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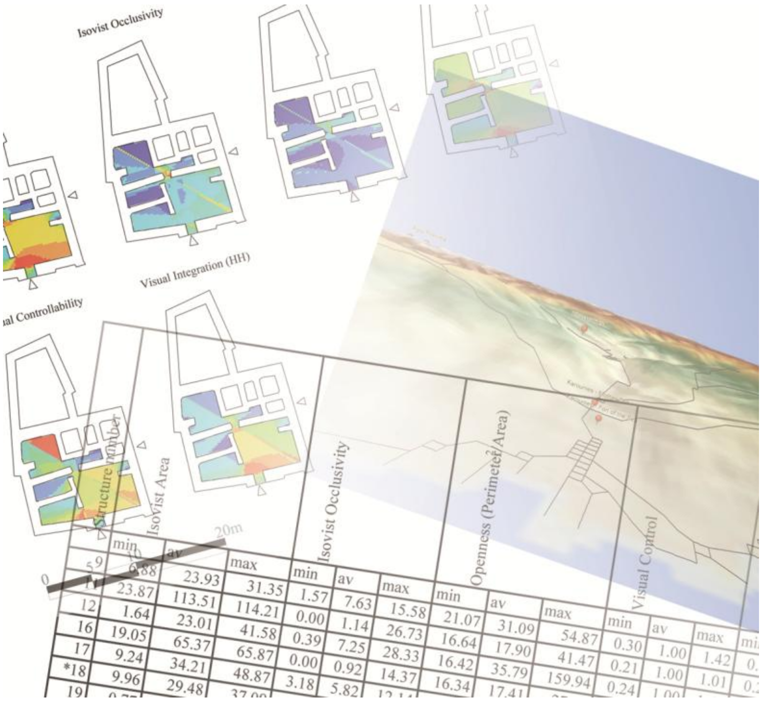

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Chronology		Ceramic sequence	Period
high	low		
	3100	EM I	Prepalatial Period
	2700	EM IIA	
	2400	EM IIB	(Court centred buildings?)
	2200	EM III	
	2000	MM IA	
	1900	MM IB	First Palace / Protopalatial Period
	1800	MM II	
	1700	MM III	Second Palace / Neopalatial Period
1700	1600	LM IA	
1600	1500	LM IB	
	1400	LM II	Third Palace / Postpalatial Period
1400		LM IIIA1	
		LM IIIA2	
	1300	LM IIIB	
		LM IIIC	
	1050	Sub-Minoan	Sub-Minoan Period

Figure 1: Chronology of Minoan Crete. Dates are in years BC; high and low refer to the different dating methods (see Shelmerdine 2008, 5-6). Based on Shelmerdine 2008, fig. 1.1, and Kyriakidis 2005, fig. 1.

1 Introduction

Until several years ago, I was fascinated by the idea of a peaceful Minoan society with its grand palaces, beautiful art and interesting lifestyles. However, the more I studied this great Cretan society, the more it became clear that this simple and perhaps naïve idea was not true at all. On the contrary, the strong and thick walls of barriers and buildings, and the collection of swords and daggers, among other things, have been interpreted as evidence of social unrest or even warfare. This was done under the assumptions, that strong walls must have a defensive function and swords are a symbol of the warrior and thus warfare. These assumptions will be discussed later in this thesis.

Some of the most interesting structures that have often been assigned a defensive function, are the Minoan guard houses. These rather small buildings were constructed and used between the early Protopalatial period and the Dark Ages. Their strong walls and their locations in the landscape are the main reasons why researchers have identified this type of structure as defensive and/or defensible. In this thesis, the main focus will be on the defensibility of these guard houses during the Minoan periods (see Figure 1 for a chronology of Minoan Crete). However, before discussing the specific research questions and how the research was conducted, it is important to give the necessary context, in which this research can be placed.

Arthur Evans was the first archaeologist to define Minoan society. His interpretations of how society on Crete functioned during the Bronze Age strongly influenced Minoan archaeology for at least until the second half of the twentieth century. Evans' most important publication 'The Palace of Minos' (1921, 1928, 1930, 1935 and 1936) promoted his ideas of a peaceful society. Interestingly, in the years before the discovery of Knossos, Evans actually already published the finding of multiple strong walls, buildings he called fortresses, bastions, etc. (see Brown 1993). In more recent works these structures have been interpreted as signs of unrest and conflict rather than peace. Although Evans had recognized those architectural remains and even published a mosaic showing a fortified town, he held on to his idea of the *Pax Minoica*. This was also because Evans thought many of the fortifications around Knossos had been abandoned in the later Middle Minoan period, except for some guard houses watching over important roads (Evans 1928, 372).

During the 1930s Pendlebury made major contributions to Minoan archaeology and laid the basis for future research. Not only did he discover several important defensive sites on the island, such as Oreino Ellinika and Stavrochori Kastro (Pendlebury 1939, 385) he was also the first to properly describe the settlement patterns on Crete during both the Minoan and the later Mycenaean periods (Nowicki 2000, 13). In a way, all later studies of settlement patterns on Crete can be seen as a continuation of his work. However, even though he had discovered more fortifications, the Minoans were still seen as a peaceful people.

During the 1950s and 1960s, large research projects were carried out by N. Platon, P. Faure and a British team including S. Hood, P. Warren and G. Cadogan. By this time, more and more evidence was found pointing to an overall less peaceful society. However, it was not until Alexiou (1979) openly doubted the peacefulness of the Minoan society, that a shift in Minoan archaeology started, gradually moving from the firm belief in a long period of peace and stability to ideas about social unrest, conflict and even warfare.

From about the 1960s onwards, warfare became a popular topic in anthropology. There it was suggested that warfare could be one of the reasons of how early states formed. Some scholars even consider warfare as one of the most important factors for the appearance of complex societies (Driessen 1999, 11-2). As with many other theoretical approaches, this anthropological theory was accepted by archaeologists as well, mainly because conflict at different levels can be a useful tool for explaining all kinds of events (Driessen 1999, 12). The combined efforts of archaeologists, anthropologists and historians have led to a better understanding of warfare in prehistoric and historic times (Parkinson and Duffy 2007, 116). From the late 1980s onwards the importance of warfare in Minoan archaeology steadily grew, with a peak in the late 1990s. This can be seen from the amount of research projects (e.g. the Minoan Roads Project, the project by Nowicki and the project by Schlager), publications (e.g. Nowicki 2000; Schlager 1997), and conferences relating to defensive architecture and warfare (e.g. POLEMOS).

Today it seems the interest in warfare and defensive/defensible architecture from the Minoan periods has died down, with only N. Schlager and his colleagues still actively studying the fortifications in mainly the Ziros region on Crete. However, in my opinion there are many questions still unanswered and further research is needed.

The above is a brief overview of the development within Minoan archaeology from the belief in peace and stability to a recognition of instability and possibly warfare. However, what is the current opinion held by Minoan scholars? What have we learned during this period of (active) discussion about conflict and social unrest in Minoan society?

For the Early Minoan periods, there is hardly any evidence available relating to conflict. However, there seems to have been more interest in settling on higher locations that were easier to defend and also harder to access (Nowicki 2000, 38). This has been interpreted as evidence for increasing insecurity from the end of the Neolithic onwards (Alexiou 1979, 55).

Nowicki (2000, 38) recognizes at least three periods of conflict and/or crisis. The first being during the transition from the Final Neolithic to Early Minoan I, which was discussed briefly in the last paragraph. The second was during EM II and after the destructions of EM II, where it seems people again moved to more defensible locations. The third period of crisis, according to Nowicki, was during LM IB. During LM IB there was a series of events that more or less caused the destruction of the Neopalatial state.

Interestingly, although Nowicki identifies at least three periods of conflict, he left out the Middle Minoan periods from these three, while it was during these periods that many of the defensive architecture was constructed. Social inequalities started to appear on Crete near the end of the EM period and became more apparent from the MM period onwards. Apart from the development of a more hierarchical society, it is also possible that population movements, especially from the southern parts of Crete to the east, caused some form of conflict (Tsipopoulou 1999, 180). During MM IB/II there was an increase in sites that were fortified and/or located on defensible locations. Not only that, it is even suggested that some of them were part of a form of organized system of defences and fortifications (Nowicki 2000, 38). Especially between MM II and MM III there seems to have been a period of unrest. Defensible sites from MM II and later are distributed over several parts of the island. This may be evidence for specific zones where conflict or social unrest was present. Nowicki suggests these areas may be showing the final phase of the division of Crete into several political zones, a process which had started already during the EM II period (Nowicki 1999, 193).

During MM IIB the most important palatial centres of the Protopalatial period (Knossos, Malia and Phaistos), and many other settlements as well, were destroyed by a fire at almost the same time (Driessen and Macdonald 1997, 12). Driessen and Macdonald suggest the possibility of warfare of some sort, based on the fact that some settlements were immediately rebuilt after the destruction while others were left abandoned. It has also been suggested that earthquakes were the cause of this destruction, for example at Phaistos (Militello 2011, 239), but not everyone agrees with this (Bintliff 2012, 137). Some areas may actually have benefited from these destructions (Nowicki 2000, 32-3). This may be another reason to suggest conflict or social unrest. Both conflict and natural disasters may be possible explanations, or perhaps a combination of the two, although it could also have been large forest fires caused by drought and high temperatures.

After the destructions of MM IIB, it seems a new political and administrative organization emerged on Crete during MM III (Nowicki 2000, 38), possibly with

Knossos as controlling palatial centre (Driessen and Macdonald 1997, 12). The Neopalatial period seems to have been an era of relative peace. This is suggested by the abandonment of most of the defensible sites from earlier periods (Nowicki 2000, 32-3). This may indicate a nonexistence of unrest or conflict.

At the end of the Neopalatial period there were two major events that eventually caused the end of the Minoan palatial society. At the end of LM IA many sites were damaged by earthquakes and subsequently abandoned, but much was rebuilt soon after (Driessen and MacGillivray 2011, 267). The destructions of this period are usually ascribed to the earthquakes that preceded the eruption of the volcano of Thera and the eruption itself (Nowicki 2000, 34). Soles (1990, 322) has reported a layer of ash between the LM IA and LM IB levels of occupation. It is assumed that this layer of ash may have covered a large area of central and eastern Crete. This layer of ash has also been identified at Palaikastro, where the layers of pure volcanic ash could reach a thickness of up to 12 cm (Bruins *et al.* 2008, 202-3). It was long thought this may have caused agricultural problems, especially where the layer of ash was thick, but this is not necessarily the case. Depending on the season, the weather, the type of crops, amount of maintenance, etc. the effect of ash on soil differs (see also USGS 2009) Actually, a recent study suggests the sulphur and minerals in the ash that is found on Crete may have had a beneficial effect on plants (Pearson *et al.* 2009, 1212). Since a certain amount of sulphur is actually beneficial to the growth of wheat, there may not have been any agricultural problems at all.

Driessen and Macdonald (1997, 96) think the events surrounding the Thera eruption caused a collapse of the existing central authority (see also Driessen 2002, 251). They argue that the break-down of the system can be explained from the way people responded to the problems they were facing. They believe that in societies like the Minoan society, with a form of central authority, but where the (extended) family still has an important rol, people will first make sure their family members are safe when natural disasters happen. Based on the extended families, some form of regionalism exists in such societies. In crisis situations, the central authority loses its power, because groups of people will manage the situation by themselves, without a need for central authority. The only way for central authority to return to power is if it manages to reclaim control (Driessen and Macdonald 1997, 96).

The above is a rough sketch of what is assumed to have been the situation during the early LM IB period. This regionalisation seems to be supported by the appearance of Linear A tablets at many different locations, compared to the few locations they were found at before (Driessen and Macdonald 1997, 96; Hamilakis 2002, 194). This decentralisation does not, however, mean a decline. After the destructions related to the

Santorini eruption, much was rebuilt (Driessen and MacGillivray 2011, 267). LM IB was the height of the Minoan civilization. The marine style pottery that appeared in LM IB can be seen as evidence of this, although this style differed from earlier styles (Younger and Rehak 2008, 153). It was not until the end of LM IB that things changed drastically. However, evidence suggests this period was not as safe as LM IA. Buildings were modified to regulate and direct movement, and defences were added to settlements. It also seems food production and industry was now done inside settlements instead of in the hinterland. Old buildings that were destroyed at the end of LM IA were sometimes repaired and/or adapted to new uses, but the quality of the architecture was not as good as before. The lack of a central authority also made the hinterland more insecure, making communication within the island more difficult. Another strong clue for a sense of insecurity among the people, is the occurrence of a large number of bronze hoards at least during LM IB, but maybe earlier as well (Driessen and Macdonald 1997, 82-3).

The above gives some examples of evidence suggesting a period in which central authority was mostly lacking and people were feeling insecure. Defences around settlements, combined with the move of important assets like industry and food production to inside the perimeter of settlements, is a clear indication that the hinterland had become less secure. Industry, like metal working, was usually carried out outside of settlements, to prevent fires. The need must have been very high for the people to accept that risk over losing production facilities.

During LM IB there was another destruction phase. The evidence suggests a "violent destruction" that seems to have been aimed especially at important political and administrative centres (Nowicki 2000, 35). This selection indicates choice, which would point towards human agents at work causing these LM IB destructions. This has also been recognised by other scholars, who have noticed a kind of preferential treatment, where, within a site, only the elite houses were burned down, while other structures remained unharmed (Driessen 2002, 251). This is something that nature just cannot accomplish. Driessen (2002, 251-2) sees five reasons why there were humans causing havoc:

1. Preferential treatment, which has already been mentioned above.
2. Burning.
3. Plunder and malicious destruction.
4. Lack of reoccupation after the destruction.
5. Important facilities for water and storage were protected by defensive walls that restricted access to these facilities before the destructions took place. This suggests a threat that can be kept out...other people. Also, there are cases where

valuables had been hidden before the destruction. Again, this seems to suggest that the inhabitants were aware of an incoming threat.

If the destruction was indeed caused by other people, there are two options. Either there is internal conflict among the Minoan population, caused by social, economical or political problems, or there is an invasion by people from outside of Crete. Driessen and Macdonald prefer a combination of these two options (Driessen and Macdonald 1997, 109). Now there seems to be general agreement about an invading force attacking Crete. Still, some interpret the destruction of LM IB as the result of natural disaster, based on the amount of damage that was done. Nowicki does not agree with their standpoint, that this amount of damage could not have been done by a human agency. On the contrary, he argue the destructive power of man is similar if not worse than nature in some cases. He, too, agrees that most of the evidence seems to suggest that invaders, possibly from the mainland, were the agent responsible for the destructions (Nowicki 2000, 35). Although there is evidence suggesting the invaders came from the mainland, this is still open to debate.

Whatever the case may be, what is certain is that the events that occurred during LM IB had a dramatic impact on Minoan society. Not only was there a large decrease in population, which Nowicki theorizes may have been caused by invaders or raiders taking many prisoners (Nowicki 2000, 259-60), the Minoan Neopalatial society was also either destroyed or severely damaged.

However, Minoan society did not completely collapse. During LM II, which was still a relatively unstable period, Minoan society slowly recovered. Because of the influences from mainland Greece, this is often seen as the start of the Mycenaean period on Crete (Preston 2008, 311), but there is clear evidence for continuity as well (Driessen and Macdonald 1997, 110-1). During LM II-IIIB, the larger and more important towns, for example Palaikastro and Knossos, were reoccupied, but many other sites had been left abandoned after the destructions of LM IB (Nowicki 2000, 35). Based on the use and spread of LM II-IIIA pottery from Knossos, Driessen and Schoep (1999, 389) believe that it is possible that Knossos was in control of a much larger area than before. This is supported by Linear B tablets that list many names of places to the west of Chania and in the eastern part of Crete. They believe Knossos managed to gain control of such a large territory by using military power and the creation of a good communication network to lay a legitimate claim on the other areas of Crete (Driessen and Schoep 1999, 389; Preston 2008, 311, 6; Schoep 2007, 215). At the start of LM IIIA2 there seems to have been more destruction at Knossos and possibly at other sites as well, as suggested by evidence from Palaikastro. It is not known whether Knossos was (partly) restored afterwards or not (Nowicki 2000, 36).

The brief outline given above discussed the major crisis events throughout the Minoan periods. Hopefully it has become clear that the Cretan Bronze Age was not just peace and happiness, but that there were major periods of distress. Some of which were caused by natural disasters, others by people, either from the island itself or from the outside. In the next section I will discuss more in debt the fortifications that have been found on Crete, moving closer towards the topic of this thesis. Before continuing, however, there is the issue of warfare that needs a little more attention.

Conflict and social unrest are one thing, calling something warfare is a different matter. The term warfare has a certain baggage of modern assumptions going with it. Our knowledge of Aegean warfare is completely based on inference from different materials and some limited textual and iconographic evidence. Therefore it is more indirect than direct evidence. The way we look at warfare is also often affected by our own assumptions about warfare, that may lead to conclusions that may not be true at all (Krzyszkowska 1999, 489).

If we look at Minoan art, for example, there is one thing clearly missing, especially when comparing with art from other parts of the Mediterranean at the time. There is almost a lack of violence and scenes of warfare. This can either be explained by concluding that the Minoans did not have warfare, or if they did have warfare, they did not like to represent it in art (Gates 1999, 277). Because of all the other evidence, as discussed above, and the doubt that any society can have no conflict at all for multiple centuries, the second explanation is nowadays accepted. However, there is still some doubt if real warfare really existed, since there is almost no real evidence for warfare. Gates (1999, 277) gives five reasons for this doubt:

1. During the Neopalatial period, there are almost no fortified settlements.
2. Although weapons, mostly swords, have been found, they are still not common.
3. The lack of war scenes in art.
4. No written reports from that time period about warfare.
5. No burials with grave goods that can be related to warfare.

However, some of these can be explained relatively easy, while some cannot. For instance, the lack of fortified settlements in a large part of Crete during most of the Neopalatial period is still not understood. More is known about Minoan writing, however. Although the Minoans did have multiple writing systems, they were mostly used for record keeping (as far as we know), so the lack of written reports about warfare from the Minoans themselves does not per se mean anything special, because they did not write about others things either. There are no warrior-related symbols, such as weapons and helmets, on Linear A tablets, in contrast to Linear B tablets, where they are represented (Bintliff 2012, 149). Other complex Near Eastern cultures may have had no interest in writing about warfare on Crete or they did not know. Either way, there are multiple reasons which could explain the lack of written reports. Interestingly, for all other East Mediterranean cultures where we have textual evidence of, warfare was very important.

A type of object that is often related to warfare is the sword. Of all the Bronze Age swords from the Aegean that have been catalogued, at least half are said to have been crafted on Crete. Together with the idea that many Mycenaean swords have actually been crafted in Minoan workshop, this seems to show a strong connection between Minoans and weapons (Peatfield 1999, 68). The high percentage of swords crafted on Crete is very interesting and seems to imply that weapons were very important for the Minoans in some way. Why else would they craft so many? However, although there is clear relation between swords and warriors in Aegean art in general, there are enough examples of swords of different types that clearly have been used for ceremonial purposes. Good examples of a ceremonial purpose are the swords found at Malia (Peatfield 1999, 69). Therefore, we must be cautious not the judge too soon when looking at the weapons that have been found, at least for the Early and Middle Bronze Age. For the Late Minoan periods, there is more evidence for the actual use of swords by warriors in art and graves (Peatfield 1999, 70; 2). A good example of this, is a rich grave that was discovered at Poros, the harbour town of Knossos, which not only included jewellery, but weapons as well (Driessen and Langohr 2007, 186).

From what has been argued above, we can say that conflict and crisis existed, but whether there was real warfare going on in Crete cannot be said with certainty. The existence of weapons is not evidence in itself for real warfare, and the lack of representation of warriors in most EM and MM art does not help us much either. During the LM periods, there is an increase in representations of warriors, and during LM II-IIIA the weapons and armour found in burials, combined with written records of weapon production, chariots, etc. on tablets, make it clear that warfare had become very important on Crete for elites to gain power (Driessen and Schoep 1999, 392-3). However, especially during LM II-IIIA these must have been Mycenaean influences.

Whatever the case may be, people felt the need to defend themselves during multiple periods of Minoan prehistory. This was either done by building a settlement on higher locations that may have been harder to access, by building fortifications of different kinds, or a combination of both. Guard houses, the main object of this thesis, are a type of fortification. However, they were part of a variety of fortifications and it is important to see them in relation to each other.

Fortifications can be divided into three categories: forts and guard houses, towers or bastions, and perimeter defence or enclosure walls (Zielinski 1998, 61). Zielinski and Schlager, among others, use the term ‘cyclopean’ for the strong and thick walls that are used for the construction of most fortifications. However, based on this type of wall more categories can be defined. Schlager (2006, 371) defined six categories:"fortifications of settlements and towns", "guard houses along Minoan roads", "sanctuaries", "town houses", "central edifices in village-like settlements" and "farmsteads". These six categories show that strong "cyclopean" walls were not only used for fortifications, but for other types of structures as well. This is important to keep in mind, because it means strong walls are not per se evidence of fortifications.

From the Neolithic through the Bronze Age, fortifications have been used to define and protect territories (Alusik 2007, 175). The amount of defensive architecture differed depending on the period. Especially in periods of crisis there seems to have been an increase in fortifications of different sorts. Two of the oldest examples of fortified sites are the bastion and acropolis at Livari, both dating to the Final Neolithic period. In both cases there was a perimeter wall surrounding the site (Schlager 2011, 272-3). Although there are some fortifications known from the early Prepalatial period, most seem to have been constructed from the late Prepalatial period onwards.

During EM III-MM I simple walls, consisting of large blocks of stones with smaller stones used as a filler, were constructed around hilltop villages for protection. Apparently, these were often placed strategically, for example at the most exposed part of the site, to control access from specific directions (Hayden 1988, 1-2). Nowicki (2000, 32) agrees that during this period there were more defensible sites than before. However, he asserts that real fortified sites are usually seen as a feature of MM II and (maybe) early MM III (Nowicki 2000, 32). This seems to fit with all the evidence that indicates an increase in defensive architecture starting from the early Protopalatial period onwards. The stronger concern with defence seems to coincide with a period of great social unrest and change, in which multiple palatial centres were developing and claiming territories of their own. Schlager proposes that these political powers wanted to define themselves and their territories, and that they saw the construction of 'cyclopean' buildings as a good method to make a clear statement of their power and status. Moreover, it may even have been the case that the opposing groups started to build defensive architecture as well (Schlager 2006, 376). Notwithstanding all this, there is still a lot of uncertainty about the function of many 'cyclopean' structures. For example, a large number of walls do not seem to have many defensive qualities at all. They functioned well enough as simple barriers and to keep animals and perhaps products safe, but had no real defensive value (Driessen and Macdonald 1997, 47).

