REMOTE SENSING ANALYSIS IN THE ARCHAEOLOGICAL CONTEXT OF LICODIA EUBEA (CATANIA)

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ABSTRACT

Archaeological research conducted at the site of Marineo, in the territory of Licodia Eubea (CT, Sicily, Italy), has revealed the existence of a group of evidence dating back to various periods, from the Neolithic to the Middle Ages. Particularly important is the presence of caves, documented through archaeological excavations at the end of the 1980s, subsequently resumed from 2017 to today. These caves were used for ritual activities, especially during the Middle Bronze Age (1450-1250 BC). The existence of numerous combustion structures associated with remains of a meal, as evidenced by remains oan f animal, and human bones in a secondary position, suggests the funerary value of the caves. Until now, however, data were missing on the identification of the settlement inhabited by communities that used caves. During the last archaeological excavation campaign, images and orthophotos were acquired through the use of drones. In this way, through the study of these images, it was possible to identify new anomalies in areas not yet investigated and placed in the vicinity of the caves. Surveys carried out in the area, have confirmed the presence of remains of walls belonging to curvilinear and oval structures. These structures are probably parts of the settlement connected to the caves whose exact location was not known until today. To support the excavation activity, GIS and remote sensing applications were implemented for predictive and postdictive analysis using only free and open source software and satellite images.

1. INTRODUCTION

In the territory of the municipality of Licodia Eubea (CT), more precisely in the Marineo mountain, they have discovered four caves of karst origin (CONSOLI 1988-89), frequented in prehistoric times, for a period between the mid-late Neolithic and the end of the Bronze Age.
Starting from 2017 (Palio, Turco 2018), Cave 3 was excavated. This cave is important because inside here it was discovered ceramic fragments of Mycenaean origin, bronze weapons (a dagger and a spearhead), and many fragments of tableware of local production that are probably also connected to ceremonial use. However, despite the importance of the cave, no prehistoric settlement or other prehistoric archaeological remains have ever been found in the surrounding areas.
The study proposed in this work is characterized by the integrated use of UAVs, GIS, and remote sensing technologies for territorial monitoring. In particular, we used high-resolution data acquired by UAVs to select areas with environmental conditions that best lend themselves to hosting possible archaeological settlements, and Sentinel 2 satellite images to perform a pixel-based classification of the areas through the calculation of environmental indices inside the GIS environment. The approach used allowed us to overcome limits due to the geomorphology of the territory thus identifying new archaeological remains.

2. THE PROJECT: RESEARCH STRATEGY AND AREA OF STUDY

2.1 The use of UAV technology and survey activities

The use of UAV technology, allows us to make images and orthophotos using aero-photogrammetric surveys. For this purpose, we used the DJI Phantom 4 PRO V2.0 drone, with which we collected hundreds of images. Drone flights allowed us to collect photogrammetric material used to create orthophotos (PICCARETA 2000, PIANI 2013 pp. 6-10, FERRARI 2015). The accuracy relating to the georeferencing of the output data from the UAV survey is guaranteed by the RTK correction on the on-board GPS, which is sufficient for the purposes of the research activity of this work.
The photographs were processed through the software 3DF Zephyr to create 3D models territory, and then orthophotos. Thanks to them, and their high level of detail, it was possible to observe in several areas the presence of anomalies on the territory of the hill. In particular, we noticed that these anomalies were concentrated on the eastern side of the plateau that represents the top of the hill in the locality of Marineo. More in detail, we observed that these anomalies, a few tens, had a semicircular and oval shape, and were scattered along the slope that precedes the summit of the hill to the southeast, occupying an area of one hectare (Fig. 1).

Figure 1. Orthophoto made with aerial photogrammetric images from drone, and with the anomalies highlighted. Cartography elaborated by the authors, scale 1: 1500.

Other anomalies were present further south, but the presence of vegetation, soil, and other debris made their analysis through images difficult. For this reason, we decided to deepen the studies of the territory using techniques connected with remote sensing. Before performing this last step, we carried out field survey activities to verify the most evident anomalies indicated during the study of orthophotos. Indeed, we can ascertain the presence of numerous semicircular and oval structures, of possible prehistoric origin, even if, in the absence of further archaeological excavations, it is not easy to date them precisely.
After the survey activities, we decided to continue the analysis in a GIS environment, so that we could create more precise archaeological maps, and to create topographical surveys. From this moment, we considered it necessary to restrict with greater precision the areas of the hill that could present remains of huts and therefore of ancient settlements. For this reason, starting from the data acquired during the previous analyses, we continued the studies using remote sensing. A possible comparison with other wall structures of the Bronze Age is represented by the ancient Bronze Age village of S. Febronia in Palagonia (Maniscalco 1993-94), or by the Middle Bronze Age structures of Murcia in Pantelleria (Nicoletti 2014).

