Master Erasmus Mundus in
QUATERNARIO E PREISTORIA

EVOLUTION OF PREHISTORIC SITES IN WESTERN SICILY
A GIS SPATIAL ANALYSIS APPROACH

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Abstract

The early human peopling in Sicily is one of the most debated topics in archaeology and anthropology (Sineo et al., 2015) since the discovery of lithic industries attributed to the LowerMiddle Palaeolithic in Sicily reported in the western of Sicily (Trapanese and southern coast areas).

The main objective of this thesis is to fill the archeology gap concerning the relationship between the distribution of the sites and environment; through the application of a multidisciplinary study (Geology, Geomorphology, and hydrography) and the use of Spatial analysis point of view.

In this work, we used GIS-based mapping methods to characterize the available archaeological data, and to develop analytical methods to assist in the identification, investigation and evaluation of the archaeological record and to highlight how the location of prehistoric sites in western Sicily are directly related to the evolution of the territory and adapted to new contexts.

We found that most of the sites in the Lower Palaeolithic the mean elevation is 150 m, far from the coastline, while during the Upper Palaeolithic and the Mesolithic, with the emergence of the Sicilian coastal plain, the beginning of the peopling of the Egadi Islands allows populations to settle along the coast. The difference between settlements on the coast or in caves in the mountains is most evident during the Neolithic. Their spatial distribution in relationship to their altimetric location results in the formation of two distinct groups of sites, one in flat areas and one exploiting mountainous areas.

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Introduction

Early human population in Sicily is one of the debated topic of archeological and anthropological discussion since the 20th century (Biddittu and Piperno, 1972; Segre et al., 1982; Zampetti et al., 2000; D'Amore et al., 2010; Chilardi et al., 2012; Sineo et al., 2015).

The history of the earliest peopling of Sicily is a topic that has long stimulated anthropological and palaeoethnological research; in recent years the number of archaeological excavations has increased enormously, but few excavators in the past were fully aware of the utility of recovering human remains, and therefore osteological studies by comparison remained relatively scarce (Becker, 2002). This bias is probably the reason why there are gaps in the archaeological record of Sicily, even if the potential record is extensive.

In this work, we intend to re-open the debate using all the available data on ancient Sicily such as Geomorphological, geological, and archaeological ones. This multidisciplinary approach aid at the purpose of an ancient reconstruction of Sicily Island and of its accessibility. The archaeological evidences fuel the hypothesis of an early human peopling of the island in the absence of Early Pleistocene human fossils.

This study begins with the creation of a database accompanied by information on the archaeological context and their dating. The Geo-referencing of this database has allowed us to offer numismatic and archaeological interpretations on Early human population, by allowing the integration of additional information such as Geomorphology, the geology of archaeological sites also allow as to study the localization of the sites.

For this reason, we propose to carry out an integrated study based on bibliographic and archaeological research intended for the geographical analysis of first settlement in Sicily.

The study consists of several stages:

1) Development of a database containing all the information on first settlement in Sicily from the bibliographic study of numismatic literature and the precise location of the find (longitude and latitude);

2) conversion of the database to a GIS geodatabase, so as to use all the GIS tools to define the link between the prehistoric zones and territory of Western Sicily (proximity to watercourses and coastline, environmental parameters such altitude, slope morphology and aspect);

3) accessibility of the database on QGIS.

4) Using the GIS and statistics tool to study the evolution of the population of Sicily by confronting the position of sites with the territory through time.

Aims of Thesis

1-1- Introduction

The only records concerning the prsesence of early human populations are surface collections of lithic pieces, without any geochronological data and are very sporadic. The objectives are, thus, to identify, describe, and date sites, making a hypothesis about their evolution and the association between geomorphology, geology and hydrology evidence. Founding more detailed data can allow us to produce a first hypothetic early human population in Sicily. In particular, the territory between coastal and interior western Sicily contains a rich matrix of archaeological resources and sites indicative of its functions at various periods in history.

With the advance of GIS-based mapping methods, it is now possible to employ more sophisticated and automated techniques to characterize the available archaeological data, and to develop analytical methods to assist in the identification, investigation and evaluation of the archaeological record.

For this reason, we have already collect data about the dynamics of human population in Sicily, and then we will apply some statistical models, using historical data from ancient surveys to identify different areas with high archaeological potential. Then we will produce a GIS analytic model in accordance with the parameters exposed in the model elaborated for other sites that have characteristics similar to our own site and the field records collected by some survey projects.

1-2- Problematics

The western of Sicily in the Mediterranean basin and its closeness to the Italian Peninsula and northern Africa, at least during low stand sea level episodes, may indicate an important role in such early colonisation (Villa, 2001). For this reason, the Sicily has been considered an open land of passage for an early human peopling coming from Africa into Europe (Alimen, 1975; Balter, 2001; Bar-Yosef and Belfer-Cohen, 2001; O'Regan et al., 2006; 2011).

In western Sicily, we found a several finds of lower palaeolithic but the history of the human remains of Favignana cave and San teodoro cave shows as that the human peopling of Sicily it's dated 20 ky, (Mannino and Thomas, 2009; Galland et al., 2019; Filippi et al., 2021) to fill a gap in the field of Sicilian Lower and Middle Paleolithic anthropological\geological data because of limited direct archaeological data, related only to the Upper Paleolithic.

Actually, the only records concerning the presence of early human populations are surface collections of lithic pieces, without any geochronological data and are also very sporadic.

For this reason, we have already collect data about the dynamics of human population in Sicily, and then we will apply some statistical models, using historical data from ancient surveys to identify different areas with high archaeological potential.

Then we will use a GIS analysis of the distribution of site to understand the evolution of space and time (or which called statistical analysis).

1-3- Objectives of thesis

In this work, we intend to re-open the debate using all the available data on ancient Sicily such as environment, geological, and archaeological ones. This multidisciplinary approach help at the purpose of an ancient reconstruction of Sicily Island and of its accessibility. The archaeological evidences fuel the hypothesis of an early human peopling evolution of the island in the absence of Early Pleistocene human fossils. The study of evolution and modelling population to Paleolithic, Mesolithic and Neolithic sites of western Sicily.

In order to overcome this objective lack, we propose a Geo and GIS statistical analysis (elevation, location, lithology and other information) and subsequently, produce a GIS analysis.

1. In the first step, we will realize a GIS database of the Sicilian site containing all the information from the bibliographic study and we will study from a statistical point of view (how many sites are located near the sea; in the mountain and other information)
2. We will obtain Geodata with a GIS analysis technique. From these data, we study the evolution of human frequentation in Western Sicily. The following step is to create, from the geo-information obtain, an archeological spatial analysis of the Sicilian archeological sites.

1-4- Hypotheses:

The early human peopling of Sicily and Western Mediterranean shores is one of the debated topic in the archaeological and anthropological literature over the twentieth century.

- ❖ Hypothesis 1: Intense frequentation in the site during Paleolithic and Mesolithic age. We will confirm this hypothesis by systematic excavations and survey activities already made. It will be complementary hypothesis to the second one.

- ❖ Hypothesis 2: Early frequentations in western Sicily. We propose to solve this hypothesis by GIS spatial analysis.

We have a problem to confirm these two hypotheses, that the data about the site are limited, to fill this gap we combine the field research with methodologies elaborated for similar sites to find traces of prehistoric human settlements. We base our proposal in an analogy argument.

Prehistory in Western Sicily

2-1- INTRODUCTION

The main intent of this chapter is a critic approach to the human peopling of Sicily during Quaternary. The history of the earliest peopling of Sicily is a topic that has long stimulated anthropological and paleo-ethnological research; in recent years the number of archaeological excavations has increased enormously, but few excavators in the past were fully aware of the utility of recovering human remains, and therefore osteological studies by comparison remained relatively scarce (Becker, 2002). This bias is probably the reason why there are gaps in the archaeological record of Sicily, even if the potential record is extensive.

2-2- PALEOLITHIC

Any proof of the existence of human beings in a definite area is based on the findings and evaluation of stone tools during that particular age. However, it isn't simple to find the needed proofs in the case if the archaeological findings are not preserved and documented well just like in Sicily compared to Sardinia where there is proof of existence of human beings in the Palaeolithic age and this could be because the island of Sardinia was huge enough for the hunter-gatherers to hunt and gather food and thus survive. But this proof is not enough to confirm this fact .(NIILM University).

During pre-historian times the sea level was lower and the islands of Sicily and Elba were linked to the mainland. Also, the Adriatic Sea started at what is the present day Gargano Peninsula Venice had a humid climate and a fertile plain. The Hominins first arrived 850,000 years ago at Monte Poggiolo. (Leighton, 1999). The existence of Homo neanderthalensis has been confirmed in the archaeological findings dated c. 50,000 years. Archaeologists have found out (Grimaldi and Spinapolice, 2010). that there are around 20 such sites for example the Grotta Guattari at San Felice Circeo on the Tyrrhenian Sea which is at the south of Rome, then there was the Breuil grotto and the Grotta di Fumane where evidences have been found out. The archaeologists and research have estimated that the Homo sapiens were present during the upper Palaeolithic age, one of the earliest site in Italy dated 48,000 years ago is Riparo Mochi. It was in the year 2011 that a discovery at Pistoccu in Marina di Arbus that made the most ancient Sardinian entire human skeleton which is known as Amsicora at Pistoccu. It is believed that the skeleton belonged to 8500 years ago which was the transition period between the Mesolithic and Neolithic ages.

Moreover, in Sicily the discovery of few sites that used stone tools of the Upper Palaeolithic which are also called Epigravettian has been discovered as well as drawings and decorations have been found in artefacts and in caves which reflects the effective cognition skills of the people during that time. We get to understand the habits and diet of the hunter-gatherers from the excavations done in caves close to the islands and coasts. Also, other findings prove that Southern-Italy which points to link between the rest of Italy and Sicily.

2-3- MESOLITHIC

In the Mesolithic age there is a steady modification in the lifestyle of the people living on the Sicily Island. The major archaeological findings were carried out in the island in the caves of Grotta dei Genovesi and Uzzo which is on the Aegadian island of Levanzo (D'Amore et al., 2010; Tusa et al., 2014; Filippi, 2015; Modi et al., 2020). The principal transformation took place in the diet of the groups wherein, fish occupied a large part of the diet amongst the hunters-gatherers and this was because of the climatic changes and decreasing number of the herd. However, the fishing activity lead to an inactive and lethargic lifestyle. Obsidian was utilised more frequently to make cutting tools. There are signs that Mesolithic clay was utilised for the first time to prepare food as a fire toughened platform. Also, archaeologists have excavated graffiti done in caves depicting human and animals in a more realistic way (Mannino et al., 2011; Filippi et al., 2021). Few famous examples are : the Grotta dell'Addaura near Palermo and the Grotta dei Genovesi on Levanzo.

