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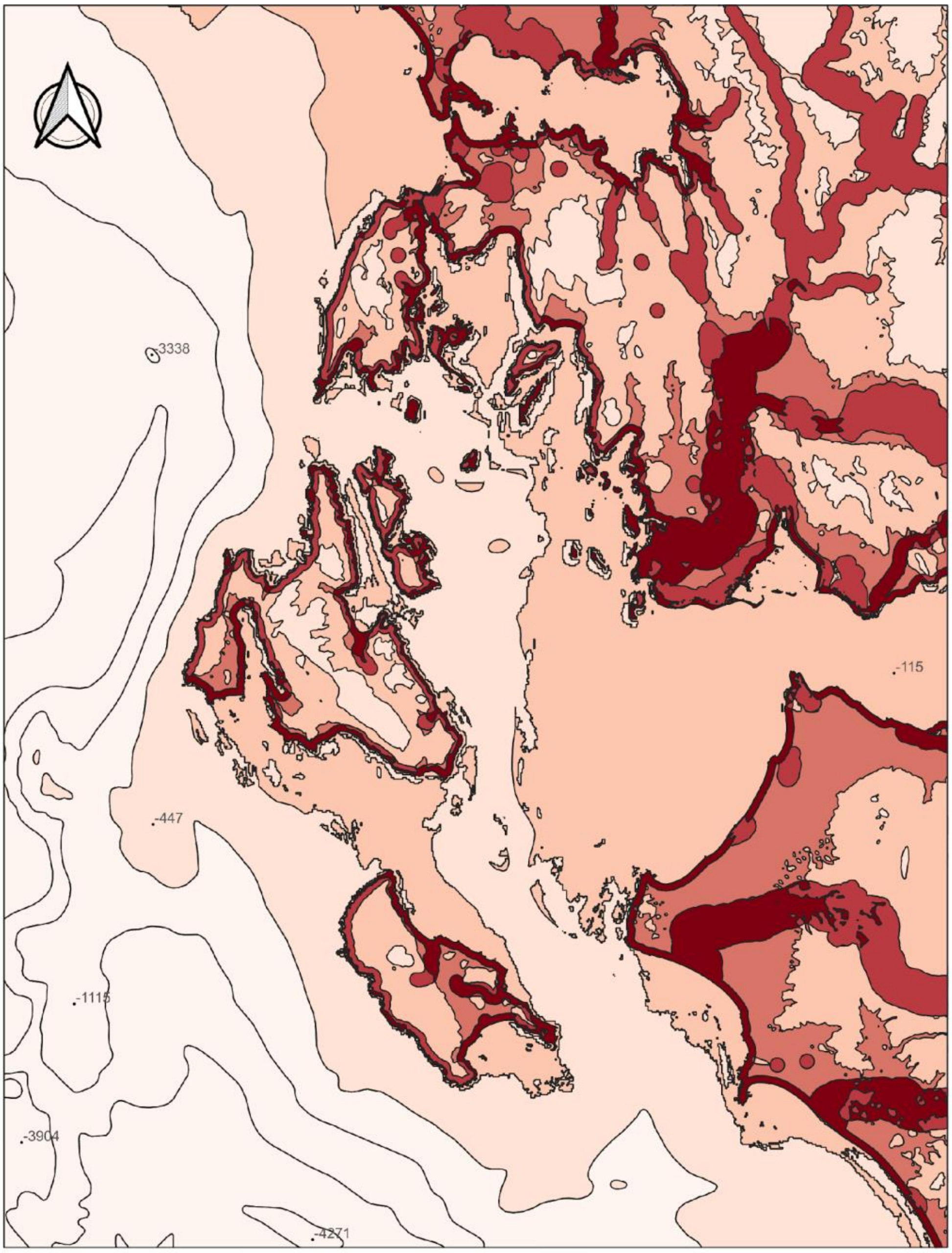

(Figure by Vezoniaraki, E.C.)

Predictive modelling of insular and partly submerged landscapes: tracing the hominin activity and occupation of the central Ionian sea, from the Palaeolithic to the Neolithic

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Master Thesis (1084VTSY)

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Specialisation: Digital Archaeology

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Leiden, 15/12/2022

Final draft

Acknowledgements

I would like to express my deep and sincere gratitude for the following people for helping me realise this thesis:

First and foremost, I would like to thank my supervisor, Dr. Karsten Lambers, for his patience, support and guidance throughout the whole process, helping me put my thoughts in an order.

Many thanks to my professor from the University of Crete, Dr. N. Galanidou, who enthused me with her passion for Palaeolithic archaeology, and for providing me with ideas and material.

To Dr. G.J.M. van Wijngaarden and Dr. E. Yiannouli for taking the time to answer my questions regarding their projects and their feedback. To Mina Nikolovieni, for providing me with folders upon folders of literature, and her ideas, enthusiasm and feedback as soon as we met.

I would also like to thank all my inspiring professors in Leiden University, and especially professors Tuna Kalayci, Aris Politopoulos and Laura Llorente Rodriguez for their ideas on the early stages of my thesis. My colleagues and friends at Leiden University: Markella, for sparking the idea for the subject of my thesis, Krijn, Anance, Riia, and Tom, for their ideas, support and feedback. A special thanks to Mr. Jaap van Belen, for always welcoming me with a warm smile along with the lab key.

Finally, this MSc thesis is dedicated to my family and friends, who believed in me and supported me in every step of the process, which seemed too long and way too short at the same time. For listening to my enthusiastic babbling and giving me feedback, I would like to thank Nikol, Irini^2, Christina and Peli. And of course, for voluntarily proofreading my entire thesis and the amusing comments, thank you Emma!

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1.1 General introduction

"Ἄνδρα μοι ἔννεπε, μοῦσα, πολύτροπον, ὃς μάλα πολλὰ πλάγχθη" [Tell me, oh Muse, of the much- travelled man who wandered far and wide] (Homer, Odyssey, Book 1, Lines 1-2, n.d.).

Long before Homer narrated the rhapsodies of Odysseia, before the renowned Mycenaean civilization and Odysseus' Ithaki, humans already wandered and sailed across the Ionian Sea. The journey on the depths of history had already begun in the earlier phases of the Palaeolithic from our species' ancestors, in landscapes very different from today, some of them long lost under the waves of the Mediterranean Sea and others buried underneath the ground we walk. Many islands were periodically transformed into peninsulas of the mainland, expanding and decreasing in size as a result of the glacial cycles, the tectonism and sea currents. The present thesis studies the complex insular and partly submerged landscapes of the central Ionian Sea, tracing the activity of hominins as reflected in the archaeological record, in order to create predictive models showing human presence in the area from the Palaeolithic to the Neolithic period. The models aim at incorporating various environmental and social factors thought to affect the presence and dispersal of early humans.

1.2 Research problem

The study of prehistory in the area of modern-day Greece has long been out-shined by research focusing on later, historic time periods (Ligkovanlis, 2014). Research projects focusing on the Palaeolithic and the Mesolithic were scarce (Tourloukis, 2010), while the Neolithic was more known since the beginning of the 20th century (Wijnen, 1982). In the 1960s the first projects began investigating the Palaeolithic in western Greece with a team under the direction of Eric Higgs in Epirus (Dakaris et al., 1964; Ligkovanlis, 2014; Papoulia, 2018b) and later on the Ionian islands by Sordinas (Galanidou, et al., 2013; Ligkovanlis, 2014).

The state of research has changed significantly during the past two decades, with an increasing amount of archaeological projects focusing on the earlier time periods (see Chapter 2), and the discovery of more locations rich in finds across Greece, dating from the Lower Palaeolithic to Neolithic times (Galanidou, 2014; Harvati et al., 2009; Panagopoulou, 1994). Even though the mainland was targeted by the majority of these projects, the Greek islands received a considerable proportion of this attention, and especially the islands of the Aegean Sea (Aegean citations). Among others, Papoulia's (2018) PhD dissertation explores the potential submerged routes and sea-crossings between the current mainland and the Ionian islands, considering the past sea level fluctuations and present raw material sources. In a second PhD dissertation Tsakanikou (2020), discussed new pathways of hominin movement, suggesting that the Aegean was not a barrier, but a bridge assisting the spread and movement of hominins, establishing mainland Greece more relevant in early hominin migrations. In this theses, the term "hominins" is as an umbrella term including all *Homo* species according to Gamble's (2007) definition.

However, along with the ever increasing number of projects and finds associated with the earlier time periods, the inherent complexity of studying these periods became apparent. Aside from the poor preservation of archaeological finds, the dynamic geological processes transforming the landscape over and over again, alongside with landmasses rising and re-submerging under the sea due to eustatism, rendering the reconstruction of the past landscape ever so challenging. Recent studies included innovative, multi-disciplinary approaches, enabling opportunities to combine information and reconstruct the earlier parts of prehistory in the area, during periods where finds are limited.

1.3 Why predictive modelling?

Predictive modelling in archaeology is a technique aimed at predicting the location of archaeological sites or finds in a chosen area, by using either the already established locations or "fundamental notions concerning human behaviour" (Kohler & Parker, 1986). As a methodology, it is not yet common practice in Greek archaeological research as it is in other countries (see Chapter 4), although it could be highly beneficial. A form of correlative or inductive modelling is applied by the Greek Ephorate of Antiquities (The Archaeological

Cadastre, n.d.) protecting the zones known to have a high occurrence of archaeological finds, and acts mostly as a preventive measure against infrastructure related disturbances.

Predictive modelling can be a valuable tool for both archaeologists and the broader public. For archaeologists, it can be a tool assisting with the optimisation of the fieldwork period in terms of budget and time, which are generally limited within the field of archaeology. It can be also used as a stepping stone for future research, upon which other researchers can compare their data, and which they can ultimately enhance to include more variables and new information.

The broader public and the economy can benefit from the application of predictive modelling in archaeology by using it as a compass for heritage management, advising developers and the public about areas of "high" archaeological value, saving or preparing them for the paperwork and potential delays, while helping prevent accidental disturbances in valuable archaeological contexts. Verhagen (2007a) briefly discusses these benefits, along with some of the main pitfalls of the method over the years it has been applied.

Accompanying the benefits of predictive modelling in archaeology, there are some risks that need to be considered, concerning both its creation and its application (see Chapters 4 & 6). In a nutshell, the risks concerning the construction of the model can be due to focusing solely on environmental aspects, while risks in its implementation regard creating self-fulfilling prophecies or providing looters with a "treasure map" they can use to locate areas with high archaeological potential, previously invisible to the public. These issues have been a part of predictive modelling since its birth and are discussed further in the following chapters.

In this thesis, predictive modelling was chosen as the final step in the process of gathering, organising and assessing available information on the chosen research area from various studies, while establishing meaningful patterns among environmental factors and human occupation with the help of geographical information systems (GIS). The models created can be a useful and an easy to navigate tool for future reference, and attempts to open the way towards a more regular application of predictive modelling in Greece.

Predictive modelling can take many forms and their usefulness and application in archaeology have been the apple of Discord for many years (see Chapter 4.1.1). The current project follows a combination of the two traditional approaches (see Chapter 4.1.2), being mostly deductive in the sense that it originates from theories and expert knowledge found in the literature, while making use of the location of associated archaeological finds. The known locations of archaeological finds and sites are split in two parts, of which 70% of the locations are used in building the model to assess the probability value of each factor considered, and the remaining 30% in testing the model produced (see Chapter 4.2.3). The reasons for this choice are further explained in Chapter 4.2 .

1.4 Research questions

Following up from the recent developments and projects, this study aims at taking advantage of the opportunity presented and exploring the area of the central Ionian Sea in Western Greece (Figure 1). Various studies have focused on human activity on the Greek mainland during the Stone Age (Darlas, 2007; Efstratiou et al., 2006; 2011; Starkovich, 2014). The Aegean Sea has already been explored, revealing a long history of hominin activity (Galanidou et al., 2013; 2016; Mavridis, 2007; Sakellariou & Galanidou, 2015; Sampson et al., 2016) and a potential passageway into mainland Greece (Broodbank 2006; Tsakanikou 2020). Could that be also true for the other side of the Pindos mountain range?

Figure 1 *Research area marked on the map of Greece*. (Figure by Vezoniaraki, E.C., source: OpenStreetMap)

There have been several research projects regarding the Ionian Islands and Western parts of Greece, proving hominin activity and occupation, and the potential presence of more archaeological sites (see Chapter 2.3). Among others, it has even been supported that the Ionian Islands were used as a migration passageway into Western Europe through the Italian peninsula (Tsonos, 2000), since the seafaring ability of the hominins occupying the area at the time has been established (Ferentinos et al., 2012; Fischer & Papoulia, 2018; Papoulia, 2016; 2018a; 2018b). The geomorphology of this area has been subjected to many changes since, resulting in a substantially different present-day landscape, with much of the older landscape and land-bridges connecting the islands to the mainland being currently submerged (Fischer & Papoulia, 2018, Lambeck & Purcell 2004, Lykousis 2009, Papoulia 2018b).

The present thesis focuses on the presence of hominins in the broader area of the central Ionian Sea from the Palaeolithic to the Neolithic times, investigating patterns of activity in the western Greek mainland and the Ionian islands. The chosen research area is discussed broadly, in an attempt to investigate whether there are any observable patterns when zooming out and looking at the bigger picture, instead of focusing in on individual parts. The available material in terms of datasets and literature is considered and assessed in terms of their openness and accessibility. The maps and models produced are created in an open software (QGIS), using open data as much as possible and the processes followed will be described thoroughly, to allow transparency and reproducibility.

This thesis aims to further existing research, by combining material provided by recent databases and publications in order to create a model that gathers and assesses the various attributes, proposing areas of archaeological interest.

Chronologically, this project attempts to incorporate a large time period, making it more challenging, but also more realistic considering the broader lack of absolute dating of the associated finds, and the often co-existence of finds dated more than one time period in each location. Since the chosen periods differ in many aspects, including environmental, economic, social and cultural aspects, the three time periods chosen are studied under their common denominator: the use of lithic tools. The size, preferred material and typology of the lithic tools also vary throughout the time periods under study, but they share the same raw material sources, and preservation potential.

In order to explore the subject of locating areas with high archaeological potential, the following three questions will be studied.

Research questions:

1. Which environmental factors were the most relevant per time period in influencing the hominin activity and occupation of each part of the study area? How are they affected by the natural and anthropogenic processes that followed their deposition?

2. Which social and cultural factors can be accounted for and included in the predictive model, and how do they change over time?

3. What are the strengths and the limitations of the available digital data on Greek prehistory, and does it allow the creation of a predictive model based primarily on open source data?

1.5 Thesis outline

The following Chapter 2, includes more information on the chosen method and research area, defining the latter geographically and describing the transformation of the landscape over the years for a deeper understanding of the case study. The chronology of different sites across the research area is studied in order to establish a baseline for the separation in different time periods. Moreover, the current state of research in the broader area is explored, by briefly mentioning recent developments and ongoing research projects.

In Chapter 3, all the relevant available material and resources are assessed along with their degree of openness and limitations. The ways this material can be implemented in the form of maps and datasets in a predictive model are also discussed, combined with a brief description of the openly available maps.

Chapter 4 is the Methodology Chapter, where there is a more in depth discussion regarding the applications of predictive modelling in archaeology over the years. Subsequently, the process followed will be described step by step to allow easier peer review and reproducibility of the results. The choices made will be explained and justified. Open science data and methods are preferred in all steps of the process (see Chapter 3).

In the results in Chapter 5, the produced predictive models are presented and described.

The final chapter of the main body, Chapter 6, is where the produced models are analysed and tested. Furthermore, the created models are evaluated to estimate their precision, overall gain and weaknesses, and there is a critical reflection on the process and the results.

The Conclusion chapter is where the research questions are answered, and where suggestions for future additions, improvements and recommendations for future research are proposed.

The maps not encompassed in the main body of the thesis are listed in the appendices, to avoid an over-saturation, without excluding any major steps of the production of the final maps.

2. Background

In this chapter, the chosen methodology is introduced, the research area is defined and its main aspects are explored. It works as an introduction to the main elements of the research area that ought to be considered before creating a predictive model and lays the foundations upon which the research questions were formed, tackled, and eventually answered.

The first part of the chapter is dedicated to predictive modelling and its application in Greece and surrounding areas. In the second part the chosen research area will be explored, its geomorphological and geological attributes are discussed, as found in the literature and the maps used. Subsequently, the topics of tectonic activity and current land use are presented, a review of the history of the research area's landscape is presented, and the dates associated with the relevant time periods and related dating issues are deliberated. Finally, the main archaeological projects in the area are introduced, showcasing the current state of research.

2.1 Modelling the Stone Age

The research area chosen has a complicated history in terms of landscape. It combines inland and coastal areas, islands, lagoons and partly or fully submerged past landscapes. Eustatism and the area's close proximity to the tectonic plates' borders further complicate matters when attempting to understand and predict the distribution of archaeological finds, especially those dated in the Stone Age. Yet, among others three cases of predictive models in Greece and Cyprus assert its effectiveness in predicting areas with a high occurrence of Stone Age finds.

The two cases of modelling in Greece, are both focused on locating early Holocene sites, with one researching Mesolithic Argolid in north-eastern Peloponnese (Runnels et al., 2005), and the other researching Neolithic Magnesia in Thessaly (Perakis & Moysiadis, 2011) (Figure 2).

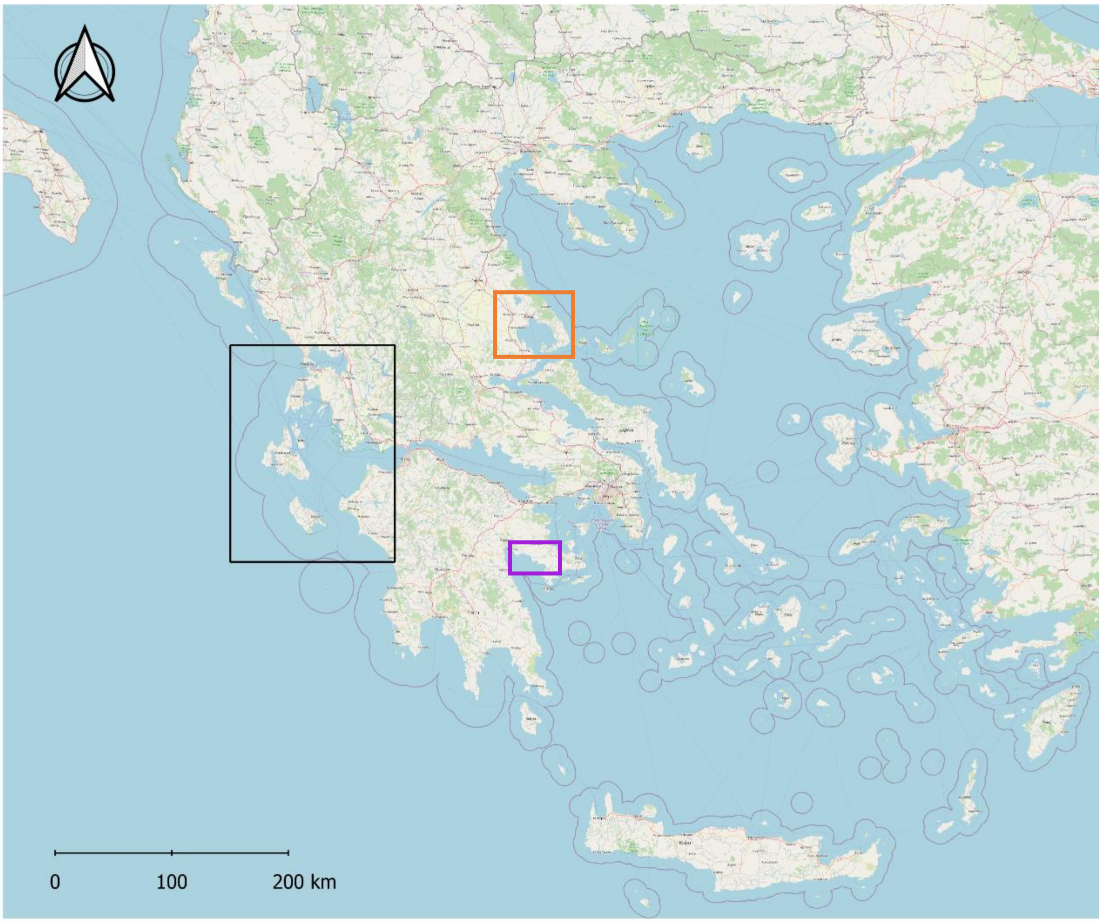

Figure 2 *Map of Greece with the mentioned areas marked*. The research area of this thesis is depicted in black, and the areas modelled by the Neolithic Magnesia project and the Kandia Mesolithic Survey are marked with orange and purple respectively. (Figure by Vezoniaraki, E.C., source: OpenStreetMap).

As part of the Kandia Mesolithic Survey conducted in 2003 in Argolid a site-location model was constructed for the coastal region of Kandia (Runnels et al., 2005). The model is studying and evaluating the factors affecting the distribution of Mesolithic sites, in times when the coastline was similar to the contemporary one. The model pointed towards a preference on areas near freshwater sources in coastal zones, and especially regions with small caves or rock-shelters that would be rich in flora and fauna. The results were tested with field research in a chosen area investigating suitable caves, and successfully locating 21 sites with lithic finds, of which 15 had a significant amount of Mesolithic finds. These locations were found to be located in the intersection of relatively low elevations, lower than 100masl, and areas overlooking either the valley or coast.

The second model uses the Dempster-Shafer theory to predict the location of Neolithic sites in Magnesia (Perakis & Moysiadis, 2011). The model evaluates elevation, slope, aspect, and present-day water network and settlement location as relevant proxies, by creating a significance weighted model. The three resulting probabilistic classes are hypothesising sites, non-sites and ignorance. The sites predicted were also located in relatively low elevations, most of them being under 150masl. The parameters studied appear to successfully explain the distribution of Neolithic sites in the area.

In contrast to the two models described above, the third model (Moutsiou et al., 2021) is targeting the Plesitocene, and the Palaeolithic occupation of the island of Cyprus. All evidence points at Cyprus being insular at the time of its first occupation by hominins during the Palaeolithic, further supporting the ability of hominins' seafaring capabilities at the time. The proxies considered as relevant are compared with the location of the known sites on the island. These are elevation, slope and aspect, distance from lithic raw material sources and water sources. Just in the case of the models presented above, the distance from water sources was estimated by the location of present day fresh water river networks and coastline. The model produced aimed at predicting the locations with higher or lower potential to uncover relevant finds. The resulting model was validated through field survey in the south part of the island, successfully locating open-air locations with lithic finds. The field survey proved raw material availability and fresh water to be a major factors, and slope to apply in cases of rock shelters and caves as well, with the scarce cases of rock shelters located on slopes more than 20% not carrying any finds. Similarly to the previous projects, the high elevations, in this case above 350-500masl were considered as of lower expectancy, as they would be visited less often by hominins and therefore be less likely of preserving material.

Even though implementing predictive modelling in submerged palaeo-landscapes works very differently from land models, in terms of the very different aspects that need to be considered, eliminating the least possible locations alone through predictive modelling is a valuable approach in underwater archaeology (Spikins & Engels, 2010). A Final Palaeolithic underwater site located around 130m from the coast of Cyprus (Bailey et al., 2020) stands proof of the prospective of including presently submerged areas in archaeological predictive modelling. In the case of this thesis, the sea is also considered in terms of its potential to hold archaeology, in an attempt to narrow down possible locations of higher archaeological potential.

These case studies are showcasing that predictive modelling can be effective in predicting Stone Age finds, having proven successful even in cases where the landscape was vastly different from the contemporary.

2.2 Research area

The study area chosen for the present project is the central Ionian Sea (figures). Even though the area used to be a popular target of archaeological projects due to its correlation with Homer's epic poem, Odyssey (Heurtley, 1935; 1939-40; Waterhouse, 1996; Brown et al., 2011), much less was known for the periods proceeding the Bronze age. The situation changed relatively recently when it became the main focus of several research projects which will be briefly presented in Chapter 2.3. This led to an increasing amount of finds and fascinating information surfacing regarding the time periods under study. The availability of material in combination with the unusual set of environmental conditions affecting the landscape of the area, deemed it a challenging but interesting candidate for a predictive model.

2.2.1 Definition

The Ionian Sea spreads along the west coast of the Greek peninsula bordering the Adriatic Sea on the north, and stretches all the way down to the south-west tip of the Peloponnese in the south, including the two islands on its south east corner, Kythira and Antikythira (Figure 1). The area is too extensive and diverse to be properly integrated into a single predictive model, so the chosen area of interest includes only the central part of the Ionian Sea (Figure 3).

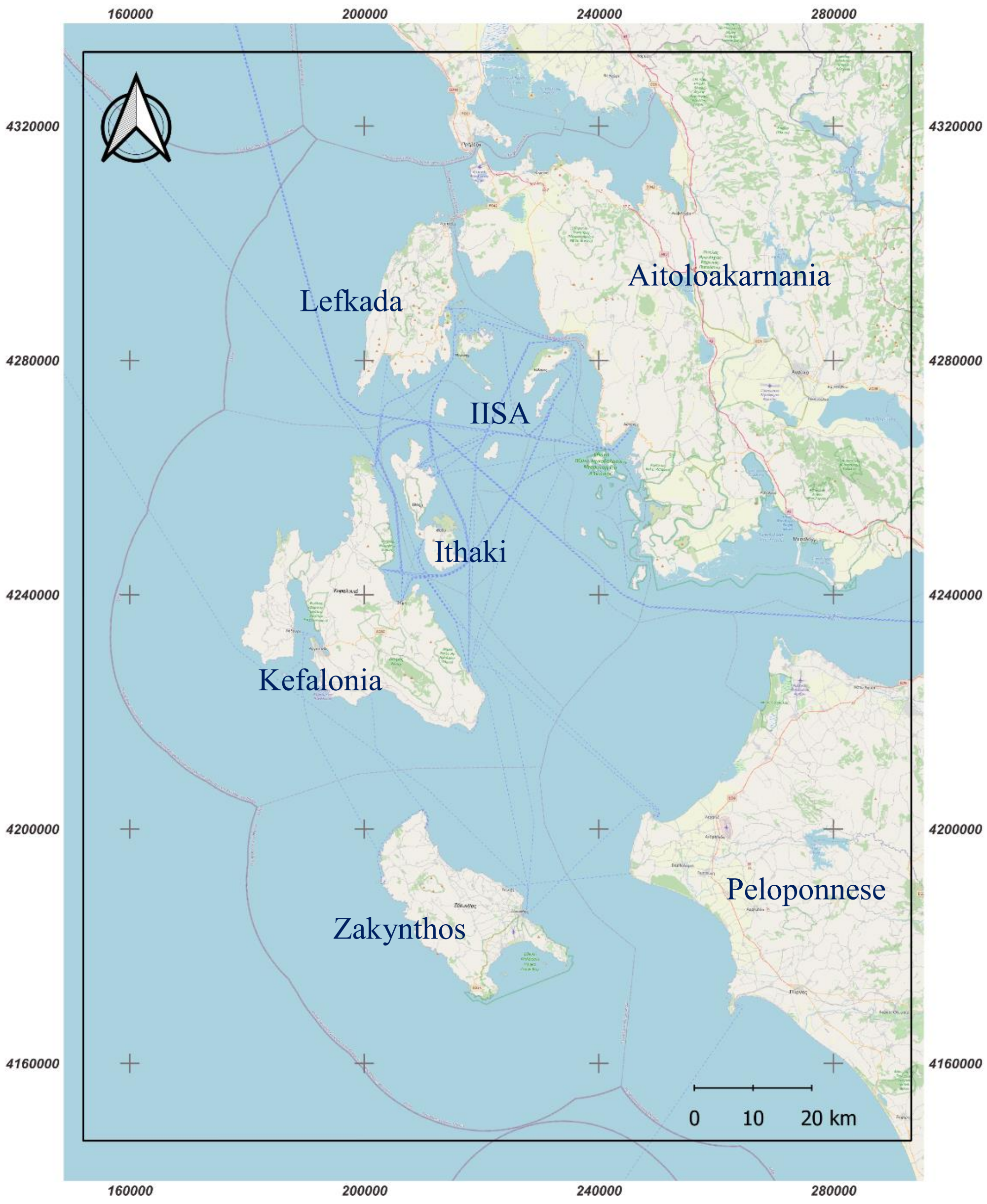

Figure 3 *Research area with the main toponyms mentioned in the text.*

The area of interest was decided upon certain criteria including but not limited to its landscape, the proximity of the islands to mainland, the geological history of the area and the islands' insularity. It consists of the central part of the Ionian Sea, comprising of both the islands and the western coasts of the Greek mainland (Figure 3). It includes the four bigger islands: Lefkada, Kefalonia, Ithaki and Zakynthos, along with the smaller islands of the Inner Ionian

Sea Archipelago (IISA). The area could not be complete without including the west coasts of the mainland, due to the significant fluctuations of the sea levels in the past in accordance to the glacial cycles, forming the landscapes and seascapes lost in time (Ferentinos et al., 2012; Fischer & Papoulia, 2018; Lykousis, 2009).

An arbitrary border was originally created, strictly encompassing the islands and the coastal zone of the mainland. Taking into consideration the large-scale changes that the natural landscape underwent since the earlier periods studied in this thesis, and for the sake of a broader, less associated with the current state of the coastline preview of the area, the final research area took the form of a rectangle enclosing the area of interest.

The parts of the mainland included in the research area are meant to supplement the outlook of the area, being the areas from which the hominins departed on their way to the islands, and having undergone dynamic changes over the years themselves. In the East, the research area includes the foothills of the Pindos mountain range, encompassing modern-day Aetoloakarnania with small parts of the prefectures Preveza, Arta and Evritania (Appendix 9). The North-western tip of the Peloponnese is also part of the research area, including parts of modern-day prefectures Ahaia and Elia. The research area did not extend any further, deeming these areas less related to the research goals and questions of this thesis, and in order to maintain a reasonably sized area fitting for a predictive model.

2.2.2 Geology

The geology of the research area varies both in lithology and in formation period. According to EGDI (Figure 4), the most common materials throughout the research area are limestone, clastic sediments and clastic sedimentary rocks. Limestone is the predominant material on the islands and is covering the west part of Aetoloakarnania up to Amvrakikos bay, while it is almost absent in the Peloponnese. Clastic sediments and clastic sedimentary rocks are spread mostly on the mainland bordering the limestone, and covering the SE valley of Zakynthos.

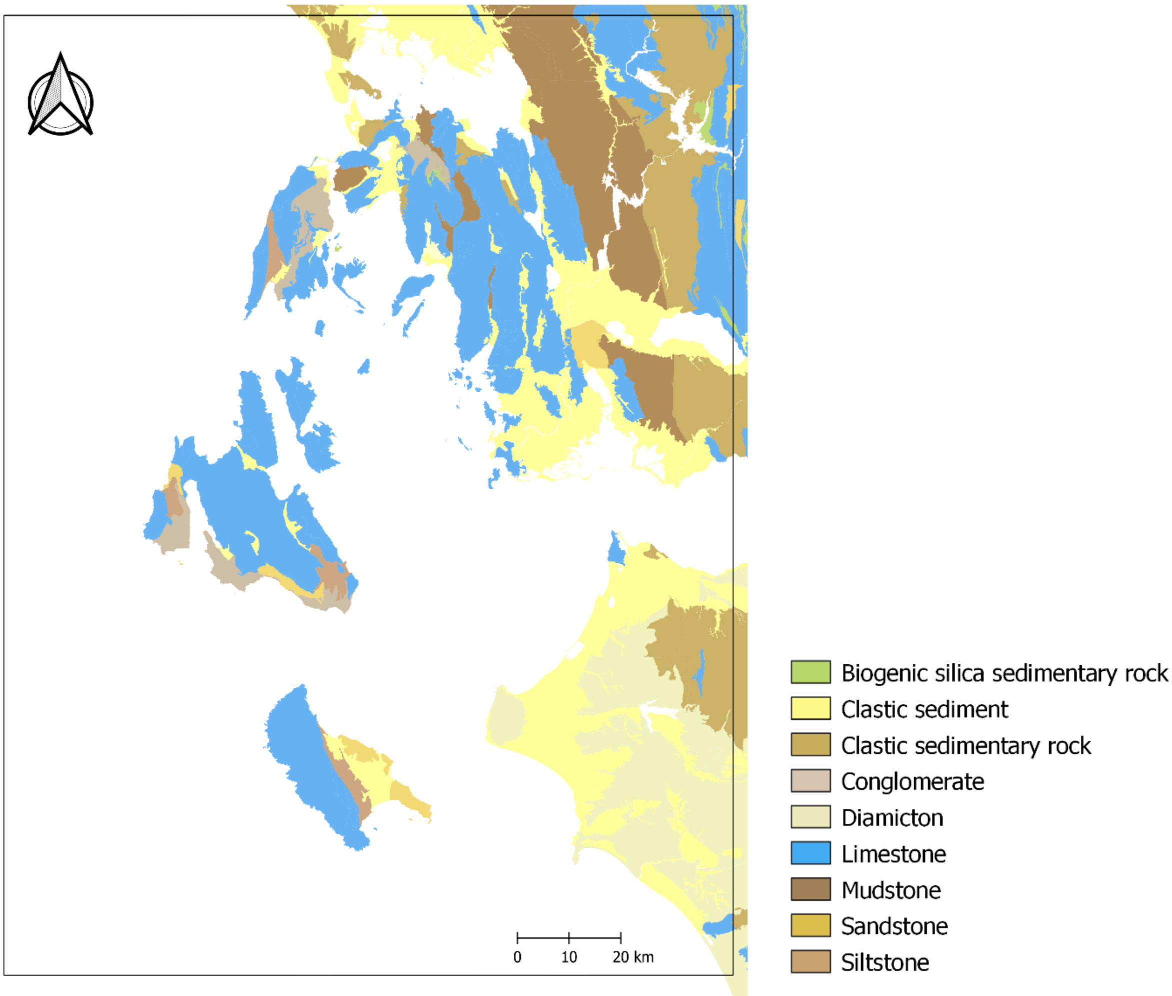

Figure 4 *Geology map*. The main lithology units of the research area. (Figure by Vezoniaraki, E.C., source: EGDI).

The other primary types of lithology found on the research area are diamicton, conglomerate, sandstone, biogenic silica sedimentary rocks, mudstone, and siltstone. On the Peloponnese diamicton occupies most of the area, which is absent in the rest of the research area. On the other hand, conglomerates are absent from the Peloponnese, but can be found to a limited extend in the rest of the research area. Biogenic silica sedimentary rocks can be found in very limited occasions, covering the island of Skorpios and the eastern side of Kremaston lake. Mudstone can be located inland in a line running parallel to the Pindos mountain range, and finally siltstone covers some parts of the biggest islands of the research area.

Time-wise, the lithology varies a lot, with the earliest ones dating back to the Triassic period and the most recent ones dated on the Holocene, the current geological period, in the case of clastic sediments and clastic sedimentary rocks (EGDI, n.d.).

2.2.3 Geomorphology

The research area is characterized by a diverse geomorphology, with relatively high altitudes even on the islands, in combination with staggering depths below the sea. The presence of water in the form of sea, lakes, rivers and seasonal streams is omnipresent. Some parts of the research area are still covered with natural forests. Below the geomorphology of each part of the research area will be briefly presented (figure with sub-regions).

The mainland of the research area is mainly characterized by the foothills of the Pindos mountain range on the East, Aheloos river valley, Amvrakios gulf on the North and Mesologgi lagoon on the South. The area includes some large lakes and some more high mountains near the coast. Separated from the mainland by the Patraikos Bay, the Peloponnese is shaped by Pinios and Alfios, its two perennial rivers and their tributaries, while the majority of the region included in the research area is relatively level.

The islands and islets of the research area also have varying geomorphologies. The northern island of the research area is Lefkada, connected on its north-east side with the Greek mainland through two narrow straights of land. The island's mountains are reaching just over 1000m above sea level (masl). The west coast of the island is very steep, forming sand cliffs and being prone to erosion (see Chapter 4.2.2).

In between Lefkada, Ithaki, Kefalonia and the mainland, dotting the sea, are the islands of the Inner Ionian Sea Archipelago (figure with IISA). Some of the islands are bigger in size, like Kalamos, Meganisi and Kastos, while others are much smaller such as Skorpios, Thilia and Formikoula. Their elevation varies, reaching up to 150-250m, and even 745masl in the case of Kalamos. Meganisi, the largest island of IISA is located very close to the South-eastern coasts of Lefkada. It is shaped as a crescent with a wider northern half and a very narrow and steep southern half. Kalamos, the second largest of the IISA islands, is located on the opposite side, in a close proximity to the mainland, and its surface is mountainous. Both Meganisi and Kalamos are presently inhabited. Out of the smaller uninhabited islands of IISA, the islets of Kythros, Arkoudi and Atokos deserve special mention, as they are relevant to the current project. Kythros is the smallest of the three located immediately on the south of Meganisi, while Arkoudi and Atokos are located in the heart of the Inner Ionian Sea. Atokos stands out in research for its exceptional visibility from the nearby coasts (Magganas et al., 2019), due to its location and high elevation, with peaks reaching almost 300masl.

On the south of Lefkada, are Ithaki and Kefalonia, separated by a narrow strait of sea. Ithaki is highly mountainous, with its highest peak standing at 809masl, followed up by many more peaks in both halves over 350masl. In its entirety, Ithaki has a sharp landscape, with only a few valleys and plateaus, mostly on the south part. Kefalonia is the largest island of the research area. Its largest mountain peak, Mount Ainos stands at 1628masl. The central part of the island is dominated by hills and mountains, forming plateaus and impressive gorges. The western coasts of the island, and especially of Paliki peninsula, are sharp and prone to erosion.

Zakynthos is the south-most island of the research area. Its surface is visibly separated in two parts. Half of the island is dominated by Vrachionas mountain range, while the rest of the island is relatively flat, with lower peaks mostly concentrated on Vasilikos Penisnula. A large valley is stretching from the foothills of Vrachionas. The western coast, just like in the case of Lefkada and Kefalonia, is much steeper than the east, and as such prone to erosion.

Although related to the parent material and lithology, soils are a different story (Gray, et al., 2016). As visible, the main soil types of the research area are Leptosol, followed by Fluvisol, Luvisol, Regosol and some Cambisol (Figure 5). The different soil types are associated with certain properties and morphologies, which are influenced by the environments and parts of the world in which they are found (Driessen & Dudal, 1989; Spaargaren, 2001; Tóth, et al., 2008). In brief, Leptosols and Regosols are associated with mountains (Driessen & Dudal, 1989), Fluvisols with periodically flooded lands (Tóth, et al., 2008), and Luvisols are layers rich in clay (Tóth, et al., 2008). In terms of erosion susceptibility, Regosols are prone to erosion (Driessen & Dudal, 1989). The study of the properties of each of these types is beyond the scope of this thesis.

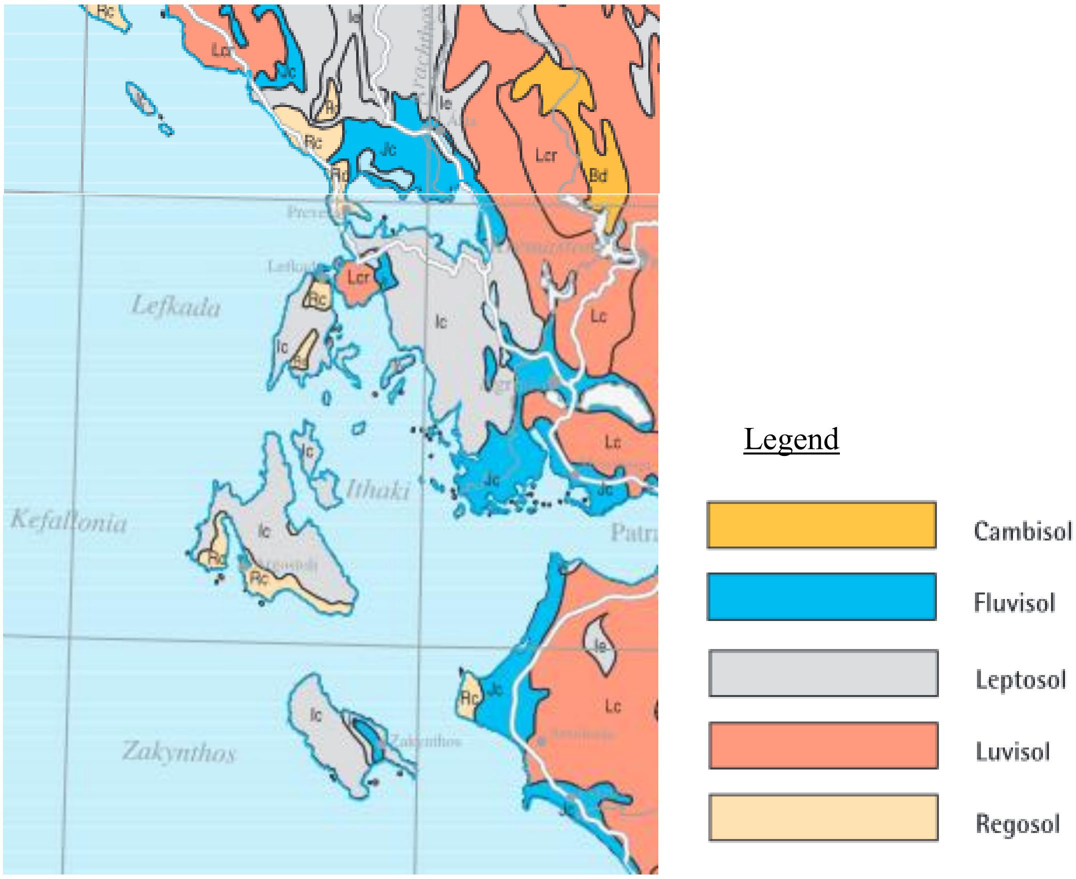

Figure 5 Soil map. Soil types according to the World Reference Base, 1:1.000.000 (Soil Atlas of Europe, n.d., plate 15).

2.2.4 Tectonic activity

The landscape of the Ionian Sea as we witness it today has not only been affected by the fluctuations of the global sea levels. Other factors had a major impact in forging the land and sea as we know them as much as the glacial cycles, leading to a very complex landscape (Galanidou et al, 2020). The most distinctive is the high seismic activity of the area (Papoulia 2018, Tendürüs et al., 2010) with the subsequent erosion and deposition of material, and even the potential of tsunamis (Brockmueller et al., 2017).

The research area is tectonically active, due to its proximity to the border of the Eurasian tectonic plate with the African plate (Brown et al., 2011). Various processes occur along this border (Figure 6), namely subduction, along the line of the Hellenic Arc south of Zakynthos, collision with the Adriatic microplate on the west of Corfu and Paxoi, and there is a transform fault on the west of Kefalonia (Brown et al., 2011; Papoulia 2018b; Pavlopoulos, et al., 2011, Tsakanikou, 2020). More detailed information on the tectonic activity of the area can be found in Rondoyianni (2011) and Sakellariou et al. (2018).