Nevertheless, perimeter walls seem to have been the most common fortifications. Many were constructed around important sites or used as field boundaries. During the Protopalatial period, several large centres gained defensive walls around them, for example at Petras and Aghia Photia. This is seen as evidence for conflict in the area (Tsipopoulou 1999, 185). On different sides around Malia, wall segments have been discovered as well, that have been interpreted as fortifications around this important town (Zielinski 1998, 63-4). However, Müller did already in the early 1990s doubt this, for three reasons: 1) the appearance and width of the segments differs greatly; 1) they do not form continuous lines; 3) in at least one case there are perperndicular walls attached to it (Müller 1992, 745). Palaikastro had fortifications as well, and the area south of Palaikastro, the territory of Kato Zakros, had a considerable number of fortifications in the countryside (Zielinski 1998, 452).

'Cyclopean' walls were either used on their own as *periboloi*, enclosure walls, or as part of another structure. This could be any type of structure, ranging from villas and farmsteads to shrines, towers and guard houses. Together these buildings and *periboloi* formed a complex defensive system (Schlager 2006, 370-1).

Of course walls were not the only type of fortifications. As was mentioned above, if only the structures are counted that really seem defensive, there were also towers, bastions and guard houses or forts. A good example of a combination of strong walls with a sort of bastions can be found at Aspro Nero. There, Schlager and his team have discovered at least two bastions connected to each other by walls. These could be dated, based on pottery finds, to the MM period and the site was probably still in use during the LM period (Schlager *et al.* in press). Guard houses will be discussed in more detail in a following section, since they represent an important type of 'cyclopean' buildings.

At the end of MM IIB, the wide destructions not only had an impact on the palatial centres and the settlements around them, but also on the use of defensive architecture, like guard houses, and many defensive sites were either abandoned or destroyed (Alusik 2007, 151). During MM III-LM I there is also evidence that defensive sites were being used, but most of them were founded earlier and were just being reused. It also seems that more settlements were now built on lower areas, suggesting a safer environment (Nowicki 2000, 33). During most of the Neopalatial period, there was a decrease in the use of fortifications around towns. A possible reason for this seems to be the network of guard houses that was spread over the countryside, especially near Zakros. These guard houses were used for watching the area for possible threats, making town walls no longer a necessity (Zielinski 1998, 524), but this is not certain at all. The change from city walls and guard houses protecting the main towns to a network of guard houses protecting the borders of territories, if that is indeed the case, may be a response to political changes. It seems plausible that when the internal conflicts were resolved and threats were almost only external, watching the borders became more important than controlling the interior (Alusik 2007, 134). This also explains why a town like Gournia, which was founded during the Neopalatial period, does not have any fortification walls around it (Zielinski 1998, 528).

In LM I there was apparently a new need for fortifications. Important settlements like Achladia, Aghia Triada, Gournia, Petras, Palaikastro and Kato Zakros received enclosure walls. In several cases, for example at Gournia, one or more towers were added as well (Driessen and Macdonald 1997, 46-7). This suggests again a threat that needs to be kept out. Although the first major destruction phase in LM I was caused by the earthquakes related to the eruption of the Thera volcano and the eruption itself, it is also possible a human threat arrived in LM IB, as has been discussed earlier.

Next to the addition of walls and towers to these palatial sites, there is also evidence at several sites, for example at Knossos, for a change in accessibility. Changes to entrances caused people's movement to be more controlled. People were actually forced to move a specific way to reach the interior. Driessen and Macdonald suggest this may either point to more social differentiation or to a need for controlling accessibility for safety reasons (Driessen and Macdonald 1997, 45-6).

After the destructions of LM IB, there was again a decline in the use of defensible sites and fortifications. One possible explanation is that the remaining inhabitants on Crete were pacified by invaders, removing the need for defences and defensible sites (Nowicki 2000, 36). However, since it is still not completely safe to assume there really was an invasion by raiders, there could be other reasons as well. Even if there were no invaders, or if they merely caused chaos and disorder and then left, the Minoan society may have been united in some way, which would also make defensible sites and fortifications more or less obsolete. During the Postpalatial period, when the Minoan civilisation was coming to an end, typical Minoan style defensive architecture was almost no longer constructed. Through time, the construction of guard houses and the methods used to modify access systems had lost their purpose (Alusik 2007, 148). In LM IIIB-C many new fortifications were constructed, consisting of massive walls and new guard houses (Alusik 2007, 154). However, from that period we start to enter the Cretan Dark Age (see Nowicki 2000, 41-222, for a catalogue of Dark Age sites), which is not the focus of this thesis.

As a final note on the significance of fortifications in general, Zielinski (1998, 528) stated that the construction of cyclopean fortifications of different kinds has played an important part in Minoan state formation. In a way it has indeed. The unrest during the Protopalatial period was followed by a defensive network of guard houses and watchtowers that helped create stable territories and states (for a while at least). Therefore, defensive structures seem to have had an important effect on how states were formed.

So far this thesis has provided a brief overview of the developments within Minoan archaeology relating to conflict and crisis on Minoan Crete. First the shift from a belief in a fully peaceful society to the acceptance that conflict and crisis were actually present. Then the discussion moved to the most important events that caused trouble within Minoan society and some possible effects, after which we took a closer look at the more prominent and surviving remains that provided evidence for unrest and conflict, namely fortifications. Having provided the necessary context, it is now possible to focus on the subject of this thesis: the Minoan guard houses.

The guard houses of Minoan Crete are an interesting type of architecture to study. Although they are usually quite small in size, there seems to be more going on than meets the eye. Arthur Evans saw the strong foundations of several guard houses and called them by different names, depending on their size and location. Examples are *frouria* (forts), guard stations and mother forts (Chryssoulaki 1999, 76). The name guard station or guard house stayed in use ever since, as is the implied function.

There are several features that have often been associated with guard houses. Although several specific guard houses will be discussed in detail in the next chapter, it is important to already give a clear idea of what is actually meant by a guard house. Chryssoulaki (1999, 78-81), who is part of the Minoan Roads research project, has presented a list of these features. This will be summarised below. It is important to keep in mind that not all features are present at every guard house.

1. Guard houses usually have a square plan of about 10x10 to 12x12m. If the building is smaller, it is either not completely preserved or it is a *vigla*, an outpost. The outer walls are constructed using megalithic masonry: large blocks of stone with small stones filling the gaps. These walls can be 1m to 1.20m thick.
2. Guard houses were always constructed with blocks of *sideropetra*, a grey limestone that was locally available. The style of construction is very typical of the MM II period.
3. There seems to be a default way of how the interior of these structures was arranged, based on some excavated examples. The main room is a paved rectangular space, surrounded by the other rooms. This is not always the case however.
4. A terrace, in many cases at the point which offers the widest view and control over the surrounding area.
5. A side entrance with a low doorway is visible in some guard houses. This is called a sally port, because of the similarity with sally ports in Mycenaean context, but it is not certain at all.

6. It is thought that the roofs have been flat, but we cannot know for sure, since roofs have not been preserved. The height is also a little problematic. The strong walls together with evidence for an upper floor suggest that they may have been buildings with multiple floors, although we cannot make any statements about their presumed height.
7. There are cases where there has been put a lot of effort in making it possible to build a guard house at a specific location. In those cases, foundations were constructed. Foundations were often very irregular, filling up ditches, levelling slopes, etc., to make it possible for a structure to be built on top.
8. Most guard houses were isolated structures in the landscape. It was not necessary for guard houses to be near any other site or settlement. The builders did their best to give the guard houses a very wide view, while making sure the guard house itself would be hard to access by hostiles.
9. Supplementary structures, to control access to the guard houses were built. Examples are strong enclosure walls that were sometimes placed in multiple rows around the guard house, and *vigla*, small look-out structures, that were placed near the guard house (although distance may vary). Sometimes these walls could be very high, as is the case at Mavro Avlaki, where the wall is preserved to a height of 2 m.
10. Guard houses were often built at natural features on low elevation that both give a good view of the surrounding area and are easily defended. Chryssoulaki sees the protection of roads as their main function. Cliff edges were often used, and when combined with walls, *vigla* and other natural features, these made guard houses very defensible.
11. Guard houses can be found in every part of the area studied by the Minoan Roads project. However, they do seem to be spread around main roads, but that was not yet confirmed when Chryssoulaki published these features.
12. In some guard houses sherds from the MM II period have been found, but LM I and LM III sherds have been found in all guard houses. Guard houses were often reused in later periods for all kinds of purposes. This later occupation can make it difficult to interpret some structures, since the sites have often been disturbed too much.
13. Some guard houses may actually not have been guard houses at all, but more like villas in the countryside. Their size, location and building quality make them stand out from the other guard houses.

The above points are the main features of Minoan guard houses. These can be further summarised into three general characteristics, namely 1) a clear defensive character, 2) a shared architecture, and 3) a close relation to the road network, with a controlling view of the surrounding landscape (Chryssoulaki 1999, 81).

Guard houses are usually subdivided into three groups. Firstly, the central posts or administrative posts, the complex guard houses. These are the largest guard houses, often built from higher quality stone. They may also have functioned partially as caravanserai. Secondly, standard guard houses. This is most common type. These guard houses are very small and simple, possibly comprising a few small rooms. Thirdly, smaller watchtowers or *vigla*. These are very small towers that seem to have served as lookouts and possibly for communication over longer distances as well. *Vigla* are often connected to a complex or standard guard house by a *peribolos* (Alusik 2007, 126). Alusik also lists as guard houses other 'cyclopean' style buildings where the defensive function was probably secondary to its primary role, for example a strongly built farmstead. According to Alusik they qualify as guard houses if they are on the right place in the landscape (Alusik 2007, 124). However, in many cases the true function of this kind of structure is hard to prove, if at all possible.

As may have become clear already, the main function of guard houses was to control movement and watch over the surrounding area. It is seen as no coincidence then, that they were mostly constructed near important roads or stone quarries. Examples of guard houses near a stone quarry are Aspres Plakes, Chochlakies, Karoumes, Polla Kladia, Mavromouri and Chiromandres (Alusik 2007, 127).

Because most guard houses share the same architectural style, it is thought that many may have been part of a large building programme, in which also the main roads were constructed, at the end of the EM period or the beginning of the MM period (Chryssoulaki 1999, 81-2). Although most guard house sites have been occupied from at least MM II, some of the earliest guard houses have been dated to MM I, for example the guard house at Myrtos Pyrgos (Alusik 2007, 150).

During the Protopalatial period, more and more guard houses and similar structures were built. Their occurrence has been related to the emergence of larger palatial territories. These centres needed to define and protect their own hinterland, hence roads and defensive fortifications were constructed. The main function of this network of roads and guard houses was, as already mentioned above, to control access to roads, which was basically a military function (Alusik 2007, 129). The most important and largest guard houses have been dated to the Protopalatial period. Not only were these located at defensible locations, they also had perimeter walls around them. The latter not only offered more defence, but also were a statement of power (Zielinski 1998, 518).

During the Neopalatial period the role of guard houses becomes more complex. Many old guard houses were still in use and new guard houses were built, often on locations that were not as defensible as before and without external fortifications, such as *periboloi* (Alusik 2007, 129). These smaller guard houses were constructed all over the territories to maximize controllability (Zielinski 1998, 519). However, at the same time, other guard houses were abandoned or adapted to fulfil a new function as farm, villa or workshop, e.g. at Sfaka. The above is probably related to a stable period without much unrest. Some scholars claim that Knossos united the island under one banner, which is still up for discussion, however, political stability, one way or another, would create a stable and safe society. Maybe because of this, guard houses were no longer needed as much to control access, but were instead used to watch over the economic activities, such as farming and crafting. These were necessary to support the palatial centres (Alusik 2007, 129).

Later, during LM II, not many new guard houses were built and the few that were built lacked the architectural qualities of the earlier periods. Also, *vigla*, *periboloi* and roads were lacking. It seems that at that moment the landscape was mostly no longer systematically controlled. The new guard houses that were constructed merely functioned as watch points or to control specific roads by themselves (Alusik 2007, 129), without being part of a defensive system.

Throughout the Cretan Bronze Age, guard houses seem to have functioned as control points, territorial defence and symbols of the status and power of the elite that was in control of the territory. All these functions can explain why these structures were mostly built on strategic locations (Zielinski 1998, 522-4). However, how defensible were these guard houses? Alusik (2007, 134-5) already noted, as a response to Zielinski, that although they were constructed using 'cyclopean' masonry, they would not last long against a real military force. Furthermore, he does not agree with the idea that during the Neopalatial period the Minoans changed to a system of border defence instead of town defence. Although there is evidence to support the idea of a territorial defence, which has been discussed already earlier in this chapter, Alusik has a good argument stating that this system would only work if the spread of guard houses across the island was regular, which is not the case. On the contrary, only in a few areas is there a high concentration of guard houses, and even in those areas the spread is not really regular (Alusik 2007, 134-5). There is a problem with Alusik's argument however. The lack of evidence for guard houses in other areas of Crete is most likely the result of no available documentation for other parts of the island that have not been studied thoroughly yet. Compared to other areas of Crete, the eastern part of the island, especially the territory of Kato Zakros, has a very high concentration of defensible sites. Many of them have been discovered by the research team of the Minoan Roads Project. These do not only include guard houses, but fortification walls and strongly built farmsteads as well.

When reading through the literature, one finds a lot of references to the defensibility of the Minoan guard houses. However, it occurred to me that this was mostly based on 1) the thick walls, and 2) their location. Thick ‘cyclopean’ walls have almost always been interpreted as defensible. When looking at the variety of functions of the different types of buildings that were constructed using this type of wall, there are more possibilities. Walls can be made strong for a variety of reasons. Thick walls are not only a sign of fortifications, but can be a way to isolate buildings to counteract high temperatures during the summer and low temperatures during the winter.

Another aspect of the guard houses that should be explored is their accessibility. Many guard houses are situated at locations that are difficult to reach. This was either because of the location itself or because of additional walls surrounding the site. There does not seem to be any previous research discussing this thoroughly, but it deserved more attention, because the identification and interpretation of guard houses are largely based on their degree of accessibility.

Because of the above questions related to the location and defensibility of guard houses, the following main research question has been studied: How defensible were the Minoan guard houses? The results thereof will be presented in this thesis.

In this study, multiple research methods have been used to (try to) get a better idea of the defensibility of a select number of guard houses. See the next chapter for an overview of the case study. The first method that was used was Least Cost Path (LCP) analysis, using GIS and a 3-D landscape model. It would be logical to assume that a defensible building is hard to reach. You would not expect such a building to be approachable from all directions, which would make it easy to attack it. Rather the opposite should be the case. To determine how many routes one could take to reach a guard house, LCP analysis was performed on a DEM of the research area. For a detailed description of the method and how it was performed, see chapter 3. For the results and a discussion, see chapter 4.

The second method that was used, is a quantitative approach which results in a Defensibility Index. This is an adaptation of a method used by Canadian researchers that studied the defensibility of sites on the west coast of Canada. Although it may not give a straight yes or no answer to the question if a certain guard house is really defensible or not, it gives an indication of its defensibility compared to the other sites in the sample. More information on this method can be read in chapter 3, and the results are discussed in chapter 4.

The third and last method that has been used is Space Syntax. The above two research methods both study the exterior of these buildings. Space Syntax was used to study the inside of the selected guard houses. Whether a guard house is defensible from the outside or not, the interior of a building can have an effect on its defensibility as well. In case hostiles get a chance to reach the guard house, there may still be a chance to defend it from the inside, or at least keep people inside more or less safe. Using Space Syntax theory and its Visibility Graph Analysis it was tried to get a first idea of the defensibility of the inside of guard houses. More information about this method can be found in chapter 3, with the results and a discussion in chapter 4.

Even though the results are already interesting, they must be looked at critically. Nonetheless, there may be room for improvement, but this thesis presents multiple new ways to study guard houses and it shows the possibilities for the future that may shine a new light on a topic that seems to have lost much interest in the last decade.

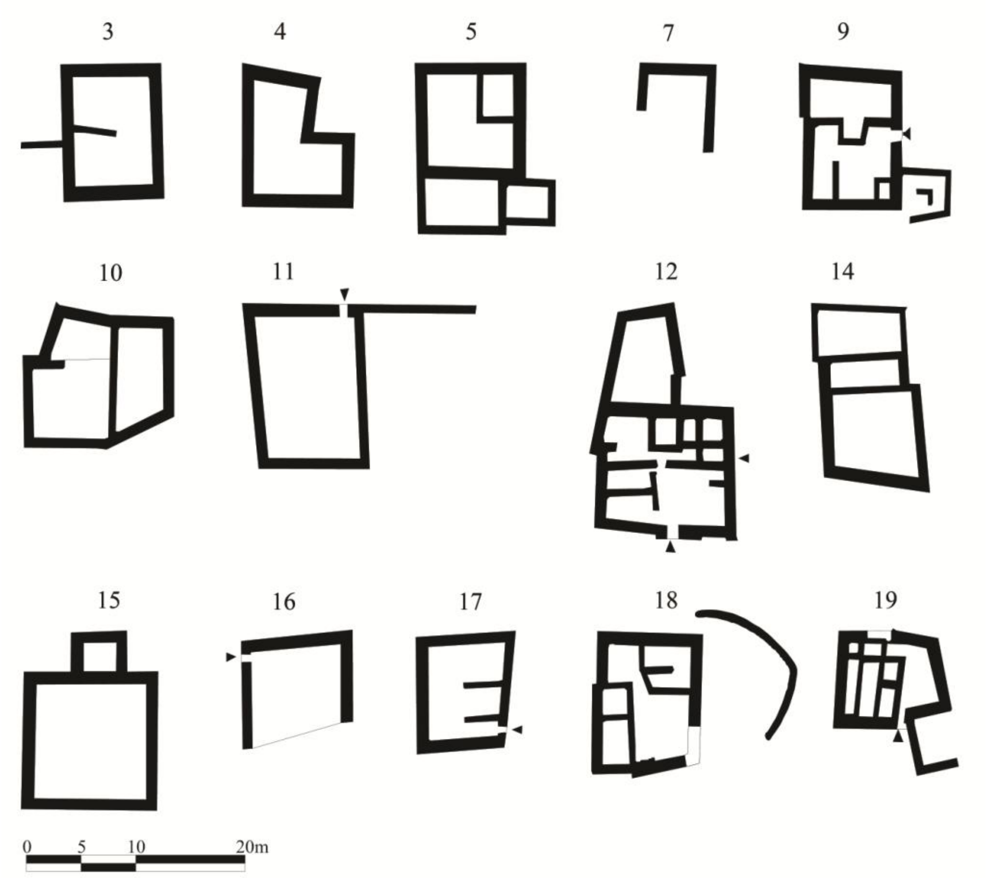

Figure 2: The structure plans of selected guard house that were studied (after Chryssoulaki 1999, plate VIIIa).

3: Plakalona
4: Farangouli
5: Mavromouri
7: Chochlakies
9: Kokkino Froudi
10: Sfaka
11: Agio Pnevma
12: Chiromandres
14: Mavro Avlaki
15: Polla Kladia
16: Kali Elia
17: Aspres Plakes
18: Karoumes – Fort of the Sea
19: Karoumes – Mother Fort

2 Case study

The previous chapter provided an overview of previous research and explained the goal of this thesis. Before continuing with the discussion of the methods of analysis that were used and the results, it is important to discuss the sample that was used for the study of the defensibility of Minoan guard houses. Figure 2 shows the selection that was made, except for three sites of which no building plan was available. Figures 3a and 3b (next page) show the area of Crete that has been studied and the locations of these guard houses on the map. This sample was mostly based on the publication of several guard house plans by Chryssoulaki (1999, plate VIIIa). A large number of these plans, however, did now have any clear entrance. It is possible that people entered from an upper floor, which has not been preserved for any of them. Also, many of the guard houses plans were too simple and/or too small to really say anything about the defensibility. At least, that was the idea before this study began. The guard houses that have been used in this research, are the ones with a more complex layout of those with an entrance, but several simpler buildings have been included as well. For the Least Cost Path analysis, the lack of an entrance, the low complexity of most of these guard houses and the lack of a building plan did not matter, so all were used. For determining a Defensibility Index, three guard houses were unsuitable for analysis, because there was no plan available to determine the size of the guard house site itself. The same smaller selection was used for the Space Syntax analysis, since this also requires good building plans.

Before providing more details about the selected guard houses, some information will be given about their discovery. Many Minoan guard houses have been discovered in the eastern part of Crete, in the area between Palaikastro in the north and Ambelos in the south. Although there have been multiple research projects in this area of Crete, the most noteworthy may be the Minoan Roads project (see Tzedakis *et al.* 1990; Tzedakis *et al.* 1989). This is a project of the Greek Ministry of Culture that was started already in 1984, with the goal to study the layout and construction of roads and a road network during the Protopalatial period. The project first started in western Crete, but moved to eastern Crete in 1986 when it became possible to date roads (Tzedakis *et al.* 1989, 45). Based on the assumption that constructing roads takes a lot of effort and required a high level of organisation and a large number of people, the project also included a study of Minoan society in this period (Chryssoulaki 1999, 75).

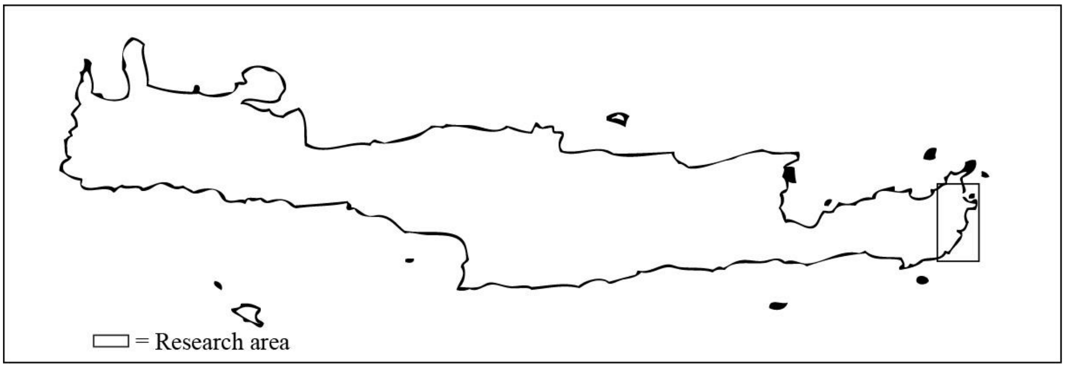

Figure 3a: Map of Crete with the research area marked.