During Mesolithic age, the Sicilian hunter-gatherers from post-glacial to the Early Holocene went through climatic changes characterized like aridity of the climate and increasing temperatures studied from Sicilian lacustrine deposits (Zanchetta et al., 2007) that led to consequences of animals and human hunting and food gathering for which accounts have been kept in few important sites. (Piperno, 1997; Cusinato and Bassetti, 2007; Lo Vetro and Martini, 2012; Forgia et al., 2014).

2-4- NEOLITHIC

The very first phase of Neolithization is currently known from a number of settlements (Natali and Forgia, 2017; Tine; 2002, 2004). On the basis of their typical pottery styles, it is possible to recognize two different horizons: the Archaic Impressed Ware, documented in the Southeast (Apulia, Basilicata and Northern Calabria), and the Advanced Impressed Ware, which displayed complex decorative motifs ("Impresse evolute"); this latter cultural aspect has been divided into different local groups, covering the whole Southern Italy, from Apulia to Southern Calabria (Fugazzola et al., 2002; Pessina and Tine, 2008).

The process of Neolithization in Sicily covers about 500 years (6200–5700 cal BC) and involves two cultural horizons: Archaic Impressed Ware or "Impresse Arcaiche" and Advanced Impressed Ware or "Impresse Evolute".

The Western part of the Sicily, where most of the archaeological research has focused, has proven quite useful in order to address the challenge about just how Early Neolithic economic strategies started interacting with the Mesolithic substratum (Tusa, 1999; Lo Vetro and Martini, 2012; 2016; Filippi, 2015; Sevara et al., 2020). At this stage, the debate is centered around two main sites: Grotta dell'Uzzo, on the North-Western part of the Island, and Grotta d'Oriente, on the small Island of Favignana (Egadi archipelago). Archaeological deposits in the above caves have been tested since the last century, but more recent research and new AMS radiocarbon dating are giving new input to the topic. The succession and, eventually, interaction, of different horizons characterize the sixth millennium BC in Sicily: Archaic Impressed Ware or "Ceramiche Impresse Arcaiche" (6200e5700 BC); Advanced Impressed Ware or "Ceramiche Impresse Evolute" of facies Stentinello I (or Stentinello/Kronio) (5800e5500 BC); Advanced Impressed Ware or "Impresse Evolute" of facies Stentinello II (after 5500 BC), in association or not with painted potteries; trichrome ware or "tricromiche" (5300e5000). According to the seasonal use of the relevant sites, early farming and herding activities in Sicily developed along coastal sites and lowland, where a still open landscape, because of a delay in the general afforestation that occurred in the Mediterranean basin, hosted Neolithic communities. At a later stage, more complex production activities (probably related to some innovations in herding), led some groups to begin the exploitation of the hilly hinterland and uplands, forcing the opening of already forested uplands.

GIS Application in Archeology

3-1- INTRODUCTION

The introduction of computing in archeology, which begins at the end of the 1960s with ambitious research projects like those of J.-Cl. Gardin (Doran, 1970), which could be classified in the applications of Artificial Intelligence in archeology or those of F. Djindjian at the beginning of the 1970s in the applications of data analysis in archeology, was then democratized in the general context of the evolution of software techniques and the emergence of software and hardware products useful to archaeologists to help them in their daily tasks: office automation, statistics, databases, cartography, publication assistance.

In the 1990s, the performance of microcomputers and office automation tools, the availability of software products, the appearance of Geographic Information Systems, the development of the Internet, will reveal all the diversity and therefore the complexity of computer applications in archeology, at the origin of inextricable problems such as data redundancy (and therefore the need for multiple entries), the lack of interfaces between software, the inconsistency between versions of different levels.

Archaeological data have a dual nature, as they are distributed both in space and time. A characteristic, common to all GIS software, is the capacity of managing multi-layer and multi-scale georefenced geographic data: this potential makes GIS applications ideal for managing archaeological data. Given the nature of most archaeological data, GIS technology is probably the most flexible and complete system for analyzing the spatial context of historical and pre historical data.

3-2- GEOGRAPHIC INFORMATION SYSTEM

A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions. GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a base-map of real-world locations.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project (*GIS for Archaeology*, 2009).

Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address. From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth (*GIS for Archaeology*, 2009).

In this work, we will use QGIS: as an open source geographic information system software. It runs on Windows, Mac OS X, and Linux. QGIS is a user-friendly GIS, providing common functions and features; also a free, collaborative, cross-platform software that is constantly developing by QGIS community (Qgis, 2017).

2-3- GEOSTATISTICAL ANALYSIS

Statistics play an important role in archeological research carried out with GIS technology. In literature, there is a great variety of statistical methods, which it is possible to divide into non-parametric and parametric methods. The first ones do not depend on the type of distribution of population and are not based upon distribution parameters; consequently, it is possible to apply them also in the case of qualitative data. The parametric methods employed in solving univariate and multivariate problems have, as a limitation, the need to use very restrictive hypotheses, often unjustified if not impossible to justify, unrealistic, not always clear, not easily interpretable, or ad hoc formulated to produce inference.
It must be added to this that the assumptions validating the application of those methods (normality, homoschedasticity, independence and equal distribution of the stochastic erratic component) are hardly ever satisfied and, in those cases where they are satisfied, results are often obtained by fol lowing approximations. Parametric tests have as a common feature the fact that their object are often parametric hypotheses, viz. hypotheses related, for instance, to the parameter value of one or more populations such as mean and variance. In the first family (non parametric tests) there are: $\chi 2$ test, MannWhitney or Wilcoxon test and Kolmogorov-Smirnov test. The most widely used parametric test is the so called T-test.

Study area (Western of Sicily)

4-1- INTRODUCTION

For better understanding the distribution of Archeological sites in western Sicily, it is necessary to have a clear understanding of the geological phenomena that have transformed the territory under investigation, from its formation to the current geo-morphological conformation. In this chapter, we will identify the geomorphological and geological background of Western Sicily.

4-2- GEOGRAPHIC SITUATION OF THE WESTERN SICILY

Sicily is located in Central-Western Mediterranean Sea and is a portion of the Alpine system that develops along the plaque border between Africa and Europe and with the Sicilian mountain system (Caracausi, 2018).

The Island of Sicily is generally considered to be the geological link between the North African Fold Belt and the Apennines, in Italy. This comes from a cylindristic meaning and is only partly exact. As a matter of fact, Sicily is essentially Greek; Ionian. Up to Middle Cretaceous time, the Sicilian area was a submerged shoal in the sea or the Panormide area, bordering the Ionian Ocean (Broquet, 2016). The Sicily has been considered an open land of passage for an early human peopling coming from Africa into Europe (Alimen, 1975; Balter, 2001; Bar-Yosef and Belfer-Cohen, 2001; O'Regan et al., 2006; 2011).

The studied territory is located within the 50 sheet 618 series at scale 1:50,000 topographic map of the Italian state generated by the Istituto Geografico Militare Nazionale (I.G.M.).

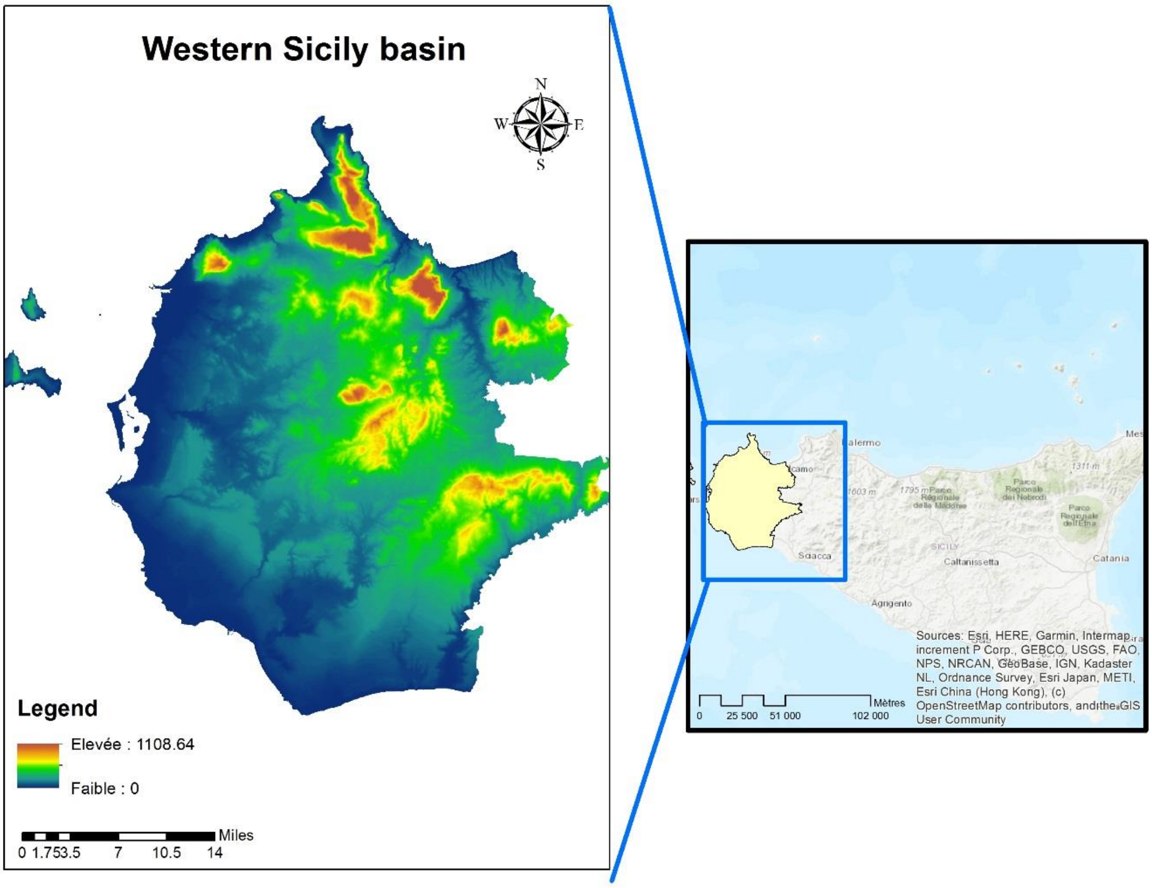

Figure 1 : Geographic situation of Western Sicily basin

4-3- GEOMORPHOLOGICAL BACKGROUND OF THE WESTERN SICILY

The geomorphological element that most characterizes Western of Sicily is undoubtedly constituted by the presence of very gentle "flat surface" (positioned at different heights) with sub-horizontal or weakly hanging towards the sea, the altitude in Western of Sicily characterized with a summit at 1108.64 m and an outlet at 0 m. Another side, the structural control on the action of morphological processes genetics is given by the presence of numerous derived structural forms, such as fault line embankments, structural control escarpments and inclined and bent structural surfaces (Catalano, 1989; Basilone et al., 2012; Broquet, 2016; Basilone, 2018).