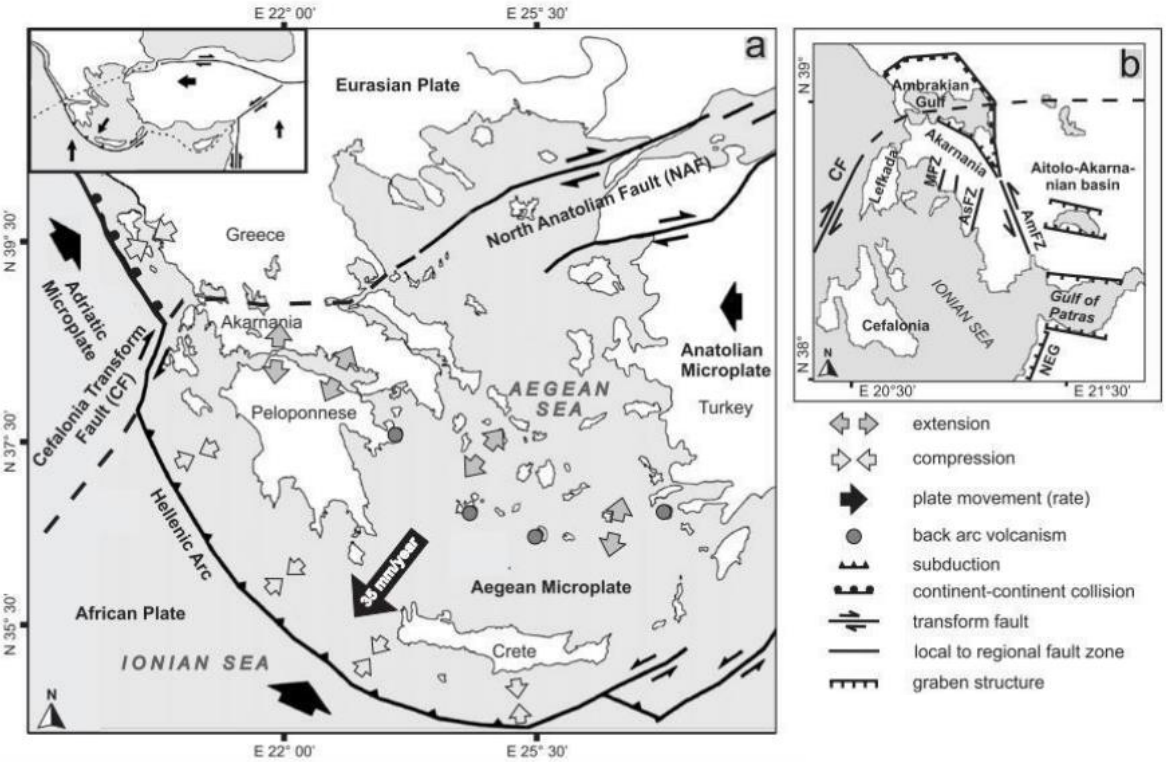

Figure 6 *Tectonism map*. Tectonic activity in the north part of the research area and Greece in general (Papoulia, 2018b).

The extensive fault lines and the subsequently frequent earthquakes, in combination with the steep landscape of the area, have led to the creation of a majorly disturbed palaeo-landscape (Magganas et al., 2019; Tendürüs et al., 2010; Waterhouse, 1996) , leaving behind very little to no in situ finds, especially from earlier time periods. As Heurtley wrote “it is literally true that not one stone has remained upon another” (Heurtley, 1935, p. 3).

2.2.5 Current landscape

The land-use of the past years can be partly traced through Corine 2018 and Lucas 2018 (see Chapter 3). Tourism has also taken its toll on the landscape during the past decades, with the tourism related infrastructure increasing exponentially as the Ionian islands became popular attractions (Souyoudzoglou-Haywood, 2008; Wijngaarden et al., 2006; Wijngaarden et al, 2009), disturbing and sealing the soils.

The research area does not include any major cities, but there are several smaller ones and many more towns and villages. The largest cities that are part of the area are Preveza on the north, Agrinio and Mesologgi in the centre and Amaliada with Pyrgos on the south. On top of these, there are the towns and capitals of the three biggest islands, namely from north to south the city of Lefkada, Argostoli which is the capital of Kefalonia, and the city of Zakynthos.

Yet, the landscape of the research area is composed mainly of coastal areas and seascapes. The rugged coastlines accompany lakes and rivers, twisting and turning their way out of the foothills of the Pindos mountain range. The natural forests have been decreased over the last decades, but there still cover various parts of the research area. Many of them are currently preserved as parts of national parks or other protected habitats by Natura 2000 (Figure 7).

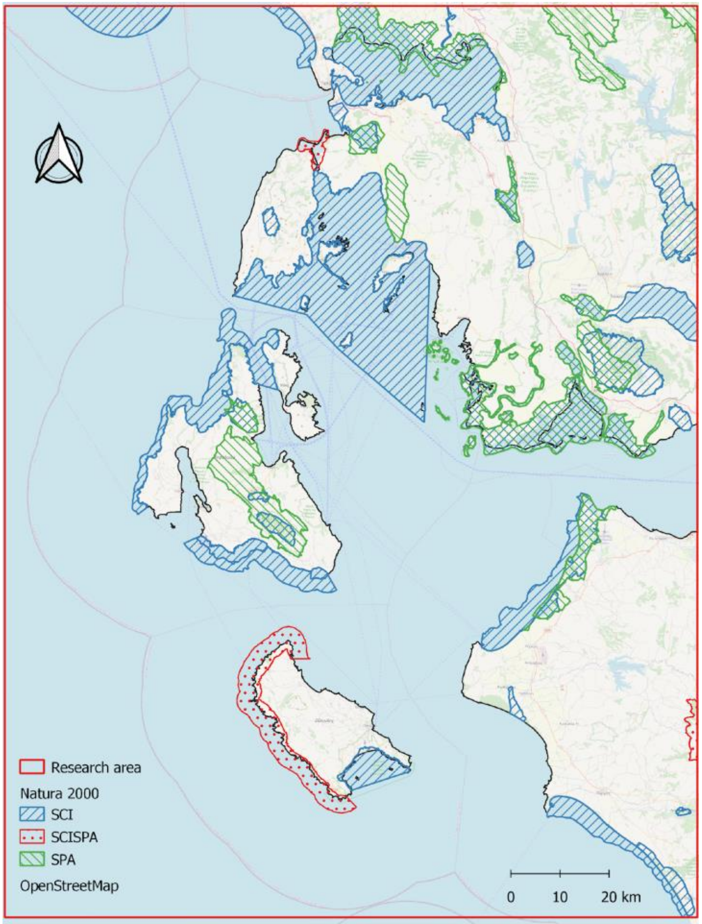

Figure 7 *Natura 2000 map*. The areas protected by Natura 2000 in the research area. (Natura 2000 - Environment - European Commission, *n.d.;* OpenStreetMap)

Natura 2000, is a Europe-wide coordinated network, aiming to protect the most valuable and endangered species and natural habitats, on both land and sea (Natura 2000, 2011*)*. Each area chosen to be under the protection of Natura 2000, receives a code describing the reason for its protection and is protected under law against certain activities. Under mandatory protection are the areas coded as SPA or SCI, meaning that they contain an endangered bird species or habitat respectively. Some areas may receive both codes (SPA/SCI). The research area has several of those areas as marked as can be seen in Figure 7. It is essential to clarify, that not all activity is banned from the areas that are under the protection of Natura 2000. Certain restrictions apply, but they do not necessarily restrict archaeological research on the region.

2.3 Archaeology and history of the landscape

Separating finds in specific time periods is often arbitrary, since different methods are applied most of the time, and the time periods do not have clear boundaries themselves, and do not present firm endings or beginnings, due to their varying nature across parts of the world. Time is a constant movement, bringing continuation and change, both intertwined in time, often hard to separate out of context. This chapter attempts to provide a chronological and spatial framework for the thesis, as discussed in the literature.

2.3.1 Time periods and dating

The time periods chosen to be studied in by this thesis, are the Palaeolithic, Mesolithic and Neolithic as can be found in Table 1. There were lots of changes during this large timespan, including changes in the climate and environment, the sea-level and landscape, hominin species, technology and eventually lifestyle, not counting changes in social and cultural behaviour which are harder to trace during these times. Due to the vastness of these periods, they will be approached broadly and according to the material record recovered in the available archaeological database (see Chapter 3.1.2). The three main archaeological periods chosen will be briefly discussed below according to the above mentioned aspects.

Table 1 *Time periods.* Approximate time boundaries for each time period under study, with the minimum and maximum time limits as found in the literature. (Table by Vezoniaraki, E.C.)

Period	Beginning	Ending	Sources
Middle Palaeolithic	130ka BP	30ka BP	Gkioni, 2008; Papoulia 2018; Galanidou, 2016; Galanidou, 2018
Upper Palaeolithic	35ka BP	10ka BP	Gkioni, 2008; Pavlopoulos et al., 2011; Ferentinos et al., 2012; Gkioni, 2013
Mesolithic	11.950 BP	8.100 BP	Galanidou, 2011; Pavlopoulos et al., 2011; Gazi, 2021
Neolithic	8950 BP	5.000 BP	Pavlopoulos et al., 2011; Avramidis et al., 2006

The Palaeolithic period is separated in three sub-periods, the Lower, Middle and Upper Palaeolithic consequently. From these time periods, according to the chosen dataset (see Chapter 3.1.2) only materials dating to the latter two are present in the chosen research area, even though Lower Palaeolithic finds occur outside the area (The Prehistoric Stones of Greece: A Resource From Field Survey, *n.d.*). Some locations inside the research area have been argued to have Lower Palaeolithic finds (Cubuk, 1976; Kourtessi-Phillipakis, 1999; Gkioni, 2008; Tourloukis, 2010; Papoulia, 2014), but since they are not included in the database, they were excluded as a separate period. In contrary, Upper Palaeolithic (Figure 8) and especially Middle Palaeolithic (Figure 9), are studied both separately and combined with broader Palaeolithic finds.

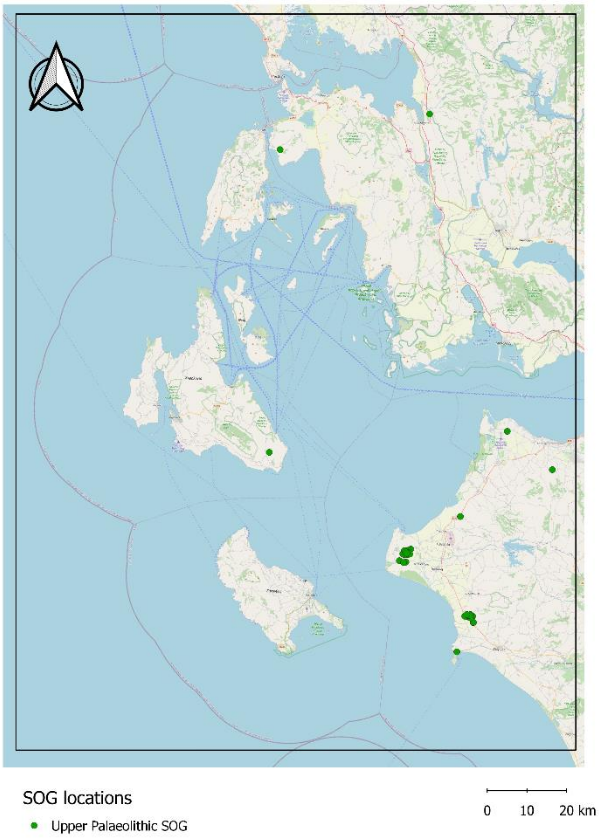

Figure 8 Upper Palaeolithic locations. (OpenStreetMap, The Prehistoric Stones of Greece: A Resource From Field Survey*, n.d.*)

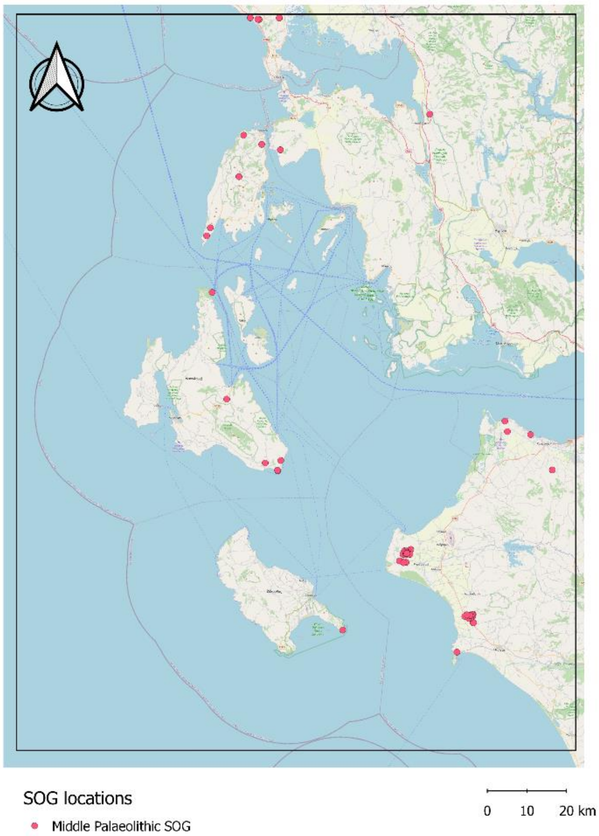

Figure 9 Middle Palaeolithic locations. (OpenStreetMap, The Prehistoric Stones of Greece: A Resource From Field Survey*, n.d.*)

The Middle Palaeolithic, is the one with the most finds out of the three sub-periods of the Palaeolithic (Papoulia, 2018a; Galanidou, 2018). It is dated roughly between 130ka BP (thousand years before present) and 30ka BP with the dates varying in each publication (Gkioni, 2008; Papoulia, 2018a; Galanidou 2016; Gkioni, 2013). The climate underwent significant changes, going through three oxygen isotope stages OIS5, OIS4, OIS3 (Gkioni, 2008) and multiple sea level changes spanning from slightly over the current sea level to -80m (OIS4) and -60m (OIS3) below the current sea level (Ferentinos et al., 2012; Gkioni, 2008; Gkioni, 2013; Papoulia, 2016). The hominins closely associated with this sub-period of the Palaeolithic are *Homo neanderthalensis*, commonly known as Neanderthals (Galanidou, 2004; Harvati et al., 2009; Papoulia, 2018a).

The transition between Middle and Upper Palaeolithic is dated around 30ka BP (Ferentinos et al., 2012), with its duration spanning between 35ka BP and 10ka BP in the literature (Gkioni, 2008; Pavlopoulos et al., 2011; Ferentinos et al., 2012; Gkioni, 2013). The Upper Palaeolithic coincides more or less with OIS2 and roughly the end of the Pleistocene, the last glacial period that ended around 11.700BP (Galanidou, 2011). During OIS2 the sea level dropped to its minimum around 18ka BP at the last glacial maximum, retreating as much as -130m below the current sea level (Ferentinos, et al., 2012; Zavitsanou 2015; Fischer et al., 2018). After that, the sea level began to rise again and continued rising, reaching as high as -25m below the current sea level (Ferentinos, et al., 2012; Yiannouli, 2017). This sub-period seems to also coincide with the first appearance of Homo sapiens, or anatomically modern humans (AMH) in the area (Gkioni, 2008). The Upper Palaeolithic has been associated with greater mobility than the Middle Palaeolithic, leading to more diverse distribution patterns of finds (Kamermans et al., 2011).

Following the Upper Palaeolithic and the transition to the Holocene, the current interglacial period, the Mesolithic has an even lower number of associated finds, while its extent has been widely discussed (Galanidou, 2011). In literature, the Mesolithic period can be found dating as early as 11.950 BP (Pavlopoulos et al., 2011) and ending latest at around 8.100BP (Gazi, 2021). The sea level kept gradually rising as the temperature rose in the Holocene, reaching approximately -10m below the current sea level during the transition to the Neolithic

(Yiannouli, 2017). The broader lack of Mesolithic finds in contrast with the previous and the following period, although partly explained by the sea level rise, is not yet fully understood (Galanidou 2003; Galanidou, 2011). Galanidou (2011, p. 230) poses the question of “whether archaeological surveys can positively identify Mesolithic period sites, be they open-air or cave sites, solely on the basis of the typology or technology of stone tools”.

Lastly, the Neolithic period is roughly dated between 8.950BP (Pavlopoulos et al., 2011) and 5.000 BP (Avramidis et al., 2006). The Neolithic itself is usually sub-divided in sub-periods, with the aceramic phase, and the late and final phases discussed separately in the literature. Here, there will be no such distinction, since the Neolithic is only briefly included in the model, due to the insufficient presence in the chosen dataset (see Chapter 3.1.2). It should be mentioned though, that the boundary between the Neolithic and the Early Bronze Age, is as hazy as the boundaries between the periods discussed, with finds often dated as Late Neolithic/ Early Bronze Age.

Precise dating is a reoccurring problem in archaeological contexts. The lithic material of the research area is no exception. The archaeological dataset is fragmented, with out of context surface finds, on soils prone to erosion and affected by the constant seismic activity. Most research projects incorporate field-walking as a primary approach, leading to an increased amount of such finds. This issue extends to the entirety of Greece regarding the lithic finds (Galanidou et al., 2022; Tourloukis, 2010). Debitage flakes found on the surface could be dated in a large time span, from the Palaeolithic to the Neolithic or even the Bronze age (Galanidou et al., 2011; Galandiou et al., 2022). Absolute dating is lacking even in more “protected” contexts and the results produced so far are adding to the complexity of the subject. Some of the absolute dating techniques that have been applied over the years to try and date Stone age finds in Greece are mentioned below.

The most common dating technique, is radiocarbon dating (^{14}C), although its application has been known to have some issues (Plekhov et al., 2021). This technique has been widely implemented in sites across the country (Stratouli et al, 1998; Galanidou, 2011) and there is a recent dataset compiling these sites in one project, called “An Aegean prehistory written in radiocarbon dates” (Katsianis et al., 2020). Another method relevant to the research area is optical stimulated luminescence (OSL), which has been applied in Zakynthos (van Wijngaarden 2008) and Thilia (Galanidou et al 2022). In the first case the sample was most likely compromised by the tectonism (G.J.M. van Wijngaarden, personal communication, October 26, 2022), in the second, the sample returned an early Holocene date, with a possibility to include either Mesolithic or aceramic Neolithic finds (Galanidou et al., 2022). In a third case in Panthera cave of Kythros islet, two samples were taken from the consolidated part of the archaeological deposits, which according to the team's working hypotheses constitutes the site's earliest component, and were dated with multi-grain OSL (N. Galanidou, personal communication, December 9, 2022), returning a late Middle Pleistocene dating around 200ka BP (Sakellariou & Galanidou, 2017). More samples are to be dated with single-grain OSL to independently confirm the previous results (Galanidou 2022 pers comm). Other methods that have been implemented in similar contexts outside the research area are Thermoluminescence (TL) in Kokkinopilos in Epirus (Tourloukis, 2010), U-series in the Apidima cave (Bartsiokas et al., 2017; Galanidou et al., 2020) and in the Kalamakia cave in the Peloponnese (Galanidou et al. 2020). OSL has also been used by the A.Sho.Re project, the results of which are under study (E. Yiannouli, personal communication, October 17, 2022). Accelerator mass spectrometry, (AMS) (Galanidou, 2011), and electron spin resonance (ESR) (Bassiakos, 1993) have also been used to date finds. In the case of Panthera cave in Kythros, a fully-fledged program of radiometric chronology is currently being undertaken for the Panthera Cave anthropogenic deposits, including AMS C14, ESR and OSL (N. Galanidou, personal communication, December 9, 2022).

Regardless, due to the nature of the majority of the lithic assemblage as described above, relative dating is still the most usual dating technique, resulting from comparisons between similar typologies and contexts in order to date located finds. This method is based on the observation that the various lithic tool industries are associated with certain sub-periods, but the subject is beyond the scope of this thesis.

2.3.2 Glacial cycles and palaeo-landscapes

There have been several reconstructions of the past landscape proposed over the years (Fischer et al 2018; Ferentinos 2012; Galanidou 2020; Wijngaarden 2013; Galanidou 2016; Brown 2011;

Papoulia 2016; Papoulia 2018b; Zavitsanou 2015), most of them based on two reconstructions proposed in the 2000s (Lambeck & Purcell, 2004; Lykousis, 2009). By studying the marine isotope levels (MIS) or oxygen isotope levels (OIS) we can get information on the glacial cycles and the sea levels of the past (Gkioni 2008; Gkioni 2013; Yiannouli 2017). Even though there are minor variations, it is proposed that the first hominins appeared in Greece around the MIS/OIS 5, between 130-75.000 BP (Gkioni, 2008). From MIS/OIS 5 until today, the sea level fluctuated between maximum -130metres below sea level (Fischer et al, 2018) and +12metres above current sea level (Gkioni, 2008), but the approximate sea level in the past was below the current sea level (Gkioni 2008; Gkioni 2013; Yiannouli 2017). According to the reconstructions Kefalonia and Ithaki were connected to each other and to Zakynthos, but separated from the mainland during the Palaeolithic period (van Wijngaarden et al, 2013; Papoulia, 2016) and the last glacial maximum at around 18.000BP (Zavitsanou et al 2015). Atokos' and Arkoudi's insularity has also been under discussion (Zavitsanou et al 2015; Galanidou 2022), and there are strong indications that Atokos was an island ever since MIS7 (Galanidou et al., 2013) . Therefore, it has been proposed that sea-crossings can be proved through the presence of Palaeolithic finds on these islands, (Fischer et al, 2018; Papoulia 2017; Papoulia 2018a; Papoulia 2018b; Galanidou 2018), and most likely by the Neanderthals (Ferentinos et al., 2012; Papoulia 2014; Papoulia, 2017; Papoulia 2018a).

As established, the glacial cycles have caused significant fluctuations in the sea level, but past landscapes have not simply been submerged. In the case of Zakynthos and Kefalonia, it has been proposed that part of the present-day land has been submerged in the past. The same seems to have happened in the case of the mainland, both in the Peloponnese and in parts of Sterea Ellada. As the surface geologic units age map from EGDI shows, several areas are covered with Holocene materials (figure of lithology ages). In the case of the two islands, researchers support that parts of the islands where once separated in the past (van Wijngaarden et al., 2013; Avramidis et al., 2017; Brown et al., 2011).

In the case of Zakynthos, the Vasilikos peninsula was separated by sea from the rest of the island before 6.000BP, and the present-day valley of Zakynthos gradually turned from sea to lakes and then the valley visible today (van Wijngaarden et al., 2013; Avramidis et al., 2017). In the island of Zakynthos, Keri Lake, also known as "Herodotus springs" in antiquity, was also influenced by the sea up until 4000BP, when peat started accumulating and the influence of the sea ceased (Avramidis et al., 2016).

A similar suggestion has been made for Paliki peninsula in Kefalonia as early as 1903 and supported by various researchers over the years (Brown et al., 2011). Gaki-Papanastasiou et al. (in Brown et al., 2011) has argued against this hypothesis, but it has recently gained more support (Spyrou et al., 2022) with a new project dedicated to discovering Homer's Ithaki in the Paliki peninsula, called "Odysseus unbound" (Rush, 2022).

2.3.3 Suggested routes and archaeology of the area

Based on the reconstructions of past sea levels, there have been some potential routes suggested that could have been followed by past hominins to cross the Ionian sea and reach the islands from the mainland. Ferentinos et al. (2012) include suggestions for when the sea level was -120m and -80m from the current sea level, at 180ka and 60ka BP respectively. Both reconstructions suggest the use of smaller islands as stepping stones in order to reach the bigger islands at the time. According to them, Kefalonia was reached through Arkoudi, Atokos and then Ithaki or directly from Lefkada, while Zakynthos was reached either from Kefalonia or through a currently submerged island between Zakynthos and the Peloponnese. These routes have been supported by further researchers (Zavitsanou et al. 2015; Papoulia, 2017; Papoulia 2018b).

Studying the finds' locations as retrieved from the SOG database, it seems like similar areas were popular across all time periods under investigation, which could potentially be related to a research bias. It is still clearly visible that locations where Palaeolithic finds have been retrieved arithmetically greatly exceed locations with Mesolithic and Neolithic finds. Many of them have been found in close approximation to roads in north Sterea Ellada, as recorded in a survey conducted by Higgs between 1962-1967. Mesolithic finds have also only been recovered in locations where Palaeolithic finds have also been found. Neolithic finds diverge more in terms of location from the previous two periods, with only two locations in Sterea Ellada and Epirus, and more in Kefalonia and the Peloponnese, often in locations relatively close to each other, especially in the area of Poros.

2.4 State of research

As mentioned before the Stone Age in the Ionian islands and western Greece was mostly unknown before the 1960s, when the first systematic projects began (Adam, 2007; Papoulia, 2018b). Most archaeological projects in the area aimed at locating the palace of Odysseus, legendary king and hero of Homer's epic poem Odyssey (Heurtley, 1935; Heurtely 1939-40; Waterhouse, 1996; 1952). There have been some chance finds, but it was only after Eric Higgs' team in 1962 work in Epirus when the broader region and time periods came to the spotlight of archaeological research for the first time (Papoulia, 2018b). Eric Higgs' association of "terra rosa" soils with Middle Palaeolithic finds (Higgs, 1964; Higgs & Vita-Finzi, 1996), has especially boosted later research projects and navigated them towards researching such areas with red soils (Papoulia, 2018b). After Higgs the area was target by several projects, mostly focusing on the Epirus like the Thesprotia expedition project (Thesprotia Expedition. 2016) but also on the Ionian islands (Sordinas, 1969; Randsborg, 2002; Koourtessi-Phillipakis, 1994).

In the past two decades, there have been a number of systematic projects investigating the area, some of them still ongoing and some are in their final phase of publication. Three of them are described in more detailed below, since their research goals coincide with the aims of this research. These are the Zakynthos Archaeology Project (Z.A.P.), the Archaeological Shorelines Research Project (A.Sho.Re.) and the Inner Ionian Sea Archipelago Project (I.I.S.A.P.).

2.4.1 Z.A.P.

The Zakynthos archaeology project (Z.A.P.) began in 2005, under the direction of professor Dr. G.J.M. van Wijngaarden from the University of Amsterdam, and C. Merkouri from the Greek Ephorate of Antiquities of Zakynthos. The project's goal was to explore and understand the archaeology of the island of Zakynthos and to relate the distribution of finds with the dynamic landscape of the island (Universiteit van Amsterdam, 2020). The project followed an interdisciplinary approach and applied a variety of methods, most of them non-invasive, to the chosen research areas. The research areas were chosen based on their geology, as they combined different types of landscapes.

Originally there were three areas to be researched, named A around Keri lake, B around Machairado (van Wijngaarden, 2006; van Wijngaarden et al., 2013) and C at Vasilikos peninsula respectively, and a fourth one which was added while the project was still conducting fieldwork at Skoulikado-Kalimachos (Figure 10). Since 2018, the project has concluded the fieldwork phase and is in its final publication phase, while there are already available the summaries of each fieldwork season and a plethora of open-access publications in peer-reviewed academic journals. Dr. Wijngaarden also kindly shared with me material (personal communication, October 26, 2022), information, and the location of some of the sites added in the model (Table 2).

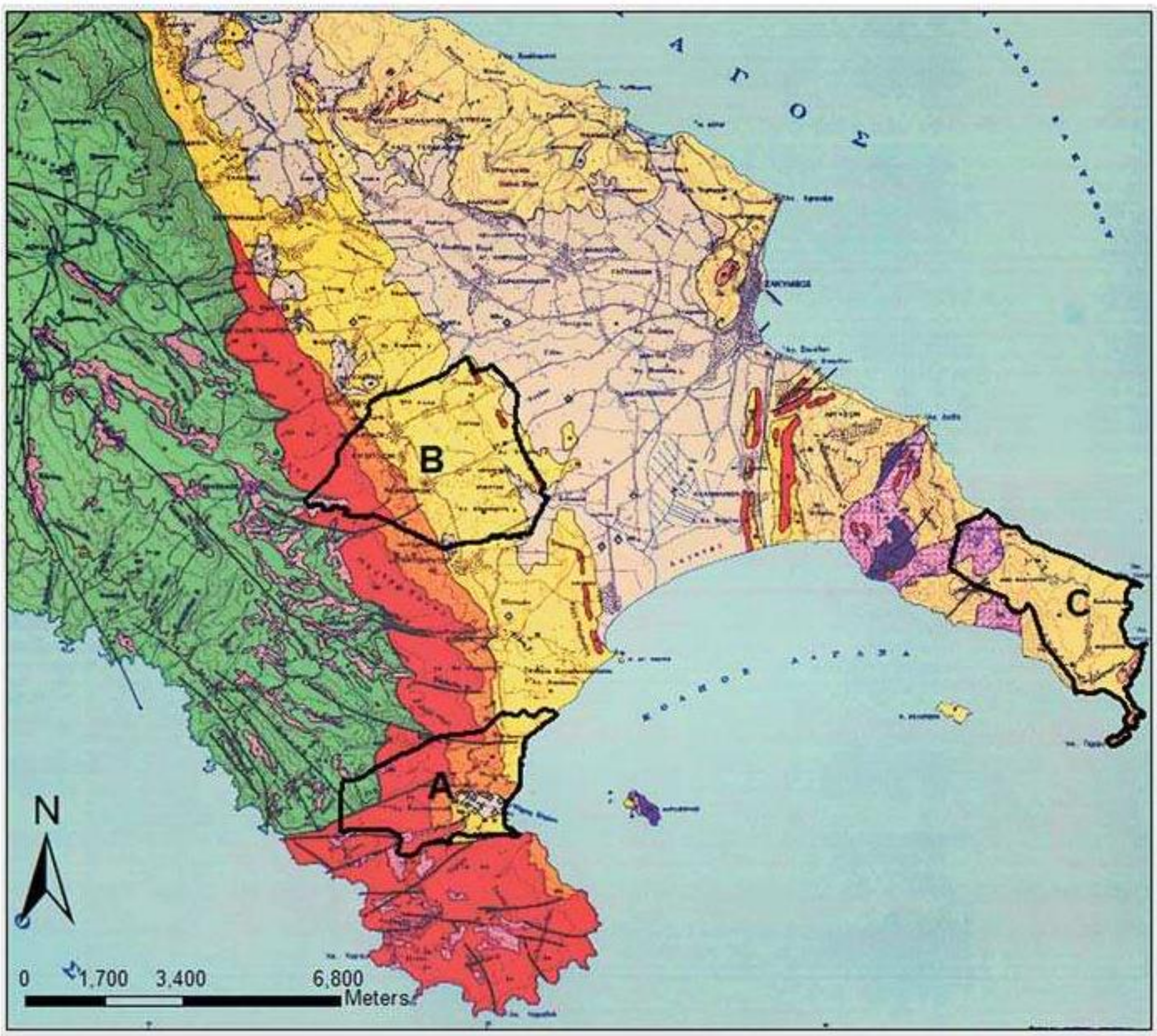

Figure 10 *Main areas research by Z.A.P.* (van Wijngaarden et al., 2013)

2.4.2 A.Sho.Re

Since 2011 the multi-disciplinary project archaeological shoreline research also known as A.Sho.Re (University of the Peloponnese, 2022) has been studying the south-eastern coasts of Kefalonia, from Pahia Punda until Lurdata, tracing the coastal zone for about 50Km (Yiannouli, 2016) (Figure 11). The project is directed by Dr. E. Yiannouli and is under the auspices of the University of Peloponnese. Its character is dual, being both education- and research-oriented. The project had two phases, one during 2011-2015, which studied the geo-archaeology of the project's research area, while extensively and systematically studying the present archaeology through field walking. The second phase began in 2017 and continues until the present-day, with more publications to follow. During this second phase, the same area was revisited, but this time targeted areas were excavated.

Figure 11 *Map of Kefalonia and Ithaki.* The shoreline studied by A.Sho.Re. is highlighted with white. (Yiannouli, 2016)

The project's goals coincide with the goals of the present thesis, in terms of exploring the archaeology of coastal areas with a focus on prehistory, both above and below the current sea level (Yiannouli, 2014; 2016). Most Stone age finds documented by the project are surface finds, but some finds are considered in-situ, supported by excavations as well as other observations (E. Yiannouli, personal communication, October 17, 2022). All in all, the project's finds attest to hominin activity on the present-day island of Kefalonia, potentially pertaining to different phases of the Palaeolithic (Yiannouli, 2016, p.182).

2.4.3 I.I.S.A.P. and Panthera Cave excavation

The islands of the Inner Ionian Sea Archipelago have been explored through two main research projects organised by the University of Crete under the scientific supervision of professor Dr. N. Galanidou. The first project called "Inner Ionian Sea Archipelago survey" took place between 2010 and 2014 (University of Crete, 2019a). It was an interdisciplinary research programme, investigating the archaeology of the smaller and larger islands through systematic field walking, combining archaeology with geology, social anthropology and ethnoarchaeology. In total the following ten islands were investigated: Alafonisi, Atokos, Arkoudi, Kythros, Meganisi, Petalou, Skorpidi, Sparti, Thilia and Tsokari. The project brought to light, among other, an impressive amount of lithic finds dating as early as the Middle Palaeolithic (N. Galanidou, personal communication, December 9, 2022).

This project was followed by a systematic excavation project in Panthera cave on the islet of Kythros which was discovered during the first project, organised by the University of Crete (University of Crete, 2019b). This project began in 2015 and it is currently still ongoing. The cave was sealed when its roof collapsed, retaining the finds in situ. The majority of the lithic artefacts retrieved from the inside of the cave are dated in the Middle Palaeolithic, with a smaller amount dated in the Upper Palaeolithic (N. Galanidou, personal communication, December 9, 2022). Along with the lithic finds there is a large amount of faunal remains retrieved, showcasing a rich biodiversity (Sovraintendenza Roma, 2022).

Besides these projects, the SOG database includes the finds of some more relevant projects, information on which can be found on the database's website (Elefanti, et al., 2015).

All in all, the research area currently consists of both islands and mainland, in a highly diverse landscape, combining high elevations with valleys, extensive coastal areas, non-saline features and low bathymetric levels. In terms of its geology, it consists primarily of limestone rich in chert nodules, providing the people of the past with good quality raw material sources. Tectonically, the area is highly active, but there are no volcanoes present. Currently, a significant proportion of the research area is under a certain degree of protection for its natural habitat, varying from strictly protected areas to national parks, while there has been a rapid increase in structures and infrastructure. The dates assigned for the periods under study in this thesis are also varying in the literature, due to the new finds coming to light and the controversial finds that cannot be securely dated within a narrow time frame. Even though archaeological projects have been going on in the area for a long time, the progress was relatively limited, up until the past two decades when the area became the focus of new research projects, many of them still ongoing.

3. Materials

In this chapter the datasets used in the creation of the predictive model are listed and analysed. Their level of openness is discussed. Each dataset and source was used for different reasons and to a different extent. There is a description on the used aspects of each source, which is continued in more details in the following Chapter 4. Lastly, the limitations of the available literary and archaeological sources are discussed as well, as it will be analysed in more detail in Chapter 6.

3.1 Datasets and openness of resources

One of the goals of this project is to be transparent on the process of the creation of the predictive model, and to stimulate further research regarding the creation of similar models through GIS. Therefore, the databases used will be presented below, both as the foundations upon which the model was constructed and as a guide for future researchers with similar goals. The openness of the resources used, will be judged according to the open definition (Pollock, 2015) and open data handbook (Dietrich et al., n.d.). The various degrees of openness of open data, can be examined through their Creative Commons (CC) licenses, explaining the terms under which they are provided (Figure 12).

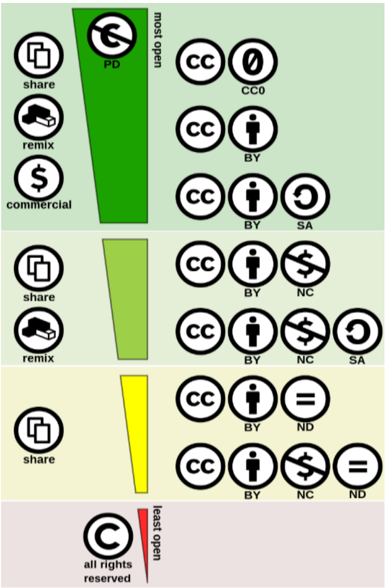

Figure 12 Creative Commons licences. (*Creative Commons License*, n.d.)

3.1.1 QGIS

In order to create the predictive model, the software QGIS was chosen and specifically the long-term release 3.22, version 9 (QGIS Community, 2022). QGIS is a free and open source software (FOSS) for desktop geographical information system applications. It is supported by many different operating systems, such as Windows, Linux, Mac and Android. The programme is driven by volunteers and frequently releases new versions. QGIS along with its commercial counterpart ArcGIS (*ArcGIS Online*, n.d.), are the leading software in creating, mapping and manipulating and spatial data. QGIS seemed the obvious choice for the present thesis which aims at being as open and accessible as possible.

3.1.2 The prehistoric stones of Greece: A resource from field survey

An archaeological predictive model would be nothing without archaeology related to the chosen case study. Even though such sets of find locations accompanied by geographically precise information are scarce, there is a database, created in 2015, collecting a large number of archaeological sites present at that point, and accumulating them in one project, which can be accessed through the Archaeology data service (ADS) repository (Richards et al., n.d.). The project is called "The prehistoric stones of Greece: A resource from field survey" (Elefanti et al., 2016), and allows the user to browse through the collected material, through various queries, such as time period, location, name of survey or type of finds. In contrast with the name of the project, the database includes more kinds of finds beside lithics, included but not limited to pottery finds, textiles, metal and many more. The queries can then be visualised on a map or downloaded in .csv files, including the toponym of each location, its id in the database, and its coordinates in decimal degrees.

The SOG database does not claim to include all finds related to the periods under study. It makes it clear in the site coverage description that there are some locations, especially with Neolithic finds, that are not part of the available datasets. One major example is the exclusion of Neolithic finds not found through field survey. Furthermore, finds that could not be securely given a set of coordinates, due to them not being located securely on the ground, were excluded, and the located surface scatters were not given a chronological division.

As part of this thesis, the extracted datasets were chosen by combining relevant chronologies with relevant regions. The chronologies queried were the following: Palaeolithic, Lower Palaeolithic, Middle Palaeolithic, Upper Palaeolithic, Mesolithic and Neolithic. These were matched one by one with the following regions: Epirus, Ionian islands, Peloponnese and Sterea Ellada. After retrieving the datasets and importing them in QGIS, they were merged by dating and clipped according to the research area.

The database, from now on referred to as SOG, is copyrighted and licensed under the ADS terms of use and access (Richards et al., n.d.). According to the terms of use and access of ADS, the material can be used, adapted and shared, as long as the creators of the dataset and related publications are acknowledged, and any alterations of the dataset are publicly distributed in a non-commercial way. Therefore, in terms of its degree of openness, the dataset is open, having a limitation in non-commercial use.

Even though exceedingly useful for this thesis, the SOG database is not up-to-date. The database was created in 2015, and shows no evidence of finds being added since, leading to many prominent finds' locations being absent. Another downside of the database was that not all locations had the same amount of information, leading to many locations disappearing the more factors you added in the query, even when the factors added were very broad like "surface collection" or "open" type of site. Furthermore, the datasets retrieved did not include more than the name and the coordinates of the locations, leaving out all other information mentioned in the database on the amount and type of finds retrieved in each location mentioned. This information is not available for all locations, and in order to study those in more detail, they would have to be manually added separately for each point for which they exist.

3.1.3 Additional locations

Beside the find locations' found in SOG, some more locations were manually added by the author. SOG was created in 2015, and as mentioned before, there are many currently ongoing projects on the research area, frequently adding new locations on the map of Greek prehistory. These locations can be found mentioned in the literature, usually with their regional toponyms and without being accompanied by coordinates. Still, it would be a tremendous loss of information if they were entirely excluded. Moreover, some older finds were also not mentioned, probably lost in the abundance of literary sources.

In order to create a broader overview of reported finds relevant to this project, a series of 27 locations (Figure 13) were added manually through the literature and other sources (The Archaeological Cadastre (n.d.). A table was created, including only the most basic information (Table 2), and their approximate location was digitized by following the, in some cases, almost treasure map-like descriptions found in the literature.

In detail, the research area was separated in six broad categories, one for each of the four major islands (Lefkada, Ithaki, Kefalonia, Zakynthos), with Lefkada including the islands of IISA, and two more for the mainland, separated in Epirus with Aetoloakarnania and the Peloponnese. When the locations mentioned in the literature were covered by the datasets of SOG they were naturally not added again. An approximate number of four to five publications were browsed for each of these areas, some containing many and some no amount of new locations. As can be discerned (Figure 13) no new locations were added in NW Peloponnese, in contrary to the islands of IISA and Ithaki which were entirely excluded in the original database. The dating of the new locations had to be cross-referenced with more literary sources, which led to some locations having more than one source.

Originally, the periods used when collecting information on their sites were only Palaeolithic, Mesolithic and Neolithic, but the dataset was then expanded to include Middle and Upper Palaeolithic when it was fairly clearly dated in one of them in the literature where it was found. At first, the table also included the number of finds, but the category was later removed since the number of associated finds was in many cases not available (Table 2). These locations were then split according to their date in order to be used in addition to the layers retrieved from SOG.

In the case of newly added sites dated in Palaeolithic, Middle Palaeolithic or Upper Palaeolithic, the following steps were taken when separating them according to their dating. When a location had been characterized as only one of the three categories in the literature, it was placed in only the specified layer based on the source where it was mentioned, even though technically both Middle and Upper Palaeolithic finds are also Palaeolithic. If it had both the characterization as a Palaeolithic and one of its sub-periods, it was placed in both sub-sequent maps (Figure 13).