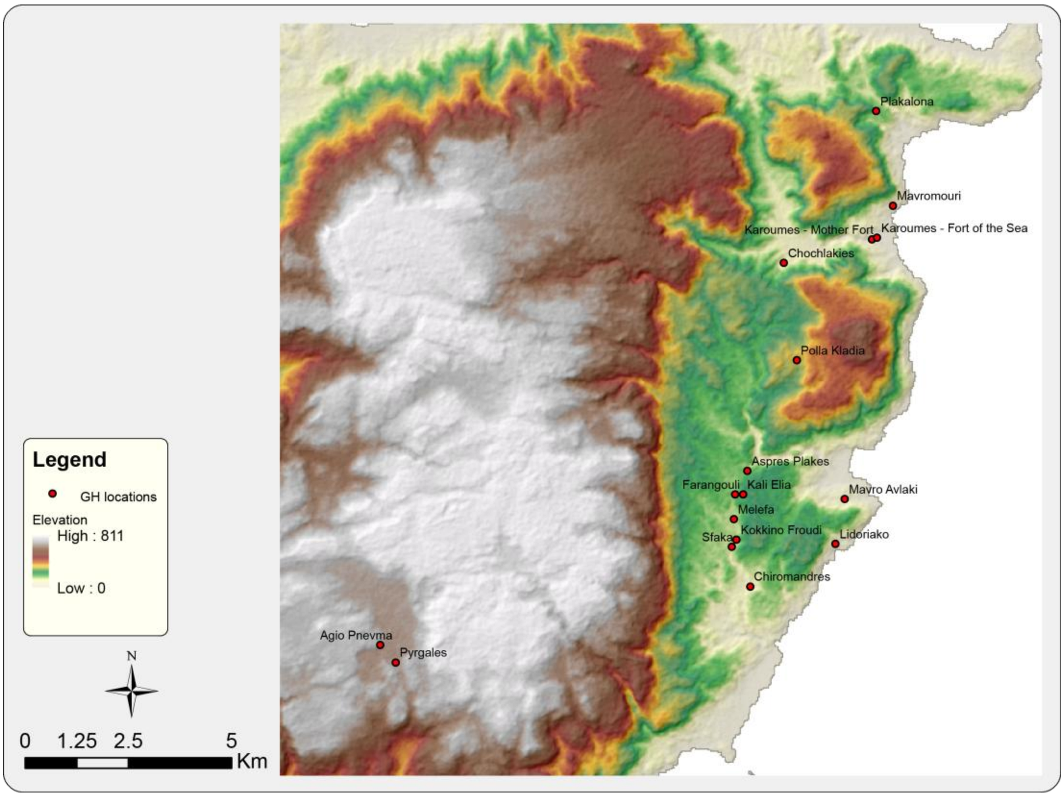

Figure 3b: Geographical locations of the studied guard houses.

The eastern part of Crete was chosen as the main research area, and in the first half of the 1990s this area was systematically surveyed. In addition to the study of the road network, it was also decided to map any archaeological sites that were discovered. Hence, the Minoan Roads projects did not only contribute to our better understanding of Minoan roads, their function, dating, and conservation (Chryssoulaki 1999, 75), but also of other sites, among which were many guard houses, *vigla* and related structures. Much of this knowledge has already been discussed in the previous chapter.
Tzedakis *et al*. (1989, 44) recognised three development stages in the construction of a road network. The first roads are very simple roads meant for communication. The second type of roads is meant for vehicles. These roads are of better construction, are wider, less steep and can be paved. The third type of roads is military roads. The latter are the most important roads that can cross a large region and extent over long distances. These roads are usually straighter, use easier slopes and are guarded by guard houses. This military function of the road network was also attested by Tzedakis *et al*. (1989, 60). Moreover, this has been used by some to explain the presence of Minoan guard houses. Zielinski, for example, suggests that the road system was constructed at the same time as the network of guard houses, beginning in the Protopalatial period with a peak during the Neopalatial period, as a means to claim territories (Zielinski 1998, 538). It is during this period of development of society that guard houses held multiple important functions. Not only did they control access to roads, they also monitored the entire region by being visually interconnected (Alusik 2007, 131-2). Based on the correlation between many guard houses and the road network, it can be established that guard houses seem to be placed in relation to specific roads, even if they were not constructed at the same time. Many guard houses that were found and surveyed during the project have been published by the Minoan Roads research team, although not all publications are easily available.

Now that the history of the project responsible for the documentation of most guard houses in eastern Crete has been discussed briefly, each of the guard houses in the sample will be introduced individually. It must be noted here, that not all of these guard houses have been described in detail in publications (or publications were unavailable). In many cases, there is little information available. However, especially for those guard houses, the results of this defensibility research are interesting. The sites will be discussed in alphabetical order. When no size information was available, the buildings were measured in AutoCAD.

Agio Pnevma: this site is located on top of a flat hill that looks over the surrounding area (Alusik 2007, 126). Similar to other guard house sites, there are one or more *periboloi* around the site following the edges of the hill (Alusik 2007, 131). This building consists of only one large room of about 11x15 m in size.

Aspres Plakes: this site is a good example of a guard house close to an important source of stone, possibly to control the quarry (Alusik 2007, 127; Zielinski 1998, 431). This guard house, which measures roughly 8x10.5 m, consists of three spaces, although it is difficult to establish whether these functioned as individual rooms. The inside is subdivided by two small walls.

Chiromandres: the site of Chiromandres has been described as a guard house, based on the topography and the archaeological finds at the site. The structure, which is about 14x28 m in total, has two building phases, one dating to MM II and one dating to the Neopalatial period. Zielinski thinks, based on comparable sites, that this structure was multifunctional, which would set it apart from other buildings that only have the guard house role (Zielinski 1998, 505). In the Neopalatial period, many guard houses were adapted to fit other purposes, so that could explain the multifunctionality that seems to be visible at Chiromandres. Tzedakis *et al.* (1989, 55) suggest the road which leads from Kato Zakro south to Ambelos passes close to this site. The middle of the building has a paved floor and there are several rooms around it. Evidence suggests a possible role as a kind of service station, because of the available kitchen, water supply and discovered millstone. These remains have been dated to the Neopalatial period and later (Tzedakis *et al.* 1990, 51).

Pottery finds at the site suggest two periods of occupation, MM IIA and MM IIIB/LM IA. This fits the two construction phases and is also similar to the dating of other guard houses and is possibly connected to the start of the Minoan road network (Tzedakis *et al.* 1989, 72; 4). Sometime during LM I this guard house seems to have been abandoned, but it was reoccupied again during LM III, possibly only for a short time (Alusik 2007, 153; 5).

The guard house is located at the north-eastern side of a plateau, where it has a good view overlooking the valley below. Around it are walls and watchtowers, but these are much smaller than the guard house itself (Tzedakis *et al.* 1990, 48). From the *periboloi* around the guard house, only the foundations have been preserved (Tzedakis *et al.* 1990, 56). At Chiromandres, the walls that surround the terraces around the site were large and connected to the main building. Alusik suggests they may have functioned as ramparts (Alusik 2007, 131). The nine *vigla* were also connected to the guard house by *periboloi* (Alusik 2007, 140; 50).

Chochlakies: this is another example of a guard house that was located close to an important stone quarry in the south-western part of the plain of Chochlakies. It was one of the later guard houses, being constructed in LM I (Alusik 2007, 127-8). This building is about 10x10 m in size and is located on a terrace that is difficult to access. According to Zielinski (1998, 504), this guard house takes a bastion position in the landscape.

Farangouli: there was no information found about this guard house in the available literature. However, it was an L-shaped guard house, approximately 10x12.5 m in size.

Kali Elia: this guard house is also located on a defensible terrace, situated above the surrounding area, with a good view towards the west from a bastion-like position (Alusik 2007, 126; Zielinski 1998, 504). There were *periboloi* following the edges of the hill around the building (Alusik 2007, 131).

Karoumes – Fort of the Sea: this is another example of a guard house close to a quarry. It is located at the eastern end of the Chochlakies gorge, with a good view of the coastal plain and the pass through the gorge. Because of its large size of 12x20m, this guard house was interpreted as an important administrative centre (Zielinski 1998, 502). It was built during MM IIA and was already abandoned during MM III (Alusik 2007, 127-8). Several *vigla* and *periboloi* were constructed near the site at the same time (Alusik 2007, 150). During LM I the guard house was occupied again and a new construction phase is visible. However, in LM IB, it was destroyed by fire (Alusik 2007, 128). Alusik suggests there was no entrance found at this guard house (Alusik 2007, 130), whereas the published plan of the building shows an entrance. There are indications that this site served multiple functions. Besides the function as a guard house, there is evidence for farming activity as well (Zielinski 1998, 432).

Karoumes – Mother Fort: this building is located very close to Karoumes – Fort of the Sea. Just like the Fort of the Sea, this guard house is located near a quarry (Alusik 2007, 127). Karoumes – Mother Fort was also constructed during MM IIA. Unlike the Fort of the Sea, this guard house remained in use during MM III. Here, too, *periboloi* and *vigla* were located around the site (Alusik 2007, 150; 2). The walls were large and connected to the guard house. Terraces had been constructed in front of the guard house, possibly as watch points, but maybe also to build a workshop or stable on (Alusik 2007, 130-1). It was approximately 10x13 m large.

Kokkino Froudi: this guard house was constructed during MM IB/II on a high point on the edge of a gorge. The guard house was surrounded by walls which possibly functioned as ramparts. During LM IA this guard house was adapted to serve as a pottery workshop (Alusik 2007, 126; 8; 31; 50). The building was approximately 9x13 m large.

Lidoriako: there is not much information found about this site in the literature. It is a *vigla* along a road towards Ambelos (Tzedakis *et al.* 1989, 75), located on a high point (Alusik 2007, 126). There is no plan of this building, hence the dimensions are unknown.

Mavro Avlaki: this is another guard house of which not much is published. Apparently, there is still a 2m high wall preserved around this guard house (Chryssoulaki 1999, 79-80).

Mavromouri: the only available information states that this building was also located very close to a stone quarry (Alusik 2007, 79-80). As can be seen from the plan, it seems to have multiple rooms that are not connected to each other and do not seem to have any entrances. Again, it may have been possible to enter from an upper floor. This guard house was about 10x12.5 m large.

Melefa: there was no plan of this guard house available, but according to Tzedakis *et al*. (1989, 75) this guard house was located along the transportation route to Ambelos.

Plakalona: other than the plan of the guard house, there was no information available. This structure is about 10x12.5 m large and has one room, which is subdivided by a short wall.

Polla Kladia: this is another guard house that is located on a terrace on a hill, close to a stone quarry, looking over the surrounding landscape (Alusik 2007, 126-7). As can be seen from the plan, there is one large room and one small room, not connected to each other and without any entrance. Again, it may have been possible to enter from above. The guard house was approximately 12x16 m large.

Pyrgales: this guard house was constructed during MM IB and it seems to have remained in use until it was destroyed in LM I (Alusik 2007, 128; 50-52). Although no building plan was available, it has been suggested that this was an important administrative post for the upland areas (Tzedakis *et al.* 1989, 75; Zielinski 1998, 452), which might suggest a more substantial layout and larger dimensions.

Sfaka: this guard house was constructed in MM IB at a high point on the edge of a gorge, but it was already abandoned at the end of MM II. During the Neopalatial period, this guard house was reoccupied and adapted to function as a workshop (Alusik 2007, 126; 9; 50-51). Zielinski only suggests a Neopalatial date, but does note the existence of a *vigla* at the site as well, and that this site was located on a ridge along the eastern side of the road from Zakros to Ambelos, possibly guarding the route (Zielinski 1998, 504-5).

The above listed sites are the guard houses that have been studied. For most of them a building plan was available, allowing all of the analyses to be carried out, while for the three guard houses without a plan only the Least Cost Path analysis was conducted. The following chapter will discuss the different analyses that have been performed on these guard houses, followed by a chapter presenting the interpretation of the results and the interesting insight that can be inferred.

3 Methodology and methods

In the last chapter, the sample of guard houses was discussed. In this chapter, the research methods are discussed and it will be explained how they have been applied to the selected guard houses from the Zakros area in the far east of Crete. This chapter is divided as follows. First the methodology foreach type of analysis will be discussed. This is followed by a description of the specific methods and tools used for the analyses. Before continuing, however, it is important to restate the goal of the research.

The goal of the research was to examine the defensibility of Minoan guard houses, by conducting Least Cost Path analysis, calculating a Defensibility Index, and carrying out Visibility Graph Analysis. By applying methods that have never been tried out before on these buildings, it may be possible to not only give new insights on the guard houses themselves, but also critically evaluate the methods that were used and to explore how to further improve them. The former may rekindle an interest in these structures and any other type of architecture that has been called defensive or defensible. The latter will show examples of methods that can be perfected in the future to widen our understanding of guard houses and similar structures.

3.1 Methodology

3.1.1 Least Cost Path analysis

In this section, the methodology behind the methods will be discussed in the order they have been applied, starting with Least Cost Path (LCP) analysis. To better understand the use of LCP analysis for studying guard houses, it is important to first discuss the relevant GIS background.

GIS software packages developed in the last one and half decades or so have made it a lot easier for people to analyse landscapes. While these packages were first used mostly by geographers, archaeology has been using it more and more for a long time now as well. GIS allows for the reconstruction of landscapes based on numerous input data. Most often Digital Elevation Models (DEMs) are used to construct the shape of the landscape, while other datasets may add vegetation, land use, etc. Another advantage that is very useful for archaeologists, is the ability to add a time factor if needed. The possibilities are almost endless.

For this study, Least Cost Paths were calculated in ArcGIS. The exact method that was used will be discussed in the Methods section, but first it is important to briefly explain what Least Cost Path (LCP) analysis is and what the (dis)advantages of this method are.

As the name suggests, this method calculates the path between two points that takes the least effort to take to move from A to B. All that is required is a cost model to generate these. The higher the quality of the cost model, the more accurate the results will be. However, cost models can be created in different ways. The most basic cost model is solely based on the DEM. Slope values can be calculated from a DEM. Obviously, the higher the slope value, the more effort it takes to move across a cell. If only the Slope variable is used as input for a cost model, the cost of moving between cells is the same as the slope values. This may or may not be enough, depending on what needs to be studied and on the availability of other datasets. For example, if land use is also taken into account, the cost of moving from cell to cell is determined by the steepness of a slope and the set difficulty of moving on a certain land type. For example, a completely flat wasteland will have much lower cost values than a forested area with high relief. There are many other variables that can be added in similar fashion. When calculating a LCP, distance is also taken into account. However, by default this is not a metric distance, but a cost distance. The result of the Cost Distance function was used as input for the Cost Path function, which calculated the LCP. This distance is based on a calculation of the cost value of each cell in the raster instead of a metric distance. These cell values are accumulative, so the further away the cell from the origin, the higher the value. Therefore, the relative distance is similar, but not identical, to the relative metric distance. This is also the reason why a LCP is called Least Cost Path and not Least Distance Path.

There is more to keep in mind, however, when doing LCP analysis. Firstly, the accuracy of the DEM that is used. To get accurate slope values, a high resolution DEM is necessary. Different options are available here. Some may create their own DEM based on their own elevation measurements. These may or may not be very accurate, depending on the distance between measurements. There are also companies that sell DEMs, for example based on high resolution SPOT satellite imagery. For those that do not have the resource available to afford these very high resolution DEMs, there are also DEMs that are freely available. Perhaps the best known of these is the ASTER GDEM. The latter is made available by the Ministry of Economy, Trade, and Industry (METI) in Japan and NASA. ASTER GDEM version 2 was released mid-October 2011, which greatly reduced a bias in the first version, uses a smaller correlation kernel for higher spatial resolution, and has better coverage, further reducing the number of artefacts and voids in the data. Compared to ASTER GDEM v1, v2 has a much higher accuracy, both horizontally and vertically (ASTER GDEM Validation Team 2011, 1-23). This DEM has a resolution of 1 arc second, which comes down to about 30 meters. Compared to the commercial DEMs this resolution is rather low, which does affect the usefulness for studies that really require a high accuracy. However, for simple landscape analysis this is sufficient. For example, Soetens *et al*. (2003, 484) used a 50m resolution DEM based on SPOT imagery for their analysis of Minoan peak sanctuaries, which was seen as accurate enough. Chrysoulakis *et al*. (2011, 157) concluded, in their discussion of using ASTER GDEM v1 for Greece, that although it does not meet the required accuracy, it can still be used for studies like topographic analysis, landscape modelling and geomorphological modelling of Greece. The ASTER GDEM v2 has a much higher resolution, so it would give even better results.

Secondly, it is important to understand two characteristics of slopes when doing movement analysis, like LCP analysis, using slope values. First and foremost, although by default calculated slope values show a linear progression, meaning that moving up a 45 degree slope is 45 times more difficult than walking on a flat surface, this is not the case in reality. Secondly, moving across slopes is not only up and down. Direction often changes in reality, as will the slope angles (Bell and Lock 2000, 88). Being aware of this, and possibly correcting the slope values, is important when calculating human movement.

Thirdly, LCPs that are created from cost models with additional datasets of land use, roads, etc. are seen as more realistic, because these additional datasets help create a cost model that is as real as possible (Gonçalves 2010, 984). However, just as important as having accurate source data, is setting the right cost values to each category (Adriaensen *et al.* 2003, 243). In most GIS software it is possible to set a ratio of importance for every dataset added to the cost model. Depending on what is studied, it may be necessary, for example, to set a higher relevance for the land-use dataset, or for specific values within a dataset. Not taking this into account may give a skewed cost model, resulting in less realistic LCP results.

Lastly, there are some flaws in the algorithm used to calculate LCPs. One flaw for example is that moving down slope is favoured over moving up slope, even when the down slope degree is very high. Direction is not taken into account. The algorithm does not know that moving down a steep slope can be as hard as moving up a steep slope. Not only does that possibly cause paths that actually have a high cost in real-life, it may also cause paths to move down a slope, while it may be less demanding to stay on more or less level ground (Bell and Lock 2000, 89-92). There is another thing that is not integrated into the LCP algorithm. Although it does not directly influence the results, it may be the most important thing to take into account: human behaviour and perception. Even if all of the above is done correctly, the algorithm used to calculate LCPs does not use human behaviour and perception. LCP analysis assumes that a person has complete knowledge of the surrounding landscape, and that that person not only is able but also willing to choose the most efficient path through the landscape (Howey 2011, 2524). For example, based on a cost surface the most efficient path is calculated to move from A to B.

However, landscape features can have multiple effects on both a physical and mental level (Llobera 2000, 72). Even though the calculated path is technically the least cost path, there may be something blocking this path or repelling movement, physically or otherwise. Also, real people do not always choose the same path again and again (Howey 2011, 2524-5; Llobera 2000, 77). People are to a certain extent attracted to adventure and like to wonder, take different paths, to see different surroundings for example. These flaws make clear that it is hard to put all factors deciding movement into an algorithm (Bell and Lock 2000, 92), especially the behavioural factors that differ from person to person.

If paying attention to the above, the LCPs that are generated can be said to be realistic. However, the algorithm does not account for multiple paths to a destination (Howey 2011, 2523-4). LCP analysis still only provides a single route between two points, the least cost route, and as already mentioned, people do not necessarily take this specific route. A possible solution to this problem is an analysis called Circuit modelling. This method, based on graph theory, network theory and circuit theory, basically sees the landscape as an array of circuits, each with a different resistance value, allowing or disallowing movement. The result is a map showing all possible routes, not just the shortest or most efficient route (Howey 2011, 2524). However, it may not always be possible to see the most efficient route in the results. Showing the least cost path on top, thereby combining the two methods, will present the best of two worlds. The LCP is clearly visible, but at the same time all other possible routes are visible as well, making it easier to give a more realistic interpretation. However, Circuit modelling is not used in this thesis, so I will keep it at this short introduction.

The above discussed the advantages and limitations of this GIS based analysis. The main advantage of LCP analysis is that the result shows the most efficient route from one point to another. Assuming people want to use the fastest route, this may represent good locations for roads, for example. However, as was shown in a study by Bell and Lock (2000, 92), it may be necessary to make some adjustments in some cases. This advantage is also the disadvantage. People do not always use the least cost path to a destination, for a variety of reasons, making only one generated path useless in a way, because human behaviour is not taken into account. Also, the results of LCP analysis are really dependent on an accurate cost model.

In the Methods section it will be explained how LCP analysis was exactly used on the selection of Minoan guard houses to study the defensibility of these buildings. However, is it at all possible to study the defensibility of guard houses by using LCP analysis? This is an important question to answer before discussing how the analysis was done exactly. How can one or more LCPs say anything about defensibility?

Guard houses are often said to be defensive and/or defensible buildings. In the case of a defensible building, one would expect access to this building to be limited. This can be done by other structures, like walls, but also by placing such buildings on locations that are hard to reach. For Minoan guard houses, the location is often one of the main reasons why these buildings were identified as guard houses. Often, they are located on high points along a ridge or gorge, which supposedly makes them hard to reach. By conducting LCP analysis and counting the number of LCPs reaching the guard house, this study attempted to gain insights into the defensibility of Minoan guard houses. As was said above, the main assumption was that a defensible building should not have many access routes. Of course there are limitations and flaws in the use of this method, but these will be taken into account and explained in the Discussion chapter (Ch.5).

3.1.2 Defensibility Index

The next method that was used is originally not so much GIS based, although the adaptations made for this research did make use of GIS. The Defensibility Index (D.I.) was originally designed by Andrew Martindale and Kisha Supernant of the University of British Columbia for their anthropological study of the defensibility of native settlements on the northwest coast of North America (see Martindale and Supernant 2009).

The different variables that are combined to form the D.I. value, Visibility, Elevation, Accessibility and Area, are mostly based on biomechanical limitations. This means that the capabilities of people to inflict damage to other people is limited by the limitations of our bodies (Martindale and Supernant 2009, 192). Basically, we cannot do more than our bodies allow us to do. The authors argued that it would be possible to quantitatively compare the defensibility of sites across cultural boundaries, because of the shared biomechanical limitations.