Based on successions of planation surfaces, erosion glacis on soft rocks and coastal terraces, developing between 1200 m a.s.l. and the present-day sea level The geomorphological processes that control the alternate between planation-abrasion surfaces are related to the trend of lowering the base level. (Agnesi et al., 2000; Agnesi, 2004; Wagner et al., 2007; Liguori et al., 2008; Di Maggio et al., 2017a).

Other geomorphological forms are marine terraces (Ruggieri et al., 1975; D’Angelo and Vernuccio, 1994; 1996). In the coastline between Trapani and Marsala Ruggieri et al. (1968) found beach deposits containing Strombus bubonius between 2 and 5 m. Southeast, between Marsala and Mazara del Vallo, Ruggieri et al. (1975) published a geomorphological map containing a first-order terrace, the so-called "Grande Terrazzo Superiore" (GTS).

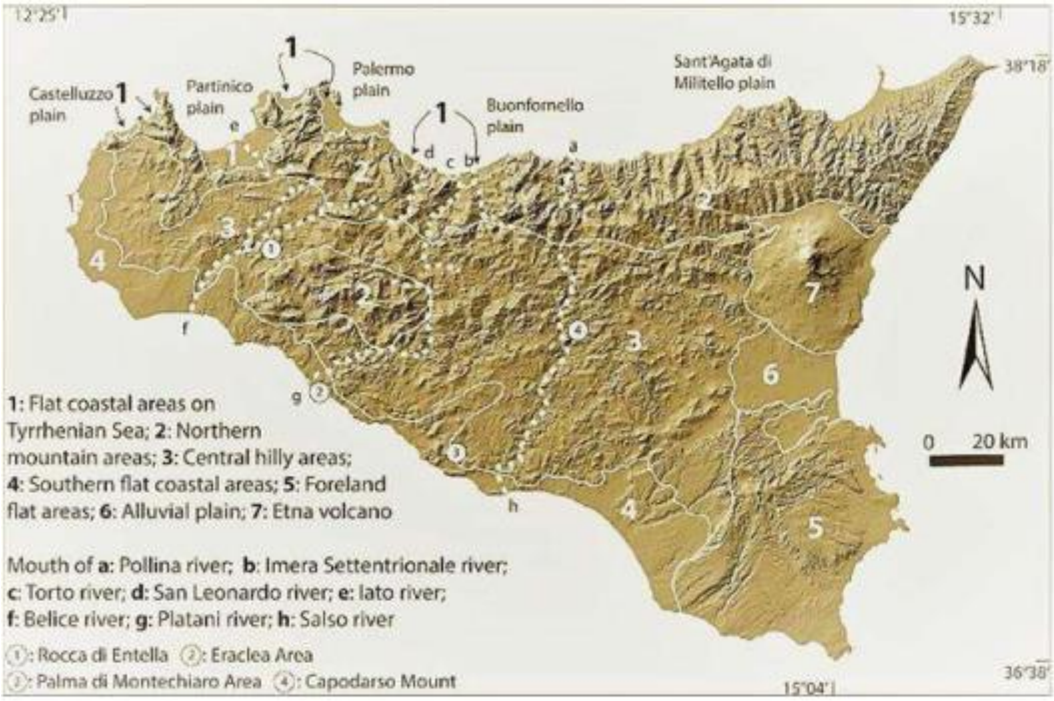

Figure 2: main geomorphological units of western Sicily (Di Maggio et al., 2017)

2-2- GEOLOGICAL BACKGROUND OF THE WESTERN SICILY

Western Sicily is part of the SE-verging Alpine orogenic belt in the central Mediterranean region (Catalano et al., 2002a; 2002b) and connects north-eastern Sicily, formed by a "European" element (Peloritani units), to the late Cenozoic Maghrebian chain. Tectonic evolution of western Sicily belt was a progressive accretion of thrust sheets (Catalano et al., 2002b). This area is the emerged portion of a larger orogenic system (Figure 1) which developed in the central Mediterranean region as result of the Neogene-Quaternary Africa-Europe collision processes (Parotto and Praturlon, 2004; Accaino et al., 2011; Napoli et al., 2012). In this continental subduction collisional complex, several tectonic and stratigraphic elements are differentiated:

1) A complex consisting of a SE-vergent fold and thrust belt, which is composed of a "Tethyan" element (Sicilidi units) and an African element (Sicilian units);

2) The Sicilidi units are represented by repeated imbricate slice stack deriving from the deformation of Upper Jurassic-Oligocene basin carbonates and sandy mudstones located in the Sicilide facies domain (Gasparo Morticelli et al., 2015);

3) The Sicilian units are characterized by allochthonous tectonic units deriving from the deformation of Permian-Miocene deepwater carbonates and bedded cherts deposited in the Imerese and Sicanian

basins (Basilone et al., 2012); and Mesozoic-Miocene shelf-to-pelagic carbonates located in the Panormide, Trapanese, Saccense, and Iblean-Pelagian carbonate platform or seamount facies domain;

4) Upper Oligocene-middle Miocene turbiditic deposits (Numidian flysch) cover the Sicilide, Imerese, and Panormide rock successions; lower-upper Miocene deformed foreland marls cover the Sicanian, Trapanese, and Saccense rock successions; Oligocene-Quaternary foreland open shelf carbonates cover the Iblean-Pelagian rock successions;

5) A thick pack consisting of middle Miocene-Pleistocene foreland, wedge-top and foredeep basin deposits (terrigenous, evaporitic, and clastic carbonate rocks), which largely form the Gela Thrust System;

6) A deepseated and buried foreland, slightly deformed, crops out only in the south eastern end of Sicily and in the floor of the Sicily Channel. Fig. x shows simplified stratigraphy and original facies domains of the rock bodies of western Sicily. The tectonic evolution of the western Sicily belt was a progressive accretion of thrust sheets (Catalano et al., 2002b) and duplex formation (Catalano et al., 1996), combined with the clockwise rotation of the allochthonous blocks (Speranza et al., 2018)

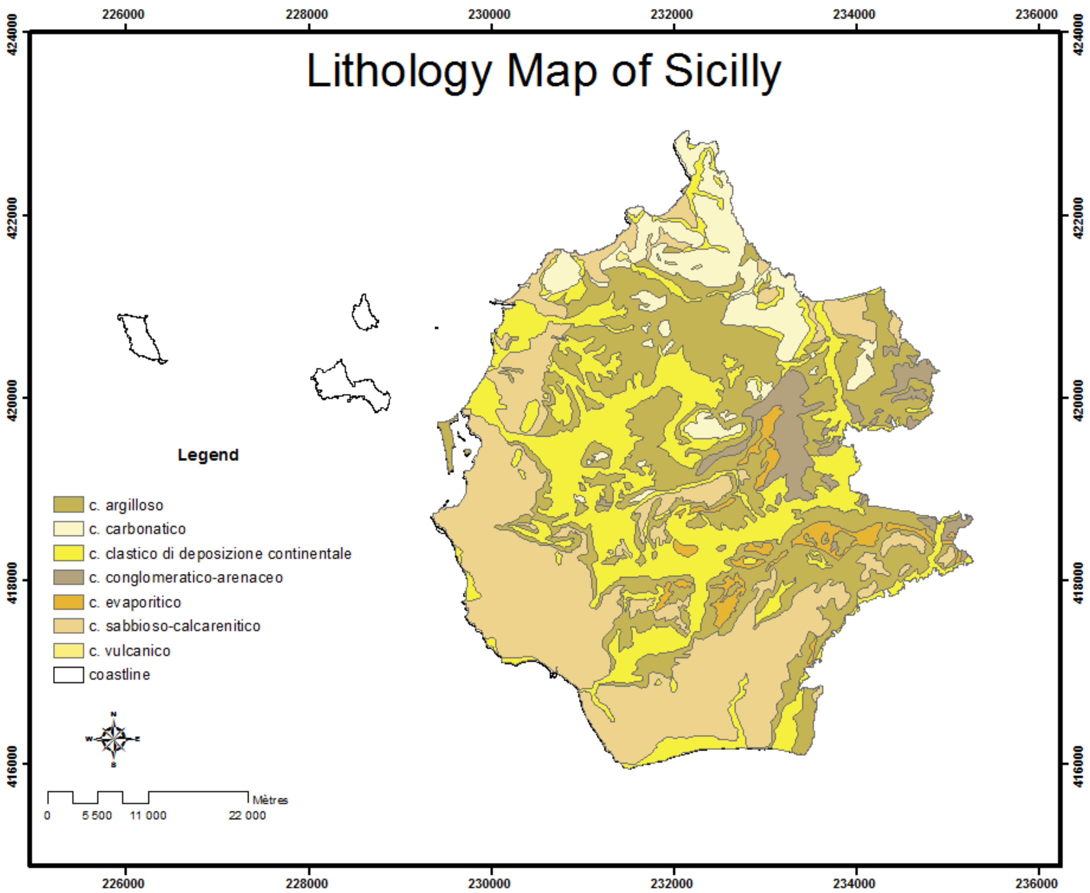

Figure 3: Lithology map of Western Sicily

MATERIAL AND METHODS

5-1- INTRODUCTION

GIS can help interdisciplinary research in archaeology. The use of GIS and relational database management technology and datasets helped manage information and increased understanding of where ancient site of paleo and Mesolithic in Western Sicily. Through improved data structuring, visualization, and analysis, GIS has also helped manage issues of uncertainty that exist in the historical record.

The objective of this chapter is the creation of a database that regroups in a common structure, the data necessary for the management of archeological sites. The structure of a database represents a basic method for the harmonization of data under a physical structure at the national level.

The scheme for the creation of Database is based on three phases. The first phase of design requires a method of analysis. The need for these methods born from the desire to standardize the consideration and resolution of certain problems in the field of archeology.

Geological and geomorphological analyses consisting of field mapping, aerial photography interpretation, and comparison with bibliographic data were performed with the aim of defining a morpho-evolutionary model of western Sicily.

Geological data were mainly obtained from previous studies (Catalano et al. 2013 and references therein) and field surveys in selected key areas (zones affected by Quaternary deposits and topographic expressions due to tectonics; as in the northern coastal plains).

Geomorphological data regarding the presence of landforms directly or indirectly produced by tectonics, and the relationships between landforms and their geological framework were collected. We searched and examined (Figs. xx) fault scarps.

The research was carried out using different study methods: mapping geology, sedimentary analysis and petrographic analysis. So GIS enable to use the capacity to extract information and build models based on geographic data aiming at the production of predictive maps supporting archaeological surveys.

Archaeological data have a dual nature, as they are distributed both in space and in time. A characteristic, common to all GIS software, is the capacity of managing multi-layer and multi-scale georefenced geographic data: this potential makes GIS applications ideal for managing archaeological data. Given the nature of most archaeological data, GIS technology is probably the most flexible and complete system for analyzing the spatial context of historical and pre-historical data.