2.2 The GIS technology

GIS technology represents a valid tool to support archaeological activities for both postdictive and predictive analysis, as demonstrated by numerous works in the literature (Candiano et al.,2019; Gennaro et al.,2018; 2019a; 2019b; Mangiameli et al., 2020). In particular, in the archaeological field, the integrated use of GIS technology and data acquired by satellite sensors represents an effective approach in difficult territorial contexts, such as volcanic areas, areas of variable geomorphology, little outcropping features, etc.
Often, the linear combination of the bands of an image acquired by a satellite sensor provides a valid input to be able to classify and determine not very visible features in a simple RGB image.
The entire study was conducted using QGIS (and its plugins), which is a free and open-source professional GIS software that allows the creation and use of georeferenced raster and vector cartography, the compilation of geographical data, the spatial analysis of such maps, the sharing of geographical information and the management of such information in a database. The software can expand its tools and install additional plugins. In particular, for this work, we used the Semi-Automatic Classification Plugin (SCP) plugin to download Sentinel-2 images and perform pixel-based classification.
After choosing the study area using the high-resolution RGB images (about 10 cm) acquired through the UAV survey, we continued our study by using satellite images, which have a lower spatial resolution (i.e. 10 to 60 m), but are multispectral. The Sentinel–2 satellite mission acquires multispectral with high spatial resolution and the optical data enables the monitoring of the global terrestrial surfaces within the dedicated free Copernicus services (Martimort). The mission is based on a constellation of two identical satellites, Sentinel–2A and Sentinel–2B, launched separately by the European Space Agency (ESA). Using the Copernicus Programme, the data acquired by Sentinel–2 are freely available. The two satellite has a swath width of 290 km enabling the global coverage of the Earth's land surface with a revisit time of 5 days. The spatial resolution goes from 10 to 60 m, distributed over twelve bands: the red – green – blue (RGB) bands and a near-infrared (NIR) band have 10 m spatial resolution; the four VNIR Vegetation Red Edge and the two short wave infrared (SWIR) bands have 20 m spatial resolution; the coastal aerosol, water vapor, and cirrus bands have 60 m pixel size (Drusch).
Here we used the Sentinel–2A data acquired on September 19, 2021, whose metadata are listed in Table 1.

Acquisition Date	2021-09-19
Acquisition Time	11:50
Cloud cover	0 %
Bands	12
EPSG	3857

Table 1. Sentinel-2 Image Metadata.

We have chosen the Sentinel-2 multi-spectral image acquired in September because in this period the crop marks are more easily identifiable. Indeed, they are more evident from spring to autumn, when the vegetation is growing.
The territorial context object of this study is particularly critical because the archaeological elements are not very outcropping, and the territory is particularly impervious. Therefore, we decided to apply the classification using the NDWI index that represents the correlation between the Green and the NIR bands and measures the crop moisture, which indirectly might suggest the presence of buried structures and is particularly effective in the spring and autumn periods (Negula et al 2020).
The NDWI equation is:

$$NDWI = \frac{(GREEN - NIR)}{(GREEN + NIR)}$$

The index was calculated in a GIS environment using bands 3 and 8 respectively for the green and NIR bands (Fig. 2).

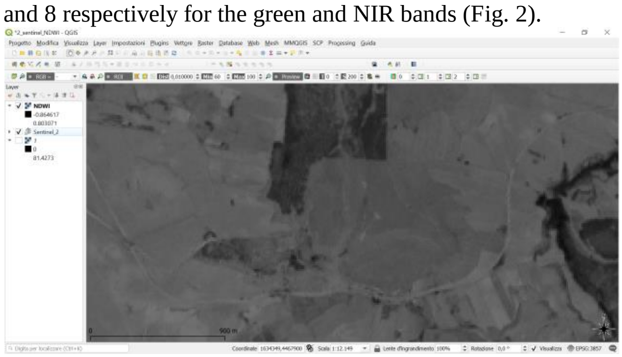

Figure 2. NDWI index managed in a GIS environment.

3. RESULTS

In this paper, we present the work carried out only in the municipalities of Licodia Eubea and Grammichele, located in the southwest area of the province of Catania in Sicily (Fig. 3).