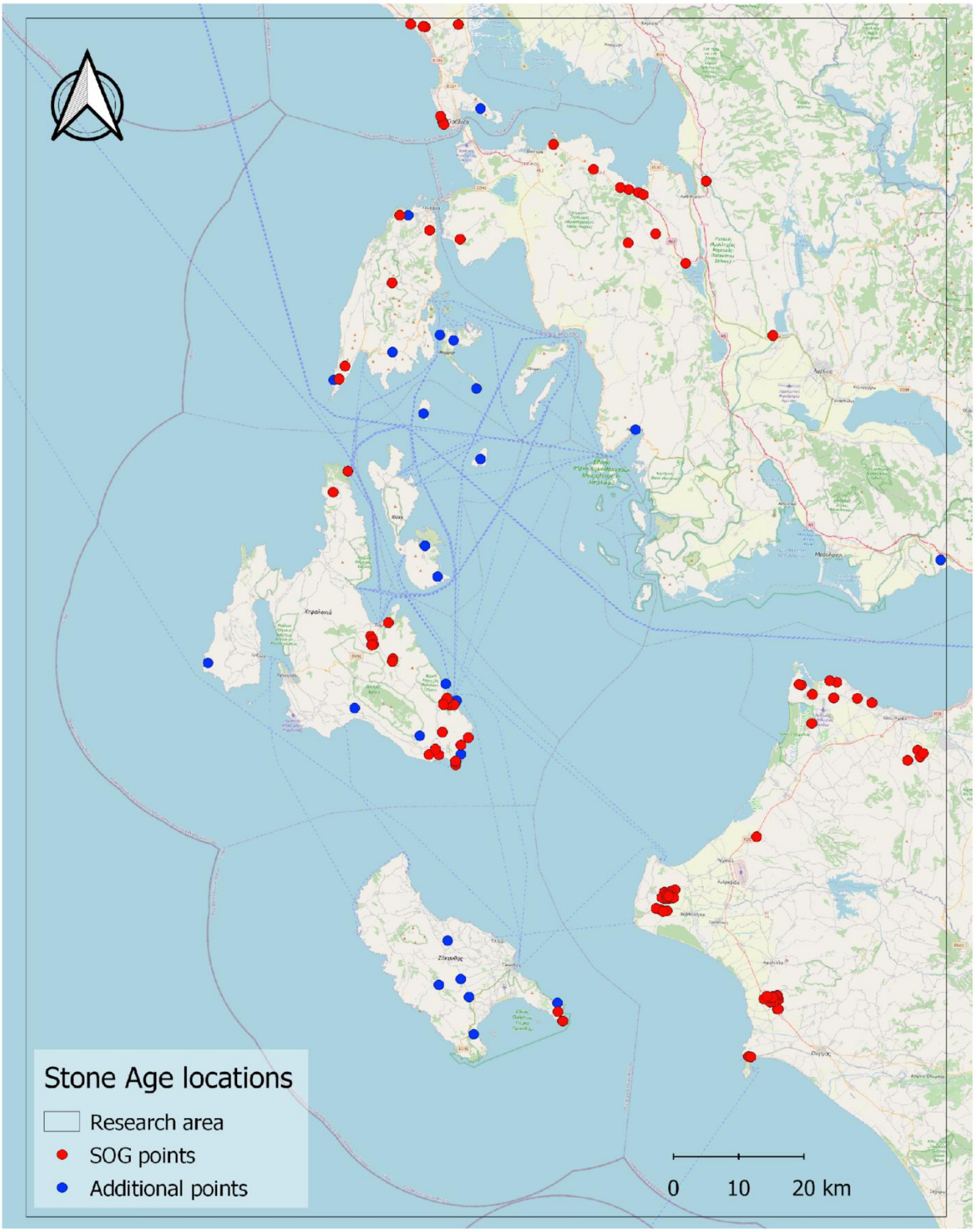

Figure 13 *Stone Age locations.* The locations of all finds' recorded manually and retrieved from SOG. Two of the additional locations in the area of Poros are clear only when zoomed in. (Figure by Vezoniaraki, E.C., sources: Elefanti et al. 2015; OpenStreetMap; and more (Table 2))

Table 2 *Additional locations.* The locations were added approximately according to their source's description. (Table by Vezoniaraki, E.C.)

Area	Site	PL	MPL	UPL	ML	NL	Sources
APA	Ayios Thomas	Y	-	-	-	-	Tourloukis, 2010; Runnels, & van Andel, 2003
	Astakos bay	-	-	-	-	Y	Benton, 1947
	Pangali	-	-	-	-	Y	Mavridis & Sørensen, 2006
ITH	Marathia	-	-	Y	Y	-	Livitsanis 2013
	Vathy	-	-	-	-	Y	Livitsanis 2013
KEF	Palliki peninsula	n/a	-	Y	-	-	Ferentinos et al, 2012
	Atros coast	Y	-	-	Y	Y	Yiannouli 2016
	Mousata	-	-	-	-	Y	Sotiriou, 2013
	Sarakinato	Y	-	-	Y	Y	Yiannouli, 2016
	Poros harbour	-	-	-	-	Y	Yiannouli, 2017
	Poros	-	-	-	-	Y	Yiannouli, 2016
	Agrinia	-	-	-	-	Y	Sotiriou, 2013
	Skala	Y	-	-	-	Y	Randsborg, 2002
LEF	Hoirotripa cave	n/a	Y	-	-	-	Galanidou, et al, 2016
	Marantohori	n/a	Y	-	-	-	Galanidou et al, 2016
	Nira	n/a	Y	-	-	-	*Navigate in Map | Archaeological Cadastre*, n.d.
	Thilia islet	-	-	-	Y	Y	Galanidou, 2018
	Meganisi island	Y	Y	Y	Y	Y	Galanidou, 2018
	Kithros islet	Y	Y	Y	-	Y	Galanidou, 2018
	Arkoudi island	Y	Y	Y	Y	Y	Galanidou, 2018
	Atokos island	Y	Y	Y	Y	Y	Galanidou, 2018
ZAK	Skoulikado-Kalimahos	Y	Y	-	Y	Y	van Wijngaarden, 2017
	Mahairado-Palaiokastro	Y	Y	-	-	-	van Wijngaarden, 2013
	Mouzaki-Brouma	Y	Y	-	-	Y	Papoulia 2016; van Wijngaarden et al. 2008, 2013
	Achiouri valley	Y	-	-	-	-	van Wijngaarden 2013
	Ayios Nikolaos	Y	Y	-	-	-	Papoulia 2016; Kourtessi-Philipakis 1999
	Keri Lake *	Y	-	Y	-	Y	Avramidis et al., 2016; van Wijngaarden 2013

Note: The "n/a" is for finds dated in part of the Palaeolithic. APA: Aitoloakarnania, Preveza and Arta, ITH: Ithaki, KEF: Kefalonia, LEF: Lefkada and IISA, ZAK: Zakynthos, Y: 'yes', meaning presence of finds.

*The Palaeolithic finds were found by Keri Lake in Perlakia.

Out of these 25 locations mentioned above, two were characterised as locations with Lower Palaeolithic finds in the literature. The first example is Ayios Thomas in Prevaza (Papoulia 2016/ Kourtessi-Phillipaki 1999) and the second is Ayios Thomas in Zakynthos (Tourloukis, Runnels and van Andel 2003).

3.1.4 Copernicus land monitoring service and related projects

Copernicus land monitoring service (Copernicus Land Monitoring Service, n.d.) along with Ypen portal maps (see Chapter 3.1.5) were the cores from which most of the layers used were derived. It is a European service, providing free-of-charge map and imagery datasets on global, pan-European and local level, with easily accessible and rich metadata. The maps can be viewed and explored along with their layers and legends on their website. After creating a free account, the majority of datasets are easy to download in raster, vector or both types of layers.

Some of the maps considered are listed here. The CORINE Land Cover 2018 map (CLC 2018), contains spatial information on the land use during the designated year. Also, the imperviousness map, which translates to the percentage of natural landscape sealed by artificial constructions, and the layers related to Natura 2000.

Additionally, Copernicus includes layers with information on forests, settlement density, urban areas, riparian and coastal zones. An interesting feature, not available for downloading but useful as a reference, was the imagery provided by the Lucas 2018 project, showing types of land cover types carried out by an in-situ survey (LUCAS*,* n.d.). The EU-DEM v1.1 (digital elevation model) was downloaded and explored in combination with the elevation maps provided by YPEN (see Chapter 3.1.5). Lastly, the EU-hydro river network database, proved to be the most useful. It mapped rivers, canals, ditches, inland water basins, river deltas and even small streams. All water features mapped and relevant for this thesis, were found under the umbrella query “Pinios”.

Copernicus is also very open in terms of accessibility and reproducibility. Each dataset includes terms of use along with the rest of the related metadata, so any additional constraint in the future can be found there. The broader terms and conditions of use can be found on their website under "privacy policy and terms of use". The database can be used by anyone, and for any purpose, as long as the credits are given to the European Union. Also, all modifications made by the users have to be made clear to the audience, and the derived products become intellectual property of the user. Finally, the user is obligated to make clear that the derived products are not officially endorsed by the European Union.

3.1.5 YPEN portal maps

The maps provide by the digital gate of Geospatial information of the Greek Ministry of Environment and Energy (Υπουργείο Περιβάλλονοτς και Ενέργειας-ΥΠΕΝ, here YPEN), were the mostly used maps along with the ones by Copernicus and EMODnet (see Chapter 3.1.6). To a large extent, the maps found in the YPEN website (ΥΠΕΝ - Γεωχωρικές Πληροφορίες & Χάρτες, n.d.) were derived from the maps provided by Copernicus, often modified and combined to highlight certain aspects. The reason why the modified versions were in some cases preferred, was that they had a consistent format, which made layering and comparing them easier (Appendix 8). Many of them were separated in specific polygons, accompanied by many different values, each value revealing a different aspect of the landscape, like elevation, land use, slope, erosion and many more. Due to the fact that the data were products derived from Copernicus, they were always used and compared with their source, in order to evaluate their accuracy. Another advantage of YPEN over Copernicus, is that all maps were location specific, only including Greece, and as a result they were often much smaller in size than their counterparts in Copernicus. A major disadvantage for non-Greek speaking users, is that the entirety of the website and provided layers are only available in Greek.

All products of YPEN could be loaded in QGIS through WMS/WMTS, WCS or WFS/OGC API features services, by connecting with the relevant mapsportal connection. Here the vector layers found in the latter were used, by connecting through their WFS service, since they were easier to use and manipulate in the creation of the predictive model.

The maps acquired by YPEN were elevation and bathymetric zones and points, maps including the location of different kinds of quarries, roads, urban and industrial areas, ports and airports, derived from the Corine land-use 2018 map. In addition to these, layers including information on the vegetation density and type, national parks with different levels of protections and population density maps were considered. Just like in the case of Copernicus, the Natura 2000 locations' map, although available, it was not implemented through this website either.

In terms of openness, YPEN aims for the wider distribution of maps and geospatial information, so it is created with free open source software (FOSS), on the open source geospatial management system GeoNode, and stored in a Greek government cloud (G-Cloud). The licence used is CC-BY-ND, which allows all kinds of remixes, adaptation and distribution as long as the creator receives due credit and the material created is used under the same terms. The metadata of each map can be accessed and downloaded.

3.1.6 EMODnet: Bathymetry and Geology

The European Marine Observation and Data network (EMODnet) provides public and private users with assembled marine data and metadata from various organisations and partners (European Marine Observation and Data Network (EMODnet), 2022). The data collected are separated into seven discipline-based themes, like bathymetry, geology and human activities. This thesis explored the datasets available on the bathymetry (Bathymetry, 2022) and the geology (Geology, 2022) services and portals. All datasets can be easily acquired after the creation of a free account.

The bathymetry service is a bit more straight-forward to use, since it only includes information on the bathymetric levels of the area of interest. The datasets can be downloaded in various forms. Just like in the case of Copernicus, the layers acquired were used alongside the vector layers of YPEN in this project.

On the other hand, the geology service includes much more information regarding the coastlines and the seafloor. Through it a number of layers were acquired, regarding the types and migration of coasts, submerged landscapes and submerged or coastal springs and even a proposed palaeo-coastline. Another very useful map found through EMODnet geology and implemented on the model was the landslide susceptibility raster layer (see Chapter 4), showing the areas underwater that are more prone to landslides.

EMODnet is open source as well, with very accessible metadata and an open terms of use policy, requiring only the credits to be given to the creators, and aiming at an interoperable use free of restrictions (European Marine Observation and Data Network (EMODnet), 2022).

3.1.7 Natura 2000

Natura 2000 is a network of 27 European (EU) countries, aiming at protecting and preserving endangered species and natural habitats (Natura 2000, n.d.). The research area under study in this thesis, has various parts under the protection of the Natura 2000 network as was established when exploring the Copernicus and YPEN databases. The datasets relating to the areas protected and the reason behind their protection can be found through the European environment agency. The datasets relevant to the current project were retrieved from the central data repository of the European environment information and observation network (EIONET), after querying “Greece”. The dataset here was licensed as CC-BY, making it freely available and open to any use, as long as the appropriate credits are again attributed to the creators.

3.1.8 OpenStreetMap

As a base map and reference in the creation of the model, a layer from OpenStreetMap was chosen (*OpenStreetMap*, n.d.). The layer can be easily implemented in QGIS, connected through XYZ Tiles. OpenStreetMaps were preferred over commercial maps like Google maps, as it is free and open, based on a community of contributors. It is again very open, licenced under CC-BY-SA 2.0, meaning that all kinds of sharing and adaptation is possible, as long as the appropriate credit is attributed and the derived products are shared under the same licence.

3.1.9 EGDI

Geological information on the land of the research area where harder to acquire in the form of a free, open digital map. After a longer search, the maps provided by E-Government Development Index (EGDI), were the ones chosen and added in the model through a WMS/WMTS connection. The map chosen was the EGDI 1:1.000.000 pan-European Surface Geology, showing the main type of lithology across Europe (EGDI, n.d.), from the basic geology section. The map layer used has no restrictions in terms of access and use, besides acknowledging the provider.

3.1.10 More sources

In addition to the sources mentioned above, Corona atlas and referencing system (Corona, n.d.) and Google Earth (Google Earth, n.d.) were used, supplementing the maps described previously with satellite images from different platforms and sensors, in order to cross-reference information from multiple sources, when digitizing features and making choices. The first is freely available to the public, restricting only commercial use and the second is a commercial product of Google, requiring proper attribution of credits and non-commercial use, and the use of a different Google platform in certain cases.

Two soil maps could be recovered through the European Soil Data Centre (ESDAC), but none were already in a format easy to import in GIS (Soil Atlas of Europe, n.d.). As mentioned before, the reason for studying the soil map was to evaluate the relation of Palaeolithic finds with red soils (terra rossa). Since neither of the found soil maps included information on the location of terra rossa soils, they were eventually not considered in the process of building the predictive model.

Besides the sources mentioned above, many more were explored and considered, which were in the end not used and therefore will not be referred to in detail. These are listed here: Google maps, Institute of Geodynamics (GEIN), Hellenic Centre of Marine Research (HCMR) and Hellenic Nave Hydrographic Service (HNHS) which are both partners of EMODnet, Hellenic Mapping and Cadastral Organisation (HMCO) and the related Hellenic National Oceanographic Data Centre (HNODC), National Archive of Monuments, Institute of Geology and Marine

Exploration (IGME) which offers digital maps for sale (Zervakou et al. 2008), SeaDataNet, Eurogeographics, and more. Finally, another database with open data and maps that deserves a special mention is Geodata (GEODATA, n.d.), available in both Greek and English.

3.2 Limitations of available resources

There were a few limitations when searching for open sources to use in the creation of the model. One of them was the availability of high spatial resolution maps on the research area. Even though the aim of this project was to step back and examine the bigger picture, the alternative was not possible based on the material available, so a relatively wide area was a requirement. In depth analysis was limited to smaller parts of the area, where related surveys have been more intensive. Most of the maps used were either focused on a national or even a European level.

As mentioned previously and as it is often the case in archaeology, due to the ongoing projects and the recent increase of interest in the research area, not everything recovered is published yet and available to the public. This limits both location of archaeological sites, but also the relevant literature. Some of the directors of these ongoing projects kindly discussed their projects and newer finds with me, but since much of it still awaits publication, it is therefore not included in this thesis.

Similarly, certain finds' locations found in literary sources, are very vaguely mentioned and as such, very hard to locate on a map. Most of them use local toponyms, known and used by the residents of the area, not mentioned in any publicly available map, or are described with approximate distances towards a general direction from commonly known settlements. This is to be expected, since cases of looting are common in the field of archaeology. It is still a limitation that needs to be mentioned, considering some of the points added in the dataset were based on such vague descriptions.

Lastly, language was also a limitation that deserves a special mention. Even though a large percentage of the literature and websites could be found in English, some could be only found in Greek. Being in English is not a requirement of Open Science, but it still assists with the communication of data on an international framework, and the open accessibility. Overall, the amount of information and datasets that can be found in English, is very high, balancing between reaching out to the wider international public and being more approachable to the Greek public.

4. Methodology

In this chapter predictive modelling in archaeology as a method is introduced and its evolution is briefly described, along with some of the controversies it has faced. Afterwards, the choices made for the creation of the model built in this thesis are discussed, along with the reasons behind each choice. Following the step-by-step presentation of the process of building the predictive model, comes the analysis of the testing method chosen and its results.

4.1 Predictive modelling

Predictive modelling as a method has been the subject of many debates among the research community (see Chapter 4.1.2). Still there are many cases in which archaeological predictive modelling is systematically implemented in a plethora of ways, constantly evolving. This part is dedicated to the history and various applications of predictive modelling in archaeology, including its main benefits and risks.

4.1.1 A brief history of the method

Predictive modelling originally had a different, less digital, form than it has today. In many ways, processual archaeology and the correlation between archaeology distribution patterns and environmental factors, was the origins of predictive modelling. Archaeological predictive modelling first appeared in the 1970s, with approaches like “site catchment analysis” (Vita-Finzi & Higgs, 1970), and the publication of “Archaeological survey of the Narrows unit project Morgan and Weld counties northeastern Colorado” (Morris et al., 1975). The materials used were statistics and analogue maps, and was aiming at correlating known sites with their physical landscape. One year later, in 1976, Jochim published his analysis on site location, this time aiming on evaluating the ecological factors upon which hunters and gatherers would have been dependent on (Jochim, 1976). The first digital predictive models, implementing GIS methods, appeared about a decade after the first project, in 1988 (Judge et al., 1988; Kvamme, 2006). There, Judge (1988) discusses predictive modelling, its limitations, critiques and the different ways through which it can be implemented, namely the deductive and the inductive approaches.

4.1.2 Predictive modelling in practice

4.1.2.1 Dichotomy

Inductive, correlative or data driven modelling, as its many names suggest, uses the spatial distribution of known sites and their observed correlation with selected environmental parameters to build a predictive model (Verhagen, 2007a). This method has been the most heavily critiqued, among others for not providing a satisfactory explanatory framework (Verhagen 2007b; Kamermans 2009; Verhagen & Whitley, 2012), for being theoretically (Verhagen & Whitly 2012) and statistically defective (Verhagen, 2009), for not being externally testable (Kamermans et al., 2004), and for not considering social and cultural factors (Verhagen, 2007a). These issues have been attempted to be tackled through a series of statistical methods (Kvamme, 2006). Despite the disadvantages of a purely inductive predictive modelling, inductive models are very useful in archaeological monument preservation, quickly and simply providing large scale results according to the available data at a low cost (Kamermans 2009). That is why this method has been preferred in culture resource management, although sometimes deductive maps are also in use (Kamermans 2009).

Deductive, cognitive, explanatory or theory driven modelling, is usually presented as the opposite of inductive modelling. In many ways it follows the opposite course of action, by originating from a hypothesis, based on archaeological theory or knowledge about human behaviour (Danese et al. 2014, Kamermans et al. 2004; Whitley 2005) and attempting to predict sites' locations without considering the already known sites. Deductive models are usually tested with the known sites' locations. Just like inductive modelling, deductive predictive modelling has also been criticised. The main criticism it has received is being too simplistic and therefore inadequate in understanding more complicated cultural processes (Kvamme, 2006).

4.1.2.2 Beyond

Purely inductive or deductive models are not the majority of archaeological predictive models. More and more researchers began proposing the combination of the two approaches (Wheatley & Gillings, 2002) in "hybrid" approaches (Balla & Pavlogeorgatos 2014, p.121), or following a Middle range theory (Verhagen & Whitly, 2012). Verhagen (2007a) discusses how even though these approaches differ in method, in practise they are intertwined (p.14).

One example was proposed by Whitley (2001), who suggested factoring three assumptions when modelling. The first one was that the choice of settling was done consciously, and the reasons behind the choices can be traced either in the environment, such as physical or economic reasons, or in the site distribution pattern, such as cultural reasons. In this case, the reasons behind these decisions should be clear and their individual influence should be measurable (Kohler et al., 1986; Whitley 2001)

Another way of settling in the middle of the two theories, is the multi-variate, multi-criteria analysis (Verhagen, 2012), using a weighted multivariate approach in an attempt to bridge the gap of the traditional dichotomy. The weights are distributed among the variables with the help of expert opinion and judgement. Using statistical methods to implement this approach, the results can be easier reproduced and tested.

Gradually, the attention of academia was shifted away from picking sides on the dichotomy, into the inclusion of more factors in predictive modelling, especially regarding ones of social and cultural nature (Kvamme, 2006; Nuninger et al., 2020; Verhagen et al., 2012), moving away from the environmental determinism that characterised the earlier applications. Moreover, the way predictive modelling was implemented became broader, modelling aspects like visibility (Verhagen et al., 2011), movement and spatial modelling (Nuninger et al., 2020; Verhagen et al., 2012; Verhagen et al., 2019), tending towards machine learning and automatization (Oonk & Spijker, 2015).

4.1.2.3 Limitations and Benefits

It is perhaps already clear that predictive modelling in archaeology has been facing a number of issues and criticism. Some of the controversies around its implementation are summarised by Verhagen (2007a, p.17), and they mostly revolve around the quality of the datasets considered and the tendency to favour environmental parameters over social or cultural ones. Another controversy mentioned, which is highly relevant with the subject of the current thesis, is the "neglect of the changing nature of the landscape" (Verhagen 2007a, p. 17). As discussed in the earlier chapters, the landscape and sea-scape of the research area have been drastically transformed since the time periods under discussion, but reconstructions are still mostly dubious hypotheses. Wheatley (2004, p.9) has even argued that predictive modelling “shouldn’t be used” in archaeology as, according to him, it has more drawbacks than benefits.

Nevertheless, considering factors besides environmental aspects, is not a challenge only for archaeological predictive modelling, but very often for archaeology as a whole as well. Especially when studying earlier time periods like the present thesis, our knowledge on social and cultural aspects of life is very limited. In addition to the lack of knowledge, these kinds of factors are difficult to quantify and map, being more subjective, and even in the cases where mapping them is possible, there are usually no available maps showcasing them. At the same time, and despite the heated debates and being heavily criticized (Wheatley, 2004, Wheatley & Gillings 2002), predictive models have been used for evaluating the archaeological potential of areas, applying different methods, and showcasing that the benefits can outweigh the drawbacks (Kempf, 2019; Wachtel et al., 2018; Yaworsky et al., 2019).

One of the advantages of predictive modelling, is that it can be an effective tool in site location, saving time and minimizing the necessary funding, by reducing the need of trial trenches (Balla & Pavlogeorgatos, p.120) or the use of expensive geophysics or remote sensing equipment. In addition to that, it is a non-invasive method, which could assist in the detection and protection of archaeology, without endangering it with exposure to the surface. Moutsiou et al (2021, p.2) discuss the advantages of predictive modelling in areas with a paucity of data, and extensive areas that more traditional surveys cannot cover. They add that predictive modelling can be a “baseline for expanding archaeological work” (Moutsiou, 2021, p.2), upon which researchers can cooperate and discuss, building and improving the models. It can also assist planners to avoid areas with high archaeological potential, saving them time and money, while it’s protecting the finds from unnecessary exposure (Wachtel et al., 2018).

Nowadays, among the most common systematic uses of predictive modelling in archaeology are Cultural Resource Management (CRM) in the United States, Canada, Slovenia (Verhagen 2007a p18) and in the Netherlands (Deeben et al., 2002; Verhagen 2007a, p. 18-19). In the case of the Netherlands a combination of the Indicatieve Kaart van Archeologische Waarden (IKAW) and the Archaeologische Monumentkaart (AMK) is currently in use, both illustrating the archaeology worthy of protection itself and the potency of recovering archaeology in escalating values (Ministerie van Onderwijs, Cultuur en Wetenschap, 2020). AMK is not currently maintained by the Cultural Heritage Agency of the Netherlands (Rijksdienst voor het Cultureel Erfgoed) and as such, it is not regularly updated since 2014.

4.1.3 Testing

Thorough testing is not always part of predictive modelling, especially in testing the absence in the areas classified as having a lower potential of holding archaeological finds and sites (Wheatly 2004; Verhagen, 2018). In many cases the models created are tested through field surveys on the areas with high archaeological potential as classified in the models (Moutsiou et al., 2021; Runnels et al., 2005), risking the danger of resulting in a self-fulfilling prophecy.

Many testing techniques have been proposed over the years, to evaluate the results of predictive modelling. Among them are statistical testing, expert judgement testing, resampling, and many more (Verhagen 2007a; 2007b). The resulting models can also be tested in other areas with similar natural and/or social factors, or with more simple internal testing techniques. These can be as simple as split sampling (Verhagen, 2007a), which can be done by separating the dataset in two equal parts, one of which is used in building the model and the other in testing. Equal division though, would lead to a severely decreased dataset used for the creation of the model (Verhagen 2007a, p. 137).

In order to tackle this issue, different percentages have been preferred in various applications of predictive modelling, even beyond archaeology. Among others, an alternative that has been proposed is a splitting the known sample in three parts, with 50% used in training the model, 25% in estimating the prediction error of the model, and the last 25% in testing it (Raykar & Saha, 2015). Another proposed way to split the sample is 80-20, with the majority of finds being used in building the model (Nicu et al., 2019). There is no clear recommendation on the sizes of the sub-parts, since reducing one will always affect the other negatively, so the division should be justified for each specific case study. The model is later evaluated according to the

Kvamme's gain (Kvamme, 1988), and Verhagen's (Verhagen 2007b) and Wachtel's suggested self-evaluation of a predictive model (Wachtel et al., 2018).

4.2 Predictive modelling in action

This part is a walk-through the layers chosen and the modifications that were done to them, starting from accumulating the data and leading all the way to the final choices that shaped the final model. The goal of this sub-chapter, is to allow full transparency on the method of creating the model, in order to allow easier evaluation, reproduction and new additions in the future. At first, the method chosen will be discussed and supported, then, the process followed will be described step-by-step.

4.2.1 Theory

The current thesis adopted a hybrid methodology, being mostly deductive, but evaluating each factor examined along with the distributions of archaeological finds in the area, looking for patterns of presence or absence. The factors examined were mostly environmental, but there were some aspects with potential social and cultural impact that were considered as well (see Chapter 4.2.2.4). After assessing each factor with the literature and the distribution of archaeological material as retrieved from SOG, the factors that seemed to both explain the distribution and correspond with the literature were selected as the main factors and incorporated in the predictive model. This way, the archaeological theory accompanies the available material and vice versa. This method was chosen since excluding archaeology in the process of building the model bares the danger of producing a model that does not correspond to the local archaeological reality. Although prone to bias, known locations of archaeological finds can still inform us with patterns of presence or absence.

"The basic assumption in archaeological predictive models is that the location of ancient sites is not random, but rather reflects human choices, and is influenced by the natural conditions and the availability of natural resources" (Wachtel et al., 2018, p. 28). The first part of the next chapter, aims at tackling the first research question, regarding the environmental factors and their role in the hominin activity and occupation of the area. The change over time of these factors as well as their influence on the finds' distribution after their original deposition is discussed. In addition to the environmental factors, certain social and cultural factors proposed in the literature are discussed and their integration in a predictive model is debated (see Chapter 4.2.2.4).

4.2.2 Application

All layers considered were worked in QGIS, exported in the local coordinate reference system (CRS): GGRS87 / Greek Grid, EPSG: 2100, and clipped accordingly. Below each aspect and layer considered will be briefly discussed from the moment it was incorporated in QGIS until its final modifications if it was eventually included in the predictive model.

4.2.2.1 Water

Water is considered as an important factor in reconstructing palaeo-landscapes, understanding and predicting hominin activity. Freshwater sources would be essential for survival, the rivers could be used for navigation across the landscape by following their banks, and attracting prey. The relationship of past people with the sea, could have only been multifaceted and complex just like today. Setting aside potential social and cultural factors, there is an abundance of evidence proving that the sea was crossed ever since the earliest periods under study (Ferentinos et al., 2012; Fischer & Papoulia, 2018; Papoulia, 2016; Papoulia, 2018b), and that fishing was also practised (Krahtopoulou, 2017). Proximity to fresh water sources has been supported as a valuable proxy in many studies (Ferentinos et al., 2012; Fischer & Papoulia, 2018; Papoulia, 2016; Papoulia, 2018b), and proximity to the coast has been proven to be relevant elsewhere in Greece (Bailey et al., 2020 2020), especially in the case of the south Peloponnese, with sites never exceeding 4km from the coast (Perlés, 2016). Coastal lagoons have also been related to past hominin activity in the general vicinity of the Mediterranean (Bailey et al., 2020 2020). Here lagoons are considered separately from the sea, as they are found also in the CLC 2018 database.

This part is discussing the effect that the various bodies of water had on the distribution of finds, how they were considered and how they could have changed over the time periods under discussion. Firstly, the inland water sources are described, followed by the sea. The landslide susceptibility of the sea-bed and the migration of the coastlines are also discussed in this part.

Rivers, lakes and lagoons

The rivers map (Figure 14) was created by compiling chosen features from the River net layer of Copernicus database (Appendix 1) and the rivers layer of the same database. Additional features were manually digitized or chosen, with the reasoning behind said choices being explained below.

The rivers layer was lacking, meaning that some main rivers, like Pinios were not represented, while others were only partly digitized, for example Alfios in the Peloponnese. On the other hand the "river net" layer was too accurate and complex to be fully adapted in a predictive model aiming to reimagine past landscapes. The parts chosen were only filling up the gaps of the river map, with a focus on fully representing the main rivers of the research area.

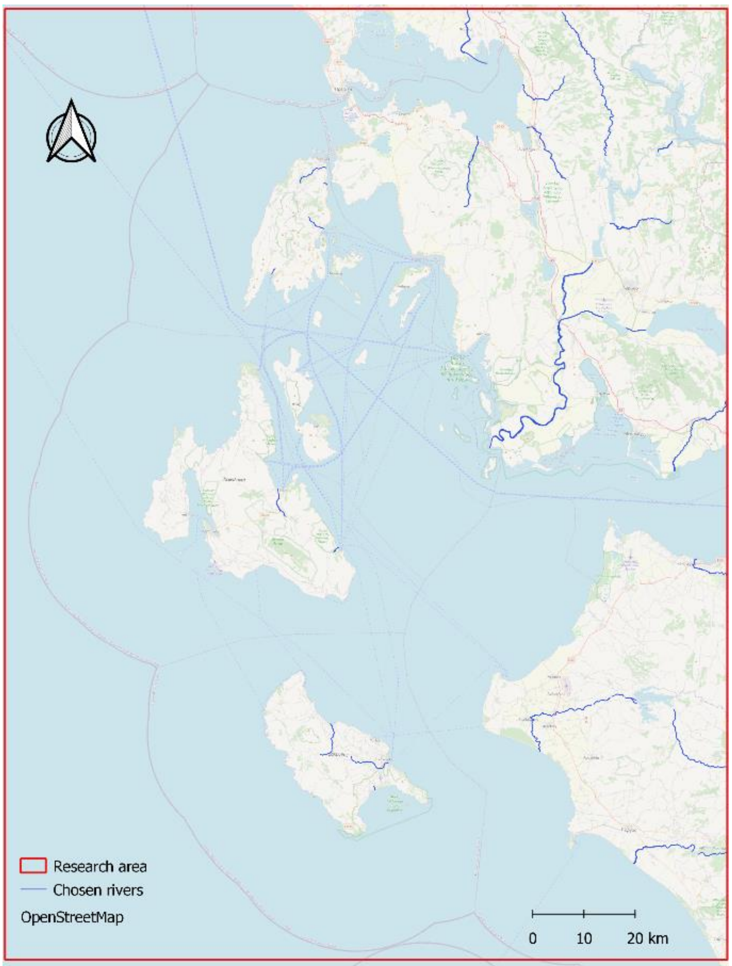

Figure 14 *Chosen rivers' map.* The map includes a selection of rivers retrieved from the datasets of Copernicus. (Figure by Vezoniaraki, E.C., source: OpenStreetMap & Copernicus)

The reason why the model includes only the main rivers is based on the assumption that these rivers, not affected by recent seasonal changes, had a greater impact and lifespan than the smaller streams and brooks. In order to decide whether a river was present in the past or not, their effect on the geomorphology of the landscape was studied, by comparing images from different maps, like OpenStreetMap, Google Earth, Google maps and Corona maps. The Corona maps were especially useful in studying these changes, since most big rivers' banks have been controlled or re-directed during the past decades.

Besides the bigger rivers, some smaller ones were added as well, if they have very visibly affected the landscape around them by either carving their way to the nearest water body or by having a wide bank in the present time or during the past. Some of them especially on the south of the Amvrakikos gulf are an example of wide eroded banks and fans, hinting at a wider lifespan or volume of water.

The rest of the additions were chosen to represent water bodies supplementing the inland water map of the same database described as mentioned earlier. The widest parts of some of the rivers received a different code in the Corine database (512) as inland water bodies, and were therefore retrieved and added in the rivers' layer.

Naturally, the river layer still does not represent how the rivers would have looked in the past, that is why a buffer was created around this layer to capture a potential change of route, without departing too much from the current form, since the change in elevation would have dictated the courses of the river. Using a bigger buffer would include a much bigger area, increasing the chances of including areas that were never part of the river bank and reducing the value of the model, and areas with higher elevation. The rivers were separated into two categories, splitting the larger ones, which were Aheloos, Alfios and Pinios, from the rest. A different buffer was used to estimate the banks of the two categories, with a 10m buffer for the smaller and a 50m buffer for the larger rivers. These buffers were considered in combination with the elevation zones, since the river-courses are affected by the terrain around them.

The lakes and lagoons were included in the map (Figure 15) by adding the polygon features from CLC 2018 map, and specifically the codes 512 for inland water bodies and 521 for marine coastal lagoons. As visible (Figure 16), there are several lagoons in the research area, and all of them are under protection by Natura 2000. The code 512 includes both lakes and the wider parts of rivers as previously mentioned, and are combined with the river layer in order to showcase the full water courses as accurately as possible. It also includes both natural and artificial lakes, which were treated equally (see Chapter 6). Of course, this is the picture of the current landscape, and more specifically, a digitized version with certain simplifications and small inaccuracies on the polygons' outlines. For this reason, just like the rivers, inland water bodies and coastal lagoons, were also buffered to compensate for these inaccuracies and potential seasonal fluctuations in their size.

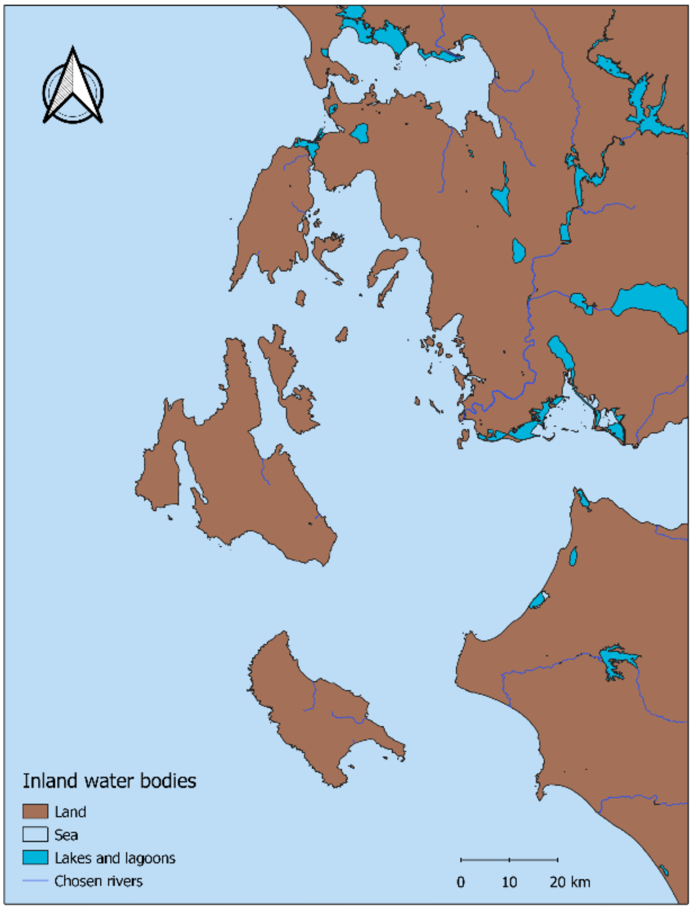

Figure 15 *Inland water bodies' map.* It combines the chosen rivers wit the lakes and lagoons of the research area. The land polygon was modified from YPEN. (Figure by Vezoniaraki, E.C., source: YPEN, Copernicus & CLC 2018)

The proximity from the various water bodies was also estimated separately for the various categories with different buffers (Appendix 2). The smaller rivers, the lakes and lagoons received a 1km buffer, and the larger rivers received a 3km buffer. The reason why the lakes also received a smaller buffer was twofold. Firstly, lakes tend to change in size, but not in terms of their location, so the buffer was created to compensate for the size alone in contrast to the river's buffer. Secondly, some of the present-day lakes are man-made through dams. These areas were not dry beforehand, they were still crossed by rivers, so using a smaller buffer seemed a reasonable middle-ground rule to apply to both natural and artificial lakes. Similarly, the lagoons, seemed more or less intact when compared with the Corona images, so there was no need to use a large buffer when adding them as a factor.

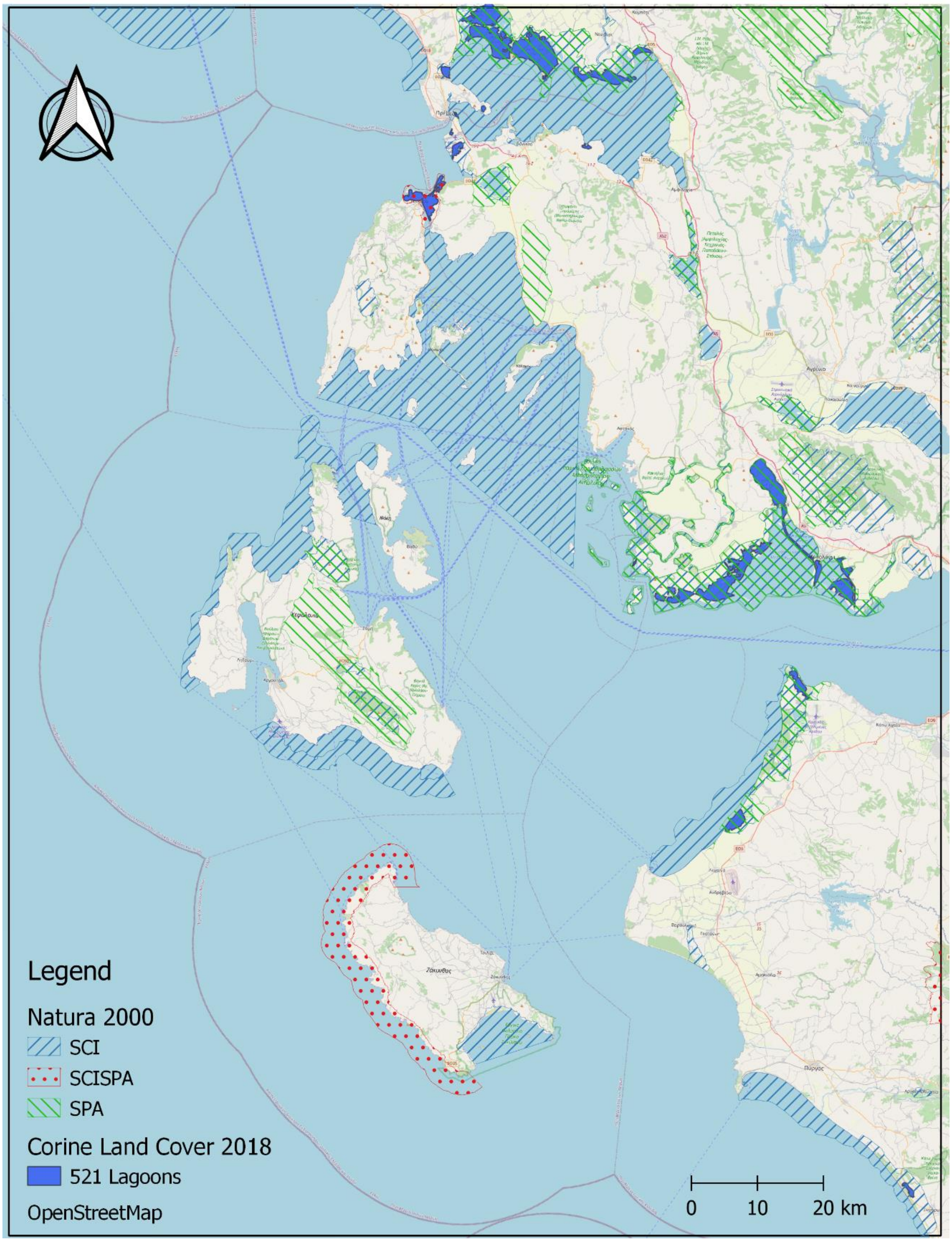

Figure 16 *Natura 2000 areas and marine coastal lagoons.* The research area is enclosed by a black polygon. (Figure by Vezoniaraki, E.C., source: OpenStreetMap, Natura 2000 & *CLC 2018*)

Sea

The sea as represented by CLC 2018, does not cover the entirety of the sea included in the research area, since it appears to be a buffer from the nearest coast. Therefore, the code 523 representing the sea, was only used as a buffer to represent the distance from the nearest coastline, since close proximity to the coast has been proven to be a positive parameter affecting the distribution (Perlés, 2016). Since the present-day sea level is on one of the highest levels it has ever been since the periods under study (Fischer & Papoulia, 2018), there was no use in estimating large buffers from the current coast. This is why a buffer of 50m inland was used, to approximately estimate the distance from the coastline during the interglacial periods.

Supplementing the CLC 2018 layer and in order to include the areas that used to be land during the glacial periods, the layer 0 to -200m from bathymetric zones in YPEN WFS was used (Figure 17). The bathymetric zones layer separates the depths from the EMODnet bathymetry in predetermined intervals, up to 200m, then 1000m and then every -1000m up until -5000m. According to the literature, the lowest possible sea level since the Palaeolithic, would have been -130m below the current sea level (Fischer & Papoulia, 2018; Lambeck, 2009). So the layer chosen would not only include the areas that were part of the coast, but also the shallower waters at the time where finds could have been deposited from paleo-rivers, seasonal sea fluctuations and even potential marine activity.

The following zone, which was up to -1000m, was considered more possible to carry finds than the deeper ones, since most of it would have been near the coasts, so it could contain finds relating to early sea crossings. The rest of the zones found in the YPEN bathymetric zones map, were considered of lower probability to both have finds and have easily retrievable finds. These layers were used in combination with the landslide susceptibility layer found in EMODnet geology.

The bathymetric depth contour lines upon which the bathymetric zones layer was build, are available in multiple CRS, and are every 50m until -200m and then every 200m. They were retrieved by the international bathymetric charts of Mediterranean, IBCM, (1:1.000.000) created in 1981 (European Marine Observation and Data Network (EMODnet), 2022).