5-2- DATA ACQUISITION

The data collected during the mapping phase of the Western Sicily territory were computerized and analyzed using the QGIS software. The Data processing starts from DEM provided by the Region of Sicily with a definition of pixels 10 m (Figure x). The DEM has considerable importance because it allows visualizing many environmental data. The analysis of spatial elevation of the hillslopes along river catchment allowed the distinction of the morphologic discontinuity of the relief and had been used to identify fluvial terraces.

Spatial data:

Spatial data are all those data to which it is possible to associate a reference system. There are a lot of systems and methods for the acquisition of spatial data, which use the typical geomatics methods and instruments such as:

- Remote Sensing techniques (digital images obtained through airborne and satellite sensors);
- Topographic techniques (total stations and digital levels);
- Photogrammetric techniques (analogical and digital images produced by aerial and terrestrial cameras);

2-3- ARCHEOLOGICAL DATABASE

This first data table (the prehistoric sites) corresponds to the entries recorded by means of the free software Quantum GIS. The choice made towards this type of software is the fruit of a little debate which is not uninteresting to discuss, the problem which may arise for others.

There are many software programs belonging to the GIS family. One of the most successful today is the ArcGis software. It would have allowed both efficient data processing and efficient cartographic creation, with the most complete panel of the various options offered by these types of software without any particular concern such as bugs or updates. But the simple cost of the software, not to mention the price of the extensions that would have been necessary to have, is around 15,000 euros, quickly made the choice to free software. Among these, it was therefore QGis that was selected12. Free, which is its main advantage, it has a neat interface and options similar to those that can be found on ArcGis.

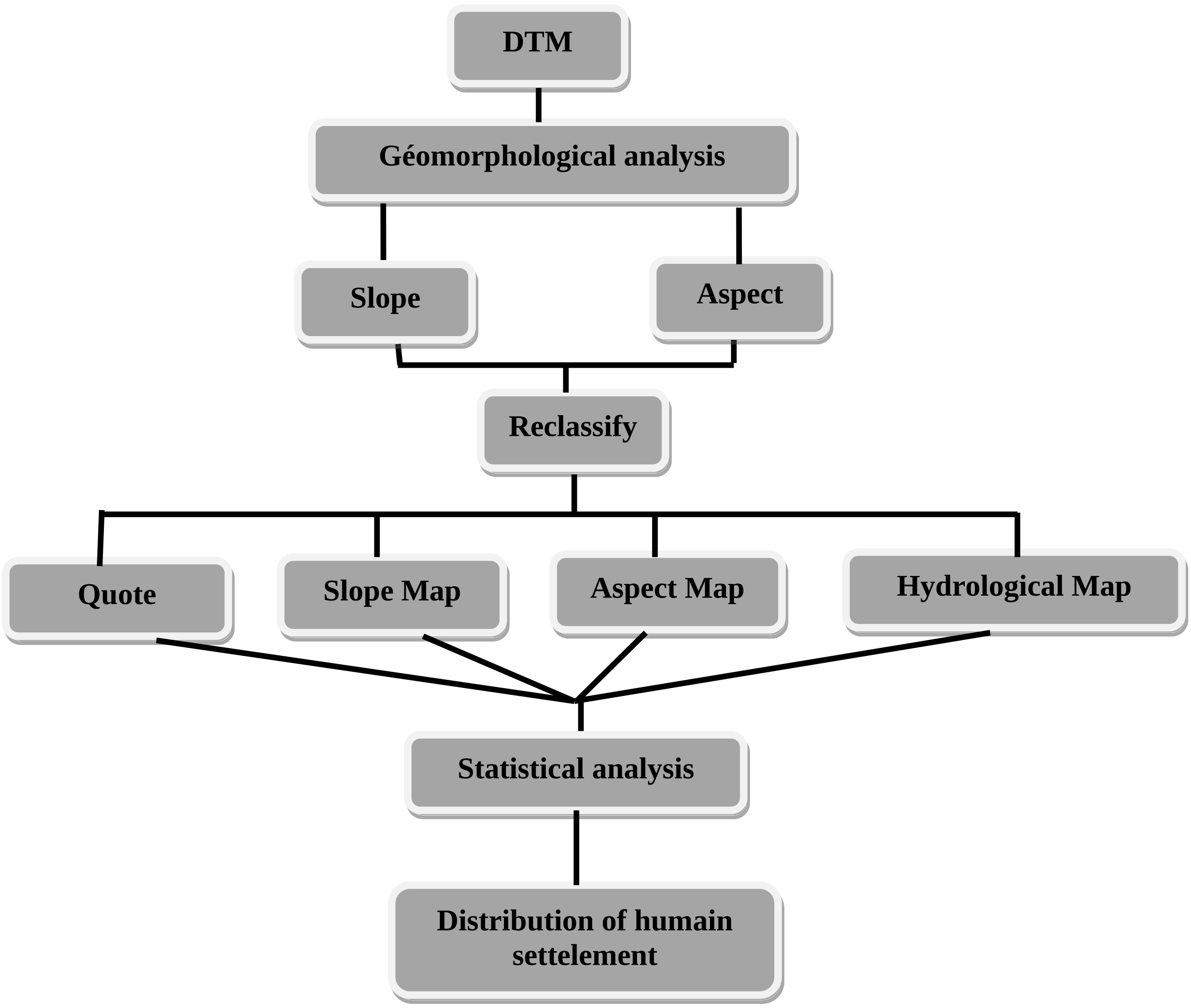

Figure 4 : Chart of methodology

Results and discussion

1-1- INTRODUCTION

The physiographic characteristics in western Sicily strongly influence the dispersion of archaeological sites, and in particular, the slope, the orientation, and the hydrography of the study area.

These factors, purely geometric or physical nature, can be easily estimated from DEM. The Terrain Elevation Model (DEM), used by NASA, is the SRTM (Shuttle Radar Topography mission). The SRTM covered approximately 80% of the earth's surface with an overall resolution of 10 meters, while the GDEM (Global Digital Elevation Model) can cover the planet from 83° North to 83° South, exceeding the SRTM that only covered 56°S and 60°N.

1-2- Slope Map:

The slope map is deduced from a digital terrain model. The DEM is extracted from Italy's SRTM (Resolution 10 m pixel). From this map, we can deduce that the slopes in the Western Sicily basin (Fig. 2) are mostly very low (less than 6°). Geographically, this slope class mainly occupies the coastal part of the basin.

The low slopes (6° to 15°) characterize the units, which are shaped like a plateau it is the middle part of the basin. While the moderate slopes (15° to 41°) to high (41%) essentially characterize the slopes of mountain.

In the slope map, we can find the upper paleolithic sites are in the flat area (Nord-West) of the map near to the sea; otherwise the lower paleolithic sites are in the mountains area where the slope is accented (Fig.3).

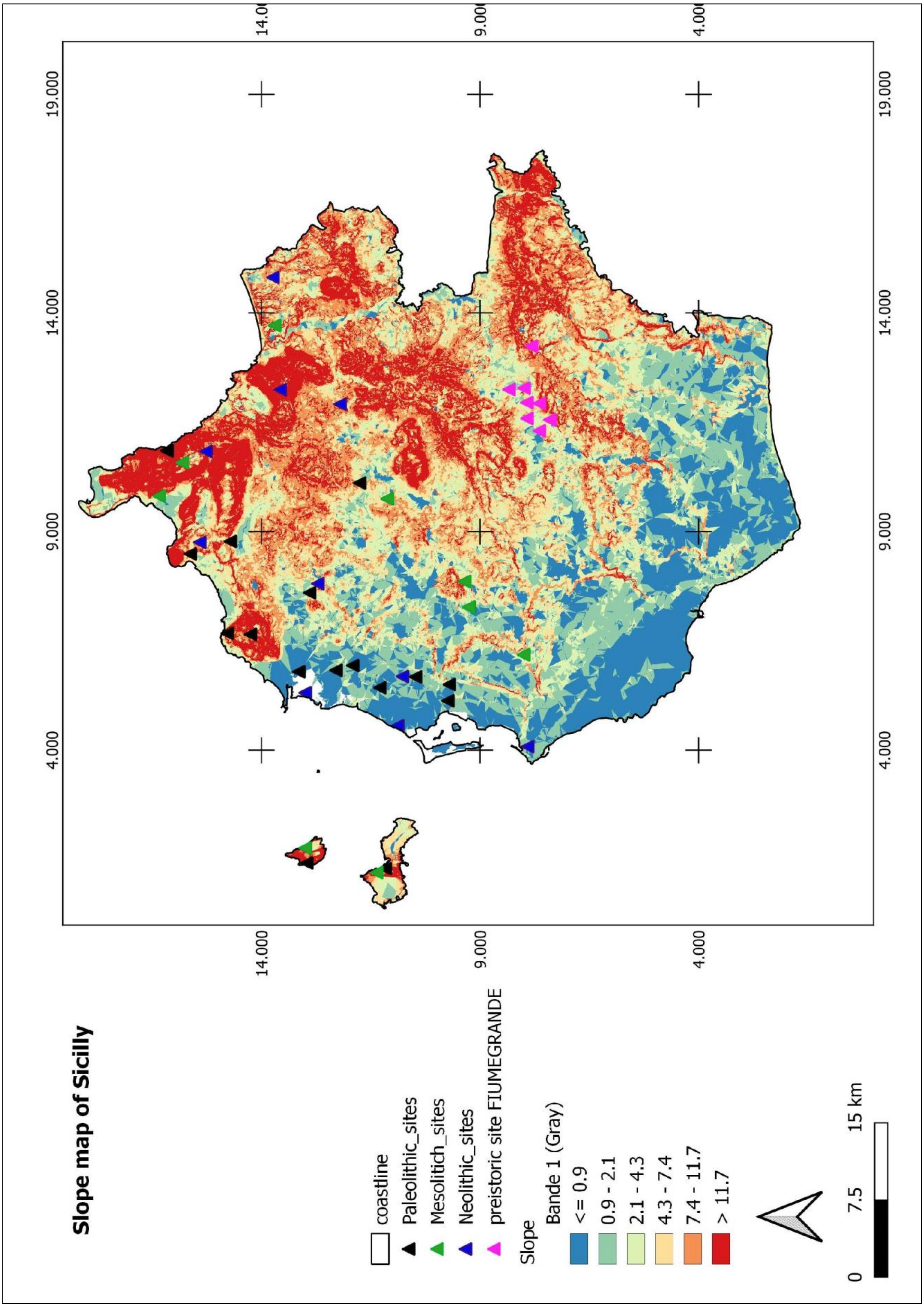

Figure 5: Slope map of Wester Sicily basin

1-3- Aspect Map:

The aspect map of western Sicily identify the downslope direction of the maximum rate of change in value from each cell towards its neighbors. We observe that the direction of Sun area is SE-NW, so it have a strong effect on climate in western sicily.