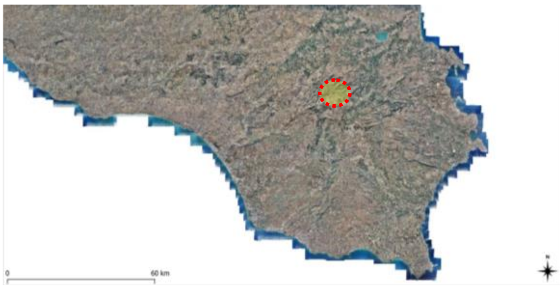

Figure 3. Identified area and linear anomalies and respective attribute table.

Using the SCP plugin in QGIS software and the NDWI index as input raster data it was possible to carry out the pixel-based classification in the area under study (Fig. 4).

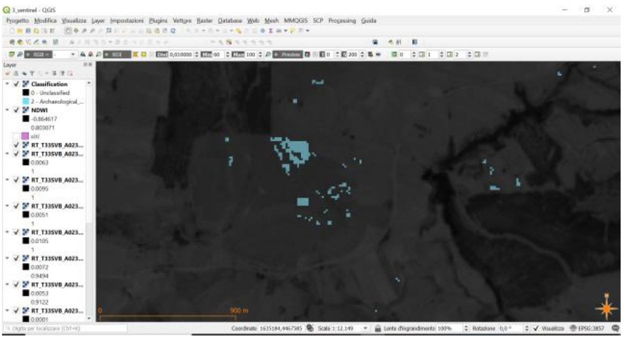

Figure 4. Pixel-based classification in the QGIS Software.

Through the study of topographic surveys, we were able to further distinguish the anomalies present on the ground. First, we mapped numerous stone accumulations, with a round and oval shapes. These structures generally have a diameter between 3 and 4 m and are arranged in rows oriented north-south. There are also stone circles, empty inside, with a diameter of about 3.5 m, and others smaller than 1.5 m. At a higher altitude,e there are remains of perfectly aligned stone structures, with a thickness between 80 cm and 1 m. It could be a wall, even if its course is not always linear, but the presence of numerous stones, scattered along the entire slope below, suggests that the interruptions are a consequence of collapses over time. According to our interpretation, they could be the remains of structures used to create terraces, on which the huts were subsequently built, as evidenced by the presence of stone circles near the walls. The need to create terraces is justified by the steep slope of the area chosen for the construction of the huts.
Moving to the top of the hill, at an altitude of just over than that of the huts, you reach a vast accumulation of stone, on average between 3 and 5 m wide, although in some areas it reaches 7 m due to the collapse of the walls. This structure is made up of medium and large stones, the latter placed above all at the base of the structure. The entire structure sits on the edge of the plateau of about 30 hectares, overlooking the slope below. We were able to identify the trend of the accumulation of stone along the hill and calculate its extension through the study using the GIS application. It looks like a monumental boundary wall at the top of the hill, as it surrounds it without great interruptions. However, in recent years the area has undergone reforestation interventions, the installation of wind turbines, and the, creation of new roads, which have made it more difficult to accurately identify the wall, which has so far been rebuilt for 1700m. The wall could be much larger, given that the area where the forest is currently present is missing from the calculation. Figure 5 shows the wall and some archaeological artifacts of the area obtained from field surveys, while Figure 6 shows the 3D model of the area under study obtained from the UAV survey, which was used to analyse the morphology of the terrain.

Figure 5. Relief of the archaeological remains made in the GIS portal, elaboration by the authors, scale 1: 1500. 1) Boundary walls 2) terracing wall 3) circular remains, probably huts.

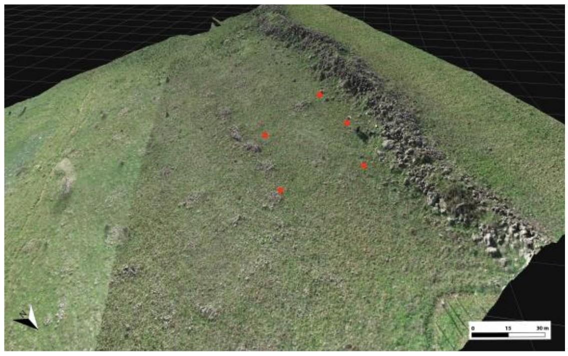

Figure 6. 3D model of the remains of boundary walls at the top of the hill.

To the east of the plateau, we identified a misalignment in the wall, which creates an opening. More in detail, it is an elevation change of about 10 m between the wall that heading south/east and the one climbing north/west. Starting from the northernmost part of the latter, an alignment of stones is generated that reaches the wall placed at a higher altitude. It looks like another wall used to bar the opening as if it were an access door to the inside of the great plateau (Figs. 7 and 8).