The architectural and landscape features that can be seen as defensible have been combined, because for the quantification of defensibility they are very similar. The effects of man-made defensive architecture, like walls, create similar circumstances as a natural barrier. Also, man-made defences are often labour-intensive, but living at locations that can be said to be naturally defensive can be just as costly (Martindale and Supernant 2009, 194).

The main advantage of this approach, is that it makes it easy to compare the defensibility of different sites, without looking at specific parts of architecture. It is the general arrangement of features in relation to each other that determines the “capacity for interaction” (Martindale and Supernant 2009, 194).

In the case of their research, Martindale and Supernant chose the four variables mentioned above, that are also often related to defensibility, to combine them into the D.I. These four variables could each have a value between 0 and 1. When combined, this would give a D.I. value between 0 and 4, with 0 being non defensible and 4 being inaccessible. All measurements were done without using GIS, but instead using tools, like a protractor, and maps that everyone can work with. The four variables will be briefly discussed.

As far as Visibility is concerned, the visibility beyond 100 m around the site was the most indicative. To determine the Visibility value, the number of degrees of visibility beyond 100 m was divided by the degrees of Approach, which was the arc around the site from which the site can be accessed (Martindale and Supernant 2009, 195).

To determine the Elevation value, the degrees of elevation difference between the highest point at the site and the average elevation outside of the site was calculated. This was then divided by 90 to get the Elevation value between 0 and 1 (Martindale and Supernant 2009, 195).

Calculating the Accessibility values is more difficult. First the inverse of Approach is calculated. Then the degrees of Access, which is the arc around the site that does not limit access because of man-made features, is subtracted from the degrees of Approach around the site. The remaining value is then divided by the degrees of Approach. The remaining two values are then added together and divided by two to determine the Accessibility value (Martindale and Supernant 2009, 195).

The Area value is the easiest one. The area of the each site is divided by the area of the largest settlement in the study area (Martindale and Supernant 2009, 195).

The D.I. is then calculated by adding the above four values together. Martindale and Supernant believe that values above three are too ideal, so they limited the effective range to 0-3. They are aware this is a rather coarse approach, but expect to see broad differences that can be compared (Martindale and Supernant 2009, 196)

The above has explained the workings of this Defensibility Index. Because of the combination of variables that are often used as indication for defensibility, and the interesting results that were published by Martindale and Supernant, this method was chosen to study the defensibility of Minoan guard houses.

However, because of the availability of GIS, some changes were made to how the data was collected in our study. In addition, the Area variable was removed from the D.I., because it did not really add much because of the small size of the guard houses and the lack of graphical information about the walls surrounding sites. Before explaining how the analysis was exactly done, it is important to first discuss viewsheds in GIS, because these were used to determine most of the values.

Viewsheds are basically the field of view from a specific location, in this case from the guard houses. Viewshed analysis has been used by archaeologists since the 1970s, in the pre-GIS era (Wheatley and Gillings 2000, 2), but GIS developments in the last two decades have made it much easier to carry out this kind of analysis. The result of a traditional viewshed analysis in a GIS is a table with 0's and 1's, showing how many cells are invisible and visible from that specific location. A cell is either visible or not, there is no in between (Wheatley and Gillings 2000, 10). However, vision is not a constant and the larger the distance, the lower the clarity. Actually, beyond about 1200 m distance humans no longer see any depth, so it becomes very hard or even impossible to differentiate between objects (Antrop 2007, 69). Wheatley and Gillings (2000, 11) suggest using fuzzy viewsheds, with values between 0 and 1, to get a far more realistic viewshed. Another way is to create what is called a Higushi viewshed. This is a viewshed based on three distance ranges, based on local landscape factors, such as the height of the most common tree (Wheatley and Gillings 2000, 15-7). By using this type of viewshed it is possible to get an idea of how well something can be seen .

In archaeological studies using viewshed analysis, vegetation, one of the most important landscape features, is often ignored. This results in a viewshed that sees nothing more than the surface of the earth, while vegetation data would provide us with more accurate information (Tschan *et al.* 2000, 34). This is a very big problem, because vegetation can really change the visibility and perception of a landscape. However, when adding a vegetation layer into a GIS, the entire field of view may be blocked by it, because the layer is seen as one block of trees, for example (Tschan *et al.* 2000, 42). The latter does not take into account that people will actually be able to look through at least the first couple of rows of trees, unless the forest is very dense.

However, for determining the arc of view, that is required for the D.I. variables, traditional viewsheds are sufficient. The higher accuracy of a fuzzy viewshed or the better visual representation of the Higushi viewshed would not add any useful information in this case. The only change that was made was setting the maximum viewshed range to 1200 m, to account for the lack of clarity from that distance and beyond.

The Methods section will discuss exactly what was done to obtain the D.I. values for the sample of Minoan guard houses.

3.1.3 Visibility Graph Analysis

The last method, Visibility Graph Analysis (VGA), was used to study the inside of the guard houses, while the methods and techniques described above were concerned with the wider area of the guard houses. To achieve a complete picture, it was considered necessary to analyse the interior as well, even though the sample was small. VGA is part of Space Syntax's theories and methods. Before discussing in more detail the specifics of the variables of VGA that were used in this study, Space Syntax theories and methods will be explained, raising also some of the problems that are inherent to this theory and method.

The last few decades have seen a large increase in the use of spatial analyses in archaeological research. Theories and methods from other fields of study, like urban planning, geography and even psychology, have slowly become integrated in archaeology, offering new perspectives and interesting results. One of the theoretical and methodological approaches that has been used more and more is Space Syntax. Space Syntax can be used to study different aspects of the built environment, both inside buildings, studying for example the hierarchy of rooms and accessibility, and outside, studying the layout of towns and important access routes. Through the years, some important relationships between people and the space around them have been defined, making it possible to better understand how people create their spatial environment and interact with it.

The ideas of Space Syntax were first published by Hillier and Hanson (1984). Working at University College London, Hillier had started a research program to develop a new way to look at space. He found that although space was seen as important in creating architecture, not enough attention was paid to space itself, what it is and why and how it matters (Hillier 2005, 2). Instead, more attention was paid to "surfaces that define the space" and "the individual space" (Hillier and Hanson 1984, 13). It must be noted here that with space he usually meant urban space, the space between and within buildings. With Space Syntax he developed a new way to look at space itself, born from the idea that space is "the common ground of the physical and the social cities" (Vaughan 2007, 207). There were earlier attempts to look at space, like territory theory, but these attempts did not see the social factor in created architecture (Hillier and Hanson 1984, 18). The main focus of Space Syntax, however, is the relationship between societies and space, by looking at the structuring of inhabited space (Bafna 2003, 17). In other words: the configuration of space.

Since 1984 a lot has changed. Firstly, the theory and method have been applied in different fields of study than urban development and architecture, for example in archaeology (see Letesson 2009; Stöger 2011, for instance). Secondly, mostly in the last one and a half decade or so, computer software has been designed to use Space Syntax, of which Depthmap (see Turner 2004) may be the most noteworthy. It is fair to say that this has had a big impact on the use of Space Syntax for research. In a way, it made applying it much easier and also made it possible to do more advanced calculations.

Interestingly, Space Syntax can be seen both as a theoretical framework and a method. One the one hand there is the theory behind it that on its own can already be useful. On the other hand there is the practical application, giving us the tools to use the theory. Using the words of Hillier *et al*. (1987, 363), Space Syntax "is a set of techniques for the representation, quantification, and interpretation of spatial configuration in buildings and settlements”.

There are several methods that are often used when Space Syntax analyses are being applied to the archaeological record. The following two will not be used any further in this thesis, but they will be touched upon, to show the variety of methods that are available. Firstly, there is a technique called ‘convex space partitioning’ that is often used to study the inside of buildings. A convex space is a space in which from every point in the space, you can see the entire space. A good example is a rectangular room. One room can, however, have multiple convex spaces. Its main strength lies in the ability to show relationships (or ‘relatedness’) within the plan of a building (Bafna 2003, 23). If the function of each room is known, it may be possible to say something about social relationships based on the relationship between the rooms. Also, the distance from the starting point to reach a certain room is measured in ‘depth’. The more steps/rooms it takes to get to the back room (or node, when looking at it as a graph), the more depth a building has. When the depth value is low, the space is ‘integrated’, which means it is easy to get to where you want to go. When the opposite is the case, when the space for example has a depth of four or higher, the space is ‘segregated’, because the ‘connectivity’ to the furthest out space is low (cf. Hillier 2005, 6; Vaughan 2007, 209). As the name implies, ‘connectivity’ is how well spaces are connected. From this, movement patterns can be retrieved and it can be calculated how well spaces are integrated or segregated and whether they generate interaction of privilege privacy.

Another method that is often used to study the movement of people through space, is ‘axis analysis’. This works by basically drawing lines of sight, the longest and fewest, on a plan of a building or even a city, whereby every line crosses at least one threshold or junction (cf. Bafna 2003, 23; Hillier and Hanson 1984, 109; Penn 2003, 35). Research has shown that axial maps have a high correlation with flows of movement as observed in real life (Penn 2003, 34). The lines that statistically have the highest integration appear to be main routes in the real world. This has interesting consequences and promises to be useful, for example in archaeology, where it may be possible to predict certain buildings or other monuments at certain locations. It must be noted that there are different types of axial analysis (see Hillier 2005, 16; Vaughan 2007, 216), but since axial analysis was not used in this research, it is enough to know they exist. Lastly, there are three main criticisms of using axial maps in Space Syntax. The first is that metric information is discarded by the topological representation of the city or building plan being studied. (Ratti 2004, 4). This may have the advantage that it makes comparisons on different scales possible, but it makes it impossible to analyse the effect of distance on connectivity. However, when metric distances are applied to axial maps, the results would be skewed, masking the relations between function and spatial configuration (Hillier and Penn 2004, 505-6). Therefore, keeping the metric information separated is preferable. Secondly, and this may be more a critique of Space Syntax itself, 3D information is ignored (Ratti 2004, 6), so the effect of tall buildings on people's perception is not taken into account. Thirdly, land use and elevation are not taken into account (Ratti 2004, 7). Although these are valid points, and indeed some data are ignored when conducting Space Syntax analysis, the correlation between Space Syntax results and empirical studies measuring real flows of movement in several cities has shown that the statistical differences are small.

Recent computer applications, like Depthmap, have made it easier to perform various Space Syntax analyses and obtain clearer results. Furthermore, Space Syntax has added VGA to the 'toolbox', adding cognitive factors such as visibility. VGA works by placing a grid on top of the building plan to be analysed. The grid size is by default set to about one real-life step, about a meter, based on the resolution of the plan itself. This size can be changed, however, to allow for more detail. Every calculation is done for every cell in the grid. Depending on the size of the plan, grid size, the complexity of the plan and the computer used for the analysis, calculations can be fast or terribly slow. However, the results are worth it.

There is a wide range of global and local values that can be calculated for each cell in a created grid over a building plan, from basic values like Connectivity and Integration to several Isovist values. The first two measurements have already been mentioned above. Connectivity is basically a measurement of how connected a location or building is. The higher the connectivity value, the more spatial units are directly connected to it (Bafna 2003, 27). Integration is similar, but has more to do with how easy it is to get from one location to another within a building. Also, the higher the integration value of a space, the more likely it is that it is an often used space, because of the correlation between integration and distribution of people, which has been shown in urban contexts (Bafna 2003, 25). Other interesting measurements are the isovist values.

An isovist is basically the polygon of the field of vision from a specific location. Besides the possibility to generate an isovist for specific points, it is now also possible to do more advanced calculations in which isovists are calculated for every point in a grid. In this way, different values can be calculated, based on those suggested by Benedikt in 1979, not only for a specific location, but for the building as a whole. The results are then displayed in a visibility graph to make it easier to identify locations of higher or lower value. Some of the isovist measurements, as defined by Benedikt (1979, 53), are isovist area, perimeter and occlusivity. Isovist area and perimeter sound rather obvious, but the latter originally was not the complete perimeter of an isovist, but only the length of those edges that connected to walls (Benedikt 1979, 53). In Depthmap, the Isovist area is, as expected, the area of an isovist, and Isovist perimeter is the complete perimeter of an isovist, including both the edges connected to walls and the Isovist occlusivity. Isovist occlusivity is the length of the edge of an isovist, behind which more open space is located. The higher the occlusivity value, the more open space is occluded from sight.

Not only do isovists give an idea of what was visible from a certain vantage point and what was more visible than other locations for a building as a whole, there have been more recent studies suggesting psychological effects that can be related to certain isovist measurements. An example of this is Openness, which can be calculated as isovist perimeter^2/area. It is suggested that Openness is related to the psychological response of prospect and refuge (Chatford Clark 2007, 92; Franz and Wiener 2005, 506) A location with a high Openness value would be a location which gives cover, while at the same time giving the possibility to view an open space. In other words, a location where one can see without being seen. In addition to the above measurements, there are several other values that are specific to VGA, like Visual Control and Visual Controllability. These measurements will be explained under Methods.

Using VGA gives a very interesting combination of results. Not only does the software show visual representations of the results of the different measurements, but the results are also available in table form. The former is useful to see at a glance which areas have higher values, while the data in the tables make it easier to compare multiple buildings with each other statistically. They complement each other. For example, looking at an isovist polygon will show the specific field of view, but no comparative statistical data, while the opposite is true for tabular data.

Using this kind of spatial analysis adds a new dimension to research. It adds spatial aspects that would normally not be identified, and allows for new possibilities of interpretation. Another advantage of Space Syntax is that is it possible to compare statistically different forms of space, even across cultures (Vaughan 2007, 207). Although specific qualities may differ, often the quantifying aspects are more or less similar. There are some methodological problems inherent to Space Syntax, like the exclusion of elevations, but it offers us a more or less neutral way of looking at space and the relationship between space and people. This is also why it is possible to apply it to the past built environment.

The sample of guard houses is small. Some would say too small. Usually, when performing any kind of statistical comparison between multiple buildings, a large sample is required to lower the effect of exceptions on the final results. However, even though the original sample was already small, some could not be used for Space Syntax analysis because the entrance was unknown. Because the sample used for this research consists of only 7 guard houses, no statistical relevance can be assumed. However, the results are interesting nonetheless and they provide us with new information regarding the defensibility of the selected Minoan guard houses.

There is more to tell about the theoretical foundations of Space Syntax, other software that is used, etc., but that would almost become a thesis on its own. In the Methods section, the entire process of the analysis that was conducted will be discussed, as well as the specific calculations that were used.

3.2 Methods

3.2.1 Least Cost Path analysis

In the previous section, it has been explained how LCP analysis works, what the (dis)advantages are, what to take into account when using this method to study the defensibility of Minoan guard houses. Now it will be explained how the analysis was performed. For detailed explanations of the different ArcGIS tools that have been used, see the online ArcGIS Desktop 10 Help (ESRI 2012).

The idea was to plot 100 points in circles of different radii (300 m, 1 km and 2 km) around the guard house sites. This would have two effects. First, calculating routes from radii of 1 km and especially 2 km would negate the effect of local conditions and choice as much as possible. As will be visible in the results, the closer to the guard houses the higher the chance of more access routes. Because of the largest distance, only the most efficient routes will be calculated. At the ranges of 1 km and 2 km, it also does not matter as much where the starting point is located (on a difficult slope or not), because there is relatively enough space between it and the guard house to return to the most optimal path. Secondly, comparing the results from all three ranges may or may not explain the results from a specific range.

This being a GIS analysis, the first thing that was needed was a DEM. Based on the reviews of the ASTER GDEM, this DEM was chosen. First v1, but as soon as v2 was released to the public, the latter replaced the former for this study. This DEM was sufficient enough. Sabine Beckmann (pers. comm.) suggested creating my own DEM by going to Crete and taking measurements in the study area to get a very high resolution DEM. She commented that there is so much relief in this area that actually none of available DEMs (commercial and free) have a high enough resolution to properly do landscape analysis. Although she is right, I was (sadly) limited to a desk based study and the ASTER GDEM was the best available elevation model.

This conversion was necessary to match the projection of the GPS coordinates of the guard houses. These coordinates were collected from the Digital Crete database project (http://digitalcrete.ims.forth.gr), of which the Archaeological Atlas was made available under scientific supervision of Prof. Apostolos Sarris. This online database has an enormous amount of data on Crete, its environment, archaeological sites, land use, etc., which can all be shown in a web-based GIS applet. For most archaeological sites on Crete there is a data sheet, listing the name, closest village, community, important publications and more. Using the web-based GIS applet, it was possible to collect the coordinates of the selected guard house sites. A point feature set was created from the coordinates. These coordinates were of the Greek national grid, so the DEM had to be reprojected before usage, from WGS84 to GGRS87/EGSA87, using ArcCatalog.

With both the DEM and the shape file of guard house locations ready, different models were made in the ArcGIS ModelBuilder to more or less automate the different steps of the analysis.

First a coastline polygon was created, which was needed later to prevent circle points from spawning in the sea. Secondly, the cost surface model was created, with slope values and land use as only input data. The latter did nothing more than give a low value to land and a very high value to sea, to keep LCPs from moving across the sea as much as possible, without setting the sea to NoData values. The latter caused some errors in the process of placing circle points along the coast. Setting the sea to Restricted in the cost surface would give it the lowest possible cost value, which would cause many LCPs to cross the sea instead. The default slope values were not seen as an accurate representation of reality. Therefore, the tangents of the slope values were calculated, which were then divided by the tangent of one degree, as suggested by Bell and Lock (2000, 88). This made the cost surface a lot more realistic, with a non-linear cost scale. In the cost surface tool, the influence of the slope values was set to 66% and the influence of land use to 34%. This kept the cost value of the sea high enough to be avoided, while still giving more importance to the slope values.

No other datasets were added to the cost surface. The reason for this is that there were no land use data available for the Cretan Bronze Age. Also, rivers and streams were not added to the cost surface, because in this area of Crete the rivers and streams are either dry or very unimpressive for most part of the year. Crossing these would have been no problem in most cases, giving it almost no value in the cost surface.

Thirdly, circles of 300 m, 1 km and 2 km were added around every guard house. In the cases where a circle would cross the coastline, the circles were clipped at the coastline. After that, using the Create Random Points tool, 100 points were spread out evenly along the edges of these circles and polygon, by setting the value of (perimeter/100) as the distance between the points. It would have been possible to use a Cost Surface which takes travel time into account, which has been done for instance by

Farinetti (2011) in her GIS study of Boeotia, and to create circles with a radius based on time-distance instead. This was not done, however, because it was not required to answer the main question of this study. The radii chosen were not meant to represent a certain walking distance. Their function was to leave the calculation of routes less to chance, especially in the case of a 2 km radius. However, adding a time factor in the future would make it possible to answer questions such as the following. How much time does it take to walk 1200m, the maximum distance of visibility, in any direction? How much time would people have had to get to safety when under attack? These questions, however, will need to be answered another time.

After all the circle points were created, LCPs were calculated from every point around a guard house to the guard house itself. As will become visible in the next chapter, most of these paths joined together, so only a select few paths actually reached the guard houses. The number of paths reaching each guard house was used to determine whether a guard house was more or less defensible. The results will be presented in the next chapter. There are some possible flaws in the calculations of these LCPs. Those will be discussed in the Discussion chapter.

3.2.2 Defensibility Index

In the Methodology section, the origins of the Defensibility Index have been briefly discussed, explaining how it works, as well as some background on viewsheds, which were used to calculate most of the values. As was already noted above, some adaptations were made and a variable was removed from the D.I. of the studied Minoan guard houses.

Because GIS maps were already available because of the LCP analysis, it was decided to use a GIS approach as much as possible, instead of the measuring all angles manually with a protractor. This has saved a lot of time and the created models in ArcGIS made it possible get all the results again within minutes, if needed. For collecting all the necessary data, the following steps were taken.

The first task was to get the degrees of a viewshed. This was achieved by overlaying the viewsheds onto an Aspect layer that was created by using a reversed distance layer as fake DEM input. A reversed distance layer must be used here, to have 0 or 360 degrees in the north instead of the south. Before the viewshed was overlaid on top of the Aspect layer, the decimals and negative value (the starting point) were removed, to have a layer of exactly 360 degrees.

The Visibility model divided a viewshed from a height of 1.67 m (based on the average height of Minoan men (Fitton 2002 in Stergiou 2010, 98) and created a polygon of only the visible cells, of which a 100 m circle around the sites was removed. Then, the degrees layer was masked by the viewshed polygon and the number of remaining table rows were counted. The number of rows should be the same as the arc of Visibility.

The Approach model outputs the last values needed to calculate Accessibility. It is assumed that slopes of 40 degrees or more block access to the sites. Although it would be possible to try and run up such a steep slope, it is very defensible from the top. This model calculates Slope again, but this time unmodified. Then, only cells with slope value 40 or higher were selected, and those cells between the edge of the site and 100 m around that edge were extracted from the Degrees layer. This was followed by another row count, which was subtracted from 360 to get the arc of Approach.

The Elevation model calculated the elevation difference between the elevation at the guard house coordinate and the average elevation of the area between the edge of the site and 40 meters around the edge. Martindale (University of British Columbia, Department of Anthropology, pers. comm.) confirmed that this would give a value similar to how they would have calculated the average around the site.

After the above values were calculated for every guard house, these values were put into an Excel table that calculated the Accessibility value and then the Defensibility Index value for every guard house. It must be noted, that the Area variable was excluded from the D.I. Because of the small size of the guard houses, this variable would not have added much to the total. Also, Martindale and Supernant (2009) use a division between land and sea, because that is appropriate for their study area. This was not done here, because the differences would have been minimal, if not nonexistent. The table of results is presented in the Results chapter.

3.2.3 Visibility Graph Analysis

In the Methodology section above, some background information about Space Syntax and Visibility Graph Analysis was presented, and it was discussed why it is such a useful tool for many fields of research, including archaeology. In the following section, the exact methods that were used in this research will be explained.

As was already mentioned earlier in this thesis, the software called Depthmap, developed by the late Alasdair Turner, was used to analyse the sample of Minoan guard houses. This software has a lot of built-in capabilities, offering the opportunity to explore different measurements. Not all measurements were really useful for this case, however, so only those that really help to explain the possible defensibility of the inside of guard houses will be discussed. Prior to the analysis, the plans of the guard houses were vectorised in AutoCAD for easier data processing and to use them in Depthmap.