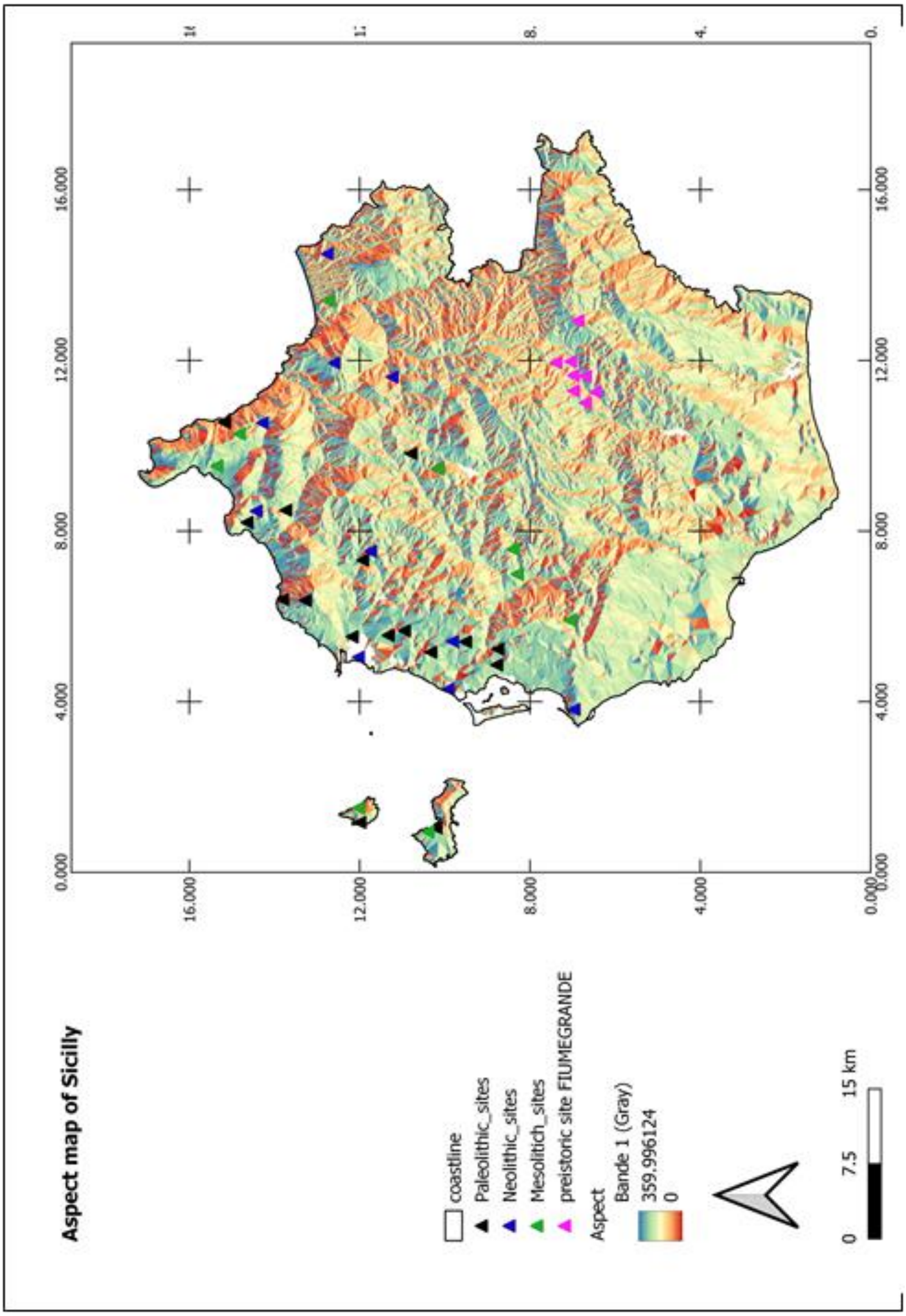

Figure 6 : Aspect map of Western Sicily basin

1-4- Hydrology Map:

Western Sicily is divided into ten hydrographic basins with similar characteristics. The waterways are divided between them by their annual flow and in their morphology.

the river network of western Sicily is made up of a few large rivers (Belice river) while torrential watercourses are more numerous (PAI, 2004). The water flow of these watercourses is scarce in summer, while in rainy seasons they have a large flow. The surface hydrography is rather poor and is barely identifiable in the clayey areas while it is poorly developed in correspondence with the calcarenite soils. The area is superficially drained by some ditches and impluvium lines of little importance. While deep and developed karst systems develop in hilly and mountainous areas (De Waele et al., 2017; Di Maggio et al., 2017b).

In the north-western and central-western areas, coastal plains and a set of rounded hills and broad valleys, from which a series of isolated reliefs of the Trapani Mountains and inland area, break the physical continuity of the mountain range. The larger distance between the mountain range and the southern coast enables the development of longer and slightly inclined rivers flowing from NNE to SSW (e.g., Belice, Platani, and Salso rivers). The lower erosional power of these rivers has produced shallow valleys with gently inclined slopes and flat or rounded bottoms, separated by low hills (Di Maggio et al., 2017b).

For the distribution of prehistorical sites, we observe that the lower Paleolithic sites are near to Delia River, otherwise the upper Paleolithic and Neolithic sites are near to the sea (Fig 4).

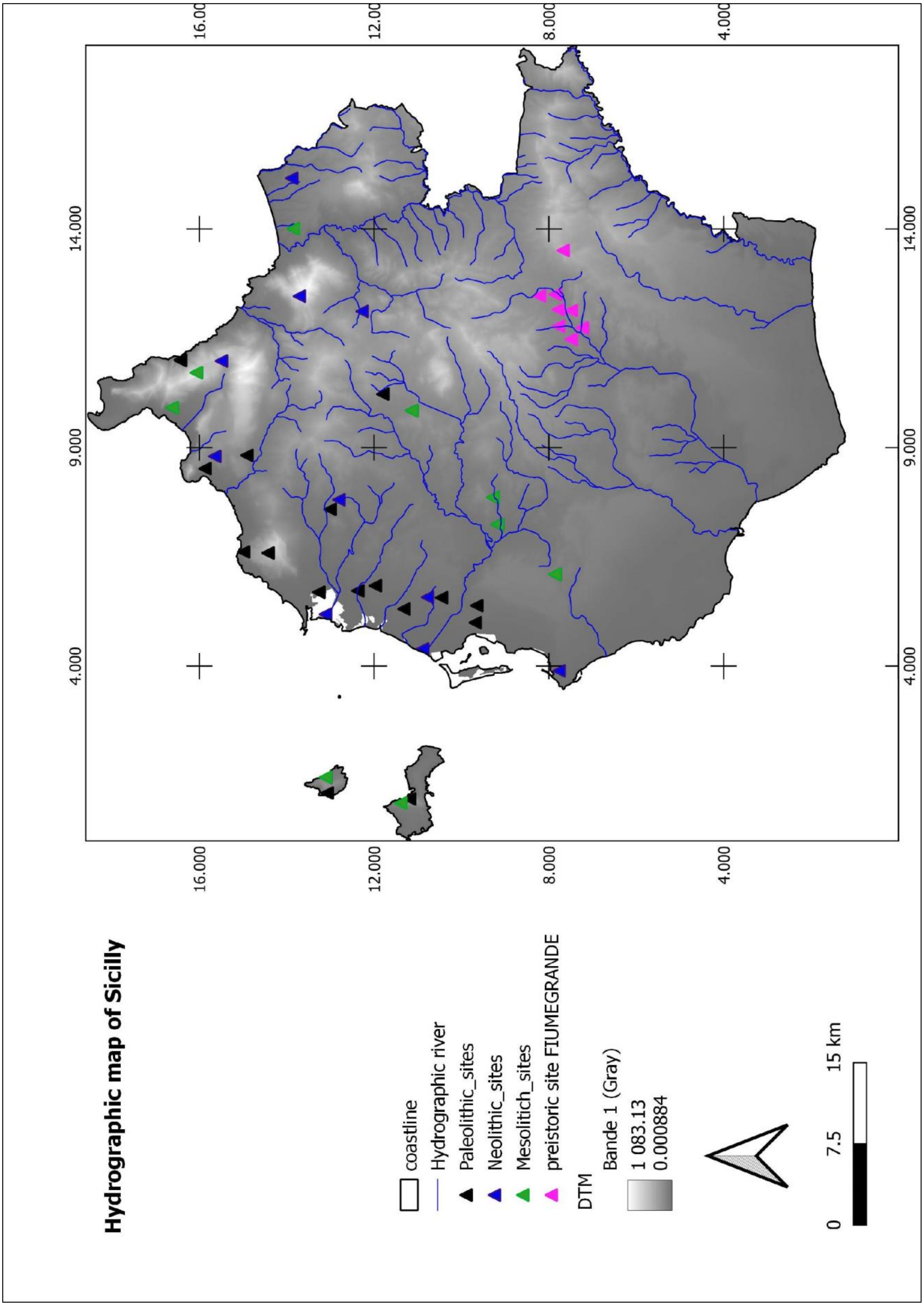

Figure 7: Hydrogrqphic mqp in western sicily.

1-5- Spatial Analysis and geostatistical approach

The application of geostatistics in the archaeological field and in spatial analysis, it's a correct methodology to investigate the distribution and understand the mechanisms for population of Western Sicily (Espa et al., 2006; Kompatscher et al., 2016; Thacher et al., 2017; Mertel et al., 2018; Gillings et al., 2020).

In this thesis work, in order to understand the population mechanisms of western Sicily, we considered the share of the prehistoric sites with respect to the sea level as the main parameter. The choice is due to the need for time optimization and data analysis, and we want to understand how the multidisciplinary approach to a problem allows us to provide more data and diversified points of observation. Through the use of the geoprocessing tools present in the Qgis software it was possible to obtain the share of the sites. Using the DTM (Digital Terrain Model) produced by the Regional Territorial Information System (S.I.T.R.) of the Sicily region and applying the "SAMPLE RASTER VALUE" tool it is possible to associate the numerical value of a pixel of the RASTER to the attribute table of a VECTOR shapefile. The result is the possibility of having quantitative data produced by the Raster and being uniquely associated with a geometry.

The table of the "Prehistoric Sites" vector shapefile contains the 61 prehistoric sites of western Sicily with the addition of the information ALTITUDE of their location with respect to the current sea level (TABLE 1).

