the selection of the appropriate algorithms and filters is closely linked to the understanding of the nature of the feature being studied (Karagianni, 2019).

In this study spatial and spectral enhancements of the satellite image were selected as effective techniques to highlight the cultural landscapes, as well as the road networks that connect them. Spatial enhancement operations improve the interpretability of features within the data by modifying neighborhood pixels values based on the value of a targeted pixel (ERDAS Field Guide, 2010). Convolution uses a matrix to average small sets of pixels across the image. The implementation of a 3x3 convolution filter resulted in Figure 8, highlighting linear and urban features through edge detection.

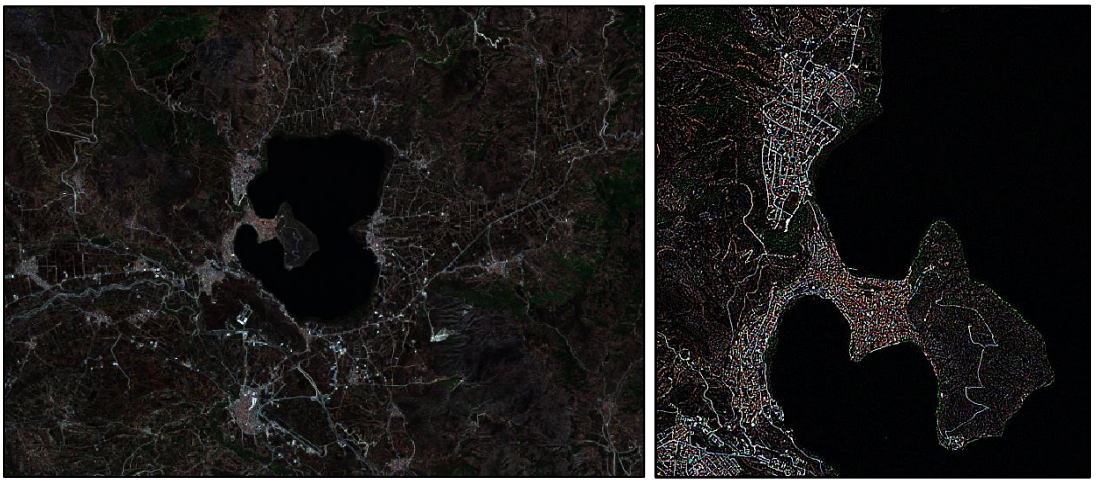

Figure 8. Sentinel-2 subsets of the study area after convolution filter for edge detection

Spectral enhancement leads to the creation of new spectral data from the available spectral bands, changing the values of each pixel in the original image by transforming these values into a multispectral image of many spectral bands (Lillesand and Kiefer, 1987). Therefore more than one spectral band is required to apply various operations. These techniques are commonly used to extract data that are more interpretable and more suitable for further analysis (Karagianni, 2019).

Decorrelation stretch is a spectral enhancement technique which applies a contrast stretch to the principal components of the image in order to decorrelate the bands and produce a more 'contrasty' and strongly coloured output image using the Principal Components transformation (ERDAS Field Guide, 2010). Figure 9 presents the study area after decorrelation stretch. Implementation of this technique led to the enhancement of the imagery, emphasizing the built-up areas and cultivated areas, as well as the road network.

Figure 9. Sentinel-2 subsets of the study area after decorrelation stretch

Subsequently, using the enhanced Sentinel-2 images as a base and refined open access data from OpenStreetMap as guides, three cultural routes were designed/digitized connecting the areas of interest respectively. The first route connects the Neolithic settlements of Avgi and Dispilio with the city of Kastoria under a circular path pattern (Figure 10).

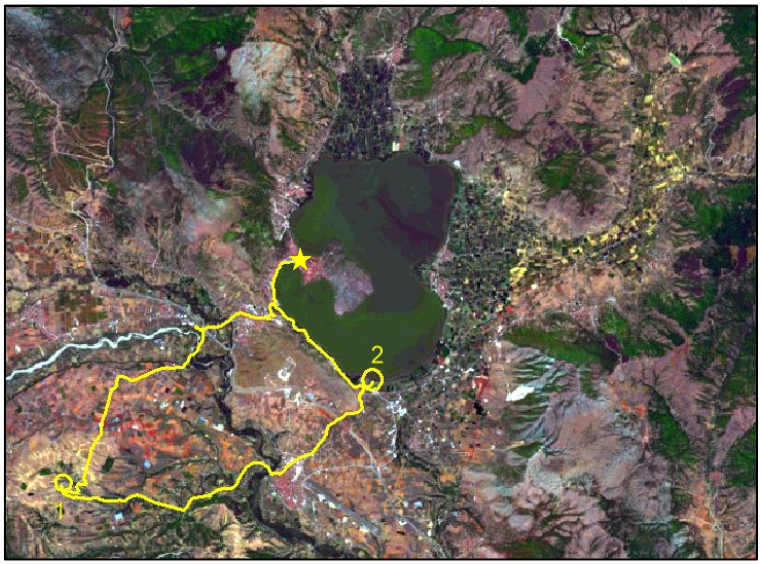

Figure 10. First cultural route (yellow line) connecting the Neolithic settlements of Avgi (No 1) and Dispilio (No 2) with the city of Kastoria, following a circular trail

The second route that is proposed connects the traditional districts of Doltso and Apozari which include mansions of interesting architecture with the byzantine monastery of Panagia Mavriotissa also under a circular pattern, surrounding the peninsula where the city is built, offering at the same time a beautiful path near the lake and the natural environment (Figure 11).

Figure 11. Second cultural route (yellow line) connecting the traditional district of Doltso (No 3) with the byzantine monastery of Panagia Mavriotissa (No 4) and the traditional district of Apozari (No 5) under a circular trail near the lake that surrounds the peninsula

The final route that is proposed offers a view of some of the most important byzantine churches built in the center of the city such as Panagia Koumbelidiki and Agios Stefanos churches. The route continues with the ascent to the hill of the peninsula offering a panoramic view of the whole area and ends again at the start point (Figure 12).

Figure 12. Third cultural route (yellow line) connecting the byzantine churches of Panagia Koumbelidiki (No 6) and Agios Stefanos (No 7), leading to the peninsula hill with panoramic view

4. CONCLUSION

The constantly evolving technologies in Earth observation (new satellites and sensors with various capabilities, high spatial resolution imagery, policy of free data, etc.) may offer continuous information regarding the study of cultural landscapes. Remote sensing could provide valuable tools that enable fast prospecting and mapping at multiple scales, analysis of multisource datasets, as well as dynamic monitoring of cultural sites and their surrounding environment. This paper presents the study of cultural landscapes using open access data through the implementation of remote sensing techniques, in order to provide useful information and propose possible cultural routes. Further extensions of the study could include the combination of satellite data with TLS techniques for building information extraction and 3D city modeling in the framework of a local sustainable development plan. In addition, the derived data could enrich digital platforms and navigable models for virtual tourism purposes.

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