It may be useful to explain the steps that were followed when performing VGA using Depthmap to get my results. For each guard house, a grid was put on top with a grid size of 0.2. Based on the scale of the plans that were used, that comes down to cells of 20 cm wide. This is obviously much smaller than human step size, but it was chosen because of the higher resolution results that would be obtained. After the grid added, the interior of the guard house was filled using the fill tool, to limit the area which would be measured. After that the analysis could begin. First, a Visibility Graph was created using default values. Second, the Visibility Graph Analysis tool was used twice. First to calculate isovist properties, secondly to calculate the visibility relationships with only local values selected. The Visibility Graph Analysis tool would generate most of the results. Thirdly, the row of entrance cells was selected and Step Depth was performed. Lastly, all the results were exported to MS Excel, where among other things the values of the specified entrance cells were extracted.

Of all the results that were obtained the following measurements turned out to be the most useful for this study:

Isovist Area: this is the area that is visible from each viewpoint, as was already discussed in the Methodology chapter. In the VGA, however, technically all possible isovists in the building are added together, to visually show the locations with the largest isovist area. It is suggested by Wiener and Franz (2005, 53) that the size of the isovist area can say something about the ability to observe or hide. The location with the highest isovist area value would give the best overview, while the location with the lowest isovist area value would be the best place to hide. Hence, the information gained from this measurement may say something about the visibility or lack of visibility of, for example, and entrance or a back room of the guard houses. In turn, this may tell us about possibility to control such locations.

Isovist Occlusivity: as was already discussed earlier in this thesis, Isovist Occlusivity is the length of the edge of an isovist, behind which more open space is located. If the Occlusivity value of a point is high, it means there is a lot of open space that cannot be seen from that location, but that can be accessed if one moved further into that direction. The reason why this measurement was chosen, is that people may be hidden from sight either in the occluded spaces or possibly at a location of high Occlusivity, depending on the circumstances.

Visual Control: this measurement shows the areas in the visibility graph that are visually dominant. A large field of view does not make a location dominant, however. For a location to have a high control value, it must be a point from which a lot of spaces can be seen, while those spaces can see relatively few spaces themselves (Turner 2004, 16). Basically, a controlling location can see a lot compared to the spaces it sees, but it is also seen by those spaces. On a visibility graph the most controlling areas are clearly visible. Depending on where the highest control values are located within a structure, it may suggest a visual control of certain spaces within the building.

Visual Controllability: this measurement shows the areas that are most easy to control. A high Control value marks the location that visually controls other spaces, whereas a high controllability value suggests a location that is easily controlled. Compared to the controlling location, the field of view is small, while it can be seen very well (Turner 2004, 16). This is interesting, because being in such a location makes you very vulnerable. These locations may actually be perceived as enclosed because of this. If the controllability of a point in space is high, it would not benefit an attacker standing on that spot at all. This, too, would give insight in the defensibility of guard houses.

Visual Integration (HH): this measurement is the most often used Integration measurement. These values are the inverse of the Real Relative Asymmetry (RRA) values defined by Hillier and Hanson (1984, 119-23). The higher the value, the more integrated a location or space is. As was said before, this measurement has shown a high correlation with the distribution of people in cities (Bafna 2003, 25), where main streets were coincidentally the areas of highest integration. This would suggest that spaces inside buildings with high Integration values would also be the areas most often used by people. Although this value was mainly used in this research because it is one of those measurements that are almost always used in any Space Syntax research, there is the fact of knowing where inside a guard house people were (theoretically) most often aggregated. Based on this information, something can be said about the ability to control access to these buildings.

Openness: this measurement, which is basically the same as the jaggedness of isovists, is a relatively new term coined by Franz and Wiener (2005, 506) to indicate the relatedness to a psychological response of prospect and refuge. A high Openness value indicates that the location would be perceived by a person as safe (cover), while being able to have a good overview of an open space. A space with a low Openness value would be perceived as an enclosed space, which may or may not be threatening. Knowing where the high and low Openness values are within a guard house, may indicate a possibility to defend the entrance, for example, while being protected by a sort of cover (behind a wall, corner, etc.).

Step Depth: this measurement basically shows the amount of steps (not footsteps) that are required to see the entire interior of a building, starting from the isovist from a selected location. This was used to be able to visualise the isovists of all selected entrance cells at once, without having to make multiple point isovists and combine those. In this case, the resulting visibility graph shows a combined isovist from the entrance of every building, with areas outside of this isovist marked.

In addition to the above, point isovists were used from the highest values of each category, except for Step Depth. This was done to get a better idea of the visibility from those 'hot' areas inside these guard houses.

The results of the above measurements were not only used to interpret the structures as a whole. Based on the Step Depth, which was calculated from multiple cells at the border of the entrance, the values for those entrance cells were extracted from the tables. This made it possible to give an interpretation of the spatial perception from the entrance, as it would have been experienced by people entering the guard houses. Some of the measurements may suggest a rather safe entry, if one does not want to be noticed, while other measurements may actually suggest the opposite.

This chapter has described the methodology and methods used for the different analyses that were applied to the sample of guard houses. All three work differently from each other, and may also provide completely different results, depending on the circumstances. The results of the analysis of these Minoan guard houses will be discussed in the next chapter.

Name	Nr.	From 300m	From 1km	From 2km
Agio Pnevma	11	3	3	3
Aspres Plakes	17	3	3	*2
Chiromandres	12	2	2	2
Chochlakies	7	4	*3	3
Farangouli	4	3	*2	2
Kali Elia	16	3	*2	2
Karoumes - Fort of the Sea	19	4	4	4
Karoumes - Mother Fort	18	4	4	4
Kokkino Froudi	9	3	3	3
Lidoriako		3	3	3
Mavro Avlaki	14	2	2	2
Mavromouri	5	4	*3	3
Melefa		3	3	3
Plakalona	3	3	3	3
Polla Kladia	15	3	3	*2
Pyrgales		4	*3	*3
Sfaka	10	4	4	3

Table 1: Final results of the Least Cost Path analysis. * = difference between this value and the previous column.

4 Results

The previous chapter focused on the different methods of analysis that were applied to the Minoan guard houses to study their defensibility. This chapter will present the results and the interpretations. As in the former chapter, the different methods will be discussed separately. At the end, the results will be compared and possible conclusions will be drawn from this. Are guard houses defensible or not? This question will be answered in this chapter.

4.1 Least Cost Path analysis

This method is based on LCP analysis and the assumption that defensible buildings do not have many access routes. Table 1 shows the results for each guard house. Figures 1 to 51 in Appendix A show the comparison between the LCPs from 300 m and 2 km for each site. In Appendix B the 3D views around each site are presented. It must be noted here that when looking closely at the centre of the LCPs, it is not exactly on top of the guard house location. This can be explained as follows. LCPs connect from cell to cell in the middle of cell. This is not the exact location of the site, but it does represent that location. Therefore, this is assumed and the number of routes reaching a site are counted on that location for every site, instead of exactly at the site coordinate.

The minimum number of paths reaching a guard house is two, with the maximum being four. Most of the 300 m and 1 km LCPs look identical around the sites. There are five exceptions, but in most of those cases the plan of the LCPs stays very similar. Comparing the 1 km and 2 km LCPs, most look identical as well. There are three exceptions here, but, as with the comparison between the 300 m and 1 km LCPs, the plan of the LCPs stays similar.

Most of the results are similar across the board, but how can the differences be explained? If the radius of points around a site is small, the diversity in elevation is possibly smaller as well. Because of the smaller differences, more paths can sometimes be plotted when they have a similar cost value. Most of the differences seem to show between the 300 m radius and 1 km radius. This can be explained by the above, but it may also suggest that a radius of 300 m does not only show the most important access routes, but also additional ones. However, the differences are small of course.

These small differences give reason to conclude that these results do not say all that much. Although one could argue that guard houses with only two LCPs reaching it are more defensible than those that have four LCPs reaching it, there is no striking difference. The other reason why these results may not really say much is the fact that they seem limited to a maximum value of four. It makes me wonder if the maximum value is limited by the usage of a raster DEM. The data is divided over square cells, and looking at the LCPs they seem to be following the cell borders in most cases. Four is obviously also the maximum number of sides of each cell, which makes me wonder. Is the number of LCPs reaching each site limited to the maximum of sides of each cell? If so, does this have any further effect on the results? Would the differences have been larger if a TIN has been used? These questions cannot be answered here, simply because there was no way to test it. However, it may be interesting to study this effect more closely in the future.

Returning to the interpretation of the results, if we ignore the possible problem of the maximum value, it may be possible to say that the guard houses of Chiromandres and Mavro Avlaki are "most" defensible. Even from a range of 300 m, which allows for a higher number of paths, these two guard houses have only two LCPs reaching them. Even though other guard houses only have two LCPs from a larger distance, Chiromandres and Mavro Avlaki have the advantage of being difficult to access. Based on the number of LCPs from a 2 km radius, it may be suggested that the two guard houses at Karoumes are least defensible. At this distance, the LCPs will only follow the actual least costly routes, and even from that distance there are four LCPs reaching these sites.

As was said already, these values may not provide much valuable information on their own. However, at the end of this chapter these results will be compared to the results of the other two methods that were used to study these guard houses. Combined with the results of the Defensibility Index and Space Syntax analysis, it may be possible to draw more firm conclusions.

After adding Palaikastro, Kato Zakros and Ambelos to my GIS maps, and after finishing the LCP analysis, I could not help but wonder what the LCPs would look like between these important towns, and whether these LCPs would resemble the reconstructed Minoan roads network, as published by Tzedakis *et al*. (1989, 44). Figure 4 shows the image of main roads as reconstructed by the Minoan Roads project. Figure 5 shows the LCP analysis between the towns of Palaikastro, Kato Zakros, Ambelos and Kastri – Ambelos. The results are interesting, to say the least. The two images do not match completely, but the road north from Chochlakies looks similar and especially the road north from Kastri – Ambelos up to Aspres Plakes seems very much the same. These results will not be further discussed in this thesis, but maybe in the future more extensive LCP analysis and/or Circuit analysis can be performed in this area to see how much of the road network can actually be found using GIS.

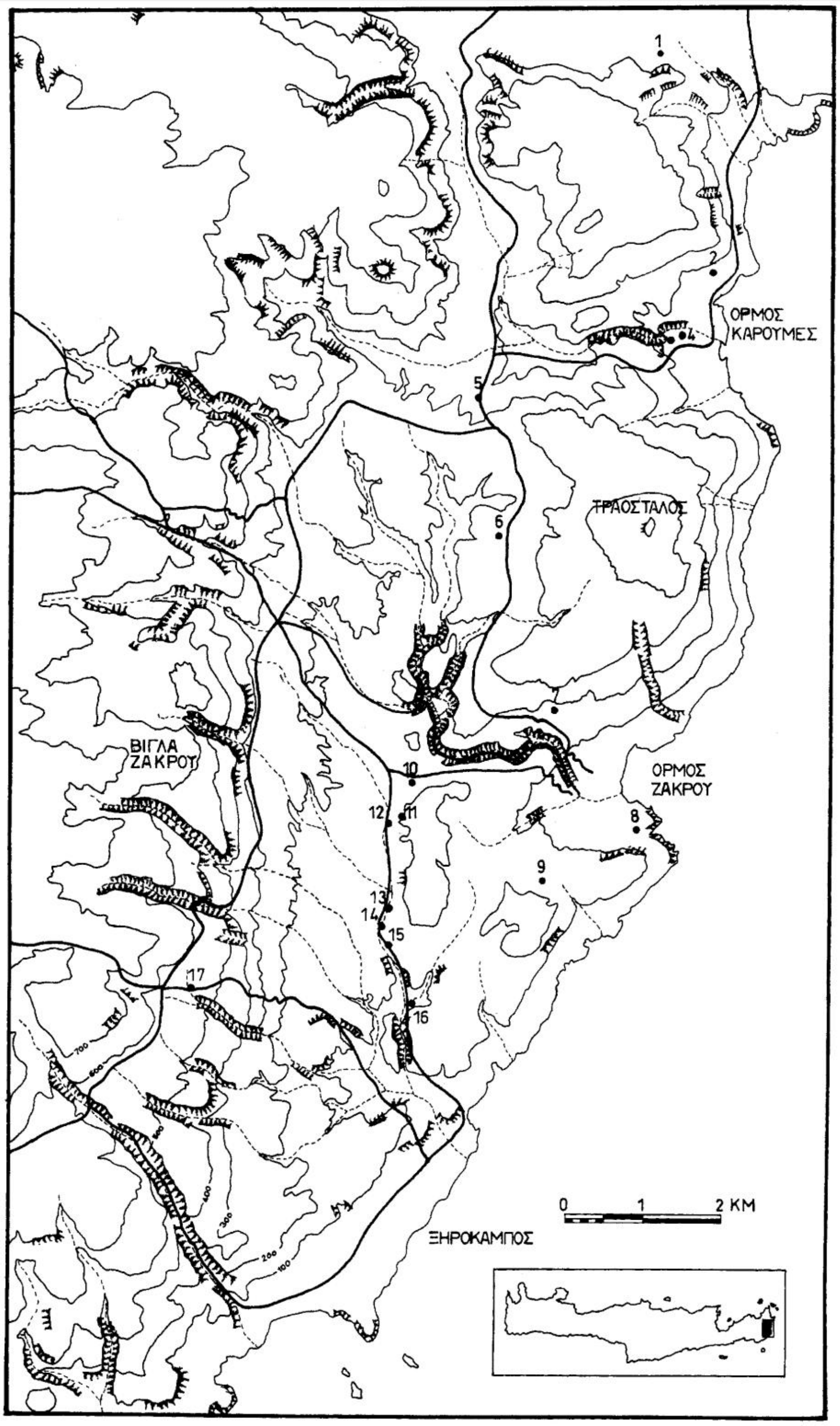

Figure 4: Map of the eastern part of the Zakros – Xerokampos region (Chryssoulaki 1999, plate VI).

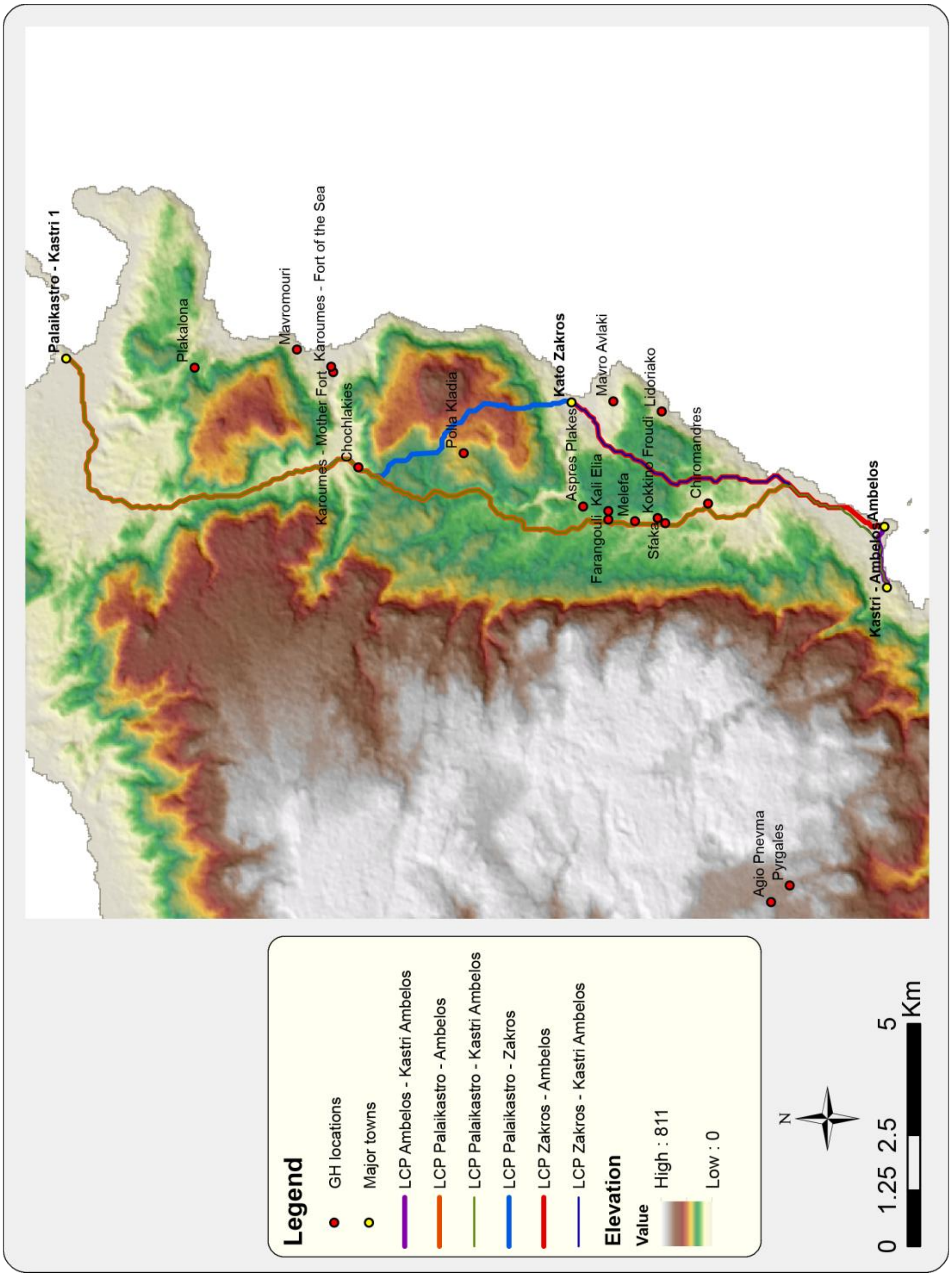

Figure 5: LCP analysis between the towns of Palaikastro, Kato Zakros, Ambelos and Kastri – Ambelos.

4.2 Defensibility Index

Next, we will turn to the results of the Defensibility Index calculations. Although the results of the LCP analysis are also numerical, this analysis is much more quantitative. The values of two of the variables are at their maximum for every guard house, making the Accessibility value 0 for all of them, the final D.I. values are kind of interesting. The results can be seen in Table 2.

The Approach values and the Access values are all 360 degrees, suggesting that all guard house sites in this sample can be accessed from all sides, but this is not the case in reality. It can be explained, however. It has to do with the slope values and unavailability of *periboloi* on maps and there in the GIS. Although there are slopes of 40 degrees or more in the eastern part of Crete, the DEM only shows some small areas, that apparently fall outside of the 1200 m range around each guard house. As was said before, eastern Crete has a lot of relief. The 30 m resolution that is offered by the ASTER GDEM is simply not high enough to get a realistic view of the relief and the slopes. Some guard houses are supposed to be along the edge of a gorge, but probably because of the resolution, this steep edges do not show up or are evened out by the Slope algorithm. Because of this, the D.I. index is practically only based on two of the three main variables, namely Visibility and Elevation.

There is something odd about some of the Elevation values, however. Some values are negative. This would suggest the area round those guard houses is on average higher than the guard house itself. Possible explanations could be that these guard houses are located in a sort of “basin” in the landscape, which may be open to some sides, causing the average elevation of the surrounding area to be higher. However, this may not be visible clearly in the DEM.

Nevertheless, the final D.I. values are quite interesting, because of the broad range. The lower D.I. value of 0.17 belongs to Kokkino Froudi, followed by 0.33, Agio Pnevma, and 0.39, Aspres Plakes. These low values can be explained by the negative Elevation values. However, this does not mean these values are not relatively correct, assuming the Elevation values are accurate. If these are indeed located in an irregular basin in the landscape, the low defensibility values would be fitting, because of the controlling area around it.

The highest value is 1.0, belonging to Karoumes – Mother Fort. This seems to be mostly related to the high Visibility from that location, which is understandable because of the open view of the coastal plain, for example. The second highest value, 0.97, belongs to Chochlakies and can be attributed to the medium Visibility value but very high Elevation value. Clearly, this guard house was located on a relatively high hill top. The

Site Name	GH nr.	Type	Approach in Degrees	Visibility in Degrees >100m	Elevation changes (m)	Degrees Access	Radius	(V) Visibility	EV angle	(E) Elevation	(C) Approach/Access	DI=V+E+C	DI Final
Agio Pnevma	11	GH	360	217	-4	360	8.9	0.603	-24.20	-0.268899684	0	0.333878093	0.33
Aspres Plakes	17	GH	360	201	-2	360	7.2	0.558	-15.52	-0.172490122	0	0.385843211	0.39
Chiromandres	12	GH	360	266	-1	360	10.85	0.739	-5.27	-0.058509337	0	0.680379552	0.68
Chochlakies	7	GH	360	230	3	360	5.3	0.639	29.51	0.32790554	0	0.966794428	0.97
Farangouli	4	GH	360	176	0	360	8.35	0.489	0.00	0	0	0.488888889	0.49
Kali Elia	16	GH	360	216	1	360	7.4	0.600	7.70	0.085511686	0	0.685511686	0.69
Karoumes - Fort of the Sea	19	GH	360	310	1	360	8.3	0.861	6.87	0.076333248	0	0.937444359	0.94
Karoumes - Mother Fort	18	GH	360	339	1	360	10.5	0.942	5.44	0.060448134	0	1.0021148	1.00
Kokkino Froudi	9	GH	360	169	-5	360	9.85	0.469	-26.91	-0.2990333	0	0.170411145	0.17
Mavro Avlaki (building)	14	GH	360	261	0	360	10.25	0.725	0.00	0	0	0.725	0.73
Mavromouri	5	GH	360	235	-1	360	9.25	0.653	-6.17	-0.068557501	0	0.584220277	0.58
Plakalona	3	GH	360	258	1	360	7.75	0.717	7.35	0.081693104	0	0.798359771	0.80
Polla Kladia	15	GH	360	215	1	360	9.5	0.597	6.01	0.066766733	0	0.663988955	0.66
Sfaka	10	GH/VG	360	225	-1	360	9.05	0.625	-6.31	-0.070060511	0	0.554939489	0.55

Table 2: D.I. research values and final D.I. score for each guard house.