The table is divided into six columns showing:

1) NAME OS SYTE: identify the prehistoric site name in the literature
2) COMUNE: identify the name of local administration where is located the site
3) PERIOD: From Lower\Middle Paleolithic to Neolithics
4) FIND: a summary of the typology of finding it's divided in; Industries on pebbles, flakes, Lithics flakes, Sporadic finds, chert flakes, Bone tools and lithics industries sensu latu
5) TYPE_SITE: identify the tipology of archeological site : open air, cave, shelter rock.
6) QUOTE: identify the altitude respect the sea level and the unit metric it's meter

The table shows how 12 sites are referable to Lower \ middle paleolithics, six of them are located in the Valle del Fiume Delia \ Fiume Grande between Salemi and Santa Ninfa and seems to be one of the oldest sites in Sicily (Venezia and Lentini, 1994; Accardo, 1997; Piperno, 1997; Caracausi, 2018). While the remaining sites should be in the final part of the Lower \ middle paleolitchs (Zampetti et al., 2000; Chilardi et al., 2012; Filippi, 2015).

Also, 18 sites are attributable to the Upper Paleolithic and are distributed over a wider area and the province including the Aegadian islands (D'Amore et al., 2010; Filippi, 2015; Filippi et al., 2021). The

Mesolithic sites also represent a stratigraphic succession of the site itself and appear to be linked to the proximity of water sources and shelters.

While the Neolithic sites are distributed in the province and are located near the coasts and in shelters.

Id	Name_sites	Comune	PERIOD	Finds	Type_Site	Quote
1	Grotta Emiliana	ERICE	Lower Paleolithic	pebbles, flake	Cave	497.99
2	Malummeri	TRAPANI	Lower Paleolithic (?)	Industries on pebbles and flakes	Open\shelter rock(?)	1.11
3	Guarrato	TRAPANI	Lower Paleolithic	Industries on pebbles and flakes	Open	38.04
4	Chinisia	TRAPANI	Lower Paleolithic	Industries on pebbles	Open	24.12
5	Granatello	MARSALA	Lower Paleolithic	Industries on pebbles and flakes	Open	20.62
6	Fiumegrande	SALEMI	Lower Paleolithic	Industries on pebbles	Open	164.26
7	Bovara	SALEMI	Lower Paleolithic	Industries on pebbles	Open	196.98
8	Borgesati	SALEMI	Lower Paleolithic	Industries on pebbles	Open	223.15
9	Canetici	SALEMI	Lower Paleolithic	Industries on pebbles	Open	203.17
10	Carnemolla	SALEMI	Lower Paleolithic	Industries on pebbles	Open	181.36
11	Fiumegrandotto	SANTA NINFA	Lower Paleolithic	Industries on pebbles	Open	142.88
12	Mulinello	ALCAMO	Lower Paleolithic	Lithics flakes	Open	101.57
22	Grotta di Cala del Genovese	FAVIGNANA	Upper paleolithic	Flakes and lithic	Cave, linear engraving	21.68
23	Grotta dell’Ucceria	FAVIGNANA	Upper paleolithic	Flakes and lithics	Cave	35.00
24	Grotta Emiliana	ERICE	Upper Paleolithic	Industries on pebbles	Cave	42.48
25	Grotta Mangiapane	CUSTONACI	Upper Paleolithic	Epigrav. Evoluto	Cave	116.95
26	Grotta Rumena	CUSTONACI	Upper paleolithic	lithics industries	Cave	125.99
27	Grotta dei Porci	VALDERICE	Upper Paleolithic	The deposit is concreted inside the cave	Cave	65.68
28	Riparo Costa Chiappera	PACECO (DATTILO)	Upper Paleolithic	lithics industries	shelter rock	81.06
29	Riparo Sciarotta	PACECO	Upper Paleolithic	lithics industries	shelter rock (?)	15.69
30	Riparo Rocche Draele	TRAPANI	Upper Paleolithic	lithics industries	shelter rock	38.10
31	Riparo Case Zena	TRAPANI	Upper Paleolithic	lithics industries	shelter rock	205.59
32	Riparo Baglio Casale	BUSETO PALIZZOLO	Upper Paleolithic	lithics industries	shelter rock	229.54
33	Grotte dell’Isulidda	SAN VITO LO CAPO	Upper paleolithic	Flakes and lithics	Cave	50.75
34	Grotta dell’Uzzo	SAN VITO LO CAPO	Upper paleolithic	lithics industries	Cave	101.53
35	Granatello	MARSALA	Upper paleolithic	Epigravett. Fin. Sporadic finds	shelter rock	41.06
36	Serra delle Rocche	TRAPANI	Upper paleolithic	Sporadic finds	shelter rock	91.00
37	Falconeria	MARSALA	Upper paleolithic	Lithics flakes	Open	52.07
38	Mondura	SANTA NINFA	upper paleolithic	chert flakes	shelter rock	196.92
39	Monte Castellaccio	SANTA NINFA	Upper paleolithic	chert flakes	shelter rock	499.50
13	Mulinello	ALCAMO	Mesolitihic	Lithics flakes	Open	101.57

14	Grotta di Cala del Genovese	FAVIGNANA	Mesolitihic	Flakes and lithic	Cave, linear engraving	160.00
15	Grotta dell'Ucceria	FAVIGNANA	Mesolitihic	Flakes and lithic	Cave	35.00
16	Riparo Case Zena	TRAPANI	Mesolitihic	Flakes and lithic	shelter rock	205.59
17	Grotte dell'Isulidda	SAN VITO LO CAPO	Mesolitihic	Flakes and lithic	Cave	50.75
18	Grotta dell'Uzzo	SAN VITO LO CAPO	Mesolitihic	Microlithics microburin…	Cave, linear engraving	793.04
19	Serra delle Rocche	TRAPANI	Mesolitihic	Flakes and lithic	shelter rock	91.00
20	Canneto d'Anna	MARSALA	Mesolitihic	Flakes and lithic	Open	124.66
21	Falconeria	MARSALA	Mesolitihic	chert flakes	shelter rock	52.07
40	Canneto d'Anna	MARSALA	Upper paleolithic	Lithics flakes	Open	124.66
41	Malummeri	TRAPANI	Neolithic	Industries on pebbles and flakes	Open\shelter rock(?)	1.11
42	Grotta di Cala del Genovese	FAVIGNANA	Neolithic	Flakes and lithic	Cave, linear engraving	160.00
43	Grotta dell'Ucceria	FAVIGNANA	Neolithic	Flakes and lithic	Cave	35.00
44	Riparo Case Zena	TRAPANI	Neolithic	Lithics flakes	shelter rock	205.59
45	Grotta dell'Uzzo	SAN VITO LO CAPO	Neolithic	Bone tools, flakes	Cave	793.04
46	Grotta Maiorana	TRAPANI	Neolithic	pottery	Cave	15.69
47	Serra delle Rocche	TRAPANI	Neolithic	Lithics flakes	shelter rock	91.00
48	Grotta Vanella	Calatafimi-Segesta	Neolithic	lithics industries	Open	204.28
49	Grotta degli Scurati	CUSTONACI	Neolithic	lithics industries	Cave	171.31
50	Castello di Calatubo	ALCAMO	Neolithic	Sporadic finds	Open	104.54
51	Falconeria	MARSALA	Neolithic	Sporadic finds	Open	52.07
52	La Fossa	LEVANZO	Neolithic	sporadic obsidian finds	Open	70.00
53	Favignana	FAVIGNANA	Neolithic	lithics industries	Open	10.00
54	Capo Boeo	MARSALA	Neolithic	Sporadic obsidian finds		16.22
55	Grotta dell'Uzzo	SAN VITO LO CAPO	Neolithic	lithics industries	Cave	548.64
56	Riparo di Bonagia	ERICE	Neolithic	lithics industries	Cave, linear engraving	497.99
57	Grotta del Cavallo	CASTELLAMMARE DEL GOLFO	Neolithic	lithics industries	Cave, rock art	879.64
58	Rocche Draele	TRAPANI	Neolithic	sporadic finds	shelter rock	37.77
59	Costa Chiappera	TRAPANI	Neolithic	lithics industries	shelter rock	155.55
60	Isola della Calcara	TRAPANI	Neolithic	sporadic obsidian finds	Open	5.00
61	Capo San Teodoro	MARSALA	Neolithic	sporadic obsidian finds	Open	15.00

Table 1: the Prehistoric Sites of Western Sicily

In this work, the age of the site with its share was also put in a graph (produced through the graph function of EXCEL) to find a possible preferential geographical distribution of the sites. In addition, statistical type analyzes (mean, fashion, mean) were carried out to compare these data with the geological context of the area.

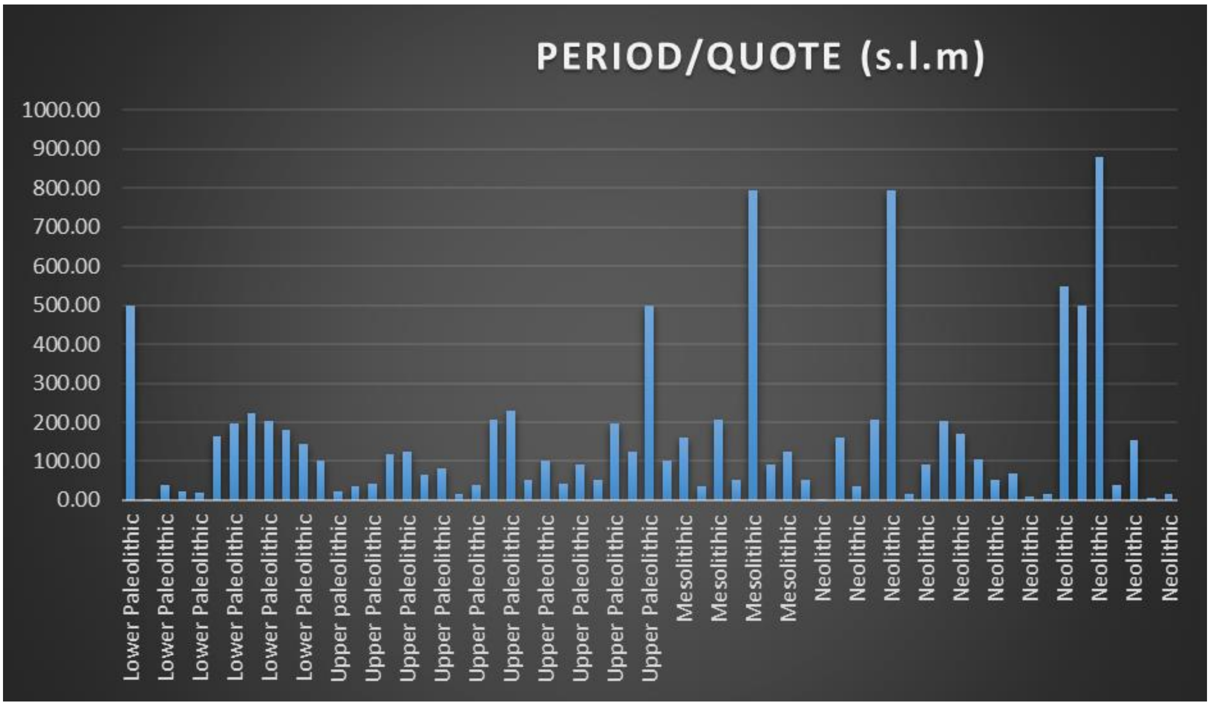

Figure 8: the bar graph show the distribution in the altitude of the archeological sites identify with the period

The first fact that can be highlighted is that the Sicilian sites are on average in the range between 0 and 200 meters and then pass directly to higher altitudes. From the graph, you can see the absence of prehistoric sites between 200 and 500 meters (figure 9).