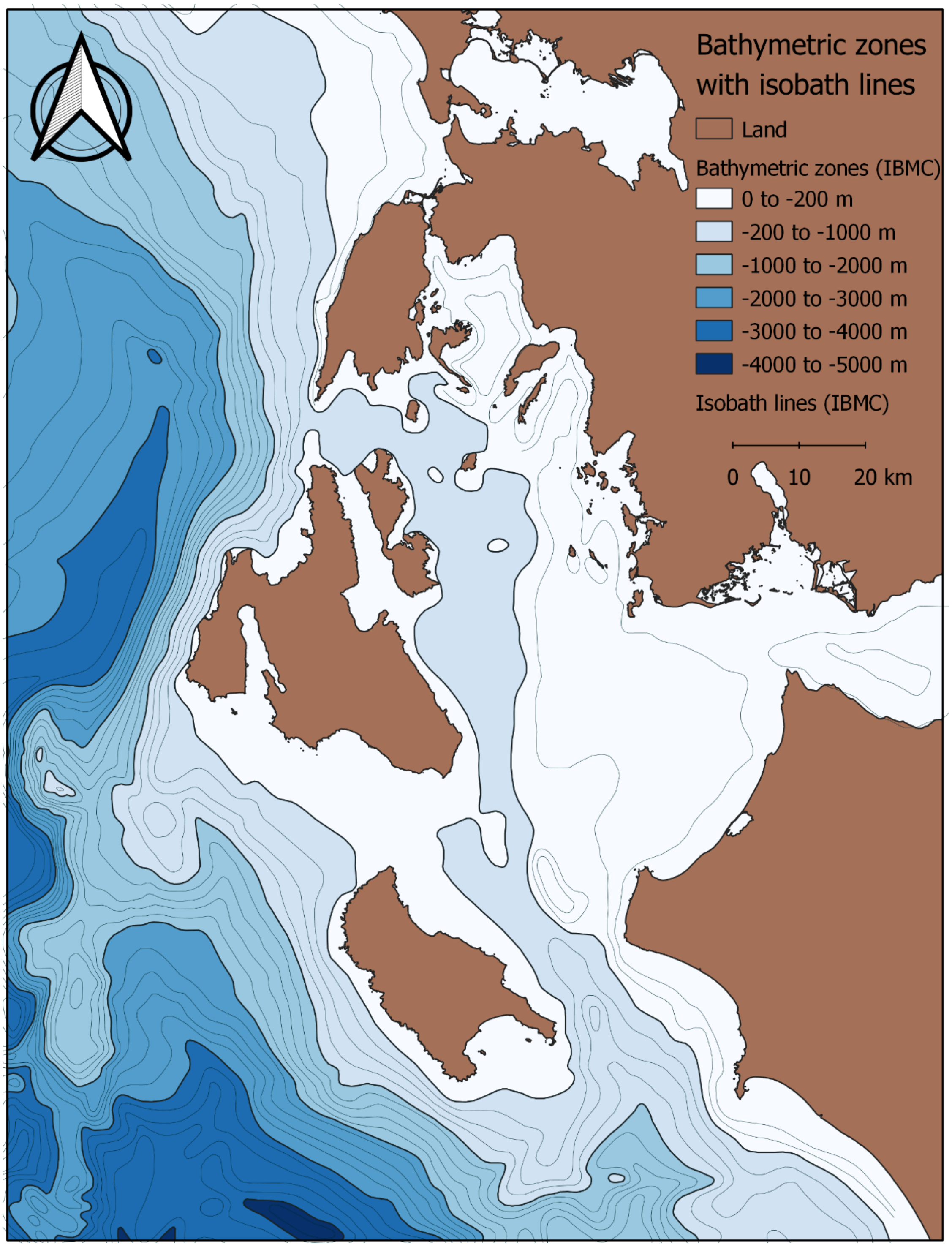

Figure 17 *Bathymetric zones and isobath lines*. The land polygon and zones where modified from YPEN, and the isobath lines from EMODnet (Figure by Vezoniaraki, E.C., sources: YPEN & EMODnet bathymetry)

Landslide susceptibility

In order to understand drastic changes on the sea-floor and the possibility of locating underwater finds, one can look into areas currently subjected to large-scale changes, like underwater landslides (Figure 19). This is just one of the factors that lead to the complexity of understanding and recreating past landscapes. Showcasing this phenomenon more clearly, the landslide susceptibility map from EMODnet geology was downloaded, clipped and converted from raster to vector. It was then further clipped along the bathymetric line of 0 to -200m, which is the most relevant to this project, holding the most potential of having archaeological finds easier to retrieve. The areas being the least susceptible to landslides were removed from the vector layer, while a series of polygons were also created to highlight the areas that are affected the most (Appendix 3). These polygons were not included in the final model, to avoid over-complication while overly exaggerating the role that certain factors played in the distribution and findability of archaeology. It is certainly an important aspect to consider, but greater precision could be misleading.

As can be seen, the border of the shallowest bathymetric zone, coincides with a zone of high land susceptibility (Figures 17 & 19), in all its length besides on the north of Lefkada were the depth is reduced more gradually the land susceptibility is lower (Figure 19). When combining these observations with proposed recreations of the past coastline, as it was when the sea level was much lower than today, they seem to be in agreement (Figure 17 & 18). The areas with the highest landslide susceptibility in the 0 to -200m zone, received a lower rank from the areas marked as less susceptible to landslides.

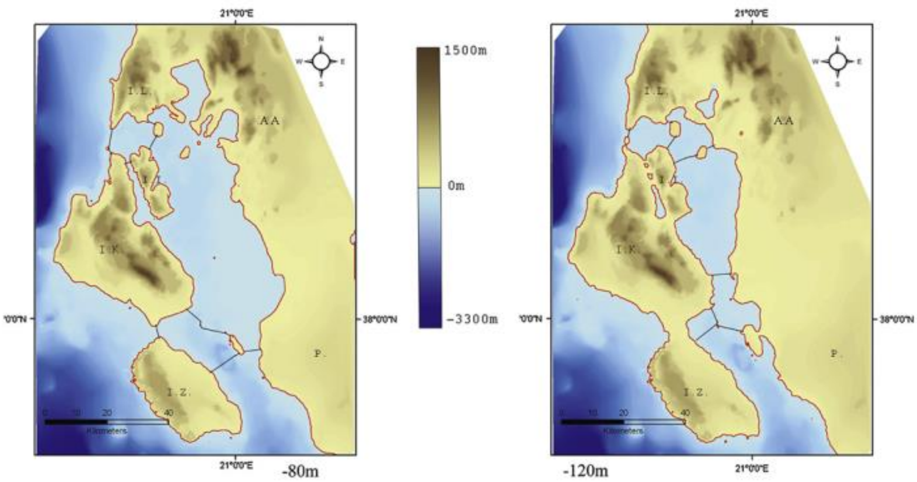

Figure 18 *Reconstructions of coastline in -80m and -120m below current sea-level.* (Ferentinos et al., 2012)

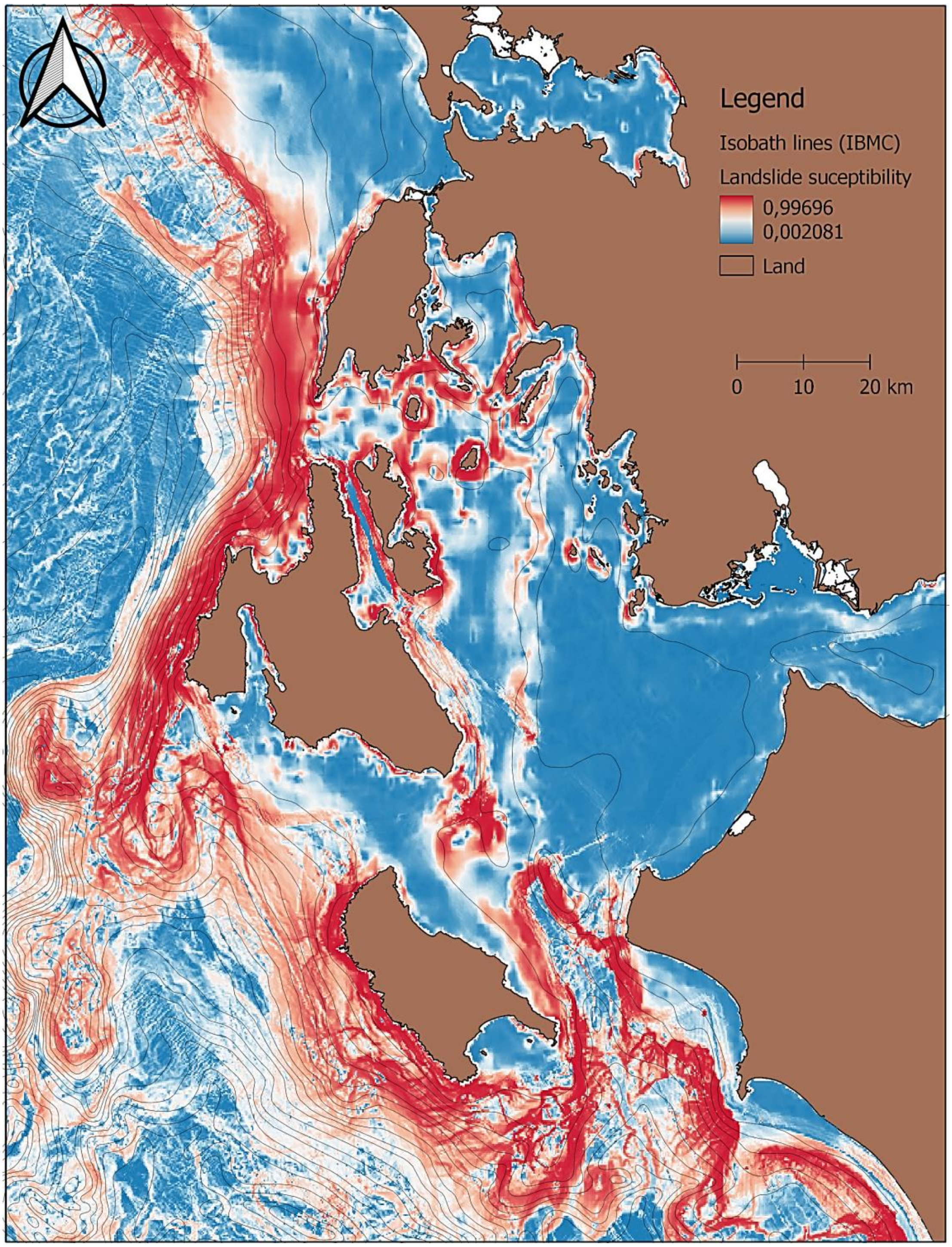

Figure 19 *Underwater landslide susceptibility and isobath lines.* Red=more susceptible to landslides, Blue= less susceptible to landslides. The land polygon was modified from YPEN. (Figure by Vezoniaraki, E.C., sources: YPEN, EMODnet bathymetry & EMODnet geology)

Coastline migration

Due to the roughness of the Greek landscape, erosion and the gradual rise of global sea-levels, many archaeological sites are currently partly or fully submerged, dating from the Palaeolithic all the way to the early Byzantine times (Bailey et al., 2020). Studying the state of the current coastline can be valuable in locating and protecting archaeology susceptible to coastal erosion.

The coastal migration layer was also acquired through EMODnet geology. It has three kinds of migration: accretion, erosion and stable (Figure 20). This layer was studied together with tectonic activity, landslide susceptibility, elevation and slope, and with the various archaeological find locations, in order to establish whether there is a presence or absence of observable patterns.

An interesting observation was that the A.Sho.Re project is studying both coasts that are eroded and that are stable, since they change around the location of Skala according to the map. Another interesting observation was that most of the western shores of the mainland have been characterised as stable, while not all eastern coasts of the islands are. Furthermore, there appears to be a strong connection between landslide susceptibility and coastal migration.

Coastal migration was not incorporated in any way in the final model, since it is only representing the present-day coastline and it could have been very different in the past. It is still considered as an important factor, regarding the protection of the finds potentially located in each location.

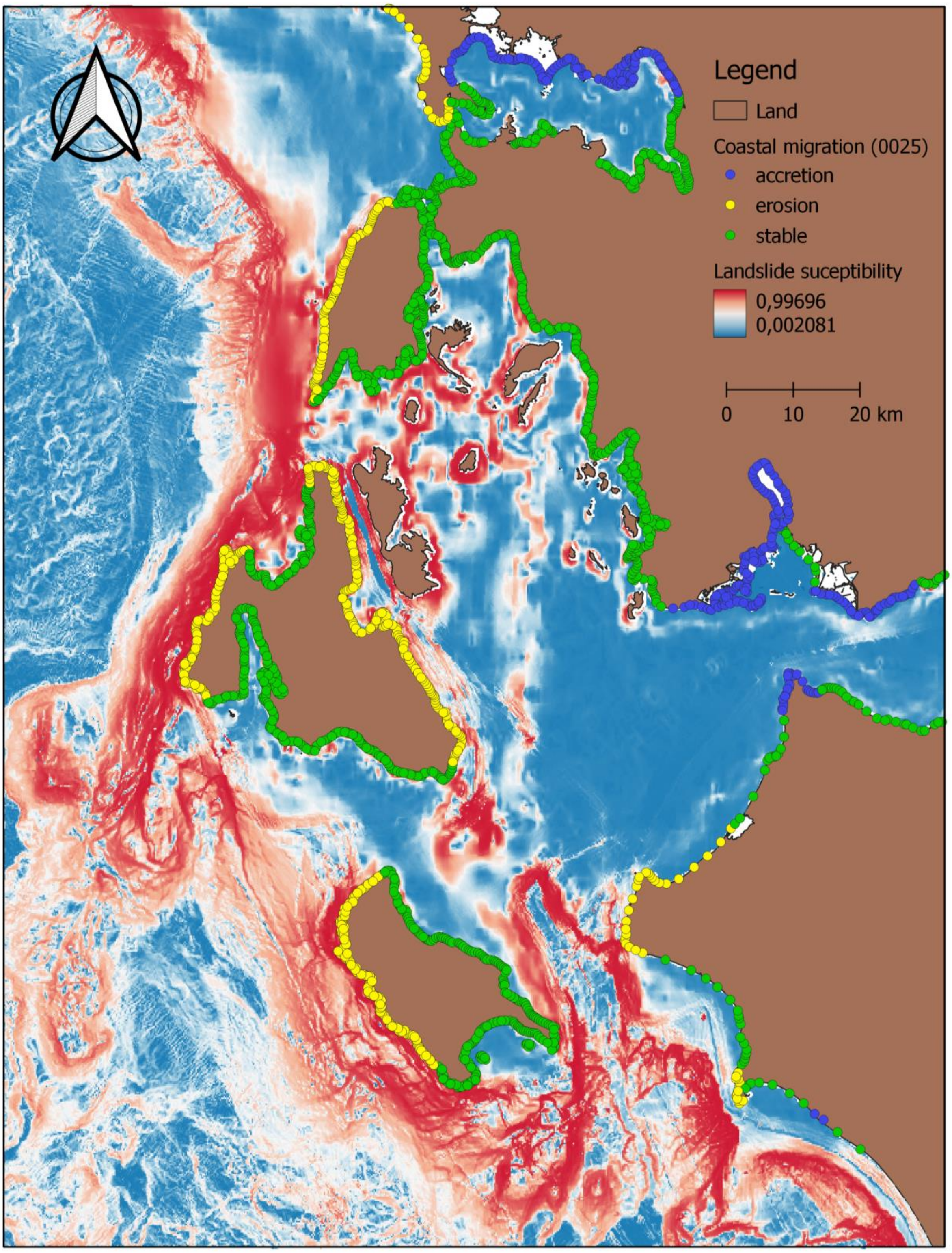

Figure 20 *Coastal migration and landslide susceptibility.* The coastal migration is represented by the 0025zoom layer found in EMODnet geology. The landslide susceptibility map is used for comparison. (Figure by Vezoniaraki, E.C., sources: YPEN, EMODnet geology)

4.2.2.2 Land

Elevation

As is often the case with archaeology, elevation is a complicated aspect to consider in the frame of the current project. When considering elevation, it is essential to always keep in mind the fluctuation of sea due to eustatism, the effects of the tectonic activity on the landscape, and other natural phenomena like seasonal springs, palaeo-lakes, and even the effect the weather had over the extensive time period separating the present landscape from the landscape of the past. All these would have a direct impact on the elevation as well as the appearance of archaeological finds on each elevation zone. The extensive erosion and deposition of material which can only go from higher to lower, in combination with the steep landscape of a large part of the research area, leads to the logical conclusion that most finds would be found on lower elevations, even when this was not the location of their original deposition. The only types of landscape relatively "protected" from these processes are upland plateaus, and even they are not impervious to change. Still, it is worth mentioning, that one of the exceptionally few areas were the finds recovered close to the surface were more or less in situ, was such a plateau in Zakynthos, in the Achiouri valley (van Wijngaarden, 2013), where several stages of the operation sequence (chaîne opératoire) were coexisting near the surface.

Elevation layers could be retrieved both from Copernicus in the form of EU-DEMs, and from YPEN where it could be found in both raster and vector layers. The vector layer from YPEN was splitting the land pre-determined intervals, every 100m until 600masl, then every 200m until 1000masl and then 500m until 2000masl (Figure 21).

According to the literature of the broader area, there has been a general notion to support that people of the past were active only on the lower elevations and avoided the mountains (Kamermans et al., 2011; Moutsiou et al., 2021; Perakis & Moysiadis, 2011; Runnels et al., 2005) which is challenged with finds on the highlands of Epirus and other areas (Bailey et al., 2020; Caracausi et al., 2018; Forsén, 2016; Papoulia, 2011). In the case of Agro Pontino in central Italy, Kamermans et al. (2011), noticed that there was a strong tendency to avoid higher elevations (>300masl) during the Middle Palaeolithic, which became slightly less prominent during the Upper Palaeolithic.

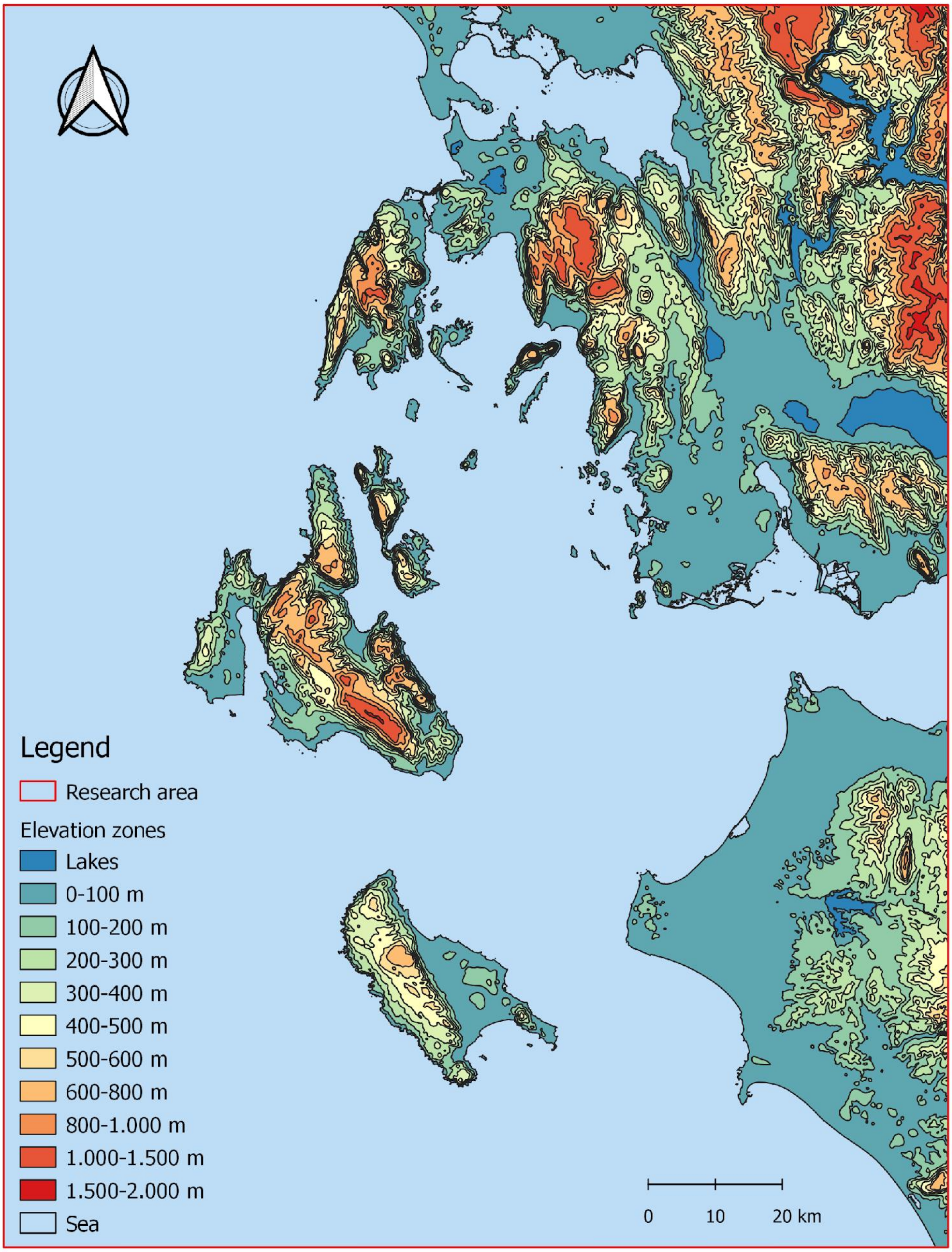

Figure 21 *Elevation zones.* The zones are based on elevation contour lines. (Figure by Vezoniaraki, E.C., source: YPEN)

In the research area, even though the vast majority of finds are on the lowest elevation zone (0-100masl) across all time periods (Table 3, Figures 22, 23 & 24), there are still locations like Englouvi, which are situated way above this zone. Elevation in terms of meters above sea level, is highly affected by the fluctuations of the sea. In periods where the sea level dropped significantly, the contemporary low elevation areas would be perceived as higher elevations. Therefore, since there have been significant fluctuations, locating finds in a variety of present-day elevations was expected. Another observed tendency is the decrease of locations found in the 100-200masl zone in each main time period, with around 10-12% of the locations in the Palaeolithic, to 6% in the Mesolithic and less than 3% in the Neolithic (Table 3).

Assessing the reasons behind the distribution of known locations across the elevation zones needs to take many factors into consideration alongside elevation itself. It could be related to other environmental factors such as geology and soil, post depositional processes, different preferences in areas of activity in the past (Kamermans, et al., 2011), or lack of research. Due to these issues, the elevation zone, even though seemingly affecting the distribution of finds to a large extent, was not considered as the factor affecting the distribution of finds the most. Still, its significant impact on the distribution cannot be ignored.

Table 3 *Elevations*. The elevations of the used locations (70%) per time period. (Table by Vezoniaraki, E.C.)

masl	PL	%	MPL	%	UPL	%	ML	%	NL	%
0-100	59	**71,0**	41	**83,7**	28	**90,3**	45	**90,0**	31	**83,8**
100-200	7	9,9	6	12,2	3	9,7	3	6,0	1	2,7
200-300	-	-	1	2,0	-	-	-	-	2	5,4
300-400	1	1,4	1	2,0	-	-	1	2,0	1	2,7
400-500	3	4,2	-	-	-	-	-	-	1	2,7
> 500	1	1,4	-	-	-	-	1	2,0	1	2,7

Note. “masl”= meters above current sea-level.

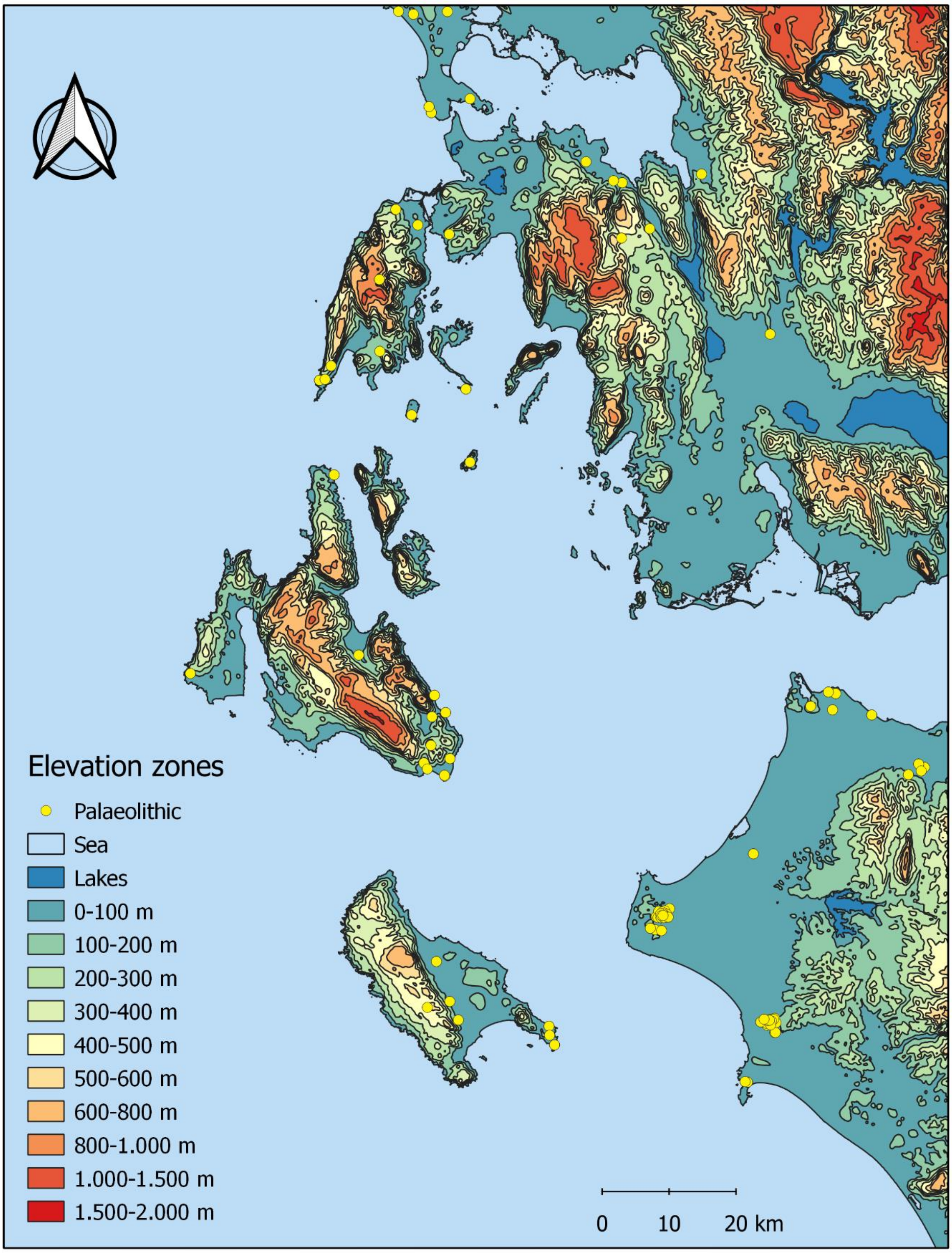

Figure 22 *Elevation with Palaeolithic finds' locations.* (Figure by Vezoniaraki E.C., sources: YPEN, SOG & more (Table 2))

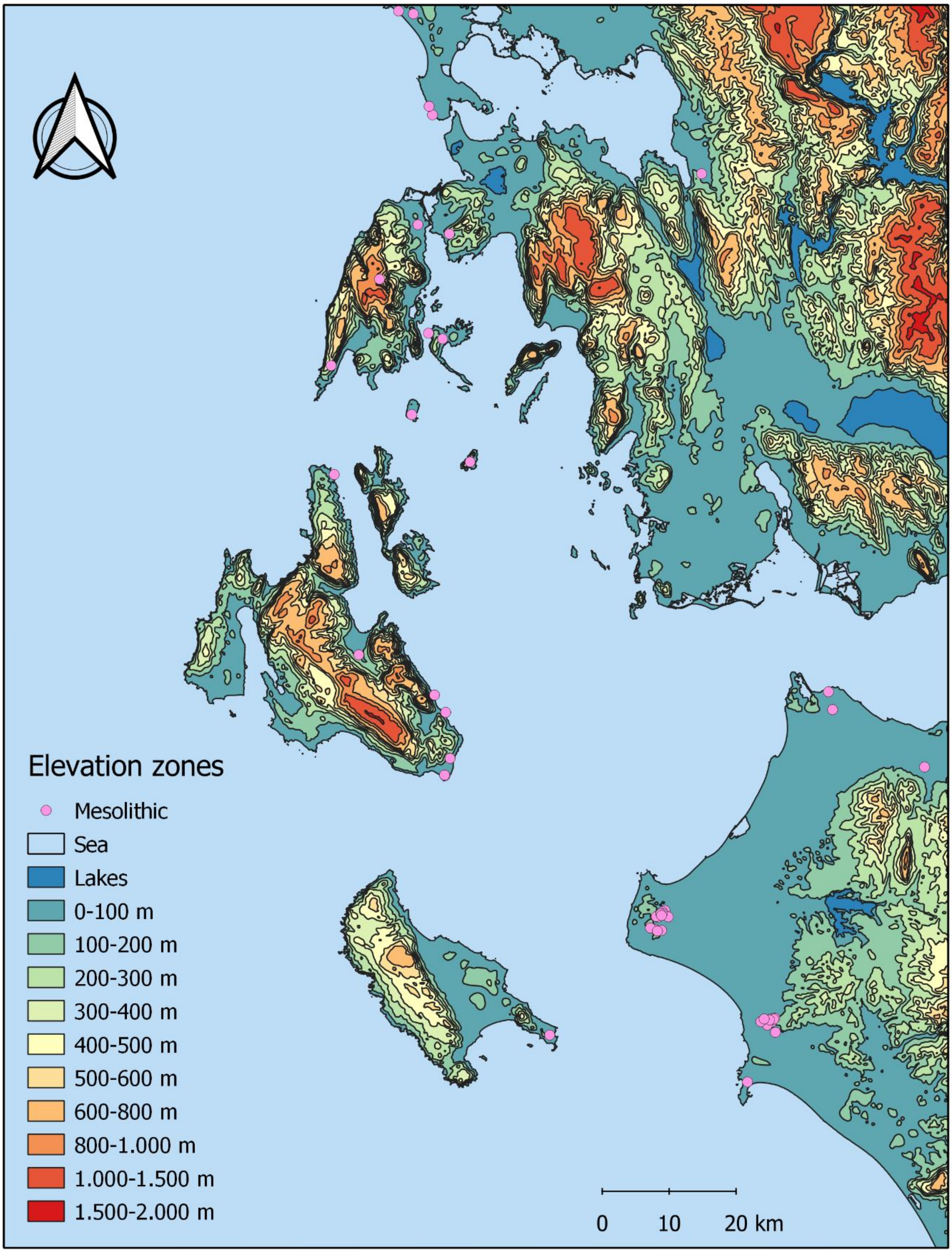

Figure 23 *Elevation with Mesolithic finds' locations.* (Figure by Vezoniaraki E.C., sources: YPEN, SOG & more (Table 2))

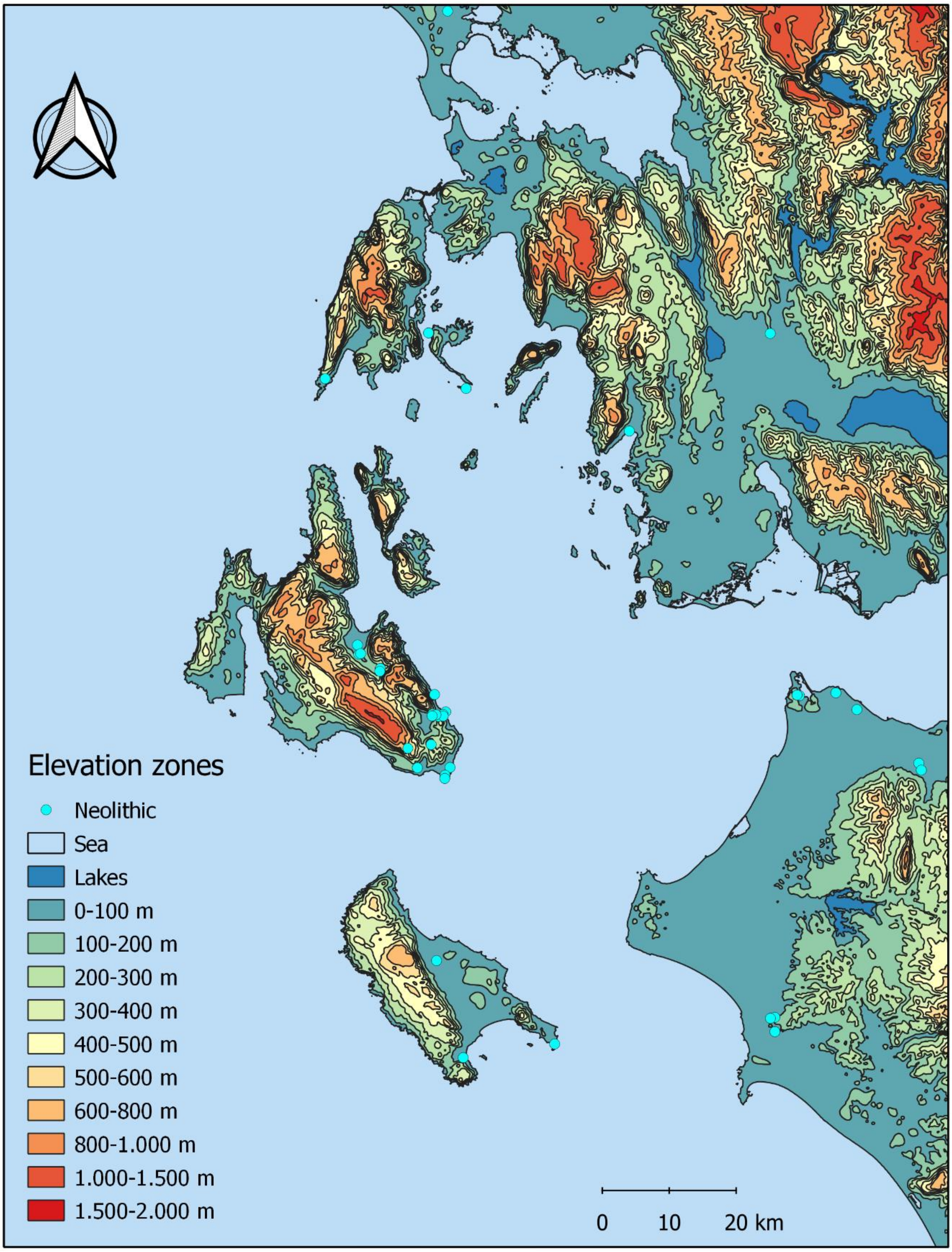

Figure 24 *Elevation with Neolithic finds' locations.* (Figure by Vezoniaraki E.C., sources: YPEN, SOG & more (Table 2))

Slope, aspect and erosion

By manipulating the clipped DEM layer downloaded from Copernicus, slope, aspect and hill-shade layers were created. These were compared with the ones found in YPEN and especially with the versions using the pre-formed polygons used in many more layers, as mentioned previously. These polygons received a value from 1 to 9, but not on a continuous scale in all cases. In the case of slope, and erosion, each factor received one of three potential values: 1=low, 5=medium or 9=high. If a polygon combined two values it received a new value, according to the value that could be found more. For example, when a polygon had primarily low and some medium values it would be marked as 2, when it had primarily low and some high as 3, when primarily medium and some low as 4, when primarily medium and some high as 6, and so on.

Slope

There were two versions of slope maps compared with the finds. The raster one derived from the European DEM available in Copernicus and a vector map found in YPEN based on the predetermined polygons (Figure 25). In the latter, the low, medium and high values represent less than 40%, 40% -70% , and >70% inclination respectively. This factor is worth considering both as an environmental factor influencing the past activity in the area and as a natural factor affecting the current location of finds, as finds in steeper areas are harder to retrieve and potentially more susceptible to erosion.

According to Gkioni (2008), slope did not affect the decisions of hominins in the Palaeolithic, since many Palaeolithic caves are located on >25° slopes. Compared to the finds' locations used in this thesis, the vast majority of them are located on the values between 1 and 5, with only a few exceptions around the broader area of Poros in Kefalonia with mostly Neolithic finds, located on a value 6 inclination, and no finds on the values 7 to 9 (Figures 26, 27 & 28). It is unclear whether the lack of finds on areas with higher inclination is due to preference or post depositional processes and lack of relevant research, but the finds located so far appear to challenge the claim made by Gkioni (2008), since almost all Palaeolithic finds' locations are in areas with primarily low slopes. Based on this correlation, and due to the large percentage of the area being assigned with low values, the parameter was considered inefficient in explaining the known distribution. Elevation seemed to explain the patterns visible when studying slope to a larger degree.

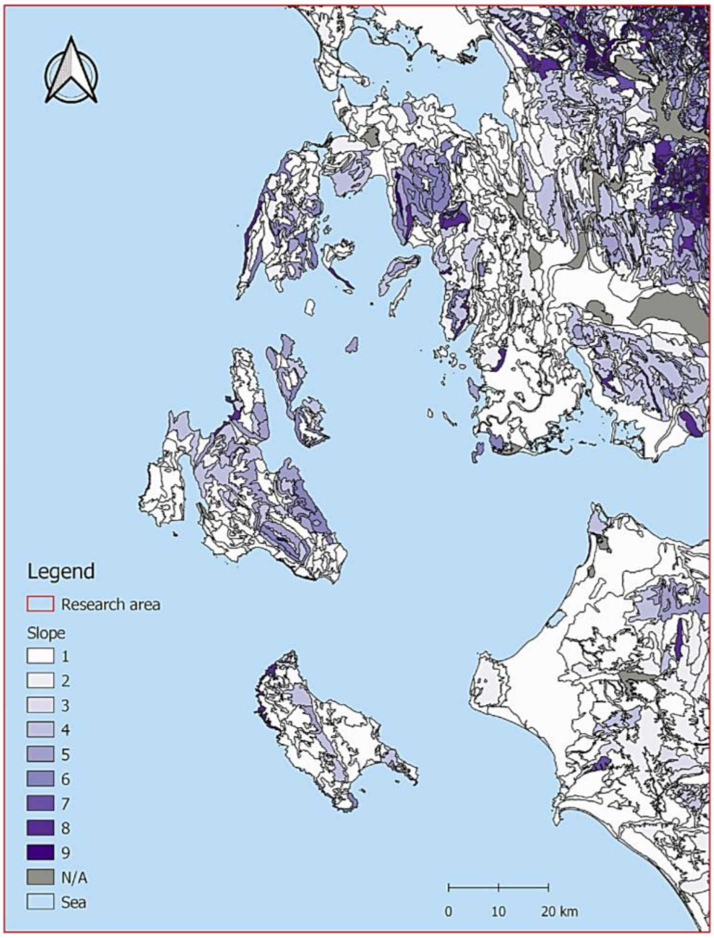

Figure 25 *Slope.* Each value corresponds to different degrees of slope on each polygon as found in YPEN. (Figure by Vezoniaraki, E.C., source YPEN)

Aspect

Among others, Gkioni (2008) also claims that aspect is not a factor affecting the decisions of Palaeolithic hominins. Mapping the aspect was done similarly to slope. Two versions were compared, one derived from the EU-DEM and the other found in YPEN. Aspect is a complex variable to map, taking into consideration the broad nature of the predictive model created. Nevertheless, the locations were compared with the aspect maps. The results do not reveal any obvious correlation with a certain direction, and the scarcity of in situ finds, would render any potential correlations invisible. For this reason, aspect was not considered any further (Appendix 4, 5 & 6).