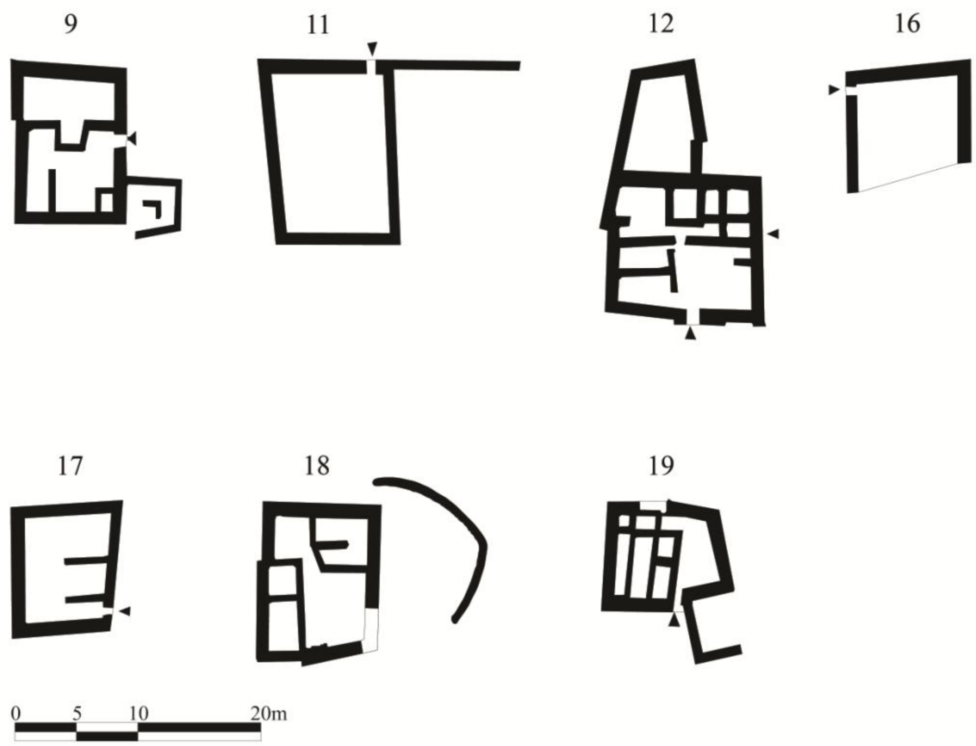

Figure 6: Sample of guard houses used for D.I. calculations and Space Syntax analysis.

9: Kokkino Froudi
11: Agio Pnevma
12: Chiromandres
16: Kali Elia
17: Aspres Plakes
18: Karoumes – Fort of the Sea
19: Karoumes – Mother Fort

Structure number	Isovist Area			Isovist Occlusivity			Openness (Perimeter²/Area)			Visual Control			Visual Controllability			Visual Integration [HH]		
	min	av	max	min	av	max	min	av	max	min	av	max	min	av	max	min	av	max
9	6.88	23.93	31.35	1.57	7.63	15.58	21.07	31.09	54.87	0.30	1.00	1.42	0.18	0.63	0.82	8.94	21.83	40.72
11	23.87	113.51	114.21	0.00	1.14	26.73	16.64	17.90	41.47	0.21	1.00	1.01	0.21	0.99	1.00	-1.00	3148.30	25479.86
12	1.64	23.01	41.58	0.39	7.25	28.33	16.42	35.79	159.94	0.24	1.00	1.60	0.06	0.49	0.81	3.56	9.29	16.32
16	19.05	65.37	65.87	0.00	0.92	14.37	16.34	17.41	27.43	0.29	1.00	1.01	0.29	0.99	1.00	-1.00	2318.82	13355.22
17	9.24	34.21	48.87	3.18	5.82	12.14	17.93	26.90	38.97	0.43	1.00	1.52	0.20	0.64	0.91	8.10	28.74	88.25
*18	9.96	29.48	37.09	1.07	7.08	16.46	16.70	29.54	54.92	0.60	1.00	1.29	0.27	0.74	0.92	8.34	35.86	89.82
19	0.77	14.41	17.75	0.58	2.79	7.51	19.04	27.14	60.83	0.12	1.00	1.40	0.05	0.81	0.99	4.65	126.95	1384.27

Table 3: Numerical results of the Space Syntax analysis.

other D.I. values are in between. There do not seem to be specific groups visible, because of the broad range of values.

Although the low resolution of the used DEM is very apparent in this table, it may still be possible to use the D.I. values for comparison inside the sample. The lack of a useful Accessibility value means the D.I. are lower than they could have been, but the relative difference between the values remains. Therefore, based on these D.I. values, Karoumes – Mother Fort is the best defensible, while Kokkino Froudi is the least defensible.

However, comparing these values with the three scales suggested by Martindale and Supernant (2009, 202), all the above values fall in the low defensibility category. It must be noted, that because the Area variable was excluded here and because of the problems with calculating useful Accessibility values, these values are lower than they should be. This assumption would place at least three guard houses (the highest D.I. values) in the medium defensibility range. If one then considers that the maximum D.I. value is 3 here instead of 4, it may be possible to say that a couple guard houses are in the medium to high range of defensibility.

4.3 Visibility Graph Analysis

Of the three methods that were used to study the defensibility of Minoan guard houses, this is the only one studying the interior. Although the sample (see Figure 6) was rather small, the results are no less interesting. Some of the results are rather obvious, but most are very interesting indeed. The results will be presented in three parts: an overview table, the visibility graphs for each guard house and a table of entrance values. At the end the possible interpretations will be summarised.

The table on the left (Table 3) shows the minimum, maximum and average of the most useful measurements for every guard house. It is immediately apparent that there are either very high or very low values for guard houses 11 and 16. Looking at Figure 6, it becomes clear why this is the case. These two guard houses are very simple compared to the other guard houses. There is just one large room. The average Isovist Area values are high because almost everything can be seen while standing inside. The low average Isovist Occlusivity values are actually higher than would be expected, because of a number of locations at the entrance which give a long open edge. The average Openness values are lower than those of the other guard houses because of the single open space, which may give a sense of enclosure when inside. The maximum Visual Control values are very close to the average of 1, which is more or less neutral. The space inside these two guard houses can be said to be not very controlling, but not very uncontrolling either. The average Visual Controllability values are close to the maximum of 1, meaning that the space inside is very controllable. This, again, is most likely because of the single open space. Almost every point inside is easily visible by any other point, but all the points do not really see much else either, because there are not other rooms. The last measurement, Visual Integration, speaks for itself as well. The average and maximum values for these two guard houses are rather extreme. Considering the minimum values are negative, which are hard to explain, the very high Integration values can most likely be explained by that. However, even though the values are extreme, they should be very high anyway. Because there is only one rectangular space, it is a very integrated space. Guard houses 11 and 16 do not really tell us much about the defensibility, because all values can be explained almost solely by the existence of only one space. It can be imagined, however, that anyone entering these buildings would be seen immediately. This would favour defensibility, because it is easy to react to hostiles entering, but the lack of any other walls inside, do not offer any possibility of hiding behind a wall to fend off enemies from there. Once enough enemies get inside, there is nothing else to do.

The above results of guard houses 11 and 16 were presented together, because they stand out from the rest. Also, from looking at the table alone, they do not seem very defensible. The other guard houses offer more interesting results, however. The other results will be discussed per measurement, to make comparing easier and clearer. The differences are overall too small to discuss the guard houses separately. It must be noted beforehand, that the results of guard house 18 should be regarded as not completely correct. The part of wall where the entrance was most likely located has been robbed out and hence the exact position of the entrance is unclear. Based on the location of the entrance in some other guard houses and the width of those entrances, several cells were selected as entrance. Most likely this will only have a real effect on the Step Depth results, but it is important to keep in mind.

Within the Isovist Area category, guard house 19 has the lowest average and maximum, number 17 has the highest. The averages of 9 and 12 are very similar, but the maximum of 9 is closer to that of 18, with the maximum of 12 being closer to that of 17. The average of 18 is more or less in between the averages of 9, 12 and 17. As was discussed in the Methods chapter, spots or locations of high Isovist Area values are considered to allow the best overview, while locations of low values are best for hiding. The differences of the Isovist Area between these five guard houses are not very large. However, several observations can be made. In comparison to guard houses 11 and 16, it is not surprising that the other five are more suited for hiding. From these five guard houses, number 19 seems to be the one most suited to hide in, while 17 has the best overview of them all. Again, however, differences are small, so it is not possible to say much about the difference in defensibility between these five guard houses.

Within the category of Isovist Occlusivity, number 9 has the highest average, probably because of the wall at the back of the room, followed closely by 12 and 18. From all five, guard house 19 has the lowest average and maximum Occlusivity. Structure 12 clearly has the highest maximum, followed by 18 and 9, while 17 lies more or less in between. Based on these values several observations can be made: in guard houses 9, 12 and 18 there is more space occluded from sight, which suggests that it was easier for people inside to hide from sight. The low average of 19 suggests the opposite. 17 seems to be in the middle, so there were areas to hide from sight, but not as much as in 9, 12 and 18. Compared to 11 and 16, however, there was clearly more possibility to hide in building 17. This could give us some indications about the defensibility. These values suggest that guard houses 11 and 16 were possibly less defensible than the other five, and from these five structure 19 was the least defensible.

Within the category of Openness, difference between the five averages are even smaller. Guard house 17 has the lowest average and maximum, while 12 has the highest. The others range more or less in between, although the maxima do not follow the same order as the averages. Again, the values of 11 and 16 are much lower than the other five, although the maximum of 11 is higher than the maximum of 17. The latter could be an exception, however. The high maximum of 12, compared to the other maxima, is also surprising. The spatial values calculated for Openness suggest that the interior of guard houses 11 and 16 was perceived as more enclosed than the other guard houses in the sample. Guard house 12 would have offered the largest interior visibility, while the viewer would not have been seen by others. In contrast, guard house 17 hardly offered any internal visibility. People inside 11 and 16 would have been less able to defend the guard house, based on the lower Openness values. Guard house 12 would be the most 'defensible' in this category.

In the category of Visual Control, it is again guard house 12 with the highest value. Since all the average values are exactly the same, only the maximum values have been considered. GH 17 has the second highest score, followed by 9 and 19. The lowest Visual Control value belongs to 18, while 11 and 16 share the overall lowest values. GHs 11 and 16, being just one-room structures have the least controlling space, closely followed by GH 18. GH 17 has the most controlling space, and is therefore the most defensible, the remaining three are very close in defensibility.

Within the category of Visual Controllability, the highest obtainable value is 1, which was reached by GH 11 and 16. Even though the other five guard houses are more complex, their maximum Controllability values are also surprisingly high. The average values give a better idea of the situation, although some are still rather high. GH 12 has the lowest average of Controllability, indicating that the building was the least controllable. The average Controllability values of 9 and 17 are very similar, both indicate increased controllability. GH 18 is even more controllable and out of the five complex guard houses, number 19 is the most controllable. What does this say about the defensibility of these buildings? A high average Controllability value suggests that a building is very controllable. However, this can work both ways, from the defending as well as the attacking side. Depending on the area of the interior where the highest values are located, either the defender or the attacker may be favoured. For now, let us assume that high Controllability values signify less defensible interiors. This will become clearer when defensibility will be discussed in relation to the results of the visibility graph analysis.

The last measurement that is shown in Table 3 is Visual Integration. As all other types of isovist values have shown, GHs 11 and 16 are rather extreme, with a negative minimum and a very high average and maximum. Clearly they are very integrated. There is a lot of difference between the Integration values of the other five guard houses, however. The least integrated guard house seems to be GH 12, with an average Integration value of 9.29. Compared to the most integrated (of the five), which is GH 19 with an average Integration value of 126.95, the difference is much larger than in the other categories, although most seem to score at the lower end of the spectrum. Looking at the averages, GHs 12 and 17 seem to be similarly integrated, but there maxima are quite apart. The maximum of 17 is very close to the maximum of GH 18, which is the second most integrated of the five. As described in the previous chapter, a high Integration value suggest an important space that is used by most people, whether that is inside a building or on a city scale. High integration also means that it is very easy to move to other spaces or spots. Putting this in a defensibility perspective, just as with Controllability, it may depend on the particular circumstances. In the case of GHs 11 and 16, the very high average Integration value is because of the single open space. Within that space, it is easy to see and move around the entire space, which can be beneficial for a defender but for an attacker as well. In the case of the other guard houses, the low average Integration may indicate that it is harder to see everything and move between spaces. This may make it possible for people to enter without being noticed. However, if the area of highest integration within a guard house is located at the right place, the opposite is true and it actually becomes hard to enter unnoticed. From a point of defensibility it can be argued that a building with high visual integration is more defensible.

The above discussion and interpretation of several isovist values have already shown some interesting observations related to the defensibility of interior of the studied guard houses. Now the visibility graphs will be discussed. Not only has the internal intervisibility of these guard houses been studied, point isovists were also calculated from the locations with the highest value per measurement. The combination of these two graphs allows us more insight in what the most important areas were, as well as the visibility from several important points.

The first guard house discussed is number 9, Kokkino Froudi. Fig. 7 shows the visibility graphs for all isovist values discussed above, and Figure 8 shows the images of point isovists placed and calculated from the points of highest values. When looking at the visibility graphs it is immediately apparent that the graphs of Isovist Area and Visual Connectivity are very similar. This is a peculiar correlation, because high Area values suggest a space that is not only very visible, but also offers a large field of view. This can possibly be explained by the small size of the interior, that causes the points of high Area value to see relatively little, causing a high Controllability on those same locations. Interestingly, although the Visual Control graph does not look very similar to Isovist Area and Visual Controllability at first sight, the area of highest values do actually overlap. The isovists calculated from those points are almost identical. If we add Visual Integration, which produces a very similar isovist to the above, we can suggest with great certainty that the small area on the left side of the guard house is one of the most, if not the most, important areas in this building. The highest Isovist Occlusivity value is measured at the entrance. Considering the isovist from this particular point, it is visible that there are quite large areas occluded from sight. The highest Openness value was also measured at the entrance. However, there are more spots revealing high Openness values at the back of this guard house, from which the entire back side and parts of the main space can be observed from behind the wall. It is interesting to note from the different isovists that the entrance is most often completely invisible from the point with the highest value, as can be seen from the different isovist graphs. The isovist calculated for the highest Visual Control value clearly suggests there was no control of the entrance. This is noteworthy, because it suggests that the entrance was not as important to watch, which may suggest a possibility for hostiles to enter the building. This makes this guard house less defensible.

Agio Pnevma, guard house 11, is one of two guard houses with a very simple layout. It has been discussed before and it is very clear again, that not much can be said about this building. Figures 9 and 10 show the visibility graphs and isovists produced for this building. Except for Isovist Occlusivity and Openness, the highest values of intervisibility are present in the main space, where practically everything is visible and an observer can always be seen. The isovist calculated for highest Integration shows that the entire space is very well integrated. Occlusivity is generally low, except for a small area

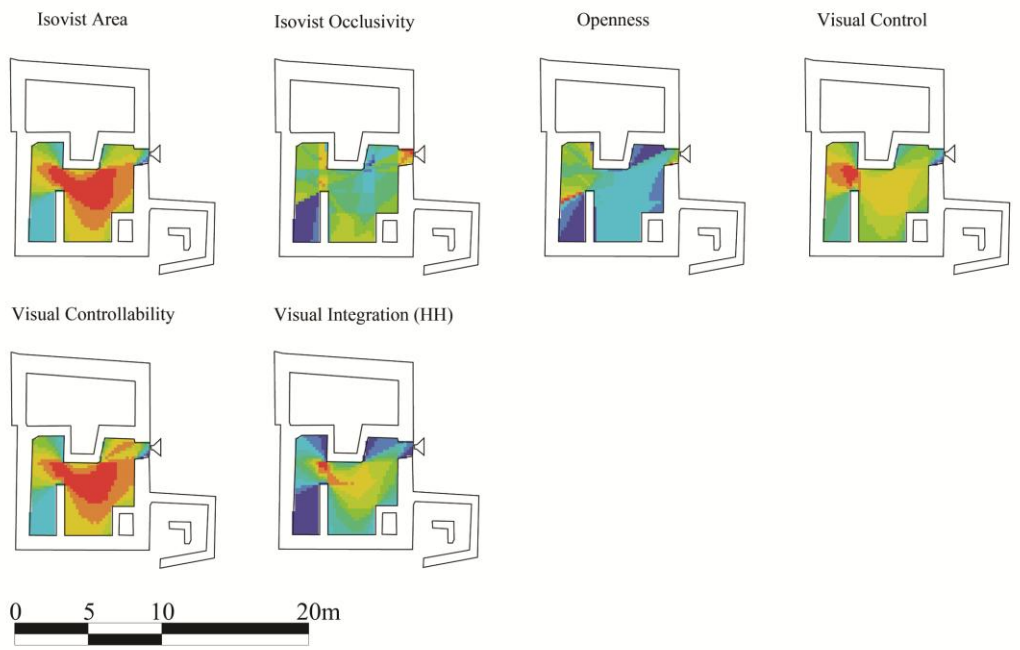

Figure 7: Kokkino Froudi - Visibility graphs.

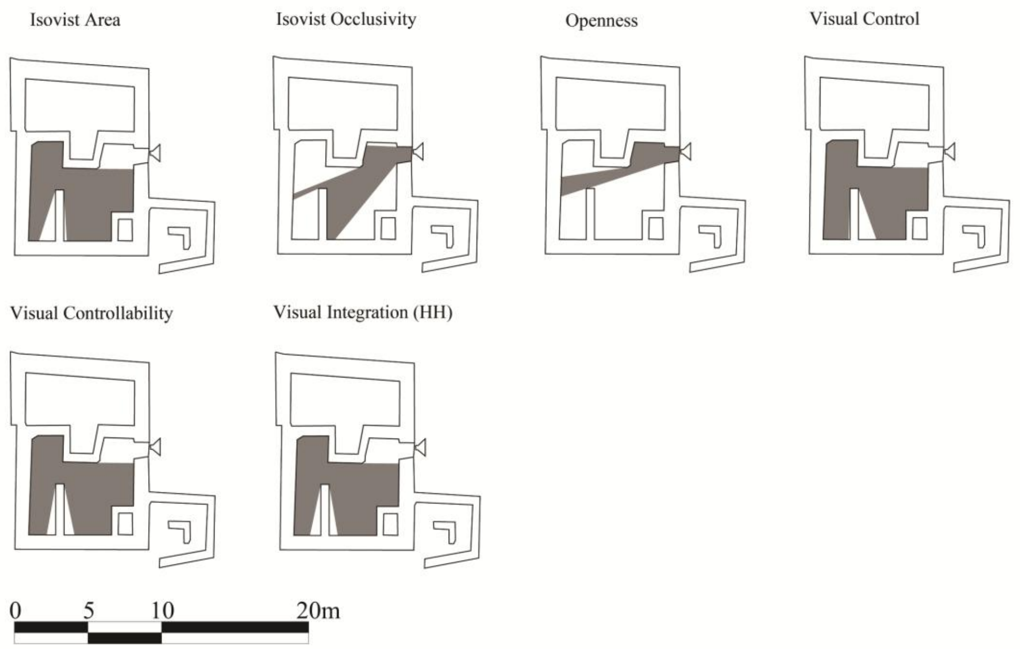

Figure 8: Kokkino Froudi - Point isovists from the cells with the highest value per measurement.

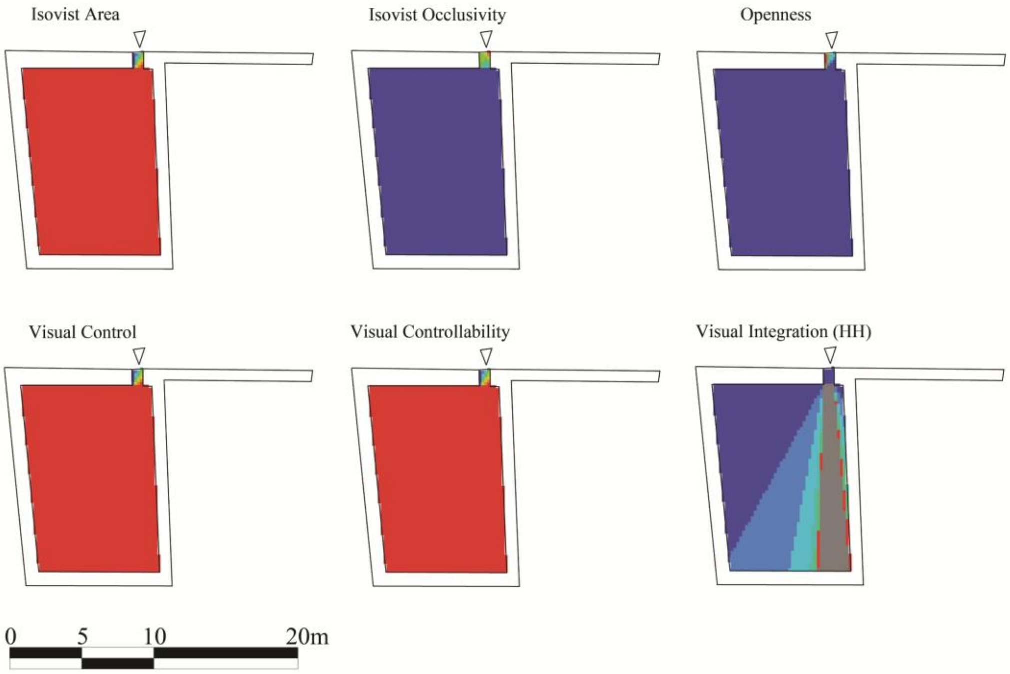

Figure 9: Agio Pnevma - Visibility graphs.