The statistical analysis done on all 61 sites shows us the following results:

- The average location of all sites stands at 157 m asl (Table 2) with different sites located between 800 and 900 meters for example "Grotta Uzzo" while if we divide the total sample of sites through the different periods it can be seen how the population dynamics, they can be different between the different periods.
- In the lower \ middle Paleolithic (tab 3) the average value of the site altitude is 149 m and we do not find sites in the current near the coastline or even at altitudes above 250 m. This is possible because about during the Middle Paleolithic Sicily was not completely emerged and probably that was the old coast as evidenced by the presence of Pleistocene marine terraces (D'Angelo and Vernuccio, 1994; Bonomo et al., 1996). The typology is almost exclusively of open sites and close to small rivers. An exception is the site of "Grotta Emiliana" (Chilardi et al., 2012) on the slope of Monte Erice probably due to a gap of systematic archaeological excavations in the area.
- During the Upper Paleolithic it is noted how the average value of the altitude is significantly lower than the previous period. In fact, we have a reduction of 50m meters of the average value because the emergence of the coastal plain of western Sicily takes place with a consequential shift of human populations. also the frequentation of caves. It can be noted that the position of these sites is strategic, in fact, they are mostly located in the northern area of the study area

(figures 5-6) where the San Vito and Castellamare del Golfo mountains are located close to the sea.

- During the mesolithic the average value remains like that the value calculated for Upper Paleolithic but lower since we have the complete emergence of Sicily with the presence of the first glacial events (Abate et al., 1991; Antonioli et al., 1999; 2012; Agate et al., 2017) moreover, the permanent attendance of some caves begins, such as La Grotta dell'Uzzo (Galland et al., 2019). In the other hand the glacial-interglacial cycle helpful the colonization of Egadi islands archipelago (Lo Vetro and Martini, 2012; Tusa et al., 2014; Filippi et al., 2021) Finally, during the Neolithic, the different population strategies of the island, from a statistical point of view, are evident. Also, we find a group of sites located between 0-200 m while another group between 400 and 800 meters.

Table 2 : the table show a descriptive statistics summary of quote value of all archaeological sites.

Total	
mean	157.6004
Errorstandard	25.11378
median	101.5294

Table 3 : table show a descriptive statistics of quote value of sicilian sites but divided to Period.

Lower Palaeolithic		Upper Palaeolithic		Mesolithic		Neolithic	
Mean	149.60	mean	112.38	mean	179.29	mean	193.78
Error	39.15	Errord	25.933	Errord	78.882	Errord	56.87
median	153.5691	median	81.057	median	101.56	median	91.004

Table 4 :The table show the frequency data of sites distribution in elevation classes.

	L.P.		M.P		U.P		N.L.	
Quote m (slm)	sites	frequency	sites	frequency	sites	frequency	sites	frequency
0-100	4	33%	4	44%	15	54%	11	58%
100-200	5	42%	3	33%	8	29%	4	21%
200-300	2	17%	1	11%	3	11%	2	11%
300-400	0	0%	0	0%	0	0%	0	0%
400-500	1	8%	0	0%	1	4%	1	5%
500-600	0	0%	0	0%	0	0%	1	5%
600-700	0	0%	0	0%	0	0%	0	0%
700-800	0	0%	1	11%	1	4%	1	5%
800-900	0	0%	0	0%	0	0%	1	5%

The settlement dynamics of this area can also be studied looking at the variation of the frequency of sites with relation to altitude (Table 4). From the Lower Middle Palaeolithic the sites have progressed more and more towards the coast, following the geological evolution of this area. Looking at the percentage changes we can see how sites between 0-100 increase from 33% to 58% from Lower

Paleolithic to Neolithic. Between 100-200 the table shows a decrease in the initial value of 42% in the Lower Palaeolithic and 21% in the Neolithic with an increase in sites at higher altitudes. From the frequency table it shows that during the Upper Paleolithics we have an increase of sites between 0-200 m, this happens because the peopling of the Egadi islands begins.

CONCLUSION

The work was carried out using different multidisciplinary approaches using GIS software (QGIS), We were used it to analysis the spatial elevation of the hillslopes along the basin of western Sicily and to understand the distribution of prehistoric sites among the study area.

We conclude, that the distribution of the upper paleolithic sites and Meso and Neolithic sites are located in the flat area (Nord-West) of the map near to the sea; otherwise the lower paleolithic sites are located near to the river in the mountains area where the slope is accented.

The geostatic and spatial analysis study has made it possible to highlight how the location of prehistoric sites in western Sicily are directly related to the evolution of the territory and adapted to new contexts.

The sites are distributed between 0 and 800 metres but are grouped in well defined elevation bands. Most of the sites between Lower Palaeolithic and Neolithic are in the range 0-200 metres, while a numerically smaller group is above 500 metres. The absence of sites between 200 and 500 metres is peculiar and could not be identified in this work. It can be assumed that the lack of sites between 200-500 m is due to the most unfavourable conditions, lack of resources in the vicinity or a gap in research in the area.

In particular, it can be seen that in the Lower Palaeolithic the mean elevation is 150 m, far from the coastline, while during the Upper Palaeolithic and the Mesolithic, with the emergence of the Sicilian coastal plain, the beginning of the peopling of the Egadi Islands allows populations to settle along the coast. The difference between settlements on the coast or in caves in the mountains is most evident during the Neolithic. Their spatial distribution in relationship to their altimetrical location results in the formation of two distinct groups of sites, one in flat areas and one exploiting mountainous areas.

Bibliography

Abate, B., Maggio, C. Di, Incandela, A., Renda, P., 1991. Nuovi dati sulla Geologia della penisola di Capo San Vito (Sicilia Nord-Occidentale). Memorie della Società Geologica Italiana 47, 15–25.

Accaino, F., Catalano, R., Marzo, L. Di, Giustiniani, M., Tinivella, U., Nicolich, R., Sulli, A., Valenti, V., Manetti, P., 2011. A crustal seismic profile across Sicily. Tectonophysics 508, 52–61. doi:10.1016/J.TECTO.2010.07.011

Agate, M., Basilone, L., Maggio, C. Di, Contino, A., Pierini, S., Catalano, R., 2017. Quaternary marine and continental unconformity-bounded stratigraphic units of the NW Sicily coastal belt. Journal of Maps 13, 425–437. doi:10.1080/17445647.2017.1314229

Agnesi, V., 2004. Sicily in the last one million years. Bocconea 17, 23–32.

Agnesi, V., Maggio, C. Di, Macaluso, T., Masini, F., Petruso, D., Simonelli, C., 2000. Quaternary Environmental-climatic changes in Sicily. Memorie della Società Geologica Italiana 55, 339–344.

Alimen, M.H., 1975. Les "isthmes" hispano-marocain et Siculo-Tunisien aux temps acheuléens. L'Anthropologie 79, 399–436.

Antonioli, F., Silenzi, S., Vittori, E., Villani, C., 1999. Sea level changes and tectonic mobility: Precise measurements in three coastlines of Italy considered stable during the last 125 ky. Physics and Chemistry of the Earth, Part A: Solid Earth and Geodesy 24, 337–342. doi:10.1016/S1464-1895(99)00038-1

Antonioli, F., Presti, V. Lo, Morticelli, M.G., Mannino, M.A., Lambeck, K., Ferranti, L., Bonfiglio, L., Mangano, G., Sannino, G.M., Furlani, S., Sulli, A., Palombo, M.R., Canese, S. Pietro, 2012. The land bridge between Europe and Sicily over the past 40 kyrs: Timing of emersion and implications for the migration of Homo sapiens. Rendiconti Online Societa Geologica Italiana 21, 1167–1169.

Balter, M., 2001. In Search of the First Europeans. Science 291, :1722–25.

Bar-Yosef, O., Belfer-Cohen, A., 2001. From Africa to Eurasia - early dispersals Ofer. Quaternary International 75, 19–28. doi:10.1016/S1040-6182(00)00074-4

Basilone, L., 2018. Introduction to the Geology of Sicily. In: Lithostratigraphy of Sicily. pp. 1–44.

Basilone, L., View, S., View, N.W.S., Basilone, L., 2012. Luca Basilone Litostratigrafia della Sicilia.

Biddittu, I., Piperno, M., 1972. Nuove segnalazioni di «Pebble Culture» in Sicilia. Quaternaria XVI, 32–52.

Broquet, P., 2016. Sicily in its Mediterranean geological frame. Boletín Geológico y Minero 127, 547–562.

Caracausi, S., 2018. Geological context of lithic industries in Delia-FiumeGrande valley, Santa Ninfa (TP): Hypothetic early human population in Sicily? 287.

Catalano, R., 1989. Geology of Sicily : an introduction.

Catalano, R., Stefano, P. Di, Sulli, A., Vitale, F.P., 1996. Paleogeography and structure of the central Mediterranean: Sicily and its offshore area. Tectonophysics 260, 291–323.

Catalano, R., Merlini, S., Sulli, A., 2002a. The structure of western Sicily, central Mediterranean. Petroleum Geoscience 8, 7–18.