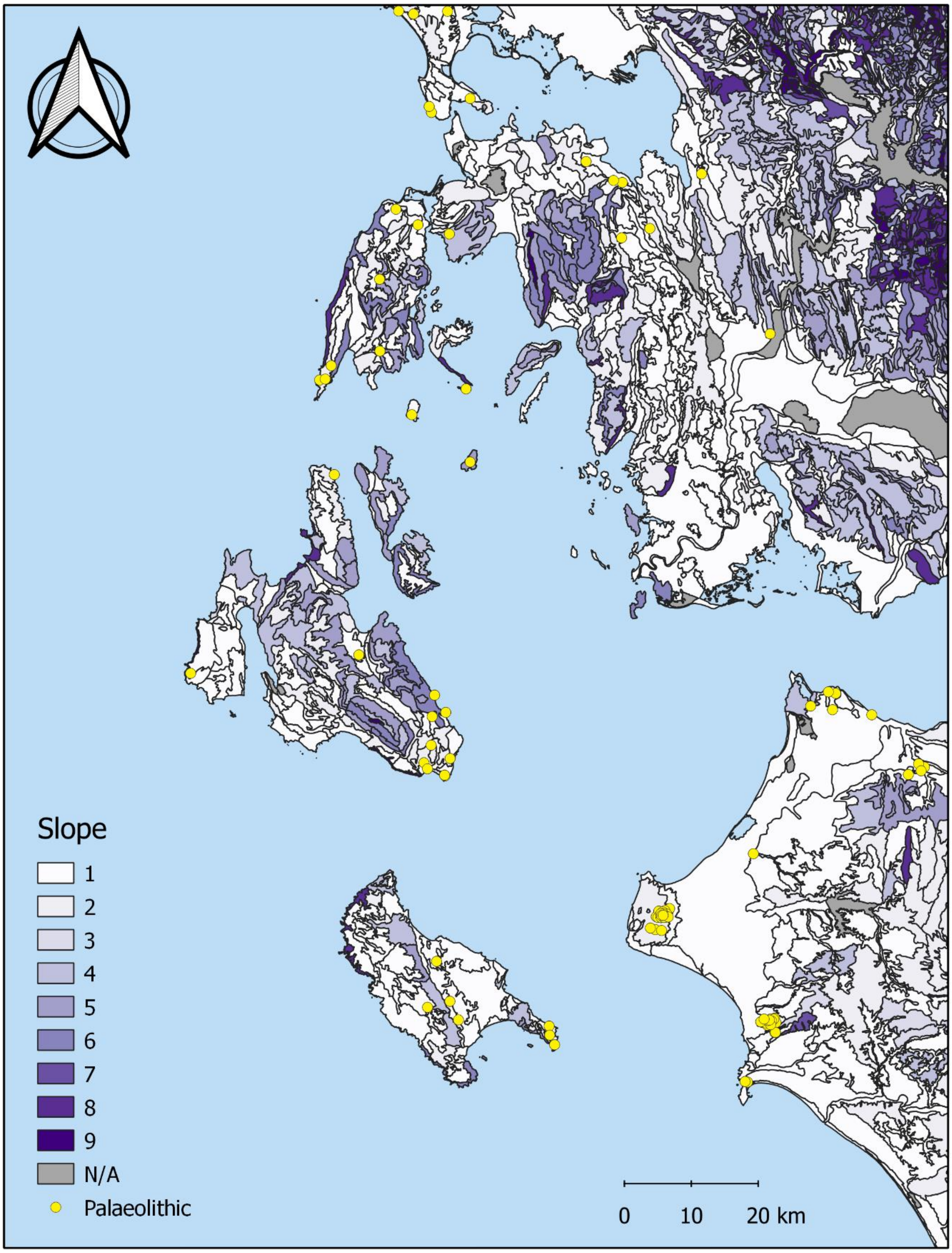

Figure 26 *Slope with Palaeolithic finds' locations.* (Figure by Vezoniaraki E.C., sources: YPEN, SOG & more (Table 2))

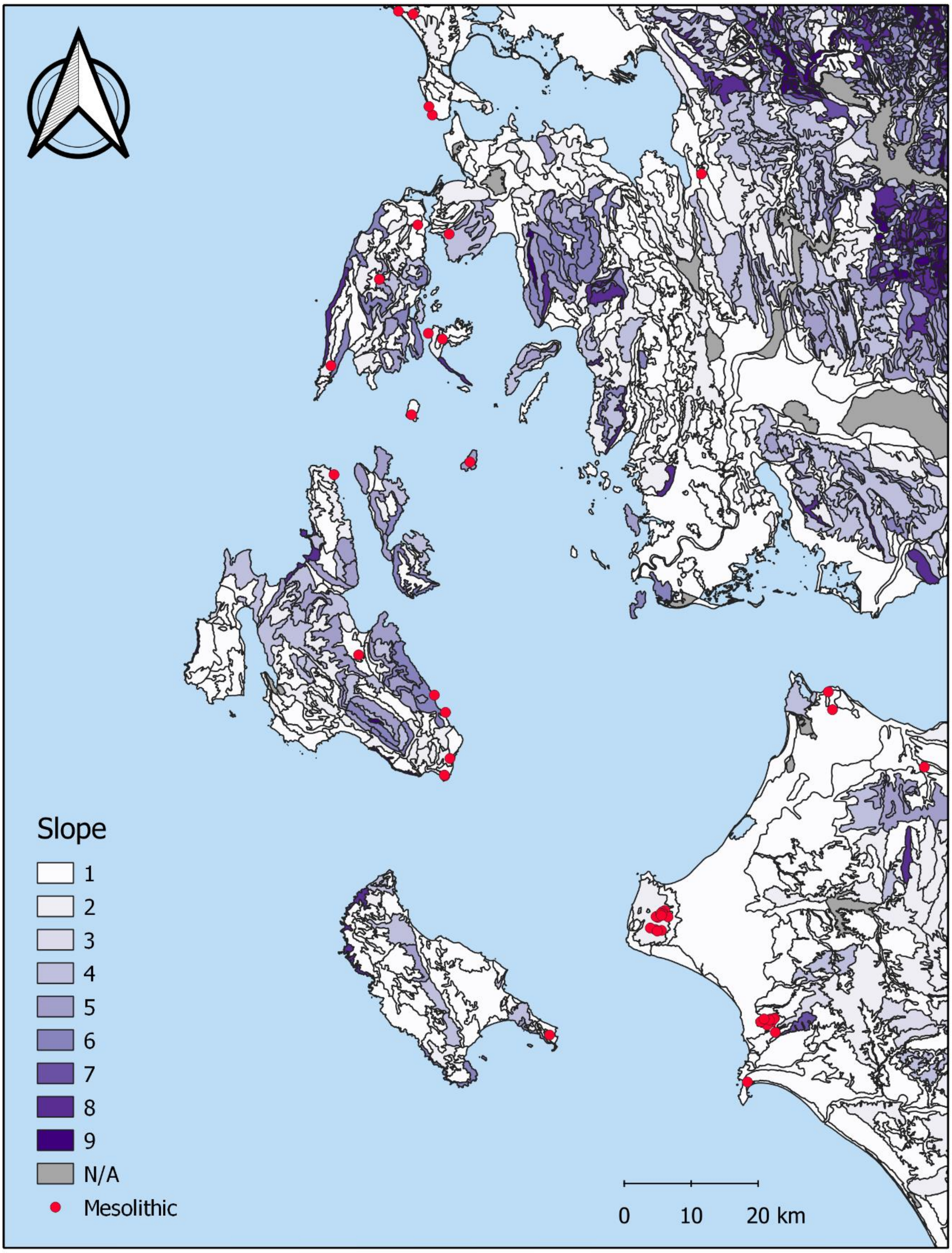

Figure 27 *Slope with Mesolithic finds' locations.* (Figure by Vezoniaraki E.C., sources: YPEN, SOG & more (Table 2))

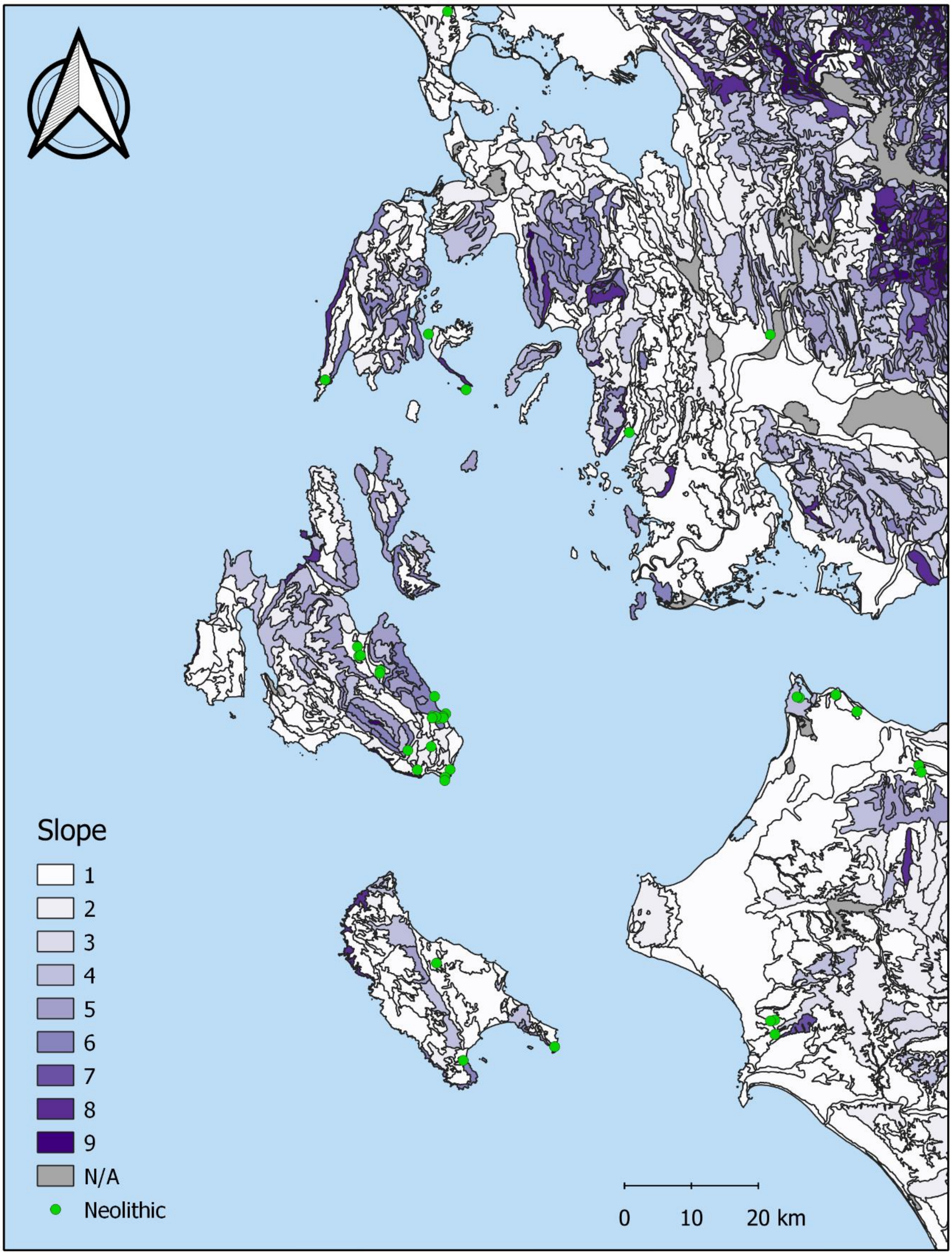

Figure 28 *Slope with Neolithic finds' locations.* (Figure by Vezoniaraki E.C., sources: YPEN, SOG & more (Table 2))

Erosion

The erosion map retrieved from YPEN was constructed mostly based on the effect of water and gorges (Figure 29). The values range from 1 to 9, while the value 0 was given to the unspecified areas. Even though the layer utilizes the predetermined polygons like the previous layers, it still represents areas affected by erosion. Considering the high tectonic activity of the area, it is surprising how very few areas are marked as impacted by intense erosion, probably due to the construction of the layer oriented around the gorges. The erosion layer is considered as one of the factors affecting the distribution of the archaeological finds after their original deposition. High erosion leads to uncovering and redepositing the finds in secondary locations. These areas are expected to have a lower archaeological potential or are in need of protection.

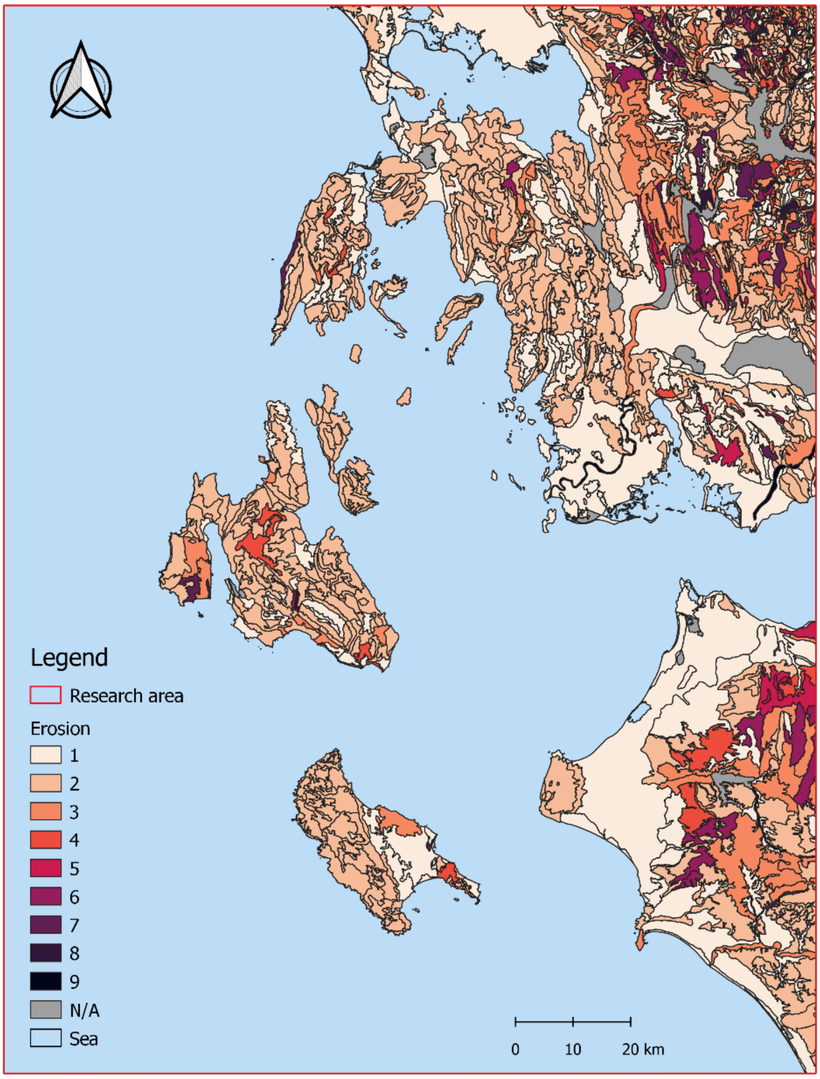

Figure 29 *Erosion.* Each value corresponds to different degree of susceptibility to erosion on each polygon as found in YPEN. (Figure by Vezoniaraki, E.C., source: YPEN)

As expected, most finds are located in areas with primarily low degree of erosion, with limited exceptions in a couple of locations in Kefalonia and Zakynthos marked as 3, and one location inland in Aetoloakarnania marked as 5.

Tectonic activity

Even though tectonic activity is an important factor directly affecting the distribution of archaeological finds, it is hard to trace and map its effect properly. Earthquakes are very common in the area, especially on the Ionian islands and sea, but their effect is not only affected by the distance from the epicentre, but also other aspects like slope, geology, soils, vegetation and more. The epicenters' locations and earthquakes' intensity could have been considered, but the process would not be as profitable as it would be time-consuming, considering the extensive effect of earthquakes and their dependency on other factors. Therefore, the tectonic activity was only considered through its result in accelerating erosion.

Geology

The geology and especially the lithology layer was considered in order to study the relationship between distributions of archaeological finds and certain types of geology. This relationship has been supported in the literature both regarding sources of raw materials and in locating sites on preferred geologies (Bailey et al., 2020).

Information on the geology of the research area was easily found through old maps and newer publications, but finding a digital, open source geology layer proved to be more challenging. There have been several studies on the geology of the chosen area, some of them broader (Bourli et al., 2021) and others focused on a specific part of the area (Brown et al, 2011). Eventually, a broader map was preferred, the European geological data infrastructure (EGDI), including information on the lithology and their formation (see Chapter 3.1.9). The latter was especially helpful in the case of the later periods, like the Holocene, revealing that some of these materials were formed after of the time periods under study. There were not too many areas consisting of Holocene materials, but they existed in both the islands and the mainland.

While studying the lithology layer from EGDI a clear distinction between sub-areas inside the research area was observed (Figure 4). The mainland could be separated in three areas, one including the Peloponnese, one parallel to the coastline from the eastern end of the Amvrakikos gulf till the eastern end of Mesologgi lagoon and the third one including the more inland parts of the mainland, closer to the Pindos mountain range. The islands seem more uniform in the presence of the various types of lithology. From the three parts of the mainland, all islands besides Zakynthos, seem to be a continuation of the coastal mainland. Zakynthos on the other hand, seems to combine the lithology of the rest of the islands with the Peloponnese, with a large part of its total area consisting of Holocene clastic sediments, just like the Peloponnese.

When compared to the locations representing archaeological finds, absence was easier to pinpoint than presence (Figures 30, 31 & 32). The sub-area closer to the Pindos mountain range, consisting mostly of Eocene mudstone and Eocene clastic sedimentary rocks, along with some limestone had a total absence of associated finds' locations. This could have been caused also by other factors like distance from the sea, elevation, or lack of research. Another type of geology that appears to be related to absence of related finds is the clastic sediments dated in the Holocene, found in the Peloponnese, Zakynthos and clastic sedimentary rocks found in the broader region of Mesologgi lagoon, also dated in the Holocene. Considering that two out of the three time periods under study in this thesis are dated during the Pleistocene, the absence of finds only suggests absence during the Neolithic period. In the rest of the areas, the type of lithology does not seem to largely affect the distribution of locations (Table 4, Figure 33).

In this thesis, since there were no obvious indications for a preference for a specific type of lithology, geology was not a factor that was added in the predictive model. In the case of absence, the total absence of finds noticed on the area closer to Pindos, could have been attributed to other factors as mentioned before, and especially elevation, and it seems to be explained better with them.

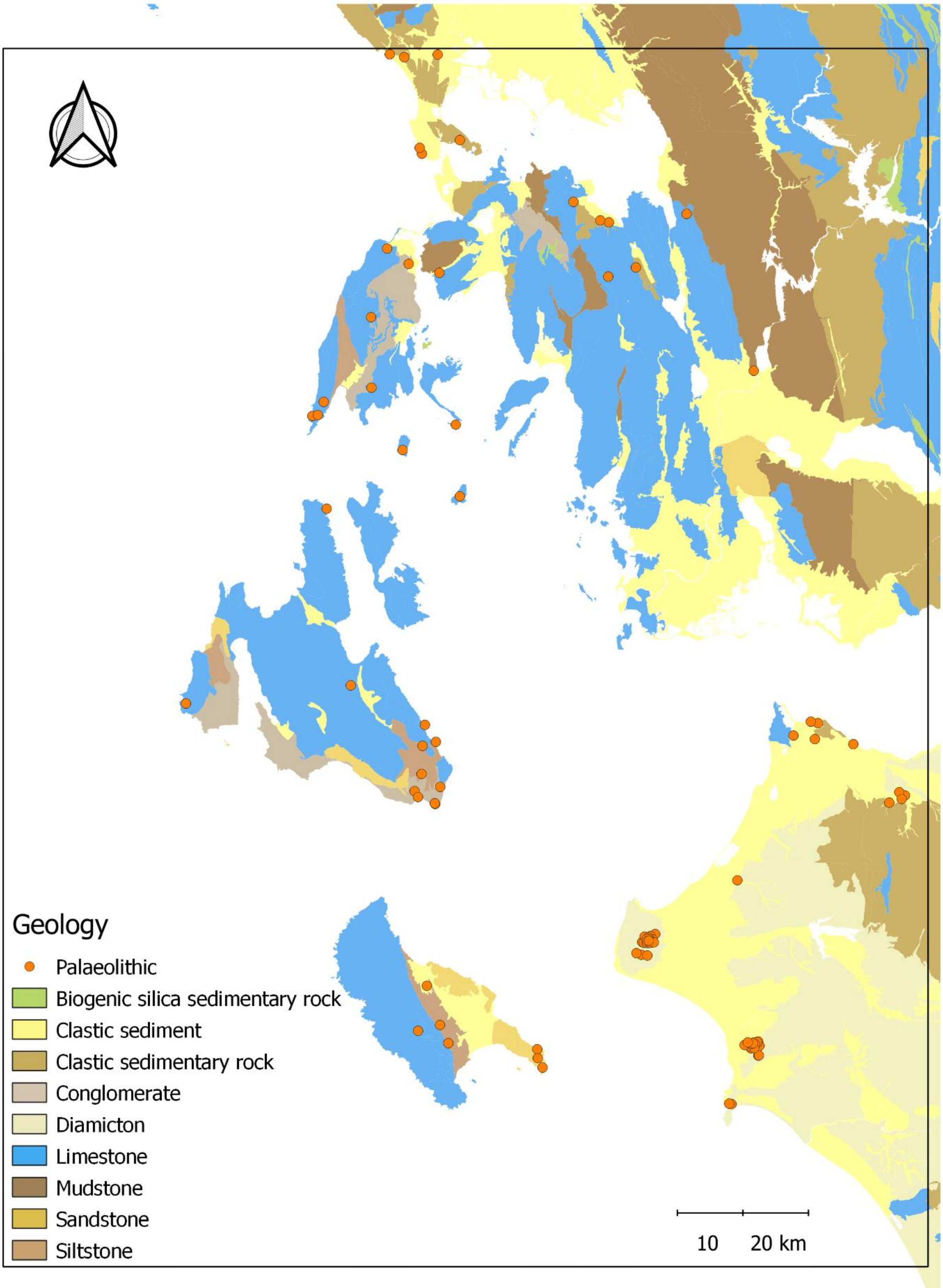

Figure 30 *Geology with Palaeolithic finds' locations.* (Figure by Vezoniaraki E.C., sources: EGDI, SOG & more (Table 2))

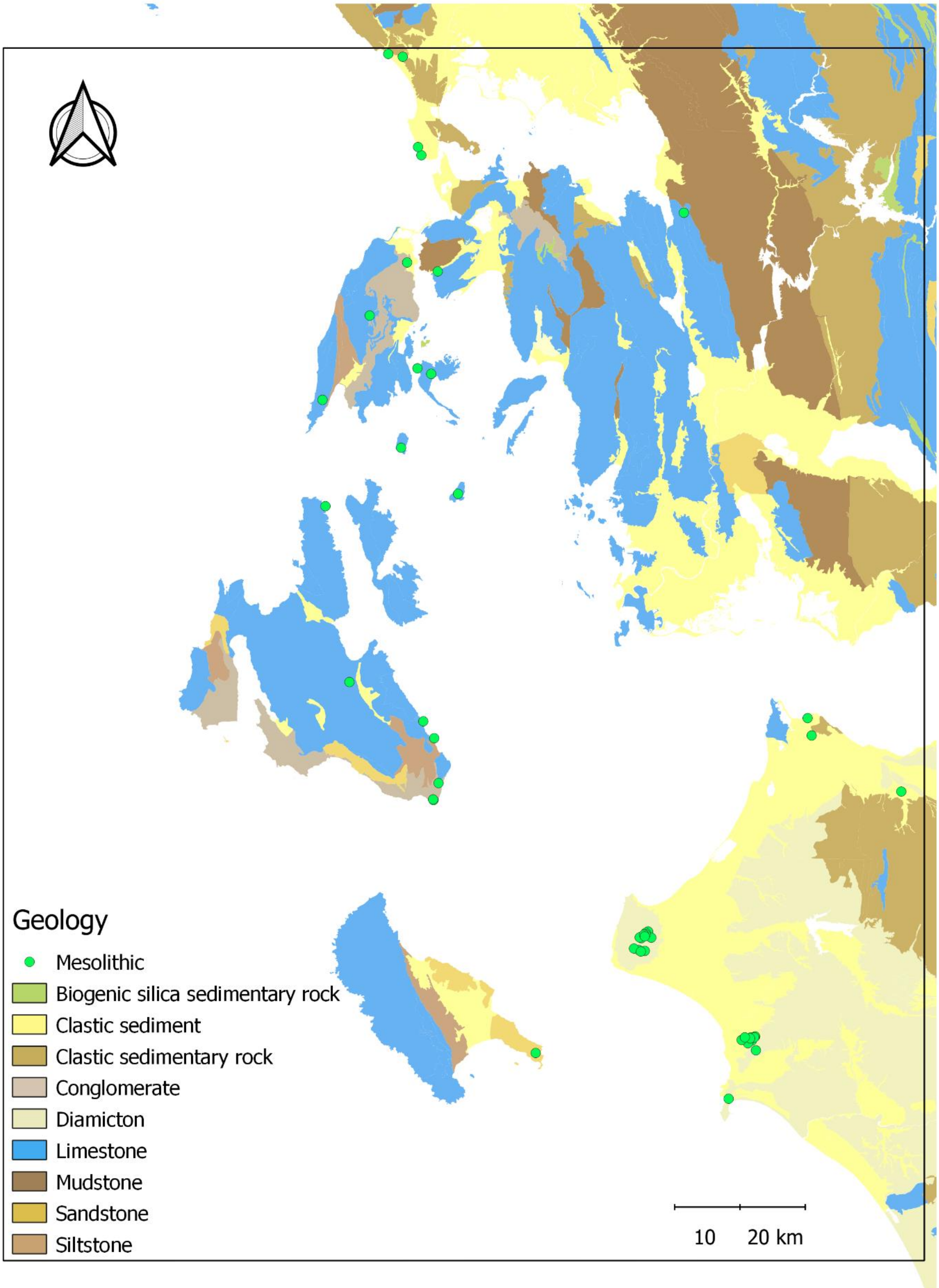

Figure 31 *Geology with Mesolithic finds' locations.* (Figure by Vezoniaraki E.C., sources: EGDI, SOG & more (Table 2))

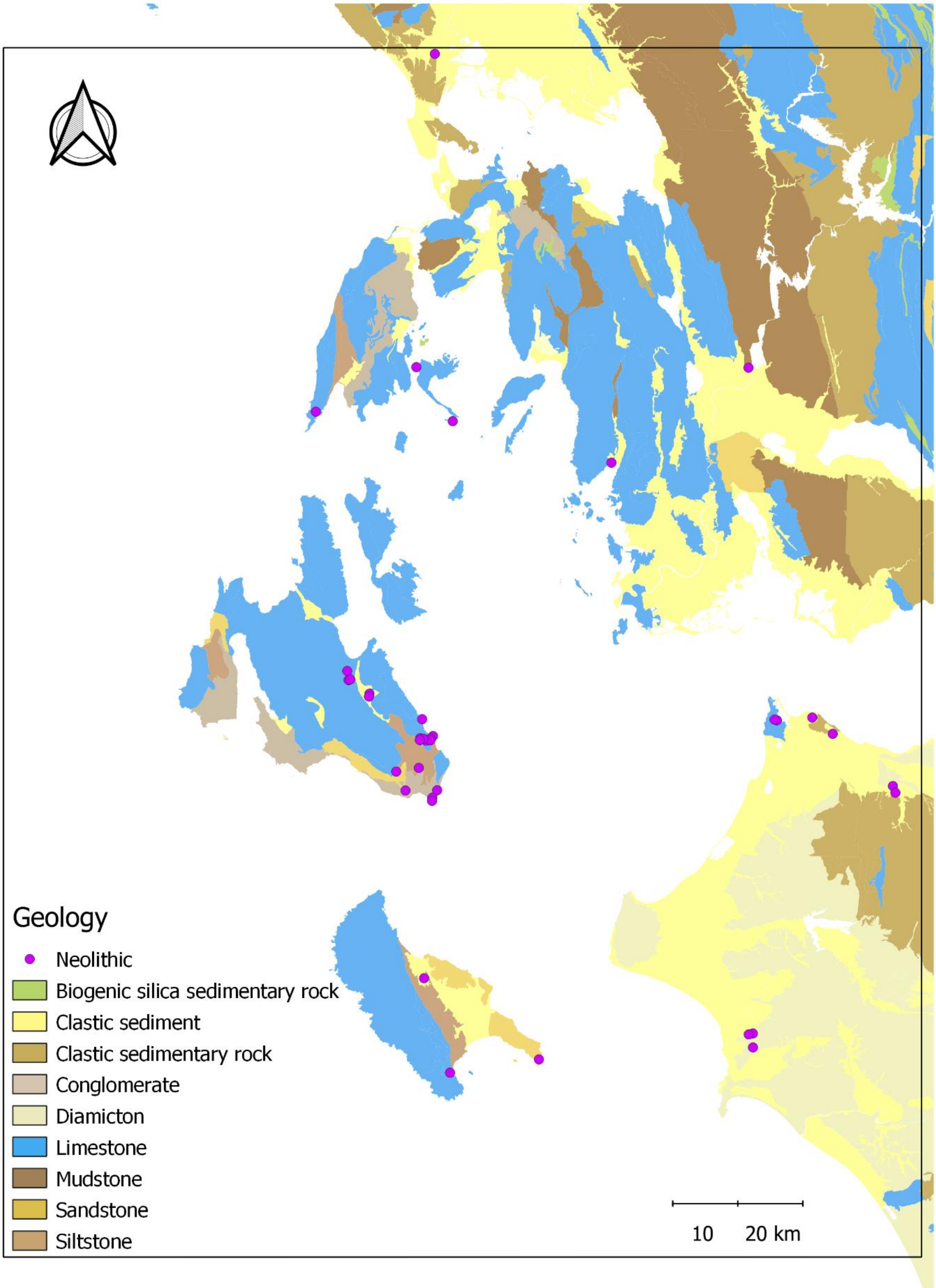

Figure 32 *Geology with Neolithic finds' locations.* (Figure by Vezoniaraki E.C., sources: EGDI, SOG & more (Table 2))

Table 4 *Geology.* The main lithology types of the research area per time period. (Table by Vezoniaraki, E.C.)

Lithology	**PL**	**ML**	**NL**
Biogenic silica	0	0	0
Clastic sediments	14	12	10
Clastic sedimentary rock	14	2	0
Conglomerate	6	3	4
Diamicton	31	20	1
Limestone	18	11	12
Mudstone	1	0	1
Sandstone	3	1	1
Siltstone	5	1	8
Total	92	50	37

Note: The "PL" abbreviation combines the broader Palaeolithic locations with the Middle and Upper Palaeolithic ones.

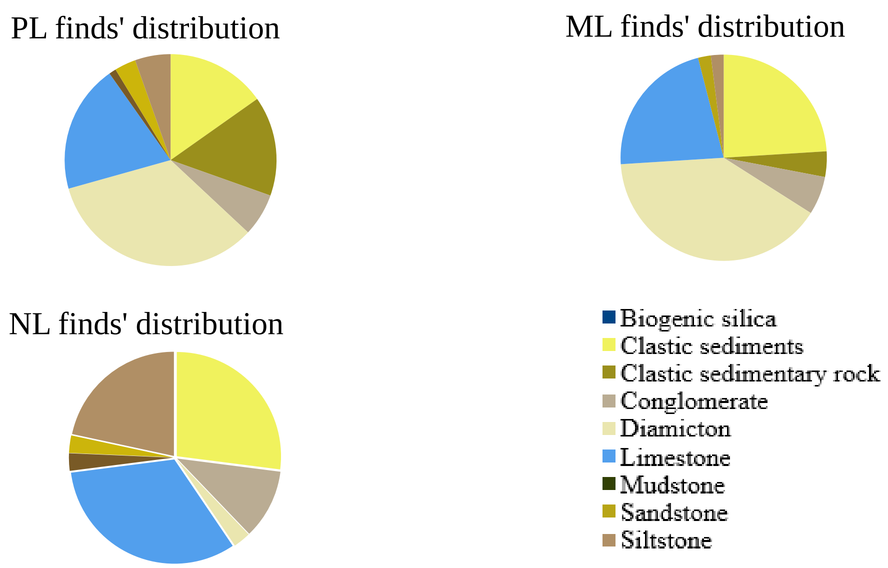

Figure 33 *Percentage of lithology types per time period.* (Figure by Vezoniaraki, E.C.)

Association of finds to a certain type of geology does not necessarily mean the presence of finds on the location of a certain geology. It could also be expressed as a distance from a certain geology, for example limestone, which was not further examined in this project.

Imperviousness

The current landscape can also have an impact on the distribution of archaeological finds. For instance, cultivation of the land, especially when prolonged, can negatively affect the finds' distribution (Wijngaarden 2008; Wijngaarden et al., 2017). Urban areas and more aspects of the artificial landscapes, like roads and quarries can also impede archaeological research and affect the distribution of finds.

Even though the imperviousness map found in Copernicus was not eventually used, a combination of other aspects were considered as factors making areas inaccessible for archaeological research. These were collected by multiple layers, found in Corine 2018 land use, YPEN and some manually digitized additions. The main factors considered when registering areas as impervious disturbed areas, were national and main roads, train rails, cities and settlements, quarries, ports and airports (Figure 34).

The roads layer was a combination of the main roads of the Ionian islands found in YPEN and manually digitised roads, using OpenStreetMaps as a base map. The roads chosen to be digitized were the National road network both old and new, including parts that are under construction. In addition, the main regional roads of the mainland were also digitised (Appendix 7).

Two things need to be noted regarding the road network considered. First, the roads on the islands were not necessarily as big as the ones digitised in the mainland, but they are still the main recipients of reconstructions as the main roads on these islands. Second, there were many find locations' related to roads, and even with smaller roads, not digitised during this project. This is up to a point related to rescue excavations during the construction of these roads.

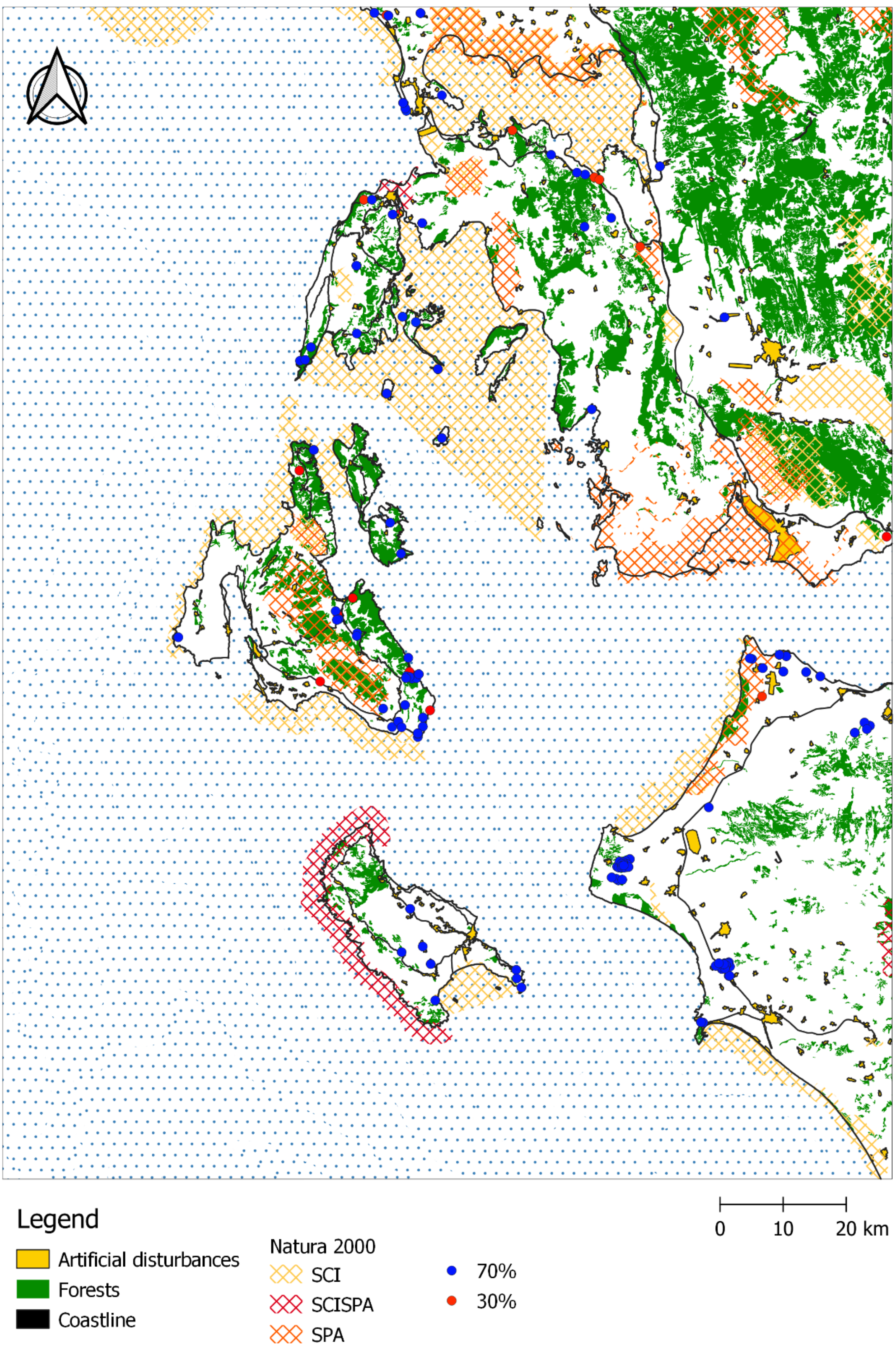

Figure 34 *Various disturbances with locations of finds.* (Figure by Vezoniaraki E.C., sources: CLC 2018, YPEN, OpenStreetMap, SOG & more (Table 2))

Vegetation

The vegetation was considered in terms of wild vegetation and forests, and cultivated land. The maps chosen were used in constructing a layer showing dense woody vegetation. The layer is indicative, and very prone to change, since forest fires are common in Greece during the hot summer months, a phenomenon that has increasingly occurred since the beginning of the Holocene (Lawson et al., 2013).

Information on the different kinds of vegetation can be found at various sources, with several layers in YPEN maps and a few more in Copernicus in the CLC 2018 and Lucas projects. Even though both cultivated land and low, wild vegetation has been mentioned in the literature as impeding archaeological research (van Wijngaarden et al., 2009; Papoulia, 2018b), the wild, woody vegetation can more actively affect both the distribution and the findability of archaeology. For this reason, woodland density was studied through the combination of three layers, and the most dense areas were considered as a significant factor (Figure 34) and added as an extra layer in the final model (see Chapter 5.3). The layers combined were the tree cover density map found in Copernicus created in 2018, the codes 3.1.1-3.1.3 from CLC 2018 and the woody vegetation map found in YPEN.

An observation made when comparing vegetation with various other layers previously mentioned, is the close correlations between vegetation density and higher altitudes. As it can be seen, the regions covered with more dense vegetation are all located on the hills and mountains of the area, making elevation even more relevant as a proxy (Figure 35). That does not mean that all peaks are covered with dense vegetation, rather that dense vegetation tends to survive more on higher peaks.

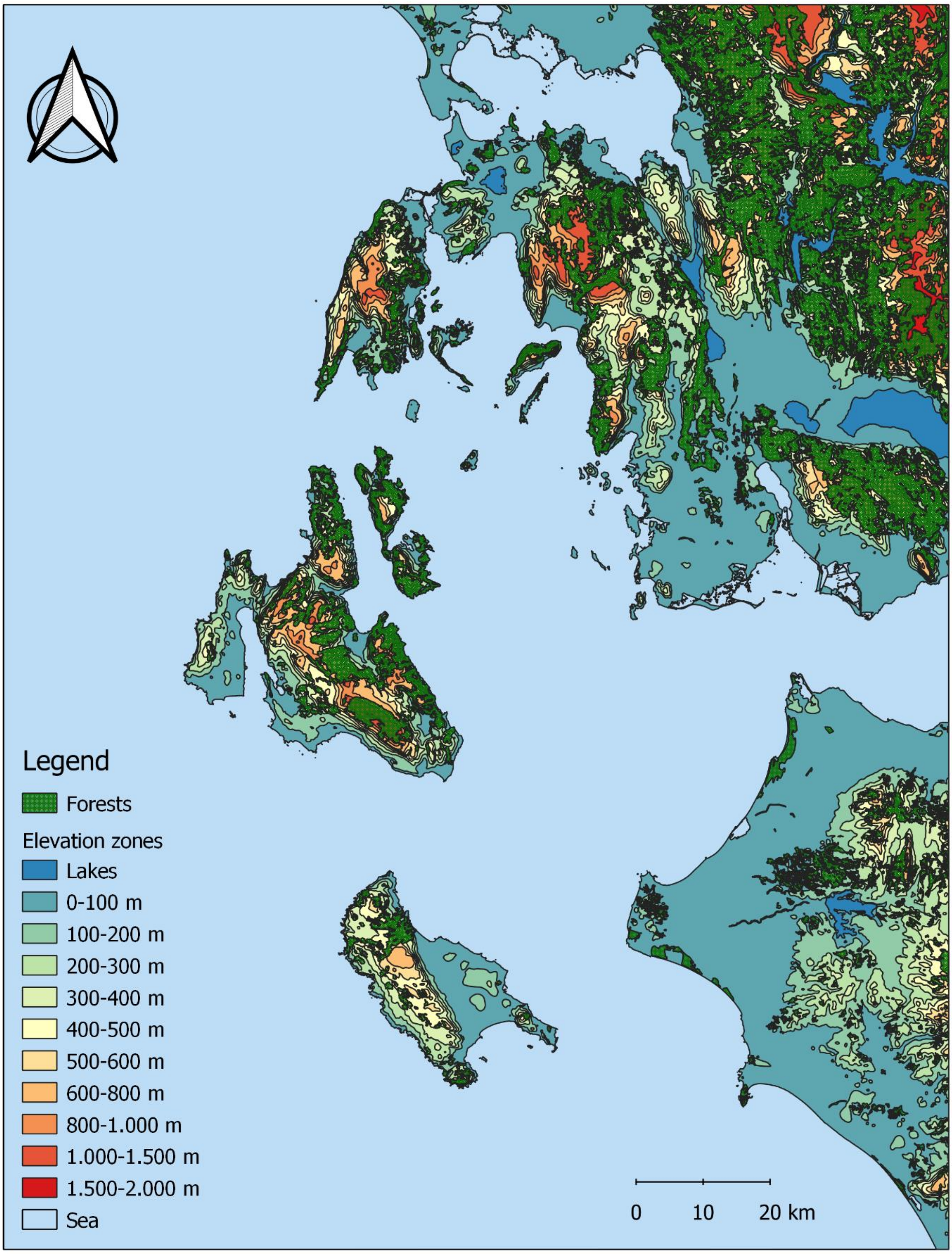

Figure 35 *Forests with elevations zones.* (Figure by Vezoniaraki, E.C., sources: YPEN, CLC 2018 & Copernicus)

4.2.2.3 Other

Soils

Geology has been considered as an important factor in literature, with many research projects focusing their research on areas with reddish soil (Higgs, 1964; Tourloukis, 2010). As in the case of geology, digital open access soil maps were also scarce (see Chapter 3.1.10). Still two maps could be retrieved from the European soil data centre (ESDAC).

The main reason for examining a soil layer, besides their properties in sustaining archaeology, is the relationship established already by Higgs (see Chapter 2.3), and supported by more researchers since (Runnels & van Andel, 2003), that red soils (terra rossa) are more likely to bare archaeological finds, and especially ones dated in the Palaeolithic (Harvati, et al., 2009; Goldberg & Sherwood, 2006; Sakellariou et al., 2015). In Epirus, just north of the research area, a large portion of Palaeolithic finds have been associated with terra rossa soils (Runnels & van Andel 2003). These soils were associated with karstic formations and past water sources, elements often associated with presence of hominins both in Greece and elsewhere in the Mediterranean (Bailey et al., 2020). Terra rossa formations can be produced from the dissolution of limestone in karst plains and cavities (Ligkovanlis, 2014; Runnels & van Andel, 2003) and were potentially important water sources in the past (Runnels & van Andel 2003; Goldberg & Sherwood, 2006, van Wijngaarden, 2008; Bailey et al., 2020). The locations of such karstic springs have been traced both on the current land and currently submerged areas (Sakellariou, et al., 2015; Konsolaki & Kontostavlos, 2004).

Protected areas

In terms of protected areas, besides the areas protected by Natura 2000, YPEN includes maps with a series of national parks with various levels of protection. They were eventually not included in the model, as they were falling inside the areas of Natura 2000 and the degree of protection was vague.

Natura 2000 was included in the model as a supplementary mask layer. The special conditions in each of the designated Natura 2000 areas need to be advised before initiating archaeological projects in the areas under its protection.

Landscape diversity and island size

Another proxy suggested from the literature, is landscape diversity. Cherry (p.191) claims that "diverse and robust biotas" were a clear preference of mobile groups when choosing areas and islands during the Upper Palaeolithic and the Mesolithic. Biodiversity is considered one of the most important environmental proxies in an islands' colonisation by Plekhov et al. (2021), while a combination of strategic hunting grounds, fauna and raw material sources is also supported in Papoulia (2018).

In the Mediterranean landscape diversity is usually related to island size, with the larger islands being more diverse and therefore more attractive than smaller islands (Cherry & Leppard, Leppard). In the case of the research area, some of the smaller islets have evidence of activity as well. This is often attributed to their connection with the mainland in times of low sea levels in cases like the islands of IISA, or due to their use as "stepping stones" in reaching the larger islands of the area (Papoulia, 2018).

In order to evaluate the effect of landscape diversity in the distribution of Stone Age finds, a better understanding of palaeo-environments is required. The relationship between island size and the occurrence of finds is also not possible in the chosen research area since there is no indication on whether the finds on the smaller islets are products of intermediate stops, seasonal exploitation or something else.

4.2.2.4 Social and cultural aspects

Social and cultural factors are often overlooked when creating a predictive model, especially for the earlier parts of prehistory, being hard to trace due to the lack of information over these aspects of life. Still, such factors could have influenced the distribution of finds in a way that could be never understood by studying environmental and economic aspects alone. Due to the large timespan under study by this thesis, it is expected that such aspects would have varied significantly for each period, hominin species and even part of the research area (Galanidou, 2011). Still, it is almost impossible to investigate their nature, and as a consequence their effect on the finds' distribution. This part is discussing some of the theories proposed in the literature that hint at such parameters, and other observations that could potentially indicate the coexistence of both environmental and other preferences.

For the needs of this project, the social and the cultural aspects of past life will be discussed together, as the aspects beyond simple environmental parameters. As social aspects, everything related to social identity, relationships and interactions is considered, and the term “cultural” incorporates all kinds of behaviour that goes beyond practicality, including potential traditions, art forms, symbolism or ritualistic behaviour.

Caves, rock-shelters and the example of Drakaina cave

One of the most prominent factors that could be related to more than environmental reasons, is the use of caves. Caves were used in all three time periods under study in Greece to a lesser or greater extent. Occupying caves was most likely common practice during the Stone age, as the numerous cave and rock-shelter sites of Greece showcase (Galanidou, 2011; Gkioni, 2008; Karkanas, 2002; Bailey et al., 2020). There are several cave sites in the research area, like Choirospilia (Ntouzougli et al., 2006), Hagios Nikolaos cave near Astakos (Benton, 1947), Choirotrypa and the Kythros cave (Galanidou et al., 2016), but the case of the Drakaina cave in Kefalonia stands out from the rest. The Drakaina cave is located in Poros gorge, in a prominent location combining strategic overview of both the valley and Inner Ionian Sea (Stratouli, 2005), with good visibility due to its location on an altitude of 70masl (Karkanas & Stratouli, 2008). The site has multiple occupational phases, the earliest of which are dated in the late Neolithic (Stratouli, 2004; Stratouli 2005; Melfos et al., 2016), and has numerous finds that have been interpreted as signs of social identity and ritualistic behaviour (Karkanas & Stratouli, 2008; Stratouli 2004; Stratouli 2005; Metaxas et al, 2014). Besides these finds, there is evidence of repetitive plastering of the floor of the cave, activity that points to specialised knowledge and communal effort, perhaps related to the seasonal use of the cave (Karkanas & Stratouli, 2008; Stratouli, 2005).The Drakaina cave knows no parallel in the research during the Neolithic but shares some common elements with later examples, such as the Kapros rock-shelter dated in the Bronze age. The similarities are limited to some hints of ritualistic behaviour, among others the excessive breakage of decorated pottery and the use of red pigment (Stratouli 2005; Yiannouli, 2022). Besides these two cases, hints of Palaeolithic ritualistic activity have been traced in some more caves on islands of the research area, but the related finds and results are awaiting publication (N. Galanidou, personal communication, December 9, 2022).