Figure 7. Orthophoto of the area east of the plateau, where there is the hypothetical opening between the walls. Elaboration by the authors, scale 1: 1500.

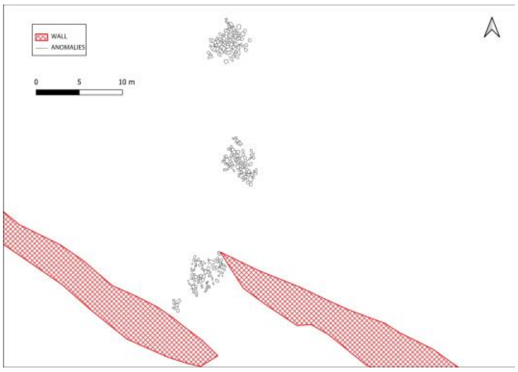

Figure 8. Relief made in the GIS portal of the area east of the plateau, where there is the hypothetical opening between the walls. Elaboration by the authors, scale 1: 1500.

We do not know if the stone circles and the remains of the terracing on the slope are contemporary with the great boundary wall. If we interpret the stone circles as huts, we believe that they cannot be contemporary with the wall, since it does not seem logical to build a village outside the defense wall. We can therefore assume that the construction and the use of the wall were more recenthanof the huts and concerns a period in which the conditions on the island forced the inhabitants to build impressive defense systems. While further research is on the ground, we cannot currently propose hypotheses on the chronology of the identified structures. Whilst we await more detailed analysis on the ground, we cannot currently propose hypotheses on the chronology of the identified structures. If the attribution of the circular structures to the protohistoric age is plausible, therefore referable to the phase of use of caves 1 and 3 (see Introduction), the lack of ceramic fragments on the surface makes this attribution only hypothetical. However, the comparison with the spatial organization of the Aeolian village of Portella di Salina, of the Middle Bronze Age (Martinelli 2005), could make our hypothesis plausible. The situation of the boundary wall is different, which could be attributable to a later date, even if, for the moment, it is not easy to identify with precision. We cannot exclude that it is connected to an Early Medieval settlement, associated with caves 2 and 4 (see introduction) and some architecture carved into the rock located on the western side of the hill (Fig.9).

Figure 9. Cuts in the rock of a possible medieval structure.

In this case, the cuts in the rock identified near the wall, on the eastern side of the hill, could be attributed to the same period.
Finally, the structures identified with the pixel-based classification and identified with the ground verification were computerized in the GIS environment as vector themes (Fig. 10).

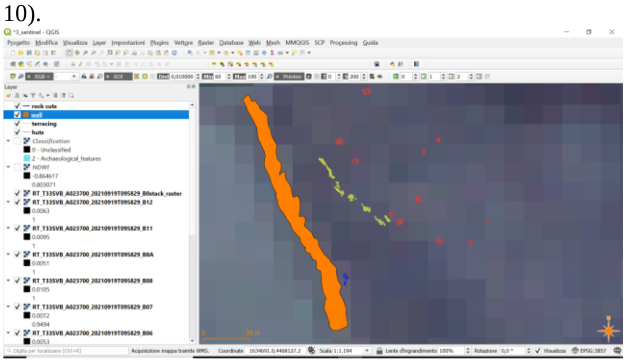

Figure 10. Archaeological features verificate: In red the hunts, terracing in yellow, in blue the rock cuts and in orange the wall.

4. CONCLUSIONS

We studied the southwest area of the province of Catania in Sicily (belonging to the municipalities of Licodia Eubea and Grammichele), which is a site well known and documented for its caves, but where any settlement has been never identified.
Given the presence of a flat area that lent itself well to the presence of an archaeological settlement and the presence of anomalies on the ground, it was decided to carry out a survey with the use of a drone in order to identify and circumscribe the area of interest. Then, we used Sentinel 2 data to perform a supervised classification in a GIS environment, in order to identify possible archaeological features. We found circular structures probably built on terraces, of which remains some rest. We also found evidence of cuts in the rock, maybe an area used as a quarry. At the top of the hill, we observed the presence of an accumulation of large blocks of stone. Perhaps it is a boundary wall around the plateau which occupies entirely the top of the hill.
The use of this multidisciplinary approach was important because has allowed us to limit the extension of the areas with signs of inhabitation during prehistoric and historic ages. It also allowed us to identify other new structures. Working in this way, we have shorted the search times.
The next step will be the programming of research activities on the ground, i.e. archaeological excavations, to validate the hypothesis arising from the detected anomalies and possibly study the chronology and the extent of the settlements and structures detected.

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