Catalano, R., Merlini, S., Sulli, A., 2002b. The structure of western Sicily, central Mediterranean. Petroleum Geoscience 8, 7–18. doi:10.1144/petgeo.8.1.7

Chilardi, S., Dominicis, A. De, Zampetti, D., 2012. La frequentazione preistorica di Grotta Emiliana (Erice, TP). In: Atti Della XLI Riunione Scientifica: Dai Ciclopi Agli Ecisti, Società e Territorio

Nella Sicilia Preistorica e Protostorica. Firenze, pp. 5–9.
Cusinato, A., Bassetti, M., 2007. Popolamento umano e paleoambiente tra la culminazione dell ' ultima glaciazione e l ' inizio dell ' Olocene in area trentina e zone limitrofe. Studi Trentini di Scienze Naturali. Acta Geologica 82, 43–63.
D'Amore, G., Marco, S. Di, Salvo, R. Di, Messina, A.D., Sineo, L., 2010. Early human peopling of Sicily: Evidence from the Mesolithic skeletal remains from Grotta d'Oriente. Annals of Human Biology 37, 403–426. doi:10.3109/03014461003712947
D'Angelo, U., Vernuccio, S., 1994. Note Illustrative della Carta Geologica Marsala (F°617 scala 1:50.000). Bollettino della Societa Geologica Italiana 113, 55–67.
D'Angelo, U., Vernuccio, S., 1996. I terrazzi marini quaternari della estremità occidentale della Sicilia. Memorie della Società Geologica Italiana 51, 585–594.
Espa, G., Benedetti, R., Meo, A. De, Ricci, U., Espa, S., 2006. GIS based models and estimation methods for the probability of archaeological site location. Journal of Cultural Heritage 7, 147–155. doi:10.1016/j.culher.2006.06.001
Filippi, A., 2015. Preistoria e Protostoria Trapanese, il sole editrice. doi:10.1145/3132847.3132886
Filippi, A., Gallina, A., Giglio, R., Mannino, G., 2021. L'arte rupestre nel territorio di Trapani (Sicilia). Le incisioni lineari: analisi dei siti e loro relazioni con il territorio. In: Carrera, F.M.P., Grifoni Cremonesi, R., Tosatti, A.M. (Eds.), L'arte Rupestre Nella Penisola e Nelle Isole Italiane: Rapporti Tra Rocce Incise e Dipinte, Simboli, Aree Montane e Viabilità. Archaeopress Publishing Ltd, pp. 271–305.
Forgia, V., Petruso, D., Sineo, L., 2014. Il popolamento umano della Sicilia: una revisione interdisciplinare. Archivio per l'Antropologia e la Etnologia CXLIV, 117–140.
Galland, M., D'amore, G., Friess, M., Miccichè, R., Pinhasi, R., Sparacello, V.S., Sineo, L., 2019. Morphological variability of upper paleolithic and mesolithic skulls from sicily. Journal of Anthropological Sciences 97, 151–172. doi:10.4436/jass.97009
Gasparo Morticelli, M., Valenti, V., Catalano, R., Sulli, A., Agate, M., Avellone, G., Albanese, C., Basilone, L., Gugliotta, C.C., Morticelli, M.G., Valenti, V., Catalano, R., Sulli, A., Agate, M., Avellone, G., Albanese, C., Basilone, L., Gugliotta, C.C., 2015. Deep controls on foreland basin system evolution along the Sicilian fold and thrust belt. Bulletin de la Societe Geologique de France 186, 273–290. doi:10.2113/gssgfbull.186.4-5.273
GIS for Archaeology, 2009.
Grimaldi, S., Spinapolice, E., 2010. The late mousterian of the Grotta Breuil (Monte Circeo, Lazio, Italy): Interpreting new and anciente data. ACTA UNIVERSITATIS WRATISLAVIENSIS No 3207 Studia Archeologiczne XLI 1–11.
Kompatscher, K., Hrozny Kompatscher, N., Bassetti, M., Castiglioni, E., Rottoli, M., Wierer, U., 2016. Mesolithic settlement and mobility patterns at high altitudes. The site of Staller Sattel STS 4A (South Tyrol, Italy). Quaternary International 423, 23–48. doi:10.1016/j.quaint.2015.12.090
Leighton, R., 1999. Sicily before history: an archaeological survey from the Palaeolithic to the Iron Age. Cornell University press.
Liguori, V., Manno, G., Mortellaro, D., 2008. Evaporite karst in Sicily. Environmental Geology 53, 975–980. doi:10.1007/s00254-007-0723-9
Maggio, C. Di, Madonia, G., Vattano, M., Agnesi, V., Monteleone, S., 2017a. Geomorphological evolution of western Sicily, Italy. Geologica Carpathica 68, 80–93. doi:10.1515/geoca-2017-0007
Maggio, C. Di, Madonia, G., Vattano, M., Agnesi, V., Monteleone, S., 2017b. Geomorphological evolution of western Sicily, Italy. Geologica Carpathica 68, 80–93. doi:10.1515/geoca-2017-0007

Mannino, M.A., Thomas, K.D., 2009. Current research on prehistoric human coastal ecology: Late Pleistocene and Early Holocene hunter gatherer transitions in north-west Sicily. In: McCartan, S., Schulting, R., Warren, G., Woodman, P. (Eds.), Mesolithic Horizons. Oxbow Books, Oxford.
Mannino, M.A., Salvo, R. Di, Schimmenti, V., Patti, C. Di, Incarbona, A., Sineo, L., Richards, M.P., 2011. Upper Palaeolithic hunter-gatherer subsistence in Mediterranean coastal environments: An isotopic study of the diets of the earliest directly-dated humans from Sicily. Journal of Archaeological Science 38, 3094–3100. doi:10.1016/j.jas.2011.07.009
Mertel, A., Ondrejka, P., Šabatová, K., 2018. Spatial predictive modeling of prehistoric sites in the Bohemian-Moravian Highlands based on graph similarity analysis. Open Geosciences 10, 261–274. doi:10.1515.
Modi, A., Catalano, G., D'Amore, G., Marco, S. Di, Lari, M., Sineo, L., Caramelli, D., 2020. Paleogenetic and morphometric analysis of a Mesolithic individual from Grotta d'Oriente: An oldest genetic legacy for the first modern humans in Sicily. Quaternary Science Reviews 248. doi:10.1016/j.quascirev.2020.106603
Napoli, G., Nigro, F., Renda, P., 2012. The interation of compressional and extensional tectonics during the Sicily Chain building. Rendiconti Online Societa Geologica Italiana 21, 178–180.
Natali, E., Forgia, V., 2017. The beginning of the Neolithic in Southern Italy and Sicily. Quaternary International. doi:10.1016/j.quaint.2017.07.004
O'Regan, H., Bishop, L., Elton, S., Lamb, A., Turner, A., 2006. Afro-Eurasian mammalian dispersal routes of the Late Pliocene and Early Pleistocene, and their bearing on earliest hominin movements. CFS Courier Forschungsinstitut Senckenberg 256, 305–314.
O'Regan, H.J., Turner, A., Bishop, L.C., Elton, S., Lamb, A.L., 2011. Hominins without fellow travellers? First appearances and inferred dispersals of Afro-Eurasian large-mammals in the Plio-Pleistocene. Quaternary Science Reviews 30, 1343–1352. doi:10.1016/j.quascirev.2009.11.028
Parotto, M., Praturlon, A., 2004. the Southern Apennine Arc. Special Volume of the Italian Geological Society for the IGC 32 Florence.
Piperno, M., 1997. Il popolamento della Sicilia. Il paleolitico inferiore. In: Tusa, S. (Ed.), Prima Sicilia Alle Origini Delle Società Siciliana. pp. 82–91.
Qgis, W.I.S., 2017. MAPPING WITH QGIS FOR 1–14.
Ruggieri, G., Unti, M., Unti, A., Moroni, M.A., 1975. La calcarenite di Marsala (Pleistocene inferiore) e i Terreni Contermini. Bollettino della Societa Geologica Italiana 94, 1623–1657.
Segre, A.G., Biddittu, I., Piperno, M., 1982. Il Paleolitico Inferiore nel Lazio, nella basilicata e in Sicilia. In: Atti Della XXIII Riunione Scientifica Dell'Istituto Italiano Di Preistoria e Protostoria. Firenze, pp. 177–206.
Sevara, C., Salisbury, R.B., Doneus, M., Draganits, E., Totschnig, R., Frazzetta, C., Tusa, S., 2020. A Landscape in Transitions: Guletta, a Multiperiod Settlement along the Mazaro River in Western Sicily. Journal of Field Archaeology 45, 334–354. doi:10.1080/00934690.2020.1734898
Sineo, L., Petruso, D., Messina, A.D., D'Amore, G., 2015. Human Peopling of Sicily During Quaternary. In: Fernández, L.D. (Ed.), The Quaternary Period. pp. 25–68.
Speranza, F., Hernandez-Moreno, C., Avellone, G., Gasparo Morticelli, M., Agate, M., Sulli, A., Stefano, E. Di, 2018. Understanding Paleomagnetic Rotations in Sicily: Thrust Versus Strike-Slip Tectonics. Tectonics 37, 1138–1158. doi:10.1002/2017TC004815
Thacher, D., Milne, S.B., Park, R., 2017. Applying GIS and statistical analysis to assess the correlation of human behaviour and ephemeral architectural features among Palaeo-Eskimo sites on Southern Baffin Island, Nunavut. Journal of Archaeological Science:

Reports 14, 21–30. doi:10.1016/j.jasrep.2017.05.004
Tusa, S., 1999. La Sicilia nella preistoria, II. ed. Sellerio Editore, Palermo.
Tusa, S., Maida, G. Di, Pastoors, A., Piezonka, H., Weniger, G.C., Terberger, T., 2014. The Grotta di Cala dei Genovesi - New studies on the Ice Age cave art on Sicily. Prahistorische Zeitschrift 88, 1–22. doi:10.1515/pz-2013-0001
Vetro, D. Lo, Martini, F., 2012. Il Paleolitico e il Mesolitico in Sicilia. In: Atti XLI Riunione Scientifica IIPP, “Dai Ciclopi Agli Ecisti: Società e Territorio Nella Sicilia Preistorica e Protostorica”. San Cipirello, Italy, pp. 19–48.
Vetro, D. Lo, Martini, F., 2016. Mesolithic in Central–Southern Italy: Overview of lithic productions. Quaternary International 423, 279–302. doi:10.1016/j.quaint.2015.12.043
Villa, P., 2001. Early Italy and the colonization of Western Europe. Quaternary International 75, 113–130. doi:10.1016/S1040-6182(00)00083-5
Waele, J. De, Piccini, L., Columbu, A., Madonia, G., Vattano, M., Calligaris, C., D’angeli, I., Parise, M., Chiesi, M., Sivelli, M., Vigna, B., Zini, L., Chiarini, V., Sauro, F., Drysdale, R., Forti, P., 2017. Evaporite karst in Italy: a review. International Journal of Speleology 46, 137–168. doi:10.5038/1827-806X.46.2.2107
Wagner, S., Costantini, E.A.C., Sauer, D., Stahr, K., 2007. Soil genesis in a marine terrace sequence of Sicily, Italy. Revista Mexicana de Ciencias Geologicas 24, 247–260.
Zampetti, D., Caloi, L., Chilardi, S., Palombo, M.R., 2000. Le Peuplement de la Sicilie pendant le Pleistocene: l’Homme et les Faunes. In: ICAZ-Archaeozoology of the Near East, IV A. Proceedings of the Fourth International Symposium on the Archaeozoology of Southwestern Asia and Adjacent Areas. Groningen, Netherlands, pp. 18–38.
Zanchetta, G., Borghini, A., Fallick, A.E., Bonadonna, F.P., Leone, G., 2007. Late Quaternary palaeohydrology of Lake Pergusa (Sicily, southern Italy) as inferred by stable isotopes of lacustrine carbonates. Journal of Paleolimnology 38, 227–239. doi:10.1007/s10933-006-9070-1

Encyclopedia of Global Archaeology. Springer, Cham. https://doi.org/10.1007/978-3-319-51726-1_1998-2