Mapping the location of caves and rock-shelters is next to impossible in the research area in the absence of targeted field work and recording of such locations. Due to the geology of the area, such openings are very common both above and on the current sea level (Bailey et al., 2020), and there have been cases in both Greece (Bailey et al., 2020) and Cyprus (Moutsiou et al., 2021) were such cases have a notable absence of finds, even though in the case of the former they have animal remains from the Pleistocene (Bailey et al., 2020). Adding a buffer around the few known cave sites would also be of no use, since according to their finds, there is no social or cultural aspect implied yet. Therefore, this parameter could not be implemented in a predictive model yet.

Raw material sources

Raw material sources are often mentioned as a proxy according to which past hominins oriented their activity (Gallou et al., 2018; Moutsiou et al., 2021; Papoulia, 2018; Kamermans et al., 2011). The research area is rich in sources of good quality cherts in both the islands and on the foothills of the Pindos mountain range (Benton 1947; Gallou et al., 2008; Ligkovanlis, 2014; Papoulia, 2018b). And even though clear distinctions exist between the sources of lithic raw materials, such as in the case of Zakynthos, were pebble flint and nodule flint are used only in the vicinity of their sources (G.J.M. van Wijngaarden, personal communication, October 26, 2022), mapping the potential sources of cherts in the research area would be a project on its own. This distinction between using pebble flint and other local types of flint can be traced in other areas as well, relating to different time periods (Kamermans et al., 2011).

Nevertheless, the choice of certain types of materials in certain areas, could be related to more than practicality. In Melfos et al. (2020), the providence of the materials found in the Drakaina cave is discussed, proving that both local and imported materials were used for different uses. Some of the material found in Drakaina, were imported from large distances, all the way to Naxos in the Aegean sea, showing that at least in some cases, raw material played an important social or cultural role. The famous “honey” flint is another example of material hinting at social or cultural importance (Randsborg, 2002). There has been a long discussion over the origins of this type of flint brought to light also in Drakaina cave, and praised for its knapping quality (Melfos et al., 2020). Some researchers are supporting origins from as far as modern-day Bulgaria (Kourtessi-Phillipakis, 2009), while others counter argue that it was a local material (Melfos et al. 2020). Due to the lack of available maps pinpointing the locations of preferred raw material sources in precise areas throughout the research area, and since the literature implies an abundance of raw material sources, this parameter was also not implemented in a predictive model either.

Prominent landscapes

High elevations and steep landscapes might be harder to approach and study, but there is a series of locations with archaeological finds in such locations, potentially implying preference of such areas. On its own, elevation's impact is hard to discern from other parameters like soil, slope and water, having similar effect on the present finds' distribution, potentially clustering them on lower elevations. As discussed earlier, active tectonism and other natural and anthropogenic processes have also taken their toll on the palaeolandscape, transforming it since the time of the primary deposition of finds.

Locations such as Englouvi and the highest part of Achiouri valley, prove activity on higher grounds. The Drakaina cave and Hagios Nikolaos' cave near Astakos (Benton, 1947), are two examples located on steep cliffs, while Atokos, although insular, has signs of hominin activity, something potentially related to its prominent landscape (Magganas et al., 2019). Elevation is one of the chosen environmental proxies used to create the predictive model of the area, but viewshed and visibility analysis could potentially have a lot to offer in investigating the social or cultural aspect behind such choices. In order for high elevations to be considered a social or cultural factor, more research needs to be conducted in the area, so this parameter was not considered separately as a parameter, but it influenced among others the decision on the value given on high altitudes (see Chapter 5).

4.2.3 Testing the model

The splitting of the archaeological finds' locations in 70-30, where a random selection of 30% of the locations of the final dataset was removed, and used for testing the model. The 70% kept was used in estimating the degree to which each factor seemed to affect the spatial distribution of the archaeological finds. This percentage was chosen as a middle ground, because the dataset includes both isolated and clusters of points, making a more radical choice less ideal. The final total of locations of archaeology per time period is listed on the table below (Table 5).

Each of these location contains an often unspecified number of retrieved finds, ranging from isolated surface finds to up to a few hundred in some cases, like the ones from the area of Skoulikado-Kallimahos, which were 310 at the time the article was written (van Wijngaarden, 2017).

As mentioned before, the database used in incorporating archaeological site locations in the maps was recovered from SOG, under relevant queries. The chosen dataset, though, did not include many finds retrieved in the research area, dated during the time periods under examination. The total points before splitting them in 70-30 were the combination of SOG locations with the locations manually added.

Table 5 *Locations' quantity.* The total amount of locations' of finds per time period, and the amount of used locations (70%). (Table by Vezoniaraki, E.C.)

Total points	**PL**	**MPL**	**UPL**	**ML**	**NL**
SOG	88	59	39	64	35
Other sources	13	11	7	8	18
Total	101	70	46	72	53
Used (70%)	**71***	**49***	**33***	**51**	**38**

Note: PL=broader Palaeolithic, MPL=Middle Palaeolithic, UPL=Upper Palaeolithic, ML=Mesolithic and NL=Neolithic.

*The broader Palaeolithic (PL), Middle (MPL) and Upper Palaeolithic(UPL) finds were used merged. The total amount of locations used for Palaeolithic after merging was 92.

At this point, a disclaimer needs to be added. Throughout the whole process of evaluating the layers described above, only the 70% of the total known locations were used (Figure 13). The remaining 30% was only considered in the testing of the model.

4.3 Predictive model

The proxies chosen to be used in the creation of the final model are proximity to water, elevation, depth and landslide susceptibility. These factors could be both incorporated in the model, and seemed to be relevant in literature (Gkioni, 2008; Moutsiou, et al., 2021; Papoulia, 2018b; Perakis & Moysiadis, 2011; Runnels et al., 2005; Sakellariou et al., 2015) and in relation to the known locations.

Chosen parameters:

i. *Proximity to water in low elevations*

In an attempt to incorporate diversity as a proxy, the combination of proximity to the water and low elevations was used as the highest value in the model. By combining the two, there is a high chance of accurately tracing the co-existence of proximity to water sources, fauna and therefore potential hunting grounds. The low elevations were chosen to be combined with water both due to the higher findability prospective and ease of access. Both proximity to fresh water sources and elevation, have been used combined as proxies in several similar cases modelling the Stone Age (Moutsiou, et al., 2021; Perakis & Moysiadis, 2011; Runnels et al., 2005).

ii. *Proximity to water*

Water could have been the first and foremost factor (see Chapter 4.2.2). According to the studied literature, proximity to sweet water sources would be the highest value if it could be traced accurately, which unfortunately is not the case. The same is true for the proximity to the sea. Since we cannot accurately trace it even compensating with buffers, it was "demoted" as a less high value.

iii. Elevation

As mentioned before, elevation seems to be the most relevant in terms of post-depositional processes and findability. All archaeological sites used in the creation of the map, are located up to 500masl in elevation. Present-day accessibility and erosion should not be overlooked though, so higher elevation zones received a lower value in the predictive model, in contrast to the lower elevation zones.

iv. Depth and landslide susceptibility

Depth had to be considered as the current sea level is higher than it used to be in the past (see Chapter 2). The 0 to -200m zone, excluding its highly susceptible to landslides, received a higher value than the deeper zones. Still the area could not receive a value higher than medium, due to the low prospects of recovering finds from these areas.

Even though the distributions are different among the time periods under study, they are affected similarly by the chosen parameters (Table 6). This is why only one model was created instead of three, since the differences among the three different maps would not necessarily reflect the distribution more precisely (see Chapter 6.1.1.2).

Table 6 *Chosen parameters and their sources.* Only the sources used in the final model and mask layers are mentioned. (Table by Vezoniaraki, E.C.)

Chosen parameters	**Use**	**Source**
Elevation	Archaeological predictor	YPEN
Rivers	Archaeological predictor	Copernicus River net & Copernicus EU-Hydro Pinios, CLC 2018 5.1.1
Lakes	Archaeological predictor	CLC 2018 5.1.2
Lagoons	Archaeological predictor	CLC 2018 5.2.1
Depth	Archaeological predictor	YPEN
Landslide susceptibility	Archaeological predictor	EMODnet
Coastline (inland buffer)	Archaeological predictor	CLC 2018 5.2.3
Known finds' locations	Archaeological predictor	SOG, Archaeological Cadastre, Literature (see Table 2)
Coastline	Reference	CLC 2018 5.2.3
Bathymetric points	Reference	YPEN
Natura 2000	Protected areas mask	Natura 2000
Forests	Natural disturbances	YPEN woodland, CLC 2018 3.1
Roads and railways	Artificial disturbances	CLC 2018 and Vezoniaraki, E.C.
Urban centres	Artificial disturbances	CLC 2018 1.1
Industrial areas	Artificial disturbances	CLC 2018 1.2
Quarries, dump	Artificial disturbances	YPEN, CLC 2018 1.3
Ports and airports	Artificial disturbances	CLC 2018
Salines	Artificial disturbances	CLC 2018 4.2.2
OpenStreetMap	Background	OpenStretMap

5. Results

This chapter is dedicated to the presentation of the final model and a brief description of its results. As mentioned before, the main factors chosen and used in the creation of the model are proximity to sources of both saline and freshwater, elevation, depth and landslide susceptibility. Supplementing these, artificial landscape elements like roads, quarries, and urban areas were compiled into one layer, representing areas with disturbed soils and a reduced probability of holding finds. In additional maps, the forested areas are depicted and the areas protected by Natura 2000.

5.1.1 Mapping archaeological potential

The predictive model created represents all three time periods under study (Figure 36). The values correspond to different levels of archaeological potency, extending from 1 to 6, with 1 being the parts with the highest probability, depicted with dark red, and 6 the parts unlikely to hold related finds, coloured in white. Each value is explained in more detail below. The rivers are narrow, linear features and are not represented separately from their buffers on the map.

The model produced for the current thesis is for all the time periods under study. The reasons behind these choices have been described in the previous chapter, and their implications are discussed in the next chapter. This chapter is dedicated to describing the model and defining the probability value assigned in each category.

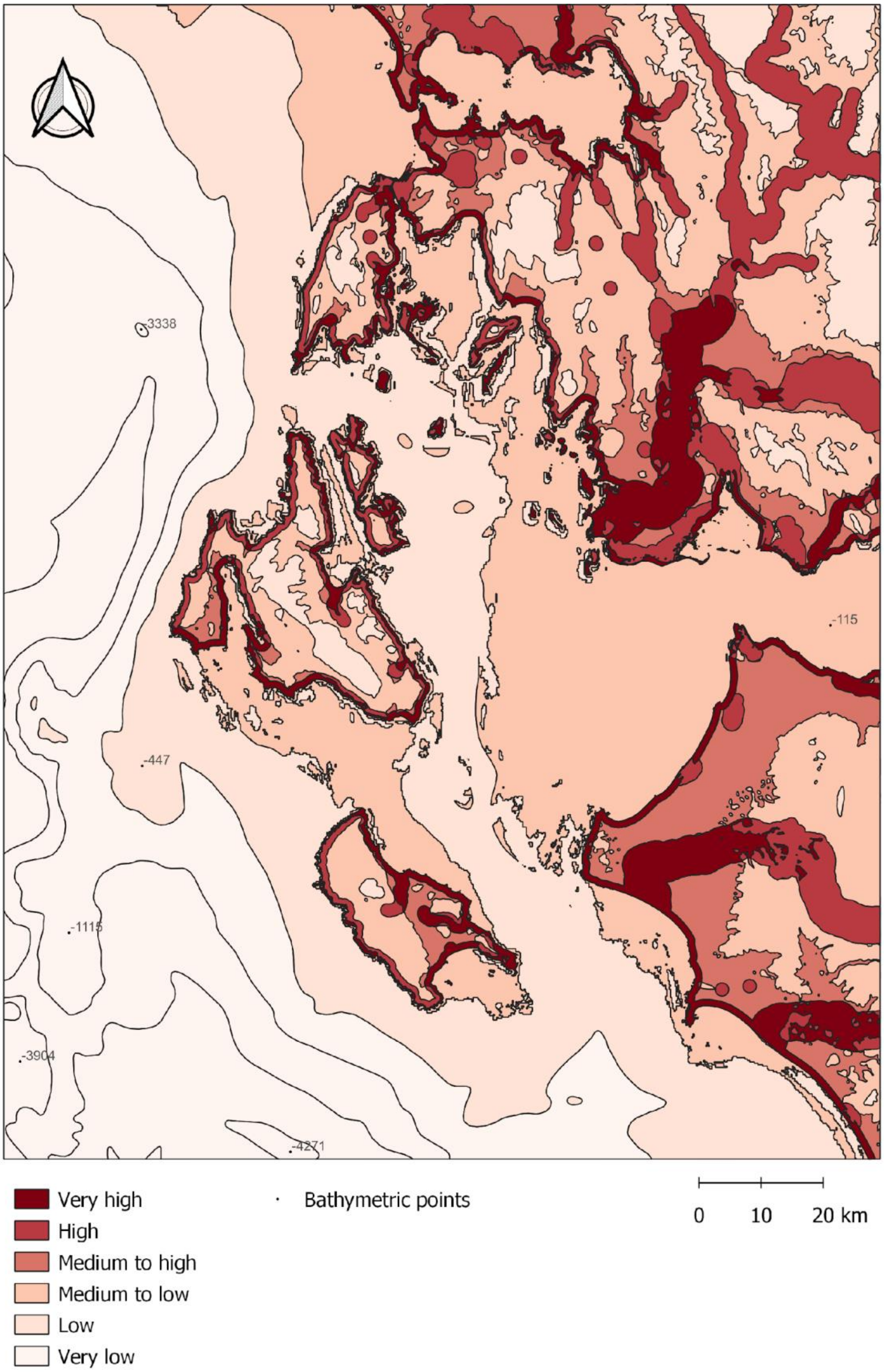

Figure 36 *Map of archaeological potential for the Stone Age*. (Figure by Vezoniaraki, E.C.)

1-Very High

The areas marked as very high are the parts of the area combining proximity to the larger rivers of the area or the current coastline, with low elevation. The areas today covered with water, like the sea and the lakes are not included in this value.

2- High

The areas marked as high are the remaining buffers around the bodies of water, regardless of their elevation. This includes the inland water bodies themselves, but not the sea.

3- Medium to High

As of medium to high probability are marked the areas located in the 0-100masl elevation zone, excluding the areas marked with higher values mentioned above.

4- Low to Medium

The medium to low value is the first value considering the sea as well. It includes the medium elevations, above 100masl up until 500masl and the shallower bathymetric zone extending up until -200m below the current sea level. From the bathymetric zone, the parts with high landslide susceptibility were removed and included in the following degree of probability. Even though the areas included in this value were included for different reasons, they are still considered equally capable of currently holding related finds.

5- Low

The areas marked with a low degree of probability, are the areas with high elevation above 500masl and depths between -200m and -1000m below current sea level. As mentioned above, it also includes the parts between 0 and -200m that are more prone to underwater landslides. High elevations are not considered as value 6, since there is no proof of absence on high altitudes yet.

6- Very Low

Finally, the rest of the area is marked as very low in terms of probability to hold finds, and are the areas deeper than -1000m below the current sea level. These areas are not only less likely to hold finds, but also less likely to hold retrievable Stone Age finds.

5.2.2 Artificial disturbances

Features like quarries, main roads with a 25m buffer around them, urban and industrial areas, ports and airports were included with a mask layer as “artificial disturbances”. These features are considered to have impacted the soil underneath them to an extend that they either already encountered or sealed the archaeology below them. These locations are depicted in bright yellow in order to be clearly visible (Figure 37).

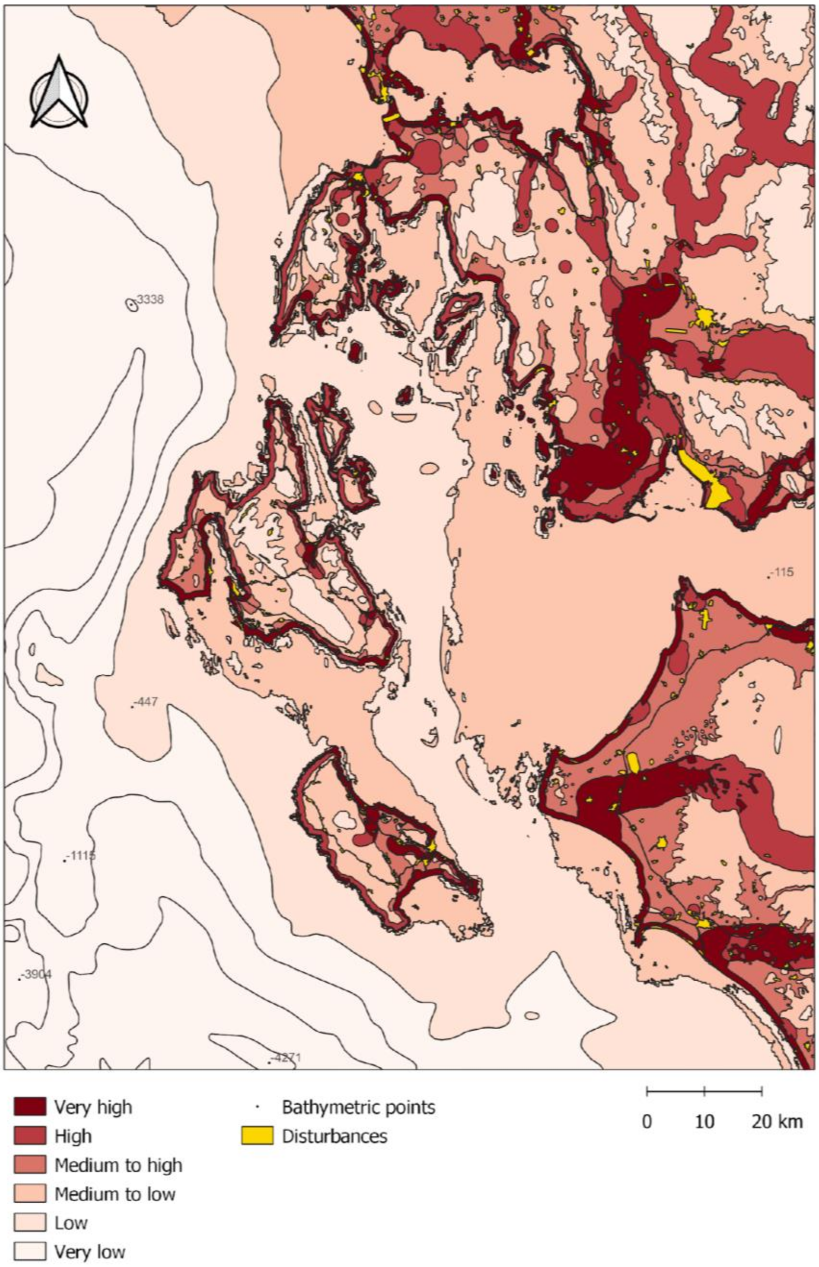

Figure 37 *Archaeological potential map for the Stone Age.* The artificial disturbances are represented in gold by a mask layer. (Figure by Vezoniaraki, E.C.)

This layer was used in two ways. In the case of Figure 38, the artificial disturbances mask was integrated in the model as of Low (5) archaeological potency, since the archaeology of these areas is relatively inaccessible or lost. In the case of Figure 37, these disturbances remained in a separate layer and were not integrated in the values of the archaeological potential map, for clarity and ease of use, and even future adaptations.

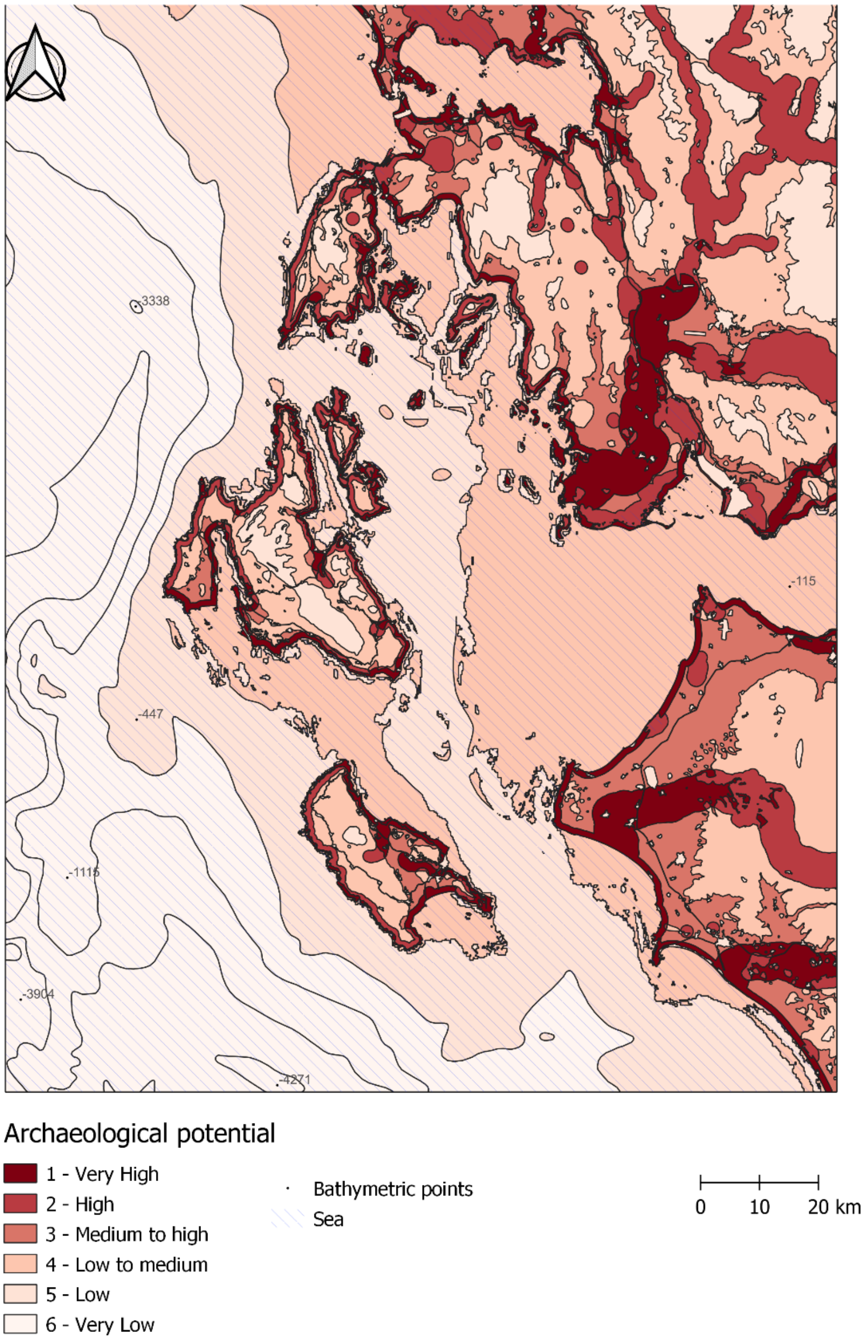

Figure 38 *Revised archaeological potential map for the Stone Age.* The artificial disturbances have been integrated as 5 - Low (Figure by Vezoniaraki, E.C.)

5.2 Forests and Natura 2000

The layer related to the forest covered parts of the research area are depicted in a separate mask as well (Figure 39). They only represent the areas covered by relatively dense woody forests and parks. This layer was considered separately due to its susceptibility to change (see Chapter 4.2.2).

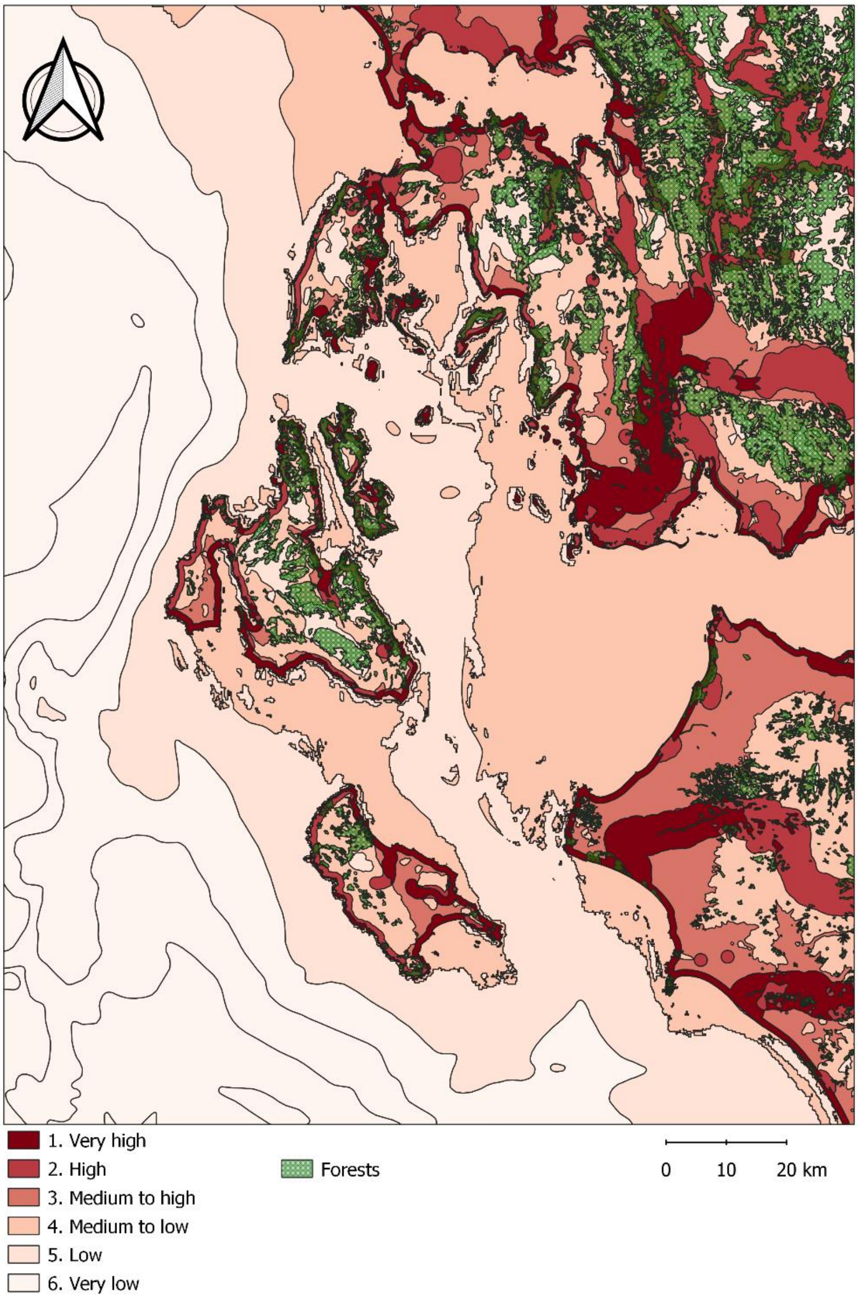

Figure 39 *Forest coverage over the modelled area.* (Figure by Vezoniaraki, E.C.)

Another mask layer created is a map showing the areas protected by Natura 2000 (Figure 40). The three types of protection are represented by different coloured meshes, so the degree of probability is still visible in the background. The protections of Natura 2000 can vary according to the species or habitat that is protected. These mask layers should be considered as indicative of potential limitations when it comes to archaeological research, both having had an impact on conducted research, and in restricting future research in these areas.

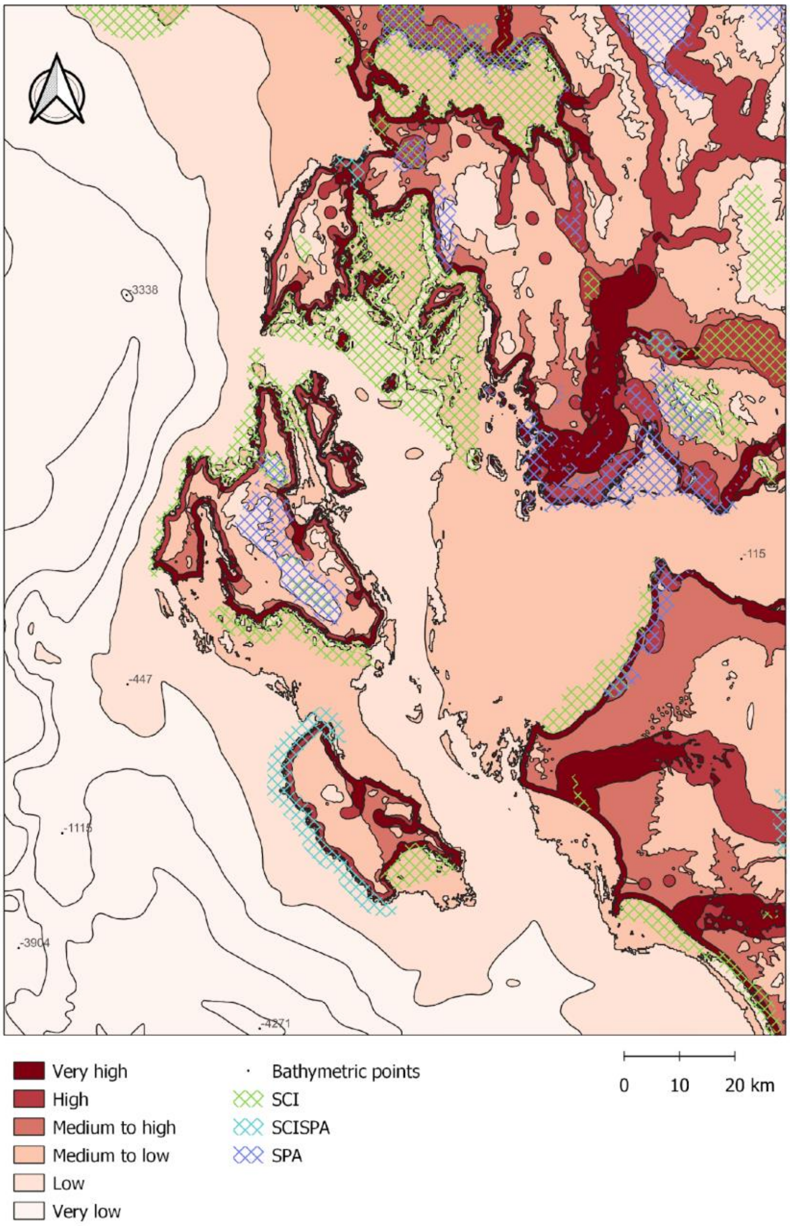

Figure 40 *Natura 2000 areas over the modelled area.* (Figure by Vezoniaraki, E.C.)

5.3 Split-test results

The following maps depict the results of the split-test, when the remaining 30% of the total finds' locations was studied along the predictive model (Figures 42, 43 & 44). The results of the split test can be found on the table and bar graph below (Table 7; Figure 41).

Table 7 *Split test results.* The results are presented per time period and per archaeological potential value. (Table by Vezoniaraki, E.C.)

Period	**1**	**2**	**3**	**4**	**5**	**6**
PL (47)	12	3	**25**	8	-	-
ML (21)	4	1	**12**	4	-	-
NL (15)	**9**	2	2	2	-	-

Note. The Palaeolithic finds include the merged 30% of broader Palaeolithic, Middle and Upper Palaeolithic. The majority of locations for each time period is bolded.

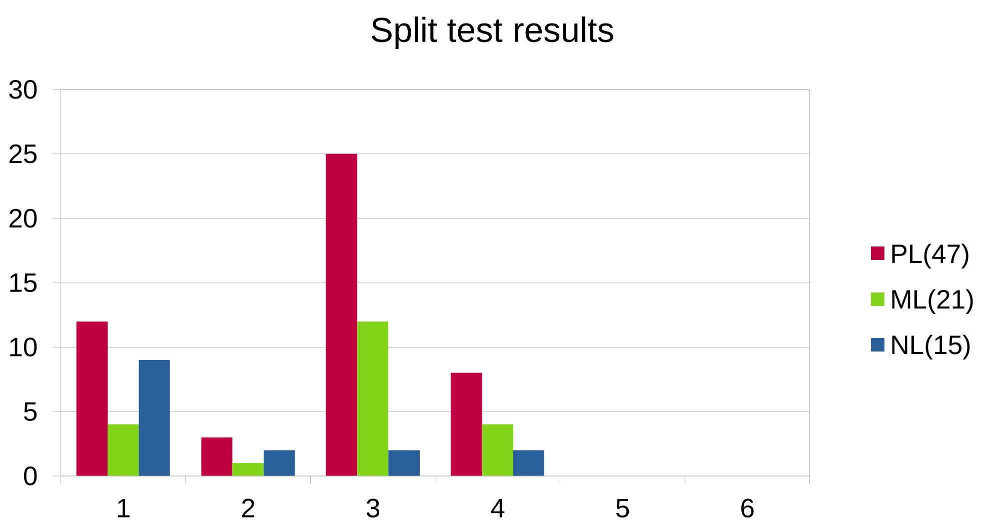

Figure 41 *Split test results per time period.* The total amount of locations of each time period is noted in the bracket next to its initials. PL=merged Palaeolithic locations. (Figure by Vezoniaraki, E.C.)

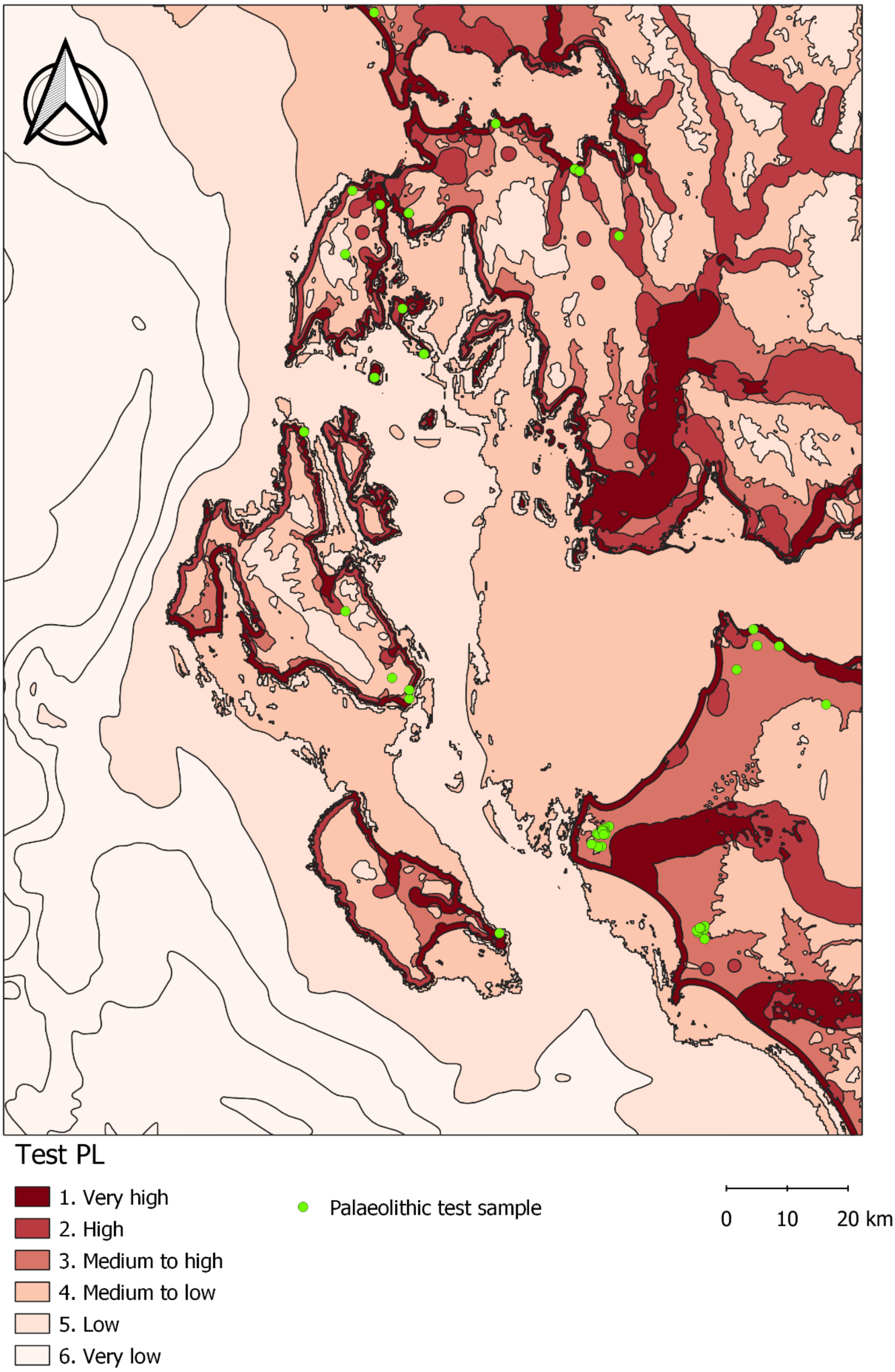

Figure 42 *Testing sample of the Palaeolithic on the archaeological potential map.* (Figure by Vezoniaraki, E.C.)

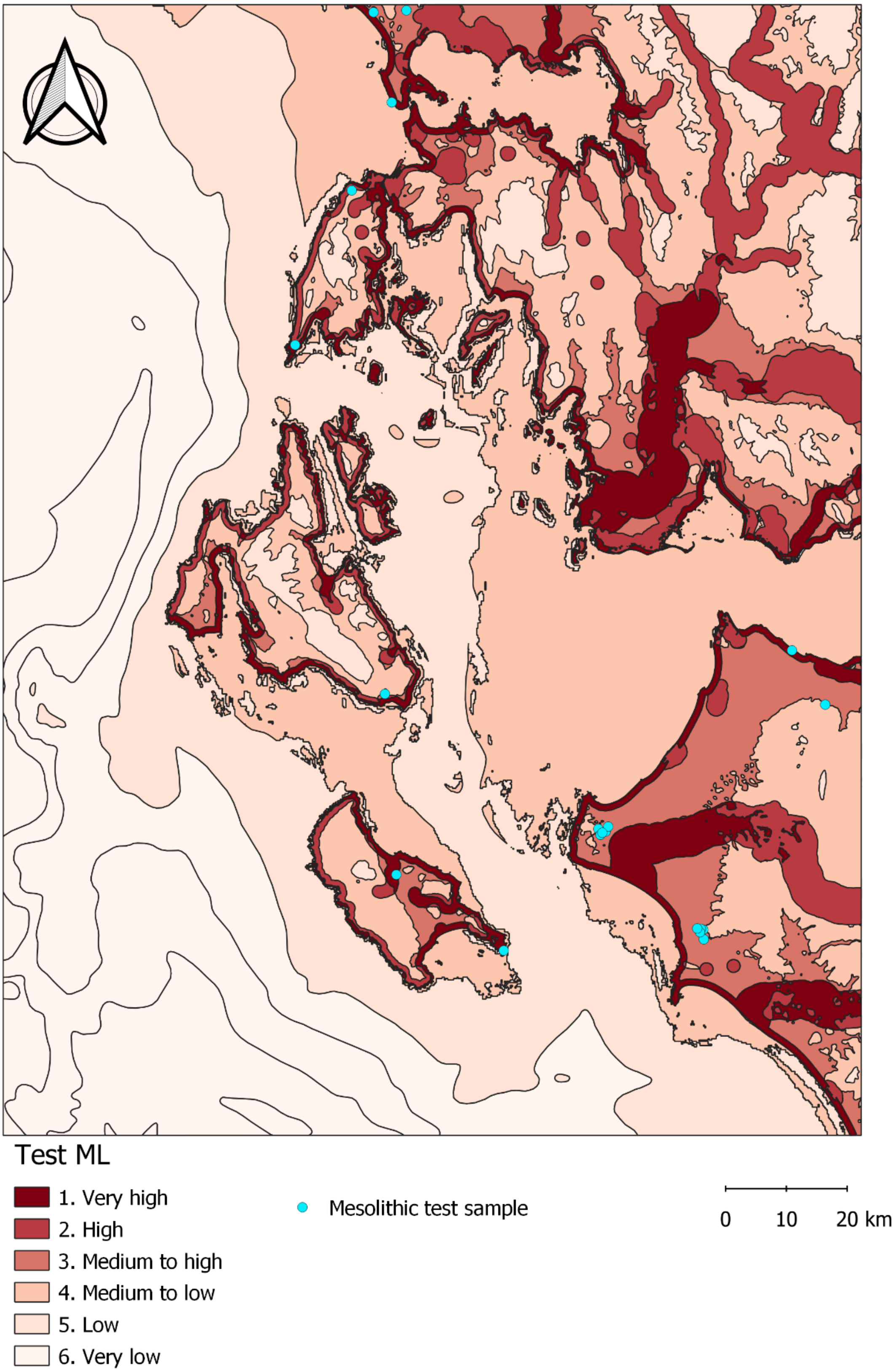

Figure 43 *Testing sample of the Mesolithic on the archaeological potential map.* (Figure by Vezoniaraki, E.C.)