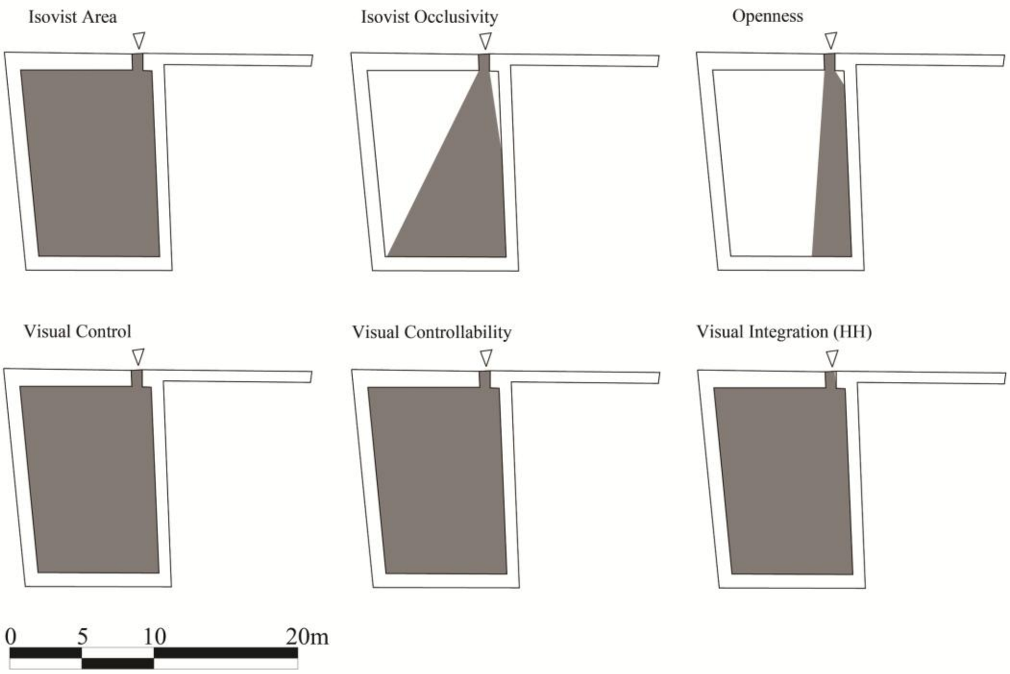

Figure 10: Agio Pnevma - Point isovists from the cells with the highest value per measurement.

at the entrance. From this specific point, about half of the inner space cannot be seen, as is visible on the isovist graph. There is a similar situation for Openness. The highest values are at the entrance, but the isovist area is rather small. The Occlusivity and Openness isovists show that the entrance is not completely visible from every location. The entrance is visible from the points of highest Integration and Control. This demonstrates that people entering will be spotted, but there is room to move temporarily out of sight. The visibility graphs do not suggest a very defensible building, because once inside all space seems equal. However, the isovists of Occlusivity and Openness add to the defensibility.

The guard house of Chiromandres, number 12, is the most complex guard house in the sample with the most interesting spatial setting. Figures 11 and 12 show the visibility graphs and the point isovists of this building. The Isovist Area graph shows the area of the largest isovists in front of the entrance. This is not surprising because a large part of the interior space is visually connected to it. While one would expect to find the highest Visual Control values in front of the entrance, which would indicate the entrance was controlled, interestingly enough the highest Control value is actually located towards the rear of the building, next to the doorway to the back room. As can be seen from the Visual Control isovist, the view from this point covers the main room and part of a side room, but not the room next to the entrance. Also, although there is no view into the back room from this location, the doorway could still be controlled. The other isovist graphs are even more interesting. The Visual Controllability, Visual Integration, Isovist Occlusivity and Openness graphs all show a clear diagonal divide extending through the building. The highest Controllability values are located near the entrance, but there is also a large area at the back of the guard house which is well controlled. This edge of this area is part of the diagonal divide crossing through the building. From the area of the entrance, part of the back room can be seen, but the area of high Controllability cannot be seen unless one moves to the back. Intriguingly, the diagonal line of sight seems to control the back area. Unless one wants to be seen, it is best not to move out of there. The diagonal line itself does not have many spots of high Visual Control values. The latter are all concentrated in the large room to the right of the entrance. This is also visible in the Visual Integration graph, where there is high Integration showing in the area to the right of the entrance. The highest Integration values are in front of the entrance. From this location, a large part of the building can be seen, similar to the isovist from the large room to the right of the building. The highest Occlusivity value is revealed along the diagonal line in the doorway to the back room. From there, the building’s entrance is visible, although one can easily move out of sight. The Openness values reveal high levels also along the diagonal line, with the highest value concentrated in the doorway to

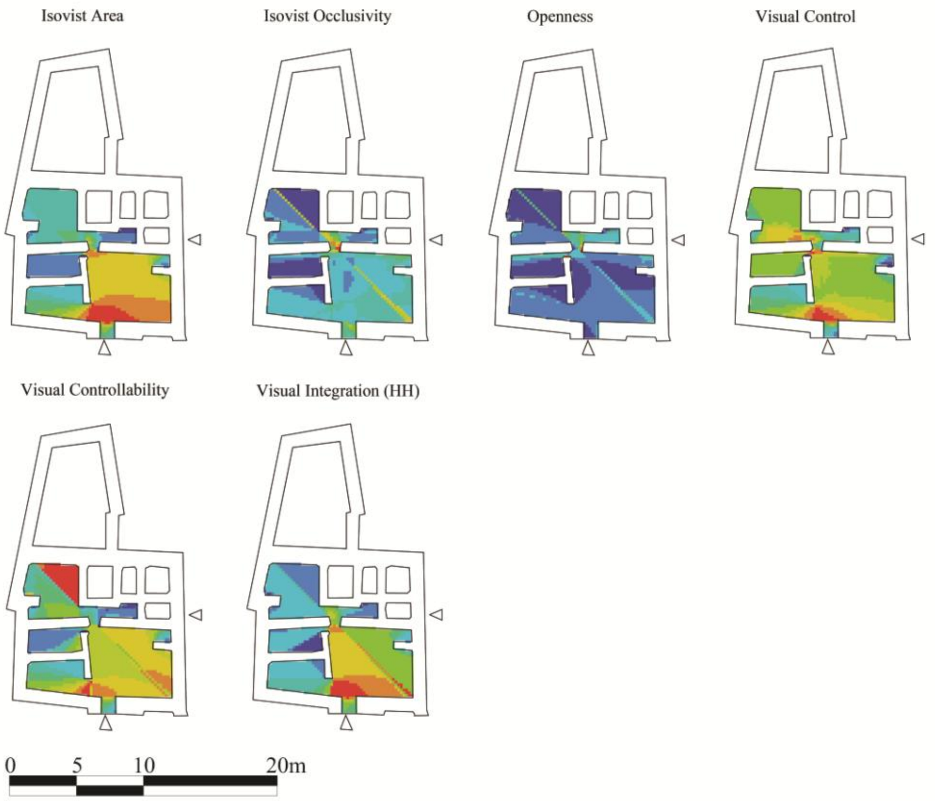

Figure 11: Chiromandres - Visibility graphs.

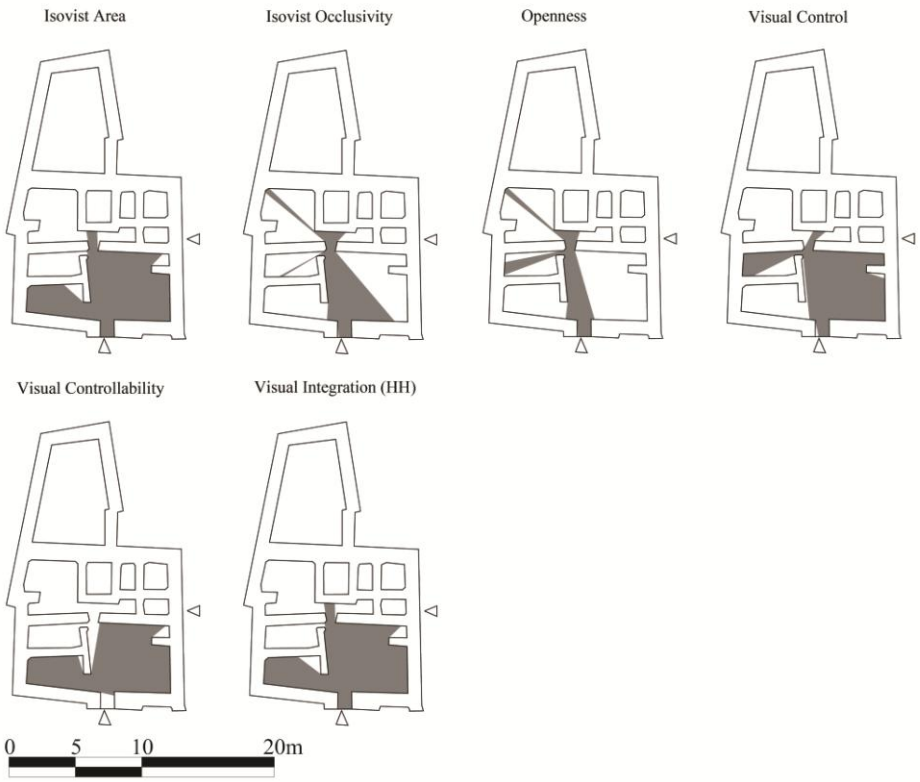

Figure 12: Chiromandres - Point isovists from the cells with the highest value per measurement.

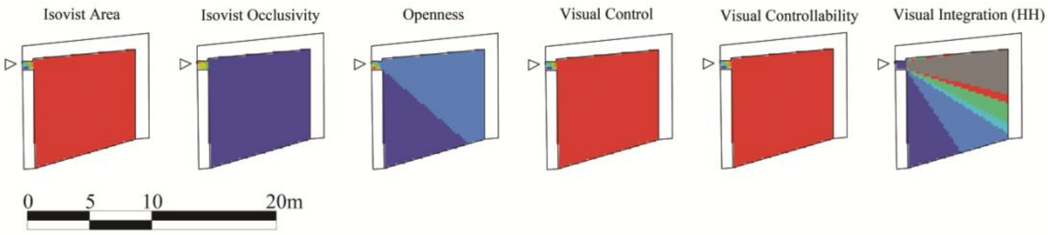

Figure 13: Kali Elia - Visibility graphs.

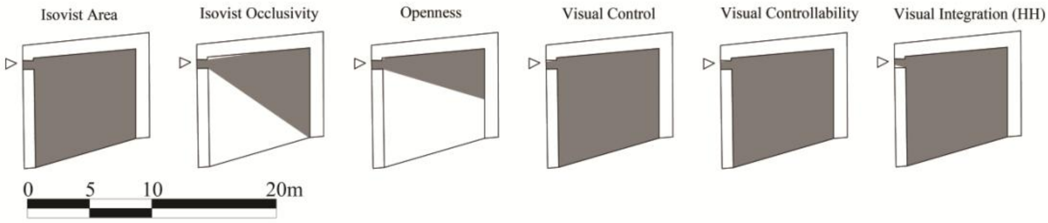

Figure 14: Kali Elia - Point isovists from the cells with the highest value per measurement.

the back room, producing an isovist that is focused on the entrance, but does not cover a wide area.

The visibility graphs and the isovists indicate that this guard house was rather defensible. The space next to the entrance is very integrated and has a high Control value. At the same time, a small area next to the entrance is also very controllable. There seems to be a good control over the back room too, as well as the doorways into the other rooms. The high concentration of activity around the entrance and the possibility of control of the rest of the interior space, with the opportunity to hide from sight, indicate a defensible building. Enemies would not be able to easily enter, and even if they did, the back room would offer a lot of protection for the defenders, forcing enemies through a small passageway.

Guard house 16, Kali Elia, is the second one that has a very simple layout. Since the results and the interpretation are very similar, they will not completely be discussed in detail. Figures 13 and 14 show the visibility graphs and the point isovists. In this case as well, all important points inside the guard house see the entrance and it is possible to move (temporarily) out of the field of view. The highest levels of Occlusivity and Openness are found at the entrance. Although the high visual integration and the lack of walls make it difficult to hold the guard house once enemies are inside, the ability to move out of sight makes this structure a little more defensible than one would expect at first glance.

Aspres Plakes, guard house 17, is not as complex as Chiromandres, but still shows some interesting features, as can be seen on Figures 15 and 16. Again there seems to be a positive correlation between Isovist Area and Visual Controllability. This will probably be for the same reason as before, namely the small size of the guard house allowing only short lines of sight, but still producing high Controllability values at locations that are very visible and have large fields of view. Looking at the Visual Control graph, there seem to be two Control hotspots, which together control almost the entire building. From the hotspot to the left of the entrance, which also has the highest value, the entire building except for the top right part can be seen. From the hotpot above it, the entire building except the entrance can be seen. The highest Visual Integration values seem to overlap with the top Control hotspot. The isovist from the highest Occlusivity point leaves the top right occluded from sight. The highest Openness values are located at the bottom left of the building. Again the top right is not visible, but now part of the entrance is not visible from the highest Openness value either. However, other locations of high Openness value allow visibility of the entrance. It is interesting to see that about half of the isovists focus on the rear of the building, while the other half

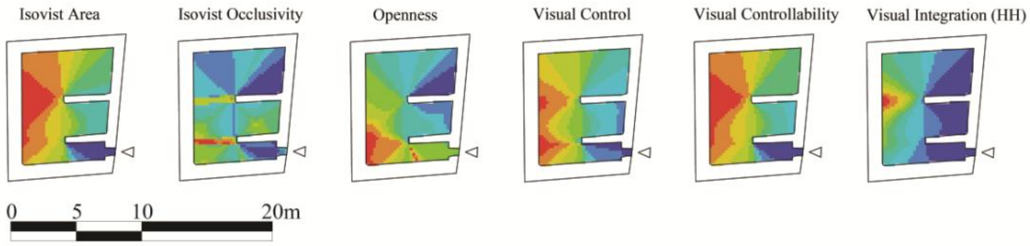

Figure 15: Aspres Plakes - Visibility graphs.

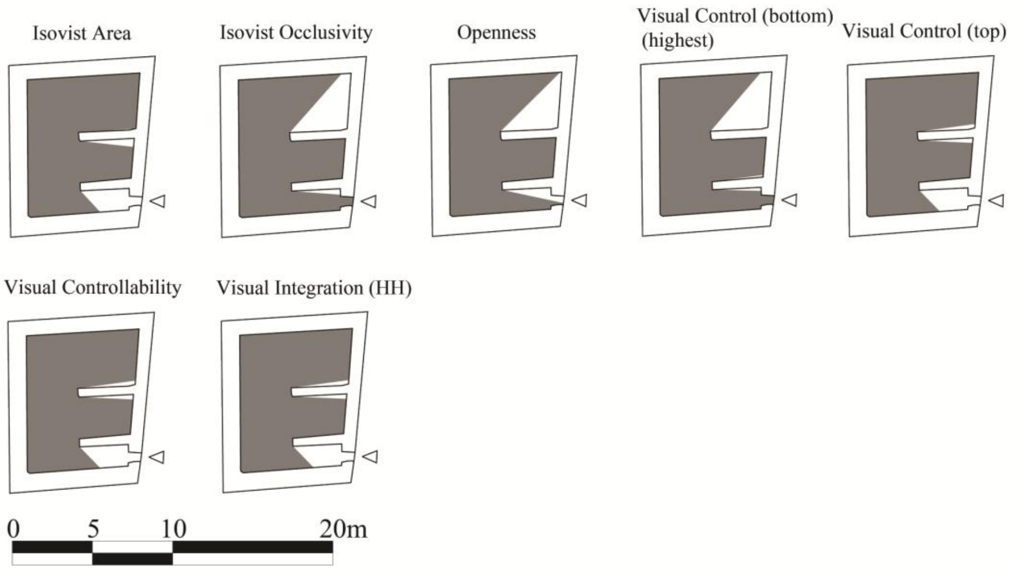

Figure 16: Aspres Plakes - Point isovists from the cells with the highest value per measurement.

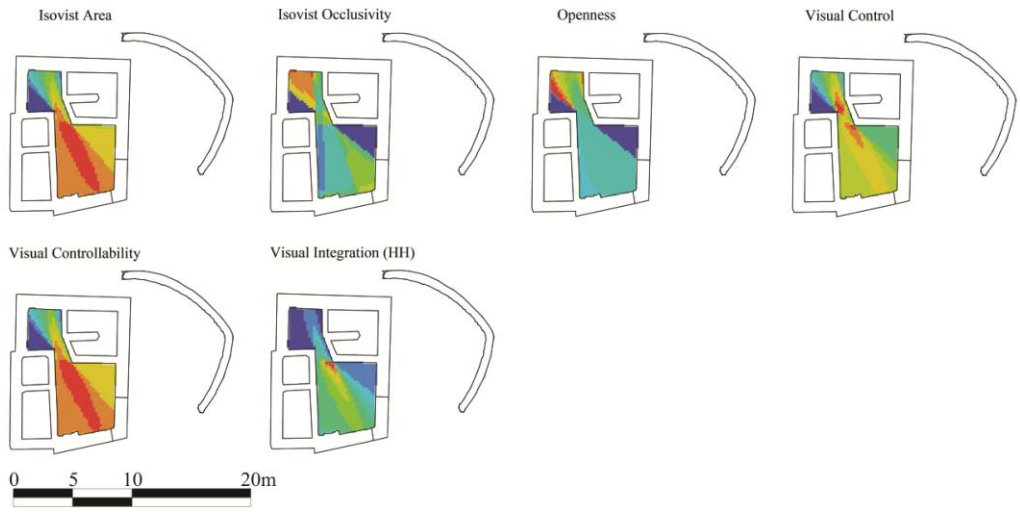

Figure 17: Karoumes – Mother Fort - Visibility graphs.

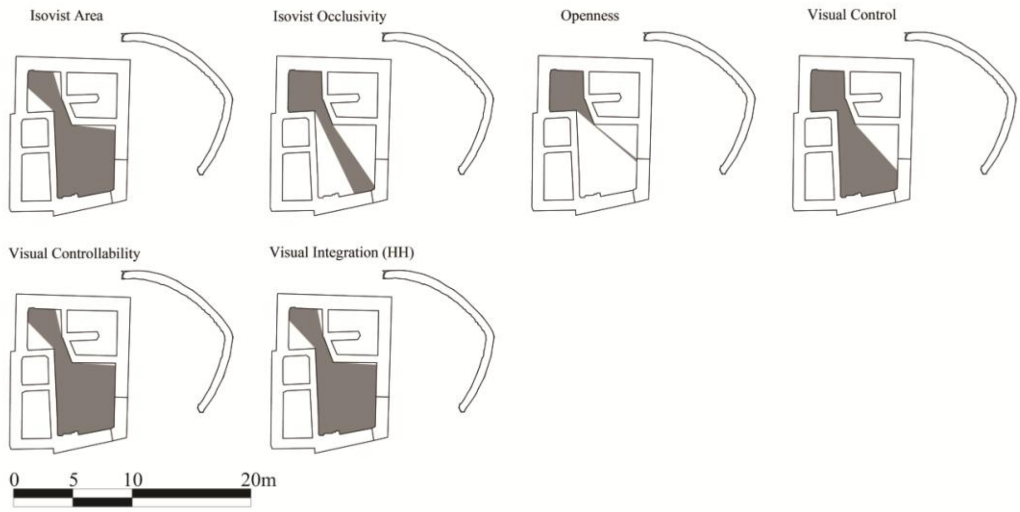

Figure 18: Karoumes – Mother Fort - Point isovists from the cells with the highest value per measurement.

focus on the front side of the building. Based on the fact that the most integrated space is located around the middle of the building, it may be suggested that most activity took place there, without much view of the entrance. However, it is possible to control the entire building from the most integrated point and a point in the bottom left, which does have a view of the entrance. Combining the evidence from the visibility graphs and the point isovists, it may be said that this building was defensible. Although most activity took place away from the entrance, it was relatively easy to keep it controlled, and in case enemies did manage to get inside, the area in the rear, which is occluded from sight, would offer protection and a position to fight back.

The second to last guard house in the sample is number 18, Karoumes – Mother Fort. For this guard house, it must be remembered that the location of the entrance was reconstructed based on its most probably location, so the graphs may be slightly off. Figures 17 and 18 show, similar to the last guard house, that there is a correlation between Isovist Area and Visual Controllability, with the highest values being close to the highest Visual Integration values. The most controlling area of the building is near the back. From there it is possible to see most of the interior, most probably including the entrance as well. The highest Integration is seen more or less in the middle of the guard house. From here the largest part of the interior is visible. The Isovist Occlusivity and Openness measurements are a little odd. Assuming that the entrance was located where it is thought to have been, it was either impossible to see the entrance, or maybe possible to see only a part of the entrance from the area with the highest Occlusivity values. Someone entering the building would have had no trouble moving out of sight. From the area of highest Openness values, it was impossible to see the entrance, but one would not have been visible either when standing there. Although the Occlusivity Isovist does not point towards defensibility, the visibility from the points of highest Control and Integration clearly do. Enemies trying to enter the building would have been seen immediately, and if needed the defenders could "retreat" to the back room, which offered some protection and defence opportunities.

The last guard house that was studied using Space Syntax was Karoumes – Fort of the Sea, which is number 19. Figures 19 and 20 show the visibility graphs and the point isovists calculated for this building. Based on the visibility graphs, most activity seems to have taken place at the back of the room, where the Isovist Area, Visual Control, Visual Controllability and Visual Integration values are highest. In this case, there seems to be a positive correlation between all four measurements. The area that emerges as the most controlling is also close to the area that is easy to control. Because of the limited space, the points that see and can be seen are similar to the point that can be seen, but do

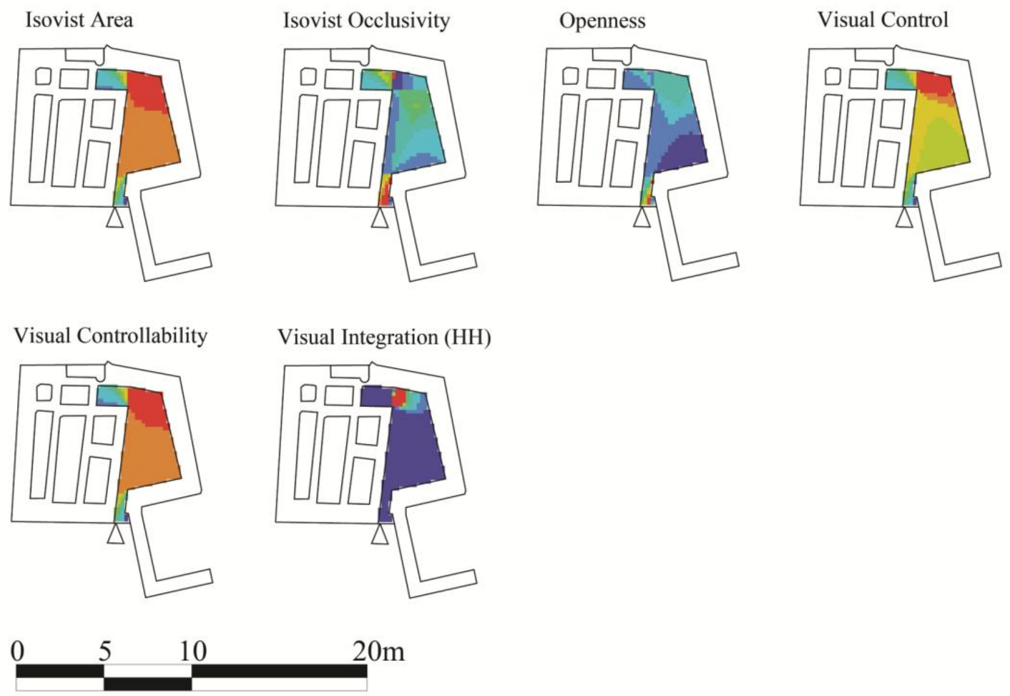

Figure 19: Karoumes – Fort of the Sea - Visibility graphs.