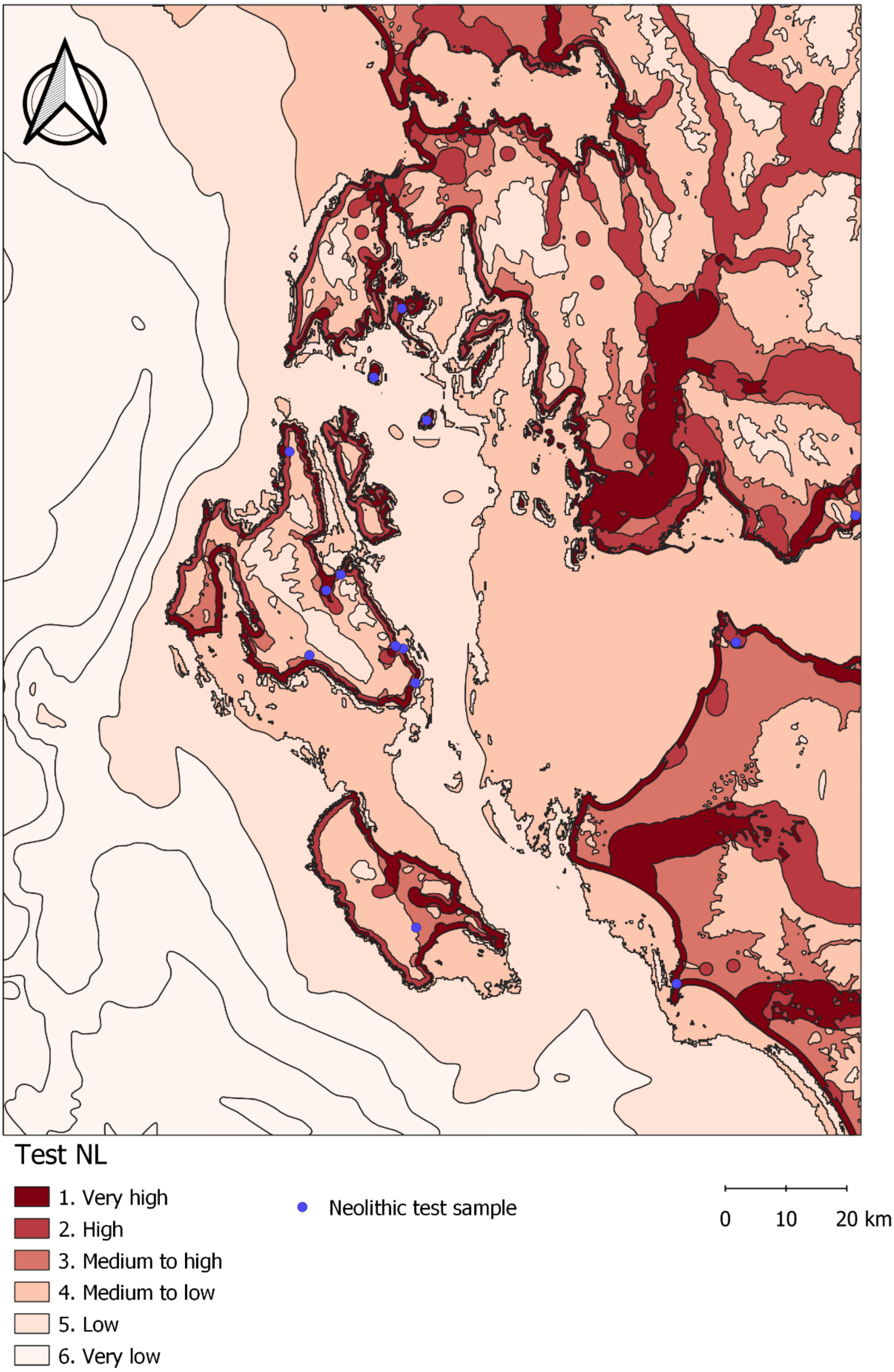

Figure 44 *Testing sample of the Neolithic on the archaeological potential map.* (Figure by Vezoniaraki, E.C.)

The test showed that the vast majority of the known locations is distributed across the values 1-4, with value 3 and value 1 including the majority of the locations, followed by value 4 and then value 2. Values 5 and 6 had no associated finds' locations (Figure 41). Value 3 represents the areas that are low in elevation and further away from the water sources as traced through buffers around the contemporary bodies of water.

Another interesting pattern is the different percentages of locations covered between the three time periods under study. While in the case of the Palaeolithic and the Mesolithic periods the value concentrating most test locations is the medium to high value (3), the Neolithic finds locations' majority falls in the area marked as very high (1).

After adding to the results the information recovered from the two mask layers including the forested areas and the ones with disturbed soils due to later activity, it is visible that both layers have finds recovered from those areas (Tables 8 & 9). This is to be expected, in the case of the first due to the multiple field walking projects and the inconsistency in the density of vegetation which is not yet mapped in detail (Table 9). Still, as it can be seen (Figure 45), the locations where finds were recovered from are on the verges of the forested areas and not in their denser parts.

In the case of artificial disturbances, finds were also expected due to rescue excavations and the field walking projects like the one along the main road in Aitoloakarnania (Figure 45). Again, a considerable amount of finds, were recovered from these areas (Table 8). The major difference among the two results is that the areas marked as artificial disturbances are less likely to hold more archaeology than the forested areas, and therefore their impact on a predictive model is more significant. The mask layers were compared to all three time periods separately for both the 70% and the 30% of the finds, in order to record and evaluate their full effect on the known finds' distribution.

Table 8 *Locations with finds' recovered in artificial disturbances areas.* (Table by Vezoniaraki, E.C.)

Period	**70%**	**30%**
Palaeolithic	9	3
Mesolithic	3	3
Neolithic	6	1

Table 9 *Locations with finds' recovered in forested areas.* (Table by Vezoniaraki, E.C.)

Period	**70%**	**30%**
Palaeolithic	14	13
Mesolithic	9	4
Neolithic	6	4

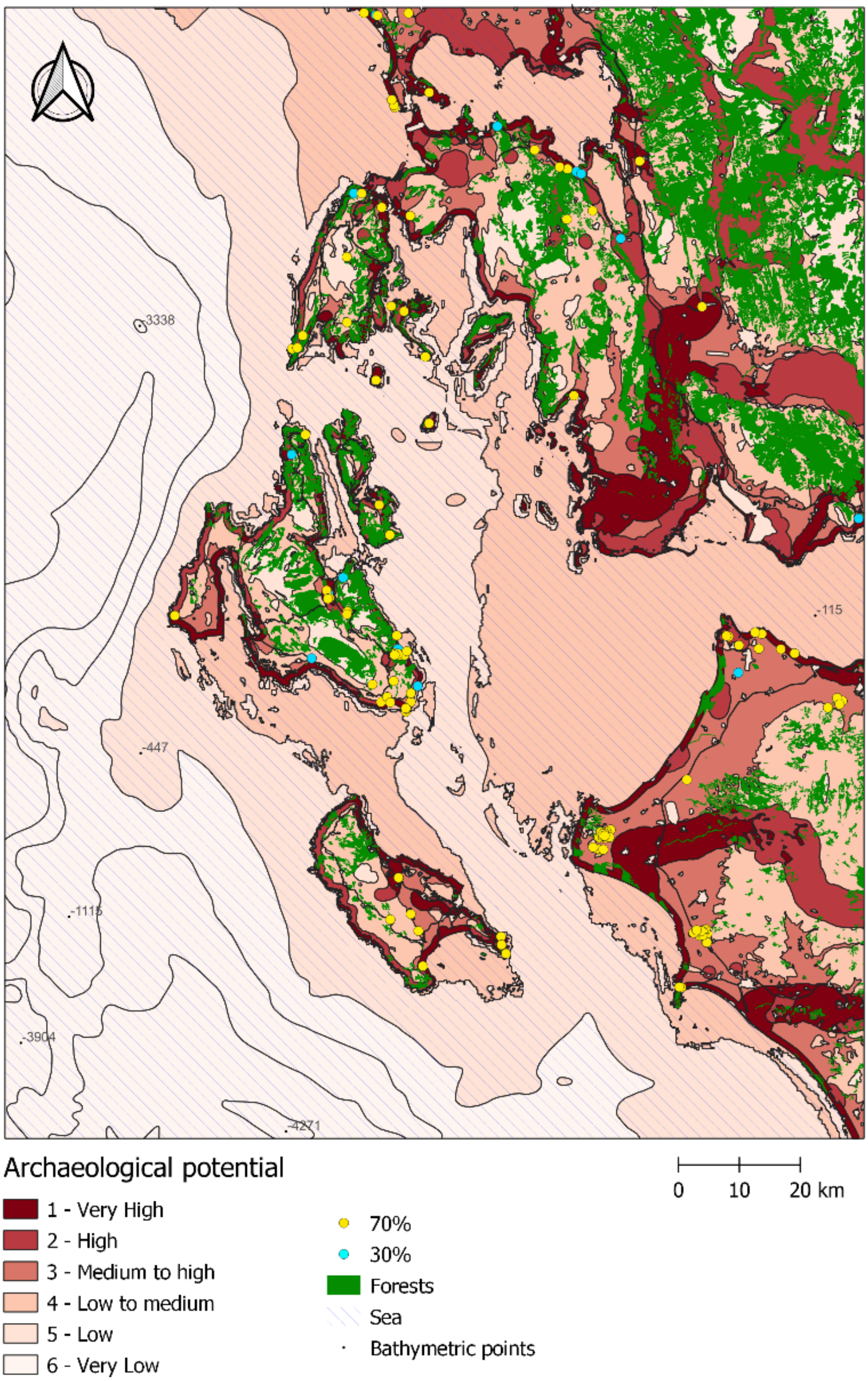

Figure 45 *Archaeological potential map with all locations and disturbances*. The artificial disturbances are integrated as 5 – Low. (Figure by Vezoniaraki, E.C.)

6. Discussion

So far, the main aspects of the research area have been discussed, the available material explored and the methods leading to the creation of the predictive model have been presented. The reasoning behind the choices made has been partly explored and the final model and accompanying layers have been analysed. Following up the creation of the model, this chapter dives deeper into the choices made and their implications, reflects on the process followed, how the model tackles the research questions and where it stands in terms of the inherent risks of predictive modelling.

After explaining, assessing and interpreting the resulting model, it proceeds in comparing it with other predictive models, with similar case studies or time periods, and challenges it with alternative methodological pathways that could have been followed. In the end, the model is evaluated, by discussing its overall limitations and benefits, some suggestions for furthering the benefits are made and the research questions are answered.

6.1 Reflecting on the creation of the model

This predictive model attempts to step back and observe the ongoing regional and local archaeological research, refraining from zooming in too much on any specific location or time period. To achieve that, it combines a variety of parameters that would reasonably affect the distribution of finds according to the literature, and note whether they seem to relate to the known distribution of relevant archaeological locations or not. In the process, open source datasets were preferred, while common limitations of predictive modelling were factored in.

6.1.1 On the methodology

This part of the discussion analyses the challenges faced during the creation of the model and the choices made along the way. This includes both the materials used and the method chosen in the process of creating the final model. In many ways, the methodology followed in this project was inspired by the predictive model created by Moutsiou et al. (2021).

6.1.1.1 Locations of finds and map layers

Archaeological finds' locations

First of all, some of the limitations of the main archaeological sites' database used in this thesis, Prehistoric Stones of Greece (SOG), need to be discussed. First and foremost, it is essential to keep in mind that SOG mostly includes surface finds which due to their exposed nature cannot be securely dated and have been found out of context. Furthermore, each point in the database could represent from one up to many dozens of finds, information that can be found on the website but is not included in the retrievable .csv files. Due to the large number of locations, the amount of finds could not be manually added for each of these points, so the locations were treated equally. These locations were not characterised as "sites" in order to avoid the implications of the term (McCoy, 2020).

In addition to this, there were some compromises that had to be made in order to study the Palaeolithic. The first compromise is related to the finds dated in the Lower Palaeolithic in the literature. This thesis does not claim that there are no Lower Palaeolithic finds in the research area. Due to the lack of Lower Palaeolithic finds' locations according to the SOG database, this sub-period was not studied separately. Since the Lower Palaeolithic finds in the research area are not securely dated and as such under debate (Tourloukis, 2010; definitely one more), and in order to avoid misinterpreting and duplicating the known locations provided by SOG, these locations when added, were considered broadly as "Palaeolithic". The second compromise that was made in regard to the broad dating term "Palaeolithic", used to describe a large amount of finds. This term was used for non-indicative finds that could be dated in more than one sub-period of the Palaeolithic, meaning that they could be associated with one of the periods already mentioned in another sub-period. To deal with such an issue, this broader category should be disregarded, or somehow merged with the finds of the other sub-periods. In an attempt to not completely disregard it due to the large amount of locations with this characterization, and since this thesis is studying the Stone age in a broader framework, the locations of this broad category were merged with the Middle and the Upper Palaeolithic ones. The locations that coincided exactly on top of others were merged in one point to avoid duplicate points. The Middle and Upper Palaeolithic periods have a lot of differences with each other, both in terms of palaeo-landscape and of types of finds.

Last but not least, it is crucial to remember that the SOG database is very limited in regard to the Neolithic, potentially excluding an invaluable amount of locations. This needs to be taken into consideration when reaching into any conclusions on the distribution patterns of Neolithic finds in the research area. As a consequence, Neolithic was treated with caution and was analysed to a lesser degree compared to the Palaeolithic and the Mesolithic.

When it comes to the extra locations added through the literature, these were chosen from a few publications per sub-region of the research area and are potentially missing locations mentioned in other sources. These extra locations were added only if they were noticeably away from the existing points, but also if they had a different assigned date or series of dates in the literature in order to fill the chronological gap.

In addition, for the sake of the broader approach this thesis adopts, the locations found in the literature were added and simplified in the database, avoiding over-clustering extensively researched small areas. In that sense, areas like Meganisi island, were represented with a single point representing finds and time periods recorded. Another form of simplification had to be made on locations with finds characterised as Neolithic/ Early Bronze age. In the cases where the separation between the two time periods could not be derived from the literature, the point was added and marked as “Neolithic”.

Furthermore, these extra points were added in approximation based on maps and descriptions found in the literature or the Archaeological Cadastre, so their association with certain environmental parameters and archaeological potential values could theoretically be inaccurate if they are located on the border between two values. This level of inaccuracy is not substantial enough to alter the resulting model, but it should still be recognised.

Map layers studied

The maps found and studied had their own limitations and benefits. Already in Chapter 3 the chosen databases were discussed along with their main features. The ones chosen and implemented on the model were analysed in Chapter 4. Here these used datasets are examined once more, according to their limitations and benefits in the broad spectrum of GIS and predictive modelling in Greece. In general, the availability and accessibility of maps was better than originally expected. Even language was not as big of a barrier in map availability for English-speaking users.

First, the quality and quantity of maps varied significantly throughout the research area, with some parts having many more and much more detailed available maps than others. This was connected to the degree in which they were studied by one or more recent projects in the area. To avoid these unequal amounts of detail, maps that spread throughout the research area were preferred in all cases, even though they were less detailed and less suitable for zooming in to specific regions. In a future project aiming to study smaller parts of the area the sources used by this thesis might not be as fitting.

Second, there was a general lack of free geology and especially soil maps in the research area. IGME offers geology maps of Greece, divided in smaller regions, but they needed to be purchased, so they are not examined in this project. Besides this case, most other maps were global or national maps, either too broad or images of old paper maps. The only exceptions were maps focused on parts of the research area, and were only used as a reference, to avoid unequal degree of detail.

Lastly, the vector polygons used by YPEN were preferred over the raster counterparts from the same source. The same holds true for all sources that provided both raster and vector layers, like Copernicus. In the case where there were no vector counterparts, such as in the case of the landslide susceptibility map, the raster layer was vectorised.

6.1.1.2 Manipulating layers and choices made

In order to create the predictive model, some choices had to be made regarding the manipulation of the chosen layers which could have led to very different results if changed. This part discusses these choices and their impact on the resulting model.

The decision with the larger impact on the creation of the final predictive model was by large the decision to make one model for all three time periods under study. The first research question of this thesis aims to study the influence of the environmental factors that affected hominin activity and occupation across the different time periods under study. In order to tackle this question and establish the different patterns, the distributions of known locations of each time period were independently compared with the layers recovered, both in terms of original deposition and present location. The different patterns were traced both in the maps and in the literature. Yet, in the end a single model was created for all these divergent time periods. The reasons behind this choice have already been partially mentioned (see Chapter 4.3), and here they are explained in more detail.

1. One of the larger changes between the three time periods is the sea level at the time. The sea level fluctuated drastically, to an extent that is not yet accurately traced. In addition, due to the dynamic changes affecting the past landscapes and coastlines, the palaeo-coastlines have not yet been reconstructed sufficiently to be integrated in the model for each time period under study. But even in the case that the coastlines of the past were known, still the currently submerged locations have less potential of presently holding retrievable Stone Age finds, that can be predicted through the available layers. Therefore, across all three models, the values assigned to each of the bathymetric zones would have been the same. An exception could have been made for the Neolithic, since the coastline at the time was closer to the present day one, but maritime activity was established, so the possibility of submerged finds that can be recovered from shallower waters is still higher than the deeper or more susceptible to underwater erosion ones.
2. In the case of Holocene soils covering some parts of the research area, these soils could have received a lower value when studying Palaeolithic distributions and treated

differently when studying Mesolithic distributions. Still, there are cases where such Holocene soils hold earlier finds, most likely due to post depositional processes, like in the case of Zakynthos (Figure 46). Therefore these regions could have been modelled differently, but this could potentially lead to biased results.

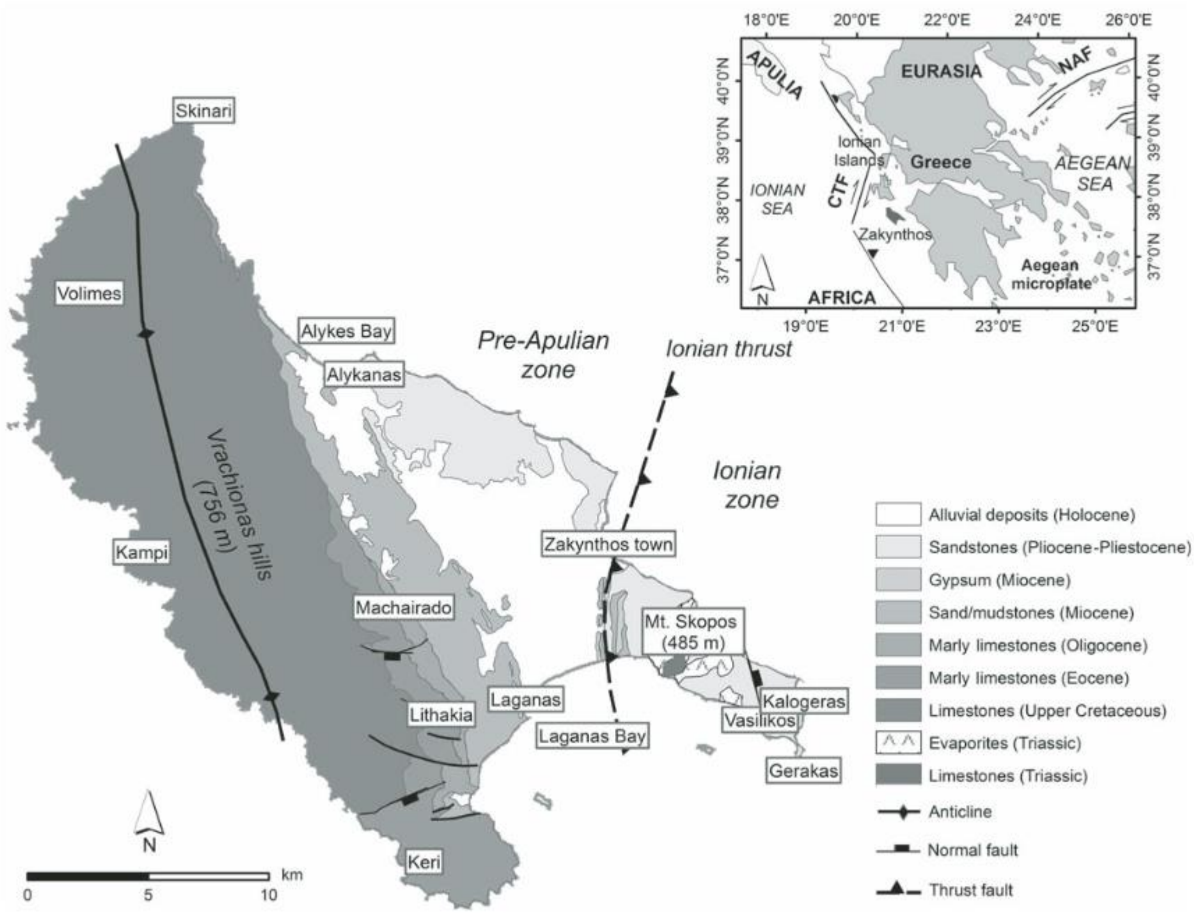

Figure 46 *Geological map and tectonic features of Zakynthos.* (Tendürüs et al., 2010)

3. In the two cases where it is hypothesised that parts of current islands were separated from the rest (see Kef and Zak), the coastline buffers during the times when they were separated would have been different. Such changes could justify the presence of finds on areas further away from the present coast, like for example along Vrachionas mountain range in Zakynthos. In the end, due to the broader stance this thesis adopts, the suggested reconstructions of the past coastline on these two locations were not implemented in the model.

4. The rest of the factors, which are elevation, underwater landslide susceptibility and proximity to inland water bodies, were based on the present day landscape. In the case of elevation and proximity to water, their effect on the finds' distribution across all time periods appeared to be the same, so there was no reason to assign different values on them per time period. High landslide susceptibility would also affect the distribution of submerged finds similarly for all time periods, although it would have been harder for Neolithic finds to have been deposited so far offshore.
5. Finally, the Neolithic was the period where the majority of changes were expected when compared to the previous two time periods, due to the change in the dominant lifestyle from a mobile to a sedentary one and everything it entails. Still, this time period's finds are severely lacking in comparison to the previous two, even so, the model produced seems to explain their distribution to a large extent. Therefore, a separate model between the two prominent lifestyles was not deemed necessary.

Besides this decision two more choices regarding the rivers and lakes made in the creation of the model should be mentioned. First, even though the combination of proximity to water and low elevation seemed to justify the location of many of the finds, it needs to be noticed that rivers could both attract hominin activity and conceal it, by washing away finds or burying them under layers of sediments when their route changes (see Chapter 6.1.2). Second, the present day rivers themselves could have been removed from the buffer as disturbances. In the grand scheme of things, they would only be represented by a line representing only their current course though, so they were not removed. Third, natural and artificial lakes were not treated differently when applying buffers around their current state. This convention was necessary due to the lack of knowledge on the pre-existing landscape, and the fact that these areas would have still be, according to the current landscape, crossed by a river.

The exclusion of social and cultural factors was made necessary due to the lack of robust evidence on the existence of such factors especially during the first two time periods. The lack of evidence along with the lack of available maps that could be used to test the theories proposed in this thesis, lead to inability to spatially map and quantify the effect of these parameters on the finds' distributions.

Finally, natural environmental factors are not always easy to tell apart from the anthropogenic changes of an environment. Such examples include the use of fire (Lawson et al., 2013), manipulation of the river networks (Parow-Souchon et al., 2022), and the impact of humans on the flora and fauna, especially during the late Mesolithic and the Neolithic (Makohonienko et al., 2021). This kind of anthropogenic influence of past hominins on the landscape was not integrated in the model in any way.

6.1.2 On the results

The predictive model produced combines parameters chosen and weighted both from the literature and through studying the known finds' locations. Being built this way, it was not adjusted in order to perfectly spatially incorporate the known finds in the high value zones. Instead it combines the patterns that could be traced both through the known distribution and the observations made in the literature. When testing the model, it became clear that the areas suggested as of higher archaeological potential, did indeed include most of the known finds' locations.

Interestingly, for two out of the three time periods under study, the areas marked as of "1 - Very High" archaeological potential were not the ones accumulating the majority of finds, nor were the areas marked as "2 - High". Instead, value "3 - Medium to High", was the one with the majority of finds for both the Palaeolithic and the Mesolithic periods. In addition, value "2 - High", accumulated the least amount of finds out of the three higher values across all three time periods. The extent of these three areas marked with higher values is roughly the same (Table 10), so size was not the decisive factor.

In order to interpret this phenomenon, one needs to discuss the parameters used to classify these areas' archaeological potentials. Value 1 includes the parts of the research area that combined low elevation and proximity to water based on buffers around the present day water bodies.

Value 2 included the rest of the buffers and inland water bodies, and value 3 incorporated the areas with elevations below 100masl that are located further away from the current water bodies. The fact that value 3 accumulates more finds than the previous two in the earlier time periods studied, suggests that elevation is a more significant factor than proximity to water, which seems to be avoided. Could it be that proximity to water is overestimated as a parameter?

Before reaching any controversial conclusions, it is essential to remember that the majority of the known locations used in this thesis are surface finds, and therefore finds greatly susceptible to post depositional processes and recovered out of context. Fresh water sources and especially rivers, although essential for survival, are ever-changing and can disturb the finds located near them when changing the courses, carrying them away or burying them under layers of alluvial sediments. In both cases, the finds located near rivers are less likely to be recovered as surface finds, which does not equal that they are absent. In the case that these finds are buried under alluvial deposits, they can still be recovered through trial trenches and excavations. In the case that they were carried away towards the sea and cannot be located near the rivers, it is possible that they can be recovered near the river deltas or buried under sediments below the current sea level.

Another possible explanation for the apparent distance of the known finds from the current water bodies, could be a result of a drastic change at some time in the past, changing the water bodies' locations so drastically, that the current water bodies are located in a totally different area than they were in the past. Though that could be proposed for the coastline, inland water bodies are framed from higher elevations, and their courses and locations can be traced in the geomorphology of the area, making such significant changes less possible. The sea on the other hand, is known to have undergone drastic fluctuations during the Pleistocene, and it is common knowledge that the paleo-coastlines are currently mostly submerged. Therefore, the known Palaeolithic finds are, to an extent, finds deposited farther away from the coast, making underwater archaeology even more necessary in the area.

All things considered, the reduced number of finds currently located near water bodies, could be explained by the above mentioned factors. Yet, one cannot dismiss alternative explanations without further research, investigating if indeed proximity to water as a parameter has a "reverse predictive utility" (Kvamme, 1988, p. 329), indicating absence instead of presence. In that case, the relationship of past hominins with water might need to be reconsidered, but such a claim cannot be proved by the current known distribution of finds. Whether low elevations further away from water bodies need to receive the highest predictive value for the Palaeolithic and the Mesolithic, due to the severe later post depositional disturbances of the finds originally located in a closer proximity to water, can also not be suggested based on the known finds' locations.

6.1.3 On material availability and openness

One of the main goals of this thesis was to assess the available digital material and whether creating a predictive model based on open source data is possible. In sum, the number and quantity of the available open source data exceeded the greatly original expectations, both in terms of literature and digital data.

There is a large amount of relatively new articles and publications openly available online, even though there are several ongoing projects in the research area. There are many examples of journals who are in the process of digitising their older issues and making them available online, for instance Pharos journal. There was at least one dataset (SOG) in an open repository (ADS), with a significant amount of finds and finds' locations, sufficient for predictive modelling even in smaller areas than the one chosen in this thesis. Naturally, the existence of free, open source maps was what made the realisation of a predictive model possible. Sources like Copenicus, YPEN and EMODnet were catalysts, making publicly available a large amount of maps, easy to incorporate and manipulate in GIS, accompanied by metadata and open to alterations and reproduction. The degree of openness and the creative commons restrictions varied among the sources, and so did the resolution of the provided maps, but ultimately sufficed in laying the groundwork for the creation of a predictive model and other GIS applications.

6.1.4 On predictive modelling

Archaeological predictive modelling as a method has some inherent issues that can result in unwanted outcomes. Some of these are listed below, along with the measures taken in this thesis in order to avoid any negative aftermaths.

Predictive modelling can often lead in self-fulfilling prophecies, especially when the known finds are used both in building and testing the model (Wheatly, 2004). Such a danger is not unique in predictive modelling. Any archaeological theory based on finds can be leading in self-fulfilling prophecies if none attempts to disprove it. The model created in this thesis was not created solely on the basis of the known finds. The suggested archaeological potential values were proposed through the combination of known locations and theory, sometimes contradicting each other, trying to remain partial and retain a broader scope of the archaeology of the research area. Still, just like any other theory and hypothesis, it can still be biased by the known distributions and current state of research.

Self-fulfilling prophecies can be also produced by going into too much detail when creating a predictive model. It is next to impossible to factor in all possible aspects that could have affected the finds' distribution, especially in such early time periods, when most aspects are largely unknown. That is the reason why a broader approach was preferred, creating a baseline model by looking at the broader picture.

Another potential danger of predictive modelling that was attempted to be tackled with, is the more than often exclusion of social factors in archaeological predictive modelling. Even though social and cultural aspects are to a large extent unknown for the time periods under study in the broader area, some potential factors have been proposed and discussed. Hopefully, in a future project more factors can be examined and implemented on an enhanced predictive model. Nonetheless, environmental determinism can be fraught with perils, but we are still creatures bound by space and living in certain landscapes, the effects of which should not be underestimated.

Finally, predictive modelling in archaeology could become a tool in the hands of people with malicious intentions against archaeology. Looting tombs and purposefully destroying archaeological sites and finds to avoid delays in constructions can be a real problem in archaeology. Yet, inclusion of the public is the inevitable step that archaeology has to make in order to leave its ivory tower. Involving the public could lead in breaking through some of these prejudices placing archaeology in the realms of treasure hunting or a burden in development and infrastructure.

6.2 The bigger picture

The following chapters discusses some examples of predictive modelling that have already been applied in similar contexts on the Mediterranean, underlining the possibilities that predictive modelling has to offer even in the study of complex environments and distant time periods. In the second part, some alternative examples of predictive modelling applied across the world are discussed. The method chosen and applied in this thesis was a very broad, simple and transparent application of predictive modelling, but there are many more types of predictive modelling that can be applied using the same datasets showcased here.

6.2.1 Insular and coastal landscapes of the Mediterranean

As mentioned before, there have been two more predictive model projects in Greece that aim at predicting locations of archaeological interest for time periods relevant for this thesis. These are on the Argolid and on Magnesia (Figure 2) and are investigating the Mesolithic and the Neolithic respectively (Runnels et al., 2005; Perakis & Moysiadis, 2011). Beyond their differences both models agree to an extent to the values relevant to the finds' distribution. In another case study in Cyprus, Moutsiou et al. (2021) reach a similar conclusion when modelling the Pleistocene occupation of the island. Past their differences, these models all agree on two factors as being of high importance in predicting stone age finds' locations; elevation and distance to water. Even though they are targeting different time periods, these proxies seem to apply to all of them.

Similar patterns are noticed in cases across the Mediterranean, agreeing with the parameters chosen to be applied in this thesis. Kamermans et al. (2011) in their study of the Palaeolithic in Agro Pontino region, Italy, which combines coast, valley and high mountains (>500masl), also conclude that elevations over 300masl tend to have less Palaeolithic finds than the valleys and coastal areas. Whether that reflects personal or social preference, practicality or lack of preservation is not known, but it is noticed that there is still evidence of activity in the higher elevations as well.

Meanwhile, along the Mediterranean coasts of France an association with Palaeolithic sites and caves, coastal lagoons and karst springs has been made, contradicting the patterns noticed on its Atlantic coastline (Bailey et al., 2020). This relation between types of preferable at the time landscape features and longitude can be supported by the results of more studies (Plekhov et al., 2021; Parow-Souchon et al., 2022), especially when studying agropastoral societies (Plekhov et al., 2021). Even though the case study modelled in Parow-Souchon et al. (2022) is also located near the Mediterranean coasts of Southern Levant, the model produced for the Upper Palaeolithic, has very divergent results from the ones presented so far, due to the largely different environment. Still, elevation and aspect are positively relevant, while slope and terrain ruggedness are negatively affecting the distribution of finds. In the case of agropastoralism related finds, elements such as area, distance, configuration, and demographic pressure have been proposed (Cherry & Leppard, 2017), while Plekhov et al. (2021) uses the term "noisier" when discussing the associated distribution patterns, being harder to trace and interpret.

Activity near the coastline seems a common denominator in many areas around the globe across the time periods under study (Spikins & Engen, 2010; Perlés, 2016; Bailey et al. 2020; Reyes et al. 2016). Due to eustatism, most of the coasts of the distant past are presently submerged. By the dawn of the Neolithic, however, the global sea level was not that different from the present day one, placing these sites very close to the coastline. On a project in the Italian peninsula, Bailey et al. (2020) noticed that the steeper western coast was richer in Neolithic finds than the Adriatic coast. If the pattern holds true, and there was indeed a preference on coastal locations, the Neolithic finds would be located further off the Adriatic coasts, since the area is more shallow compared to the western coast (Bailey et al., 2020).

In this project, depth and underwater landslide susceptibility were proposed as an outset in including submerged landscapes in archaeological predictive modelling of the Stone Age. The different underwater conditions should be, however, also ultimately considered when creating a predictive model including submerged and partly submerged landscapes. Conditions like for example the levels of salinity, the temperature and the anaerobic conditions related to local seabed fauna could highly influence the preservation and distribution of archaeological finds (Benjamin, 2010). Therefore, just like modelling the land, each case study considering submerged and partly submerged landscapes should consider a variety of parameters and be treated in its own context (Benjamin, 2010).

6.2.2 Alternative approaches

Eustatism had a global effect and there are many more areas with high tectonic activity near the coastlines. Each combination of factors might differ but studying how similar case studies were treated, can provide interesting alternatives in applying predictive modelling in the research area and validating the produced models' results. This chapter studies different ways that the Stone Age has been modelled in Greece and parts of the world, seeking to compare the results and potential effectiveness.

Some of them have already been implemented in other contexts in Greece, like the Dempster-Shafer theory (Perakis & Moysiadis, 2011). This method has some advantages over simple statistical modelling, because it can represent ignorance "spatially in a quantitative way" (Perakis & Moysiadis, 2011, p. 430). Another advantage of this method is the possibility of increasing and decreasing the effect of each variable per time period, which in its turn produces models focused on a very specific time period. The method has been proven to successfully predict Neolithic site locations in the case of Magnesia, although it was not used for the separate phases of the Neolithic period. The model has not been tested on periods prior to the Neolithic either, but the proxies studied are not too different from the ones used in building the present model. Water, based on the current water network, elevation, slope and aspect, and modern-day settlements were studied, while the known archaeological sites were used in training the model.

A broader methodological framework has been proposed and explored through the example of Macedonian tombs in northern Greece (Balla et al., 2014). The authors propose a selection of research data and approach, followed by a quantification of the chosen criteria, and then the appointment of weighted values in each of them. These criteria are then combined in a predictive model, tested for its predictive gain and value. Attributing and calculating the weight of each criteria can be done either through statistics or with a relative correlation of the chosen values as in the predictive model created. The models produced were tested with the known locations. Even though it succeeded in pinpointing the most important factors, this approach risks resulting in a self-fulfilling prophecy.

Besides the various applications of predictive modelling in Greece, other parts of the world have a similar degree of complexity in terms of the factors affecting the Stone Age and lithic tools' distribution. One interesting case in point, is tackled in Omar et al. (2018). They study and reconstruct the shorelines of Chonos archipelago in Chile by studying the anthropological deposits on various distances from the present-day coastline. The area studied is also greatly affected by the tectonic activity, although in this case it mostly takes the form of subduction of the Antarctic plate under the South American plate. Using the archaeological deposits as palaeo-indicators the study estimates the sea level rise and drop of the past, through the existence of finds associated with risen or subsided landforms. In the research area under study the main tendency over the years was that of gradual submersion of past landmasses, but studying material recovered from underwater archaeology could be very valuable indicators of past landscapes.

Following an unusual approach as well, Schoville (2013) studies the edge damage of Middle Stone Age points recovered from two caves in South Africa. By approaching taphonomical processes as causal agents of the wear imprints on the tools, he is seeking to reconstruct the palaeo-landscape through studying the located finds, letting them narrate their stories themselves.

Wachter et al. (2018) follow a different approach, comparing the results of applying two different predictive modelling methods in two very different case studies. The two methods compared are logistic regression and maximal entropy. Logistic regression is based on presence or absence of sites according to the known locations, with no possibility to factor ignorance in, like with the Demster-Shafer theory. Also, absence is generally avoided since it is usually not explored to the same degree as presence, and absence of known finds most often does not mean absence of finds. Maximal entropy runs simulations studying all sites alongside all parameters before reaching into the most likely conclusions agreeing with both the known distribution and all the relevant parameters. Maximal entropy performed better with both small and large datasets, could be implemented in shorter time periods and generally produced models with a higher predictive gain in both cases.

Lastly, there are some more aspects worth studying when trying to predict the distributions of finds on an area. Knowing the environmental sustainability (Plekhov et al., 2021) and carrying capacity of the different parts of the research over time would be very useful in predictive modelling, assisting with tracing the non-environmental factors behind the distribution of finds. Studying other aspects of past life, like diet can have the same effect. Perlés (2016) studied the exploitation of littoral resources and how it changed from the Upper Palaeolithic to the Mesolithic. The study proved that the choice of food resources was not strictly dictated from their availability and ease of access, but also preference. Such indicators of culture could be relevant for the research area as well, but there is no evidence so far proving or disproving such observation.

6.3 Predictive model in retrospect

"The fact that it has been possible to construct a predictive model does not in itself guarantee the accuracy of its predictions" (Conolly and Lake 2006, p.184). In the following chapter the final model will be examined in retrospect, ultimately judging its contribution in the archaeological research of the area by evaluating it through three efficiency evaluation methods proposed in the literature. Finally, the overall benefits and limitations will be discussed.

6.3.1 Evaluating the model

The chosen inner evaluation methods chosen to be discussed are Kvamme's Gain (Kvamme, 1988), Wachtel's performance effectiveness evaluation (Wachtel et al., 2018) and Verhagen's criteria for quality definition of a model (Verhagen, 2007b). These methods have been chosen due to their different approach on the subject, being more statistical, quantitative or theoretical.

6.3.1.1 Kvamme's Gain

The first method was proposed by Kvamme (1988) and is defined with the following equation:

$$\text{Gain} = 1 - \left(\frac{percentage\ of\ total\ area\ covered\ by\ model}{percentage\ of\ total\ sites\ within\ model\ area} \right)$$

This method aims at assessing the gain of the model, by estimating the portions of areas in which the majority of finds are located. The possible gain varies from 1 to -1, with 0 being the least indicative value, with basically no predictive value. Above 0 means positively predictive, with the closer to 1 the higher the precision. On the other hand below 0 means "reverse predictive utility" which can still be of use, but it is not ideal (Kvamme, 1988, p. 329). The following table (Table 10) shows the results of applying Kvamme's Gain on the model, using the entirety of the area with the total of known locations. The positive values are bolded.

Table 10 *Kvamme's Gain.* The Gain was calculated based on Kvamme (1988). (Table by Vezoniaraki, E.C.)

VALUE	AREA %	LOCATIONS %			GAIN		
		PL	ML	NL	PL	ML	NL
1	5%	30%	31%	55%	**0,82**	**0,82**	**0,90**
2	6%	4%	3%	11%	-0,52	-1,33	**0,43**
3	6%	48%	54%	21%	**0,87**	**0,89**	**0,71**
4	31%	17%	13%	13%	-0,80	-1,45	-1,32
5	25%	0%	0%	0%	-	-	-
6	27%	0%	0%	0%	-	-	-

Note: Palaeolithic (PL) is merged, Middle and Upper Palaeolithic were not evaluated separately.

It becomes immediately apparent that values "1 – Very High" and "3 – Medium to High" are scoring very positively across all time periods, in contrast to values "2 – High" and "4 – Medium to Low". Generally the first three values carry the vast majority of the finds as they should, but the prominence of value "3 – Medium to High" is once again clearly shown. In sum, the first and third values are highly positively predictive. Still the absence of known locations on the second value should be further explored before it can be safely assumed that it is indeed reversely predictive.

6.3.1.2 Performance effectiveness evaluation

The second evaluation method has been proposed by Wachtel et al. in 2018, when comparing the performance between two different predictive modelling methods in two dissimilar case studies. Wachtel et al. (2018, p. 33) suggest that in order for an archaeological predictive model to be deemed effective, the 80-85% of its total finds need to be located in less than 33% of the total research area marked as of high probability. They propose separate tests for used and control group locations, in various re-selection combinations. In the following table (Table 11) the control group and training data are presented together. Due to the small percentages of area that the three first values cover, they were evaluated together as the values with the higher archaeological potential. No further random re-selection and sub-division was applied to the known locations, due to the high performance across all time periods. As the table demonstrates, across all time periods more than 80% of the finds are in an area much smaller than 33%.

Table 11 *Performance effectiveness evaluation.* The performance effectiveness was evaluated based on Wachtel et al. (2018). (Table by Vezoniaraki, E.C.)

Total Area (Values 1-3)	**PL**	**ML**	**NL**
17%	82%	88%	87%

Note: Periods include 100% of finds. PL stands for is merged Palaeolithic, including broader, Middle and Upper Palaeolithic.

6.3.1.3 Quality definition

Verhagen (2007b) has proposed a series of five criteria that can evaluate the predictive quality of a predictive model. These criteria will be briefly discussed for the predictive model produced.

1. "Good models should provide an explanatory framework of the observed site density patterns" (p. 285). During the process of creating the predictive model, the reasons behind the observed patterns were always considered in relation to the environmental aspects under study and the theories proposed in the literature.
2. "Good models should be transparent" (p. 285). This criteria has been also considered, and each step of the process of creating the model was thoroughly described in an effort to make it easy to reproduce.

3. “Good models should give the best possible prediction with the available data set” (p. 285). When considering the seemingly unorthodox conclusion with the high predictive value of value “3 – Medium to High”, this point appears to not have been entirely fulfilled. Yet, when considering the overall precision of the high values with Kvamme’s Gain, the model is precise enough, since two out three values score higher than 0.5 across all time periods.

4. “Good models should perform well in future situations” (p. 285). In this case the sample of known locations withheld from the sum of locations. As it can be seen when comparing the locations of the control sample side to side with the used locations, the sample is a good representation of the various qualities of the locations of the original dataset. Still, testing both the high and the low values of the model with fieldwork would be useful as a next step.

5. “Good models should specify the uncertainty of the predictions” (p. 286). The implications of the ascribed predictive values and their results have been by now extensively discussed and analysed. Each value has been separately evaluated through Kvamme’s Gain and overall performance effectiveness of the model has been explored comparing the finds’ occurrence against the entirety of the area they are located in per time period.

6.3.2 Overall implications and benefits

The process of creating the model has faced various implications, both material-wise and methodological. The lack of certain reconstructions of the palaeo-environments has led to a series of compromises that could potentially negatively affect the resulting model. This is mostly visible in the case of palaeo-river and palaeo-lake reconstructions, but also the lack of evidence on social and cultural aspects, which in the end could not be modelled. In addition, it should be kept in mind that the effect of natural and anthropogenic post-depositional processes on the finds’ distribution, though it appeared to be very high, could not be clearly distinguished. In spite of that, these processes were discussed and their effect taken into account when choosing the parameters and building the predictive model.

In contrast to many archaeological predictive models, it proposes ways to incorporate underwater and submerged areas in modelling. Archaeology can highly benefit from investigating submerged landscapes, especially in times where underwater archaeology is becoming increasingly popular and feasible. Even by narrowing down the areas where archaeology can be recovered underwater could be an important first step.

Through the split-testing results and the inner evaluation methods applied, it has been made clear that the predictive model has some issues regarding the lower value assigned in the zone including the low elevations far from water bodies, but it is generally scoring very high in terms of precision in two out of the three high values. This means that it can successfully identify locations to further investigate and use to test the relationships proposed, as an archaeological predictive model ought to achieve (Graves, 2011).

It should be kept in mind that this model was created as a baseline, and it can be built upon, including more variables, adapted and enhanced with the inclusion of new theoretical insights. The model produced should not be dealt as set in stone, rather as a non-static outcome, open to enrichment and future additions and alterations. As a baseline predictive model, it has proved to be a reasonably adequate start, aiming to encourage future predictive models, using the present as a stepping stone for exploring the unknown seas of modelling the Greek Stone Age.

7. Conclusion

“Σα βγεις στον πηγαιμό για την Ιθάκη,

να εύχεσαι να 'ναι μακρύς ο δρόμος,

γεμάτος περιπέτειες, γεμάτος γνώσεις.”

[As you set out for Ithaki, hope your road is a long one, full of adventure, full of knowledge] (Kavafis C.P., 1911, lines 1-3).

Long before Homer’s epic poem Odyssey made Ithaki the inspiration of millions of people over the years, long before even the landscape as we know it today was formed, traversing submerged lands and unknown waters, hominins were already crossing the Ionian Sea and inhabiting its islands. This thesis aimed in tracing the earliest activity in the area, studying the central Ionian Sea during the Palaeolithic, Mesolithic and Neolithic periods, establishing meaningful patterns through which the area can be modelled, and the archaeological potential of its regions explored and predicted.

7.1 Conclusions

Archaeology is always working with fragmented datasets and is constantly constructing working hypotheses, being in the constant risk of misinterpreting finds or creating biases and self-fulfilling prophecies. Archaeological predictive modelling is no exception to that rule, with the extra challenge of spatially incorporating archaeological knowledge in maps, ideally including both environmental and sociocultural parameters. The effectiveness of the various archaeological predictive methods have been argued upon for a reason, since their application can be fraught with the perils discussed in the previous chapters. Yet, such risks are intertwined with archaeology as a science, and can be dealt with by improving the method through trial and error.

The chosen approach of this thesis was discussing the available maps in comparison to the known locations in order to establish patterns of presence and absence for each period, eventually creating a predictive model making use of the most relevant factors. The method used was a hybrid form of predictive modelling, utilising both theories suggested in the literature and part of the known locations for the building of the model. The resulting map was evaluated with a simple split test, using a control sample with 30% of the known locations.

7.2 Answering the research questions

In the process of creating the predictive model the research questions posed were explored. The challenges faced and the answers of the questions are discussed below.

"<u>Which environmental factors were the most relevant per time period in influencing the hominin activity and occupation of each part of the study area? How are they affected by the natural and anthropogenic processes that followed their deposition?</u>"

Various environmental parameters have been studied and compared with the 70% of the known locations per time period and relationships proposed in the literature, in order to establish which are more relevant in explaining the known distribution. In the end it was decided that low elevation and proximity to water were the most relevant factors, while depth and underwater landslide susceptibility could be also used in evaluating the archaeological perspective of the underwater parts of the research area. Eustatism played a major role in framing the landscape, submerging and resurfacing areas. Since the majority of the finds recorded in the used archaeological database are surface finds, it can be presumed that the patterns derived are mostly reflecting post-depositional influences. This creates a bias towards lower elevations were the majority of finds, regardless their original elevation, were re-deposited. Besides these parameters and according to the literature, biodiversity, geology, karstic features, terra rossa soils and proximity to raw material sources are also relevant parameters. These correlations could not be proved through the available material studied in this project.

The archaeological finds' distribution has been highly affected by both natural and anthropogenic processes after their deposition. These were studied through investigating features like roads, quarries, cities and other large scale infrastructure areas, which received a lower value due to their sealing and disturbing the soils and potential archaeology. In terms of natural post depositional processes, the dynamic tectonic and seismic activity, along with the effect of water, both in terms of sea fluctuations and inland bodies of water, greatly transformed the landscape over the years. The effect of the latter could be the reason behind the lower number of recovered finds near the present day major rivers of the research area.

"Which social and cultural factors can be accounted for and included in the predictive model, and how do they change over time?"

A number of social and cultural parameters have been suggested and discussed in an effort to include more than environmental parameters in the derived model. Among them, the use of caves, the prominent landscapes and raw material sources were explored as potential indicators of such aspects that can be spatially implemented in a model. None of these factors were managed to be incorporated in the model due to lack of information, but they could be potentially explored further in the future. Unquestionably, such aspects of life would have varied significantly between groups of peoples, hominin species and time periods, and would have played a major role in the original finds' distribution, but the available material used was not sufficient for any correlations to be made.

"What are the strengths and the limitations of the available digital material on Greek prehistory, and can it allow the creation of a predictive model based primarily on open source data?"

The available digital material on Greek prehistory suffices for a solid baseline predictive model. There are enough open source databases for maps both in English and in Greek, from multiple sources, with the ones compiling the most maps being Copernicus, YPEN and EMODnet. Stone Age archaeological finds locations' coordinates can be retrieved from the SOG database, openly available in the ADS repository. More information on locations can be found in the abundance of older and recent publications of the archaeological research projects in the area. Besides the material used, there is an ever-increasing amount of publications and finds becoming available, choosing an open science and F.A.I.R. approach, that could be utilised in a future project. The model created followed a similar approach in order to allow future additions and improvements.

There are still some limitations, though, that need to be considered. The available maps have different resolutions, which makes a broader model possible, but it would be restrictive in the creation of a predictive model in a smaller area. Moreover, there is a lack in some aspects of the landscape, such as the palaeo-river water courses and to an extent the paleo-coastlines, which would both be invaluable in reconstructing the past landscapes. Lastly, the archaeological finds' location is more often than not provided coarsely, for their own protection, or they cannot be retrieved from digital databases, making their inclusion in GIS more challenging, but not impossible.

7.3 Next steps

As it has been made clear, this predictive model aims in exploring both the archaeological potential of the research area and the potential of predictive modelling of the Greek Stone Age. In hindsight some parts of the modelling process could have been dealt with differently, still the choices behind the current model have been explained and justified.

A future model could benefit from the addition of some aspects that were not fully explored in this thesis, due to lacking available material or the time restriction. These include a viewshed and visibility analysis in order to establish if it was a common denominator and as such a preferred feature of the landscape, and a more thorough research of caves for potential social or cultural related activity. Both these parameters are hinted by a handful of cases in the research area, but they could potentially reveal previously unexplored patterns. Similarly, investigating the biodiversity of past environments further, through exploring the flora and fauna of the past, would be vital in understanding both the observed patterns and the degree of insularity of landmasses over time. Correlations between certain types of soils, including but not limited to terra rossa soils, with certain types of finds, could be also a strong indicator that can be incorporated in a future predictive model.

Exploring the relationship between each parameter in more depth and separately for each time period and each sub-region of the area could be very critical in a deeper understanding of the patterns proposed here. In that case, separating the Middle and Upper Palaeolithic would be crucial. Further zooming in, investigating the relationship between the products of certain lithic industries, and *Homo* species through their technology, with other aspects such as elevation or proximity to water, could reveal correlations that would explain the observed patterns even more accurately. Applying underwater archaeology more systematically in areas known to have been submerged during certain time periods, could both benefit and be beneficial for archaeological predictive modelling.

Methodologically, the parameters and research area chosen for this thesis could be re-evaluated through different predictive modelling methods, such as the Dempster-Shafer theory or Maximal Entropy, in order to establish the optimal predictive modelling method. Utilising machine learning and artificial intelligence in future projects of predictive modelling might still be challenging, but it could ultimately be an irreplaceable tool, especially in complex case studies such as the one under study by this thesis. Finally, establishing patterns of absence as well as presence, through projects aiming to confirm absence in zones of low predicted archaeologic potential would be the ultimate test of ensuring a precise and reliable predictive model.

Abstract

The primary objective of this thesis is to construct a predictive model that can be used to study the Stone Age on insular, partly submerged and submerged landscapes of Greece. The chosen research area is the central Ionian Sea, as it combines diverse landscapes that have undergone dynamic changes due to eustatism and high tectonic activity. In detail, the model aimed at studying various environmental factors and their effect on the distribution of finds across the three main time periods of the Stone Age, both in terms of their original deposition and their present-day location. In addition, it aimed at studying and integrating social and cultural factors, to explore the available digital material and to use primarily open source data. The materials used were known locations of archaeological finds based on the "Prehistoric Stones of Greece" dataset, and a variety of digital maps, retrieved by European Union sites such as Copernicus and EMODnet and Natura 2000, and by national sites, for example YPEN. These datasets were open source with various Creative Commons licenses. The resolution of maps varied across each source. In order to properly examine the datasets and assess their contribution, the following process was followed. First, the known locations per time periods were split in two parts, from which the 70% was used in building the model and the rest 30% was kept for testing the model. Subsequently, the known locations were studied along with a series of maps in order to establish patterns, which were then compared to the literature. The main potential disturbances of soil and factors hindering research and findability of finds were also considered.

The main factors affecting the distribution were considered to be proximity to water, elevation, depth and landslide susceptibility. No social or cultural factors could be integrated in the model. Three more factors were modelled and added, including the Natura 2000 areas, forested and increase artificial disturbances areas. Six predictive values were created, with number (1) combining low elevations (<100masl) and proximity to modern-day water bodies, and the lowest (6) being the underwater areas with depth higher than -1000. One model was created for all three time periods, due to the overall similarity of observed patterns. The resulting model was tested with the withheld sample of locations and it showed that the values carrying the majority of finds are Value 3 and 1 for the Palaeolithic and the Mesolithic, and Value 1 and then 3 for the Neolithic. In conclusion, post depositional processes seem to have largely affected the

distribution, but predictive modelling can still be effective. In term of social and cultural factors, more research is needed before they can be integrated in a model, especially on the first two periods of the Stone Age. Finally, it is possible to create a predictive model of the Greek Stone Age by using mostly open source material and open data.

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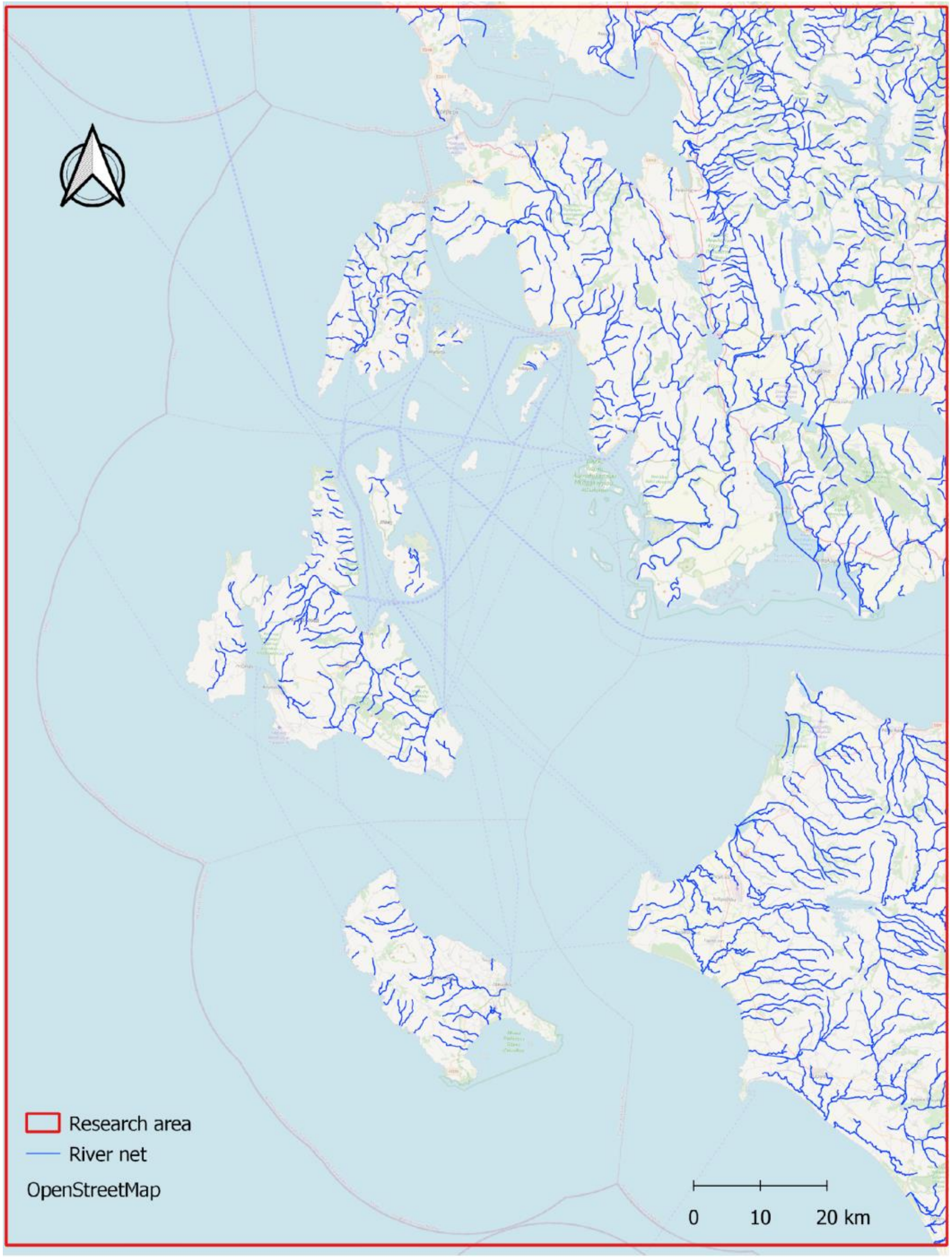
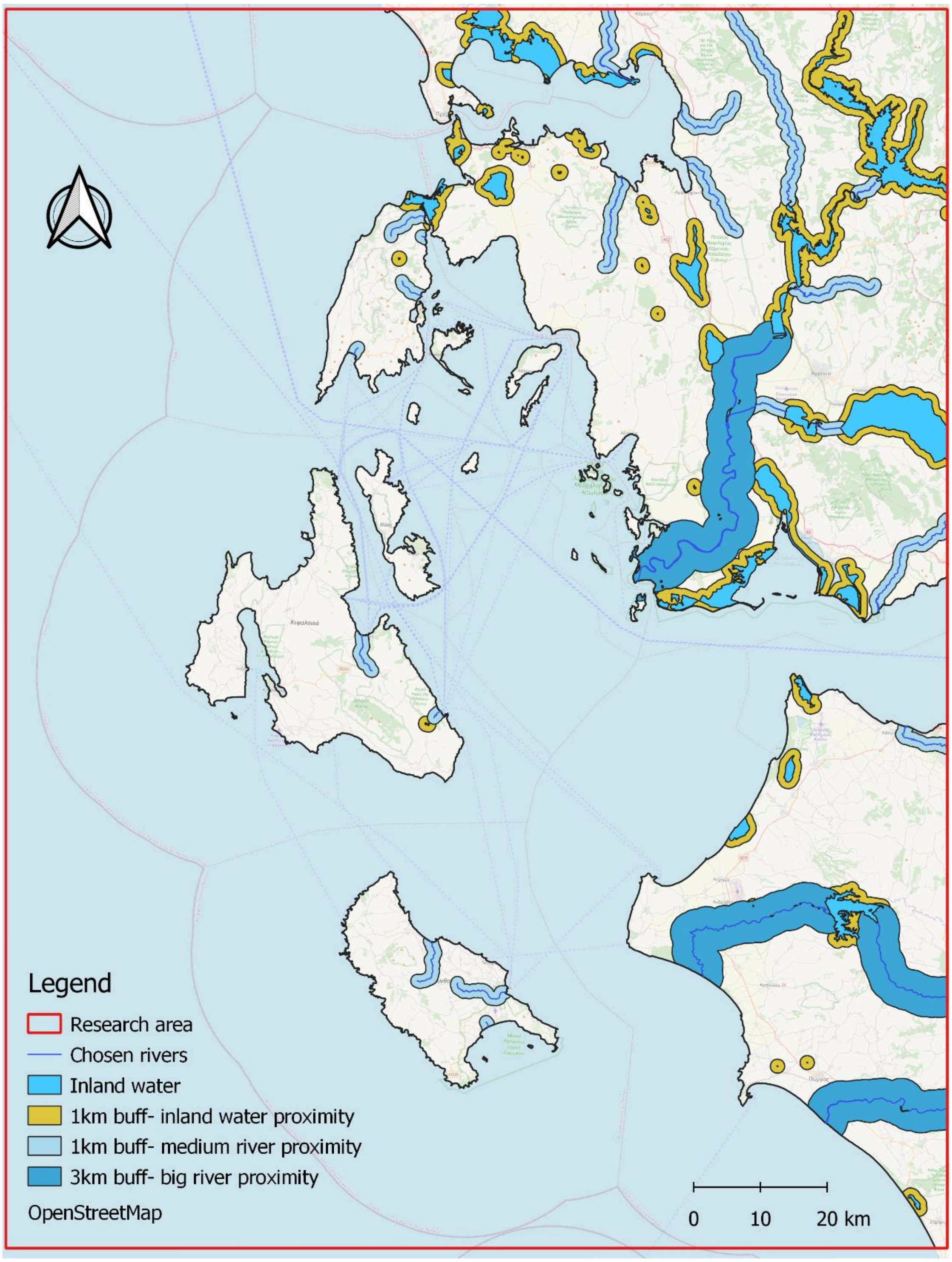
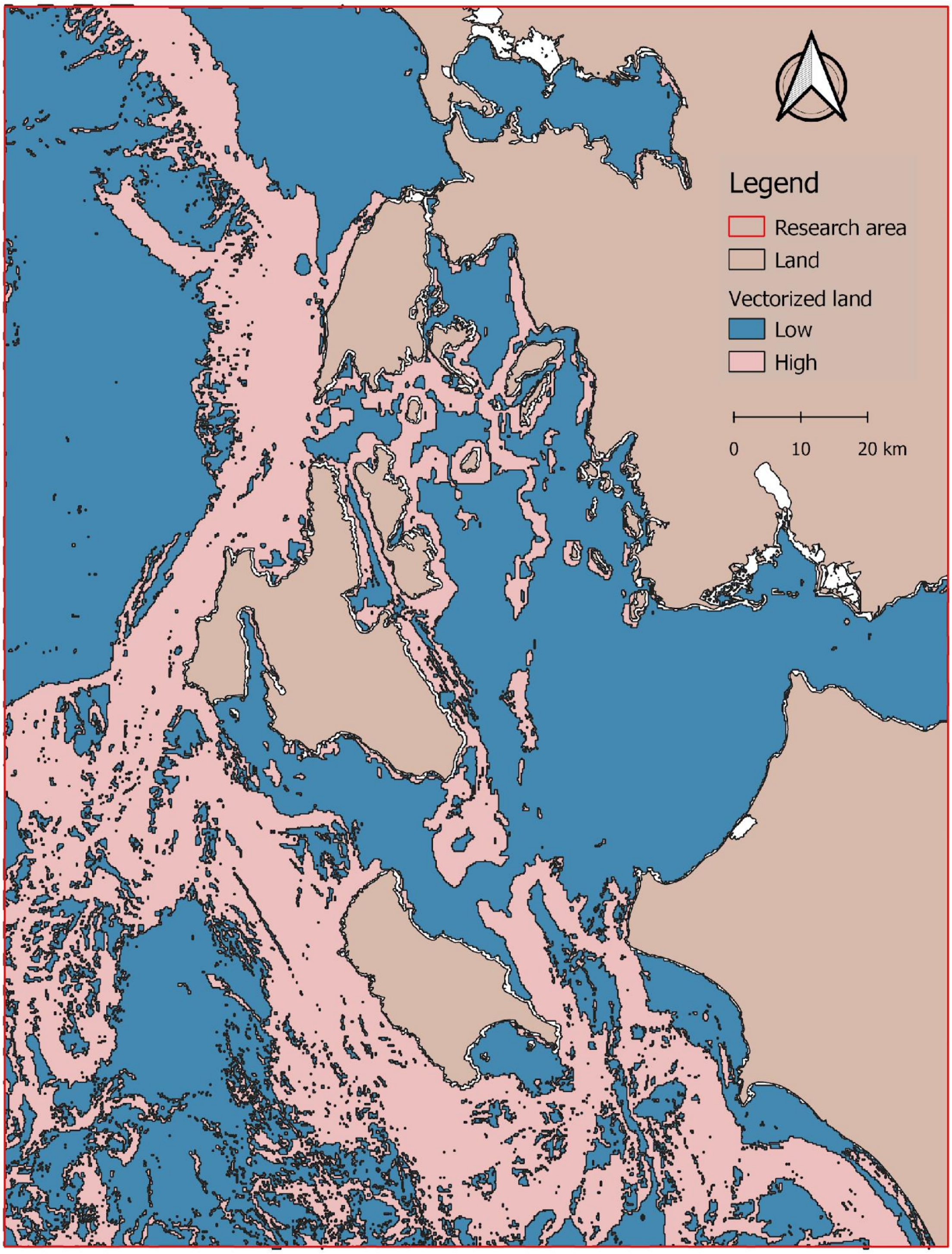
Appendices



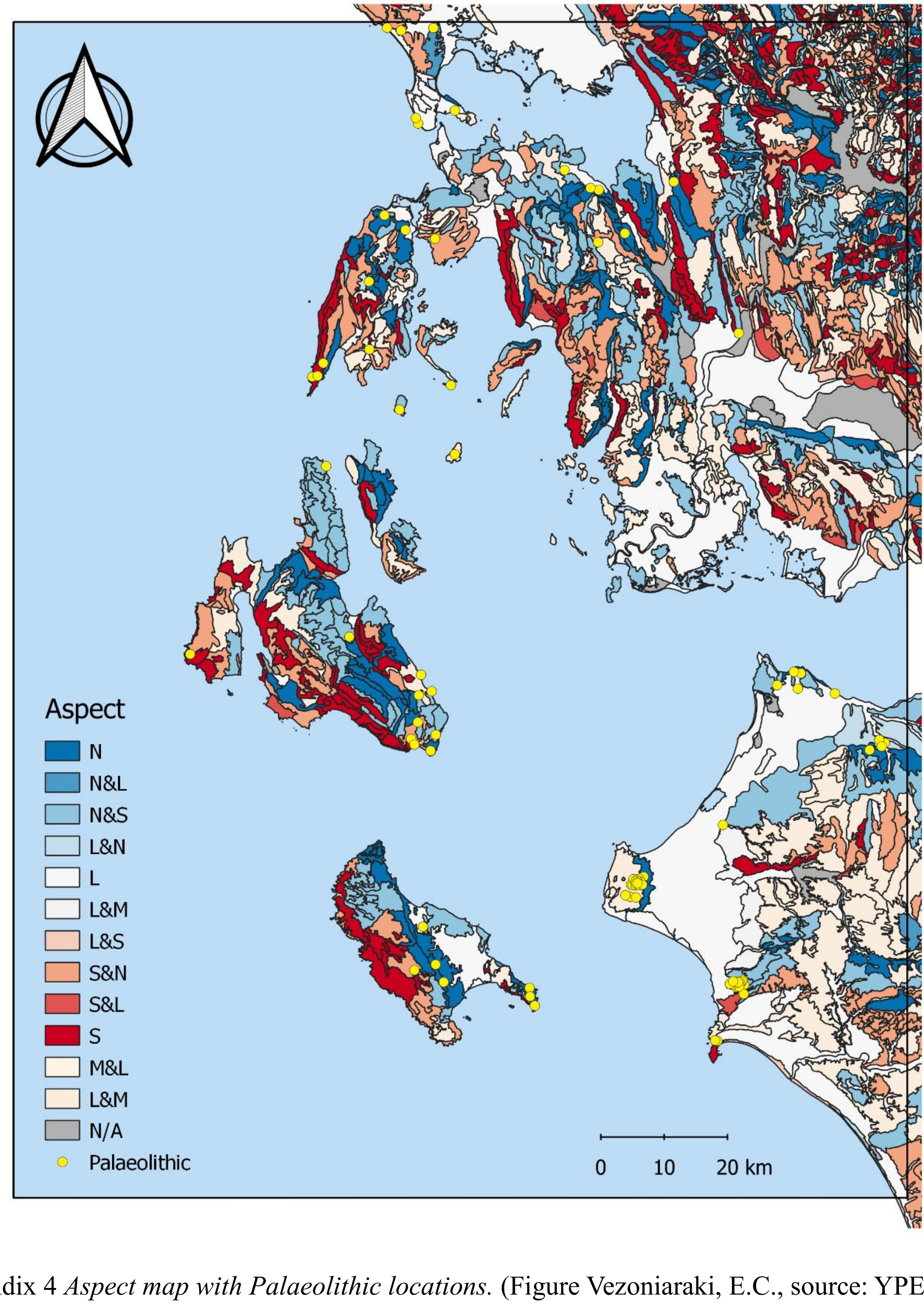
Appendix 1 *River net layer*. (Figure by Vezoniaraki, E.C., source: Copernicus)



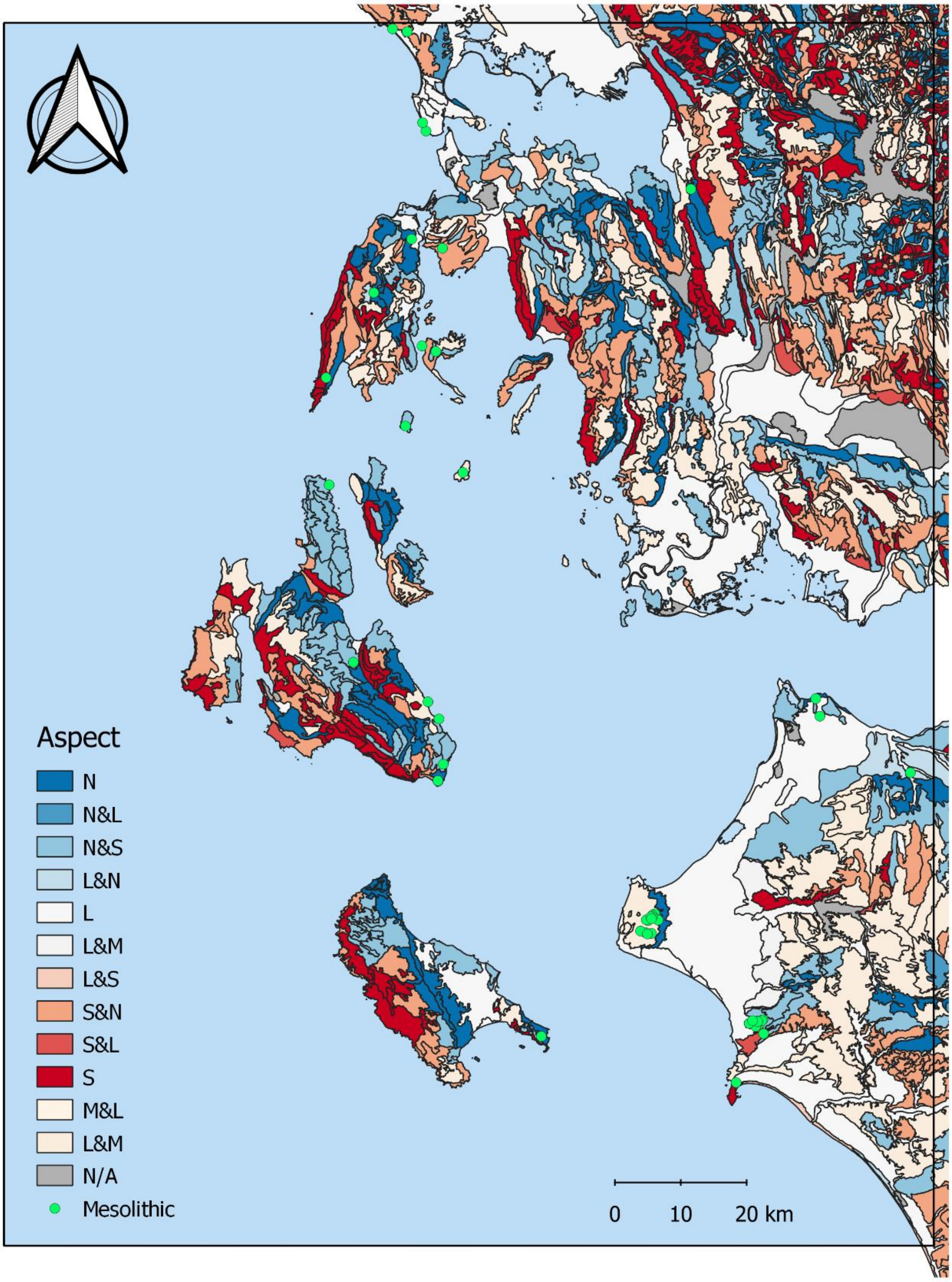
Appendix 2 *Buffers around inland waterbodies*. (Figure by Vezoniaraki, E.C., sources: Copernicus, Corine



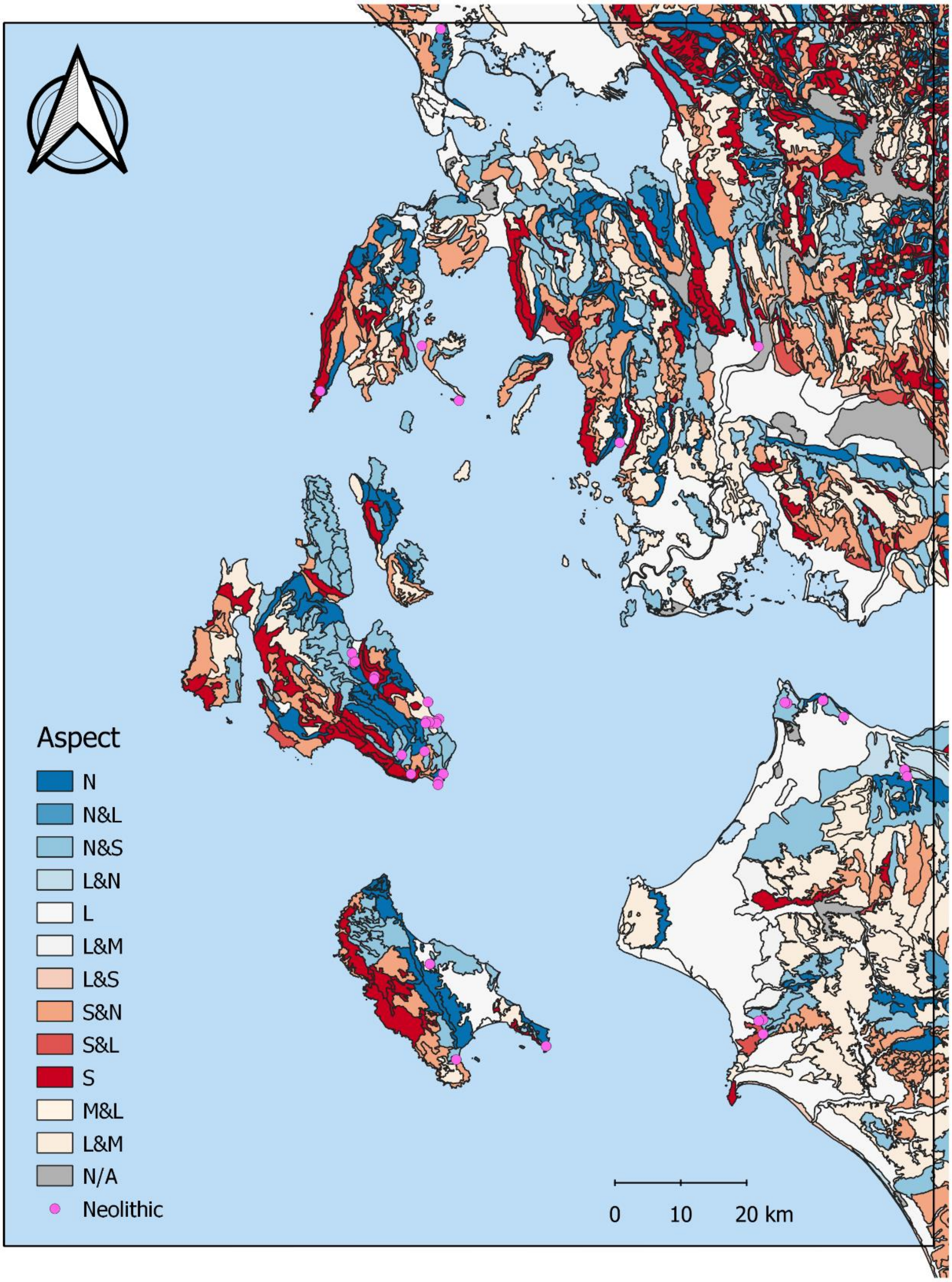
Appendix 3 *Vectorised landslide susceptibility map.* (Figure by Vezoniaraki, E.C., source: EMODnet geology)



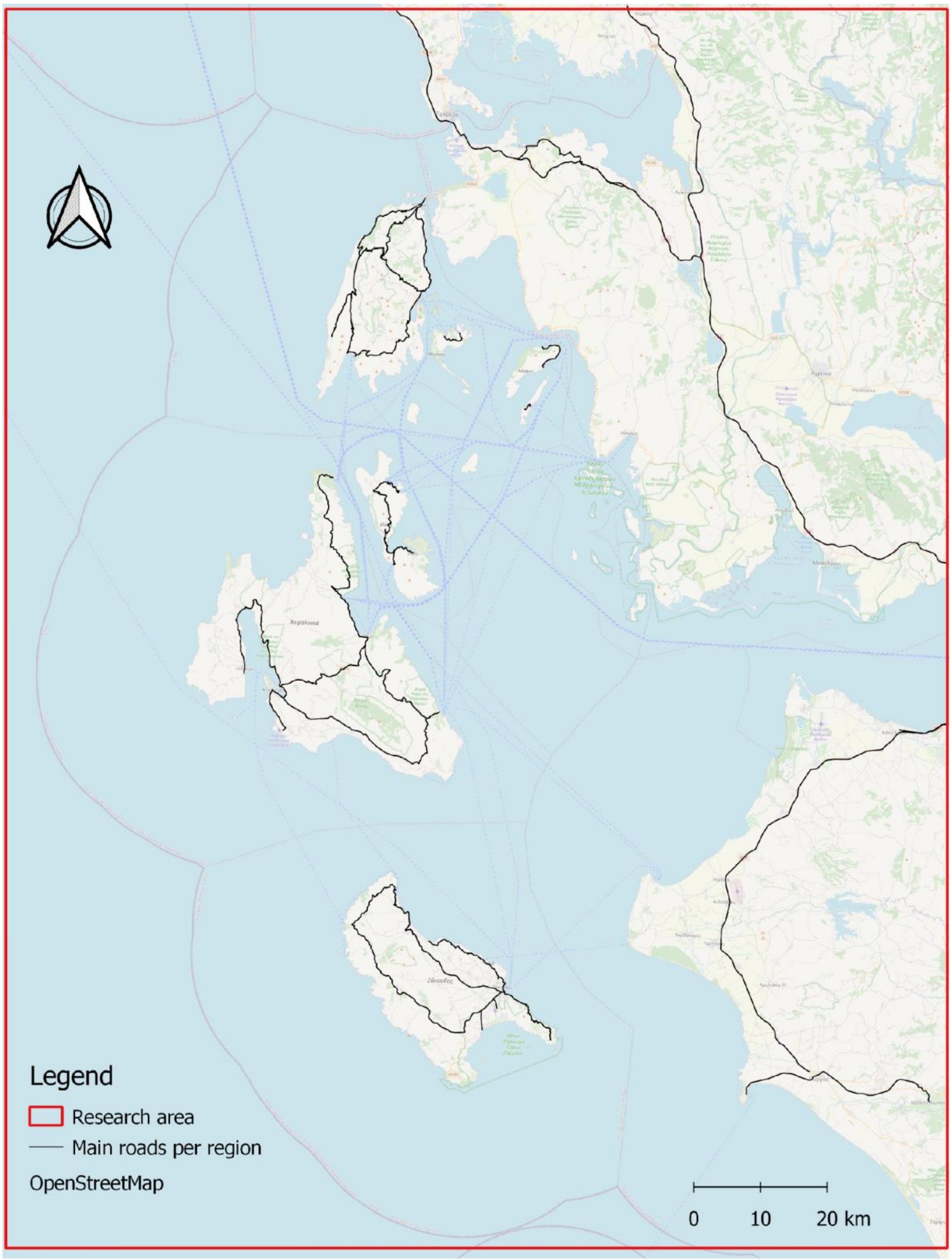
Appendix 4 *Aspect map with Palaeolithic locations.* (Figure Vezoniaraki, E.C., source: YPEN)



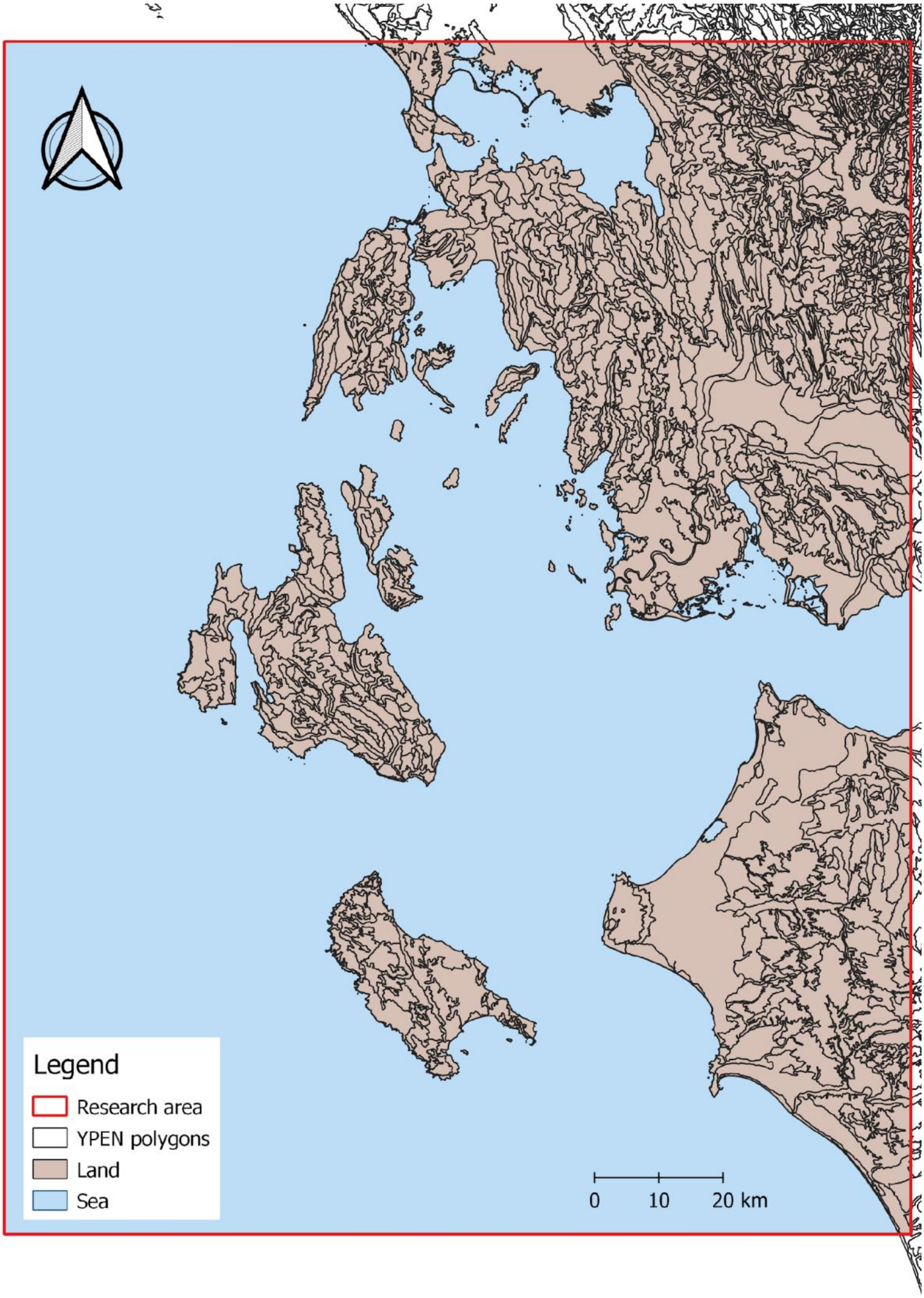
Appendix 5 *Aspect map with Mesolithic locations.* (Figure Vezoniaraki, E.C., source: YPEN)



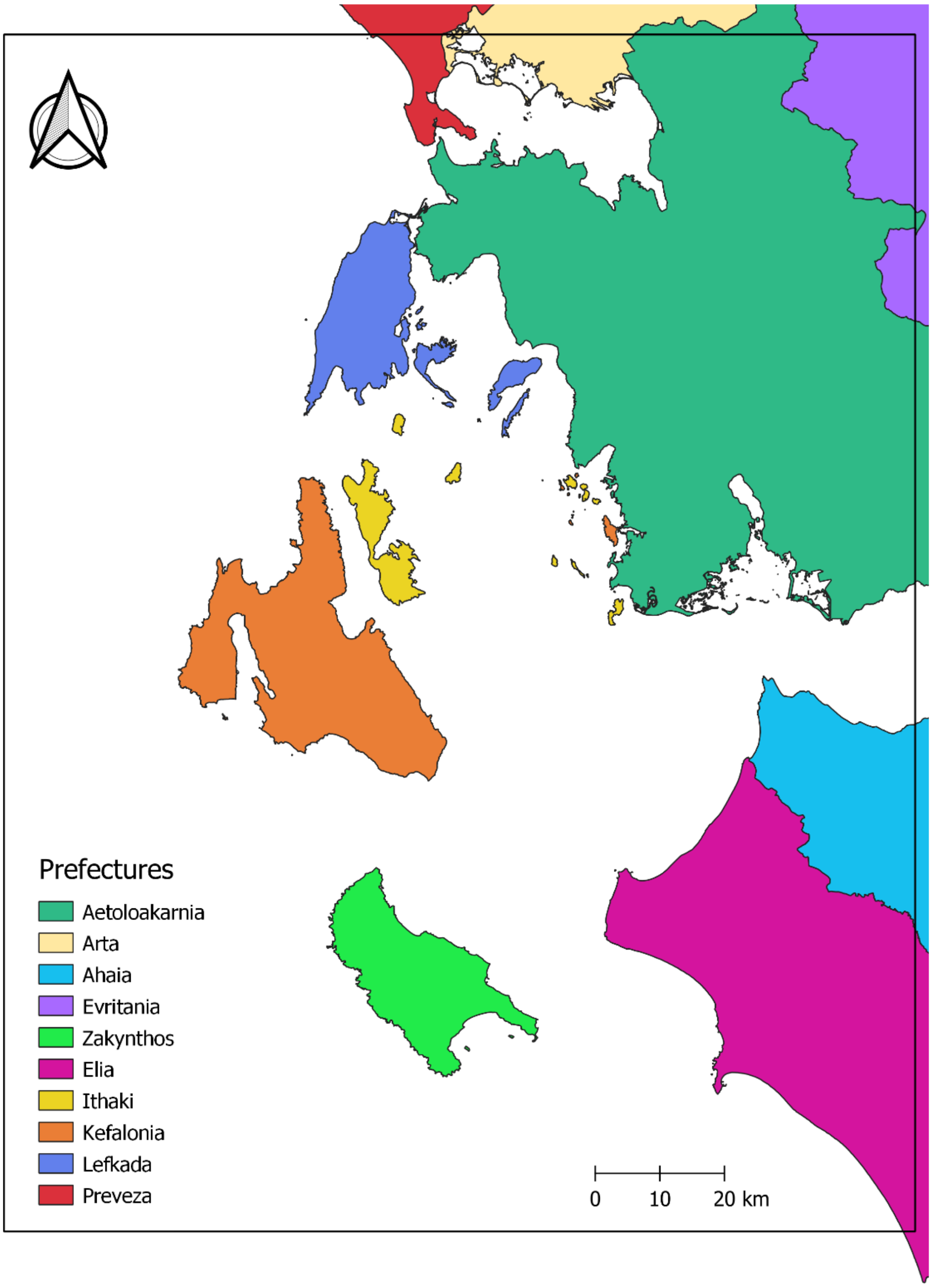
Appendix 6 *Aspect map with Neolithic locations*. (Figure Vezoniaraki, E.C., source: YPEN)



Appendix 7 *Main roads of the research area.* (Figure by Vezoniaraki, E.C., sources: OpenStreetMap, CLC 2018)



Appendix 8 *YPEN polygons*. (Figure by Vezoniaraki, E.C., source: YPEN)



*Appen*dix 9 Prefectures of the research area. (Figure by Vezoniaraki, E.C., source: YPEN)