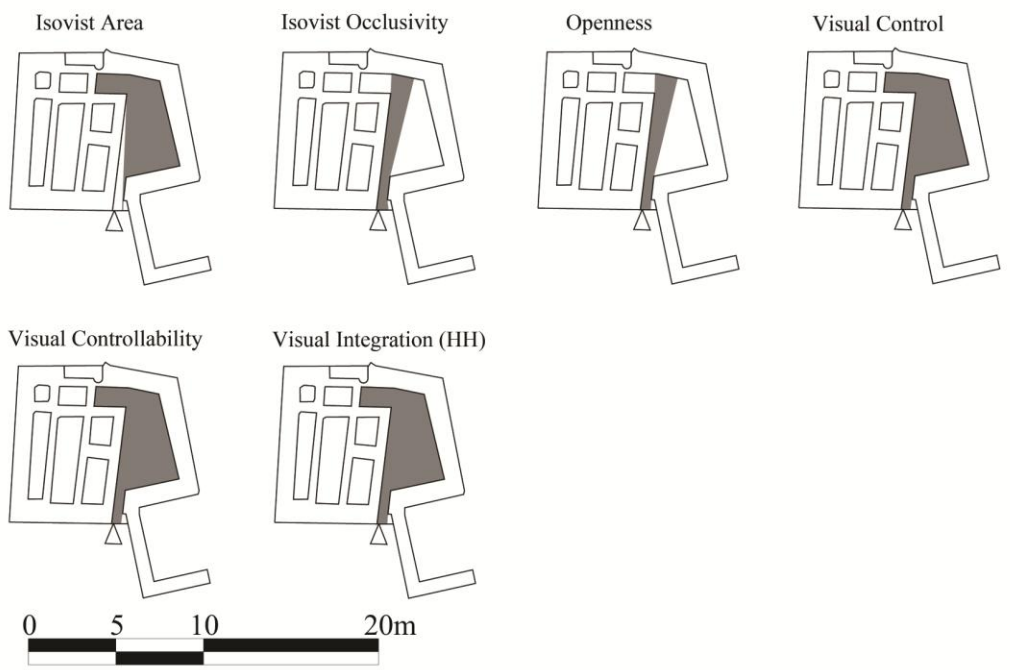

Figure 20: Karoumes – Fort of the Sea - Point isovists from the cells with the highest value per measurement.

not see much. The highest Isovist Occlusivity and Openness values are again found at the entrance of the building. From most of the highest points the entire interior can be seen, except in the case of the Occlusivity and Openness isovists. Because of their location at the entrance, their visibility is rather limited. The correlation between the areas of highest Integration and Controllability make this guard house not really defensible. Someone entering almost immediately has a controlling view, even though the highest Control values are to the back of the room as well. However, because the view from the entrance at first is rather limited, it is possible for people inside to move out of sight and prevent entrance past the short corridor. This adds to the defensibility.

We have now discussed the general table and the visibility graphs of the small sample of guard houses. Based on the assumption that enemies would enter through the door, the values per measurement of the entrances were collected as well. The averages of each guard house can be seen in Table 4. The entrance of guard house 11 has by far the largest Isovist Area, followed by guard house 16. These values are obvious because of the simple layout of these buildings. Of the other five, guard house 12 has the largest Isovist Area, closely followed by number 18, although this value is very questionable. Guard house 19 has the entrance with the smallest Isovist Area. Based on these observations alone, guard houses 11 and 16 are the least defensible, because of the field of view from the entrance towards the inside. Instead, because of the smallest Isovist Area, guard house 19 would be best defended.

The higher the Occlusivity from the entrance, the more defensible the building is, because it offers defenders the option to move out of sight and strike back. With this in mind, guard house 12 would be the most defensible, followed by 9. The least defensible would be guard house 17.

The more controlling the entrance was, the more it gave benefits to the attacker, unless the entrance was also the most used area of the building. This is different from using the Control value for the building as a whole, where high Control is actually more defensible. Based solely on the Control values, guard house 12 is the least defensible. However, as we have seen, the area around the entrance has the highest integration and is probably used a lot by people, negating this lack of defensibility. It is actually guard house 17 that is revealed as the most defensible one, because of the low Control value of the entrance, closely followed by guard house 19.

The higher the Controllability value of the entrance, the more defensible the guard house is. Guard house 16 has the highest values, because of the open entrance. 18 ranks second, while guard house 11 is third, also because of the open entrance. Of the more complex buildings, number 9 is the most defensible, while guard house 17 is the least defensible.

Structure number	Isovist Area	Isovist Occlusivity	Isovist Perimeter	Openness	Visual Control	Visual Controllability	Visual Integration [HH]
9	22.7065	11.8487	26.2905	30.7560	0.8937	0.6092	17.6182
11	85.9976	10.3025	40.6245	21.2085	0.7612	0.7503	74.6536
12	33.7605	12.7669	35.4734	37.7634	1.2418	0.5561	13.5075
16	55.6641	7.8300	31.6180	18.0117	0.8522	0.8426	64.0184
17	10.6368	4.2423	17.5051	28.8158	0.5288	0.2292	8.5325
*18	32.8823	10.4813	31.6924	30.5470	1.0585	0.8169	40.6441
19	8.6159	6.9105	18.3593	39.9403	0.6585	0.4787	12.2666

Table 4: Average values of the measurements taken at the entrance of the guard houses.

	GH number	**9**	**11**	**12**	**16**	**17**	***18**	**19**
General table	Isovist Area	5	1	6	2	3	4	7
	Isovist Occlusivity	1	6	2	7	4	3	5
	Openness	2	6	1	7	5	3	4
	Visual Control	3	6	1	6	2	5	4
	Visual Controllability	2	6	1	6	3	4	5
	Visual Integration	6	1	7	2	5	4	3
Visibility graphs	Defensibility score. 1 is high, 3 is low	3	2	1	2	1	2	1
Entrance values	Isovist Area	3	7	5	6	2	4	1
	Isovist Occlusivity	2	4	1	5	7	3	6
	Openness							
	Visual Control	5	3	7	4	1	6	2
	Visual Controllability	4	3	5	1	7	2	6
	Visual Integration	4	1	5	2	7	3	6
	Total score	40	46	42	50	47	43	50

Table 5: Synthesis of the results of the three Space Syntax analyses, presenting the final score based on this method.

The more integrated the entrance, the more defensible the building, because the presumed activity around areas of high Integration would have made it harder for enemies to enter and easier for people inside to defend. Again, guard houses 11 and 16 have the highest values, followed by 18. Of the remaining complex buildings, guard house 9 is again the best defensible, followed by guard house 12. The least defensible building is number 17, judging by integration values alone.

So far in this section, the results of the Space Syntax analysis have been presented. Based on the results of the various Space Syntax analyses (visibility graphs, point isovists and entrance values), the defensibility of guard houses has been determined. However, this has been determined for each measurement separately. Next, the combined Space Syntax results will be presented. This offers a clearer pictures of the defensibility of these buildings and which guard houses was the most defensible.

Table 5 shows this synthesis. The values represent a ranked order of defensibility, with 1 being the most defensible and 7 being the least defensible, for the general table and the entrance values. For the Visibility graphs row, 1 is defensible and 3 is not defensible, with 2 being moderately defensible. The bottom row shows the final score. The results of the above Space Syntax analysis reveal guard house 9, Kokkino Froudi, as the most defensible one, closely followed by 12 and 18 (although 18 may not be entirely accurate). The least defensible are guard houses 16 and 19.

So far in this chapter, the results have been presented of the different methods with which the defensibility of a selection of guard houses has been studied. It should be noted that for the Defensibility Index and Space Syntax the sample was a little smaller than for Least Cost Path Analysis, because building plans were not available for every guard house. These results are not combined in one table, since they are mixed and are of different quality. Extrapolating the true defensibility of the studied guard houses from a table of combined results would not give an accurate picture. It is better to look at the results of the different methods separately.

Before continuing, there is something else that will be briefly touched upon. One may have noticed that several guard houses, for example Chiromandres and Karoumes - Fort of the Sea, have multiple rooms that seem to have no way of access. There may have been an upper floor, but no hard evidence for this has been found so far. However, these rooms were still part of the building as a whole. The VGA that has been applied to the buildings did not take these rooms into account, but there is another way to see the possible relation between these separated rooms and the rest of the buildings, namely by using justified graphs (or j-graphs for short). J-graphs are a form of Access Analysis, showing the connections between each convex space in a building. Each convex space is represented as a node and the links between the nodes represent the accessible connections (Bafna 2003, 23). Assuming there was indeed an upper floor, which is a rather big assumptions, it is possible to assign a node to this upper floor, which then connects back to the separated rooms on the ground floor. Figure 21 shows the j-graphs for each of the studied guard houses. Because stairways also have not been documented, it was decided to connect to the assumed upper floor from the convex space at the back of each building, where applicable. These j-graphs are obviously very subjective, but at least they give an idea of how rooms may have been connected. J-graphs also offer several statistical analyses, but because of the assumptions of the upper floor and the locations of the stairways, these would probably not be accurate. Therefore, they are not discussed.

J-graphs offer the opportunity to compare the layout of different buildings very easily. For the sake of completeness, the above j-graphs were compared to those of several normal Minoan houses (see Figure 22), because of their similar size. As can be seen, there seem to be some similarities with houses Da, Db, Fi and Hb, but most of the houses seem to be more complex than the studied guard houses.

Doing a complete j-graph analysis of guard houses goes beyond this thesis, but the above has at least shown some possibilities for future research, which may add even more knowledge about the defensibility of guard houses as well.

The next chapter will briefly discuss the outcome of each of the main methods discussed in this chapter, and will explore the defensibility of the guard houses in the light of these new results.

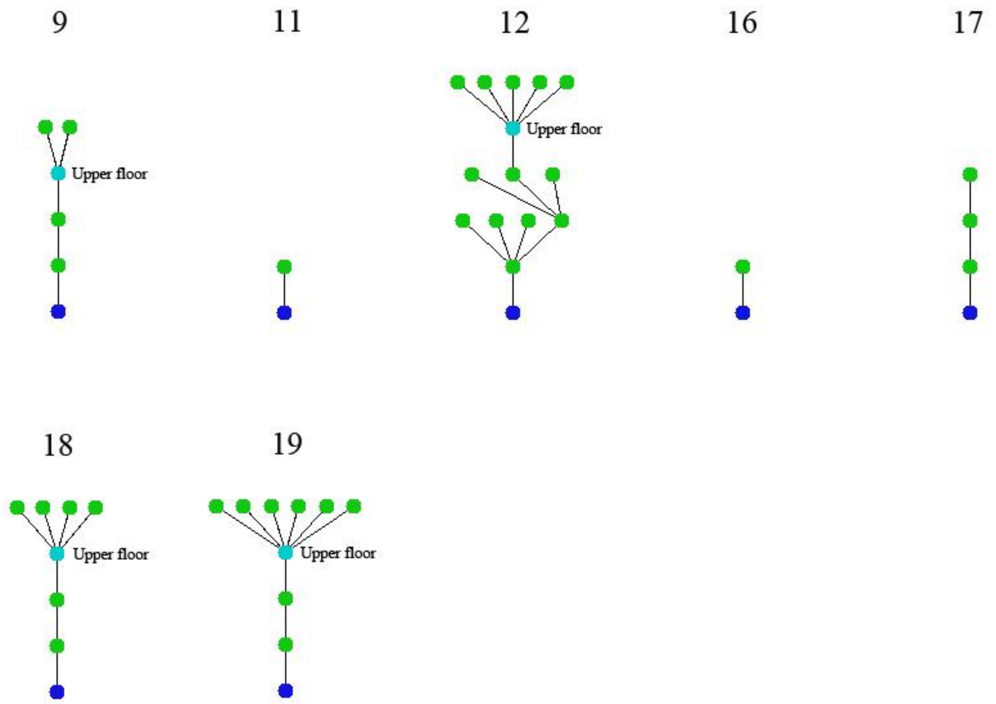

Figure 21: J-graphs of the studied guard houses.

9: Kokkino Froudi
11: Agio Pnevma
12: Chiromandres
16: Kali Elia
17: Aspres Plakes
18: Karoumes – Fort of the Sea
19: Karoumes – Mother Fort

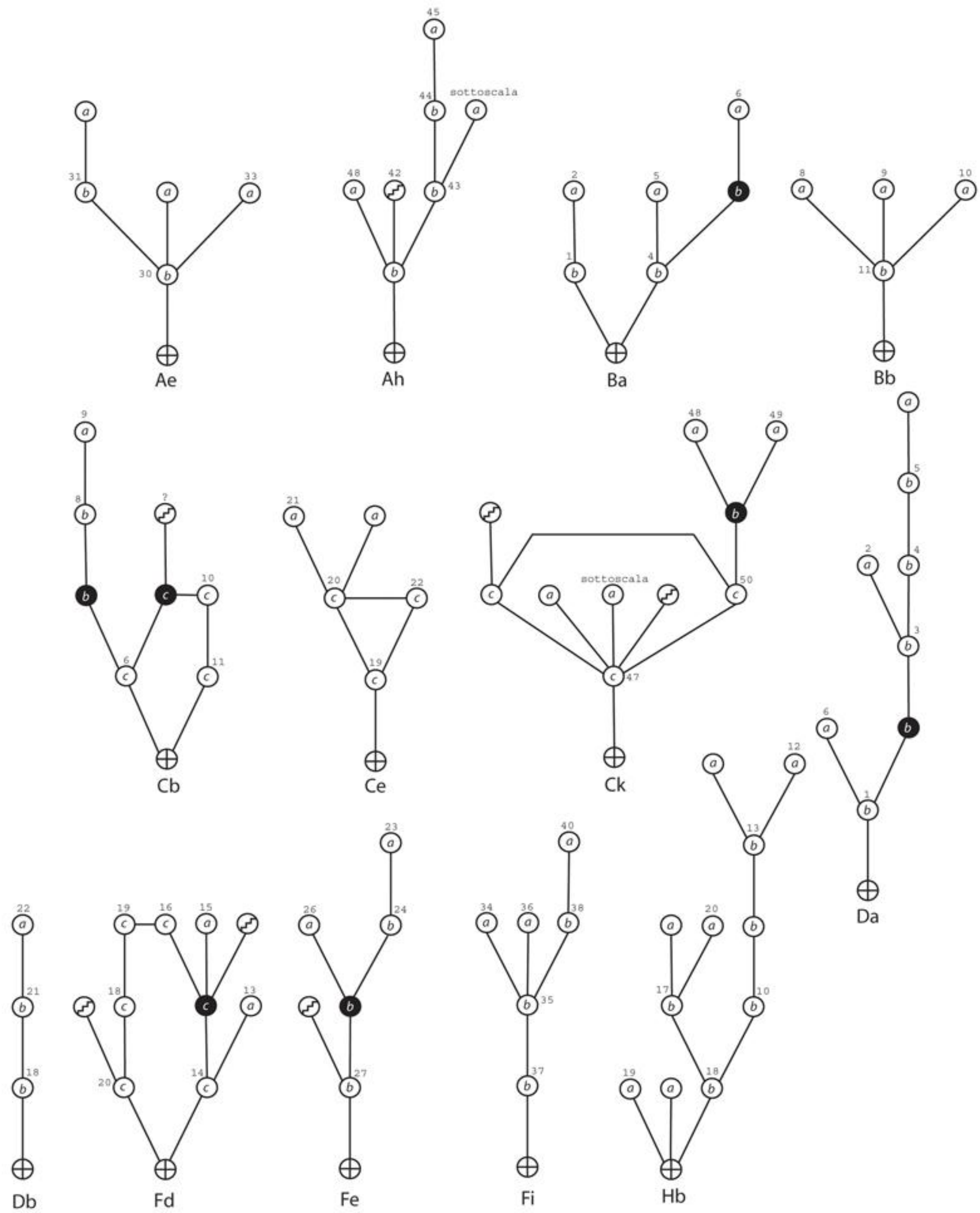

Figure 22: Justified graphs of a selection of houses at Gournia (Letesson 2009, 213, Fig. 388).

5 Discussion

This chapter is focused on the comparison between the three methods that have been used. Each of them has advantages, but they have flaws as well, which has certain implications. Also, the effect of the results on the interpretation of guard houses and similar buildings will be discussed.

In general, the results are very interesting. Not only is it the first time these methods have been used on Minoan guard houses, it is also the first time they have been combined to give a better idea of the defensibility of these buildings from both the outside and the inside. Having said that, it is interesting to note that the guard house of Kokkino Froudi, which seem highly defensible from the inside, actually has the lowed D.I. score. The opposite is true for Karoumes – Fort of the Sea, which has a low defensibility based on Space Syntax analysis, but has one of the highest D.I. scores. Taking these two as an example, combining the results of just the D.I. and VGA alone, would give an average that does not do them justice. Thus again, looking at the different results separately and giving an interpretation from a specific perspective is most useful here. However, there are flaws in every method.

There are several problems that affect the outcome of the GIS results, both LCP analysis and the Defensibility Index calculations. Maybe the most important "problem" has to do with the GPS coordinates. It is unknown how accurate these coordinates really are and where exactly the coordinates were measured. Were coordinates taken in the middle of each guard house, or somewhere outside. This has a large effect, especially on the results of the Defensibility Index calculations, where viewsheds were used from that specific point and buffers clipped at a certain distance from these coordinates.

The effects on the LCP analysis are a little unclear. It is likely that the LCPs would still come together at the same location, because a variance of, for example, a few meters would be only small compared to the grid size of almost 30 meters. However, this has not been tested.

The resolution of the DEM is another problem. For LCP analysis it seemed to be sufficient at first, but the results of the D.I. calculations have made the inaccuracy of the DEM very clear. It was expected that important breaks in elevation would have been included, but apparently that is not the case with the ASTER GDEM. It is a little disappointing, but on the other hand this DEM would still have been chosen, because it is the best freely available DEM. It must be stressed here that, because of the low resolution of the DEM, the images in the Appendices do not show an accurate representation, but merely show the possibilities. Also, a possible side effect of the low resolution is that the LCP images may look rather isotropic. However, this would imply uniformity in every direction for every guard house, giving images that would be exactly the same. This would be possible on a completely flat surface, but since the surface of Eastern Crete is not isotropic at all, the LCPs are not either. Straight lines are caused by low terrain detail as well.

Another problem that affects both GIS-based analyses, or at least the interpretation of the results in the case of LCP analysis, is that *periboloi* and *vigla* were not visible on the plans of most guard houses. There is the exception of the map of the area around the guard house of Chiromandres, for example, but those walls were left out to make the comparison more fair. If these digitised into the GIS, the number of LCPs reaching that guard house may have been even less. D.I. values would have been higher, because the arc of Access would have been much lower.

In general, the sample size was also too small. It would have been much better if actually all guard houses would have been studied, not only to better compare the LCPs, but especially for the D.I. and Space Syntax results to have any real statistical relevance.

Nonetheless, this is the first time these methods have been used on Minoan guard houses. In the future the methods may be perfected, for example by using a very high resolution DEM, having better GPS coordinates and actually having enough information about *periboloi* and *vigla* around guard houses, or any other building for that matter, to get very accurate results. Another possibility for future research would be to calculate LCPs from known routes of movement in the region.

However, even though there are flaws, these flaws do not decrease the usefulness of these methods. With the right datasets, the methods themselves are fine. The LCP analysis and the D.I. calculations give insight in the accessibility and defensibility of guard house from the area around them, with the Space Syntax Visibility Graph Analysis providing a detailed picture of how the insight of these buildings functioned, what were important space, defensible or not, etc.

Even though the results are not flawless, there is definitely a thing or two that adds to the knowledge and interpretation of Minoan guard houses. It has for a long time been said that guard houses were defensive and defensible buildings. The results of this study have shown that this was indeed the case, although it must be noted that there are guard houses that are less defensible than others. It also depends on what is looked at. Again taking the example of Kokkino Froudi, of which the results suggest a low exterior defensibility, but a very high interior defensibility. The sample is too small to say for sure, but it may even be the case that guard houses at less defensible locations were given a very defensible interior on purpose. As a compensation as it were. Since people usually try and exploit weaknesses to their advantage (Martindale and Supernant 2009, 196), this would be a good way to compensate for the weakness of the exterior.

The results may not be perfect, because of the flaws inherent to the methods that were used and the small sample size, but nonetheless some insight has been gained into the defensibility of Minoan guard houses. More importantly, some new methods for studying these guard houses have been tested that show much promise for the future.

6 Conclusion

The Minoan guard houses are very interesting structures. They have been called guard houses and defensible buildings, based mostly on location and strong walls, but a high location and strong walls do not per se make a building defensible. The goal of this thesis was to answer the question: how defensible were the Minoan guard houses? To study this question, three different methods were used on a selected number of guard houses, each with different results. These methods were Least Cost Path analysis, the calculation of a Defensibility Index value, and Space Syntax's Visibility Graph Analysis.

First, Least Cost Path analysis was done, to try and determine the accessibility of the guard houses from a wide area around them. The hundred LCPs that were plotted per radius per guard house all joined together until 2 to 4 LCPs reached the guard houses. For the longer radii there are a couple of examples where the numbers of LCPs reaching the guard house decreased, but overall the results were rather stable. Chiromandres and Mavro Avlaki share the same value and are interpreted as most defensible here, while both forts at Karoumes are interpreted as least defensible. The LCP images in the Appendices may look a little isotropic, but as was discussed in the previous chapter, this is not the case, but merely a side effect of the low resolution DEM.

Secondly, Defensibility Index values were calculated, based on an adapted version of the D.I. research by Martindale and Supernant (2009). This GIS version made apparent the low resolution of the ASTER GDEM v2 that was used for both LCP analysis and this method. However, the final D.I. values were quite interesting, since in especially two cases there seemed to be an inverse relationship with the results of the Space Syntax analysis. Taking into account that the Area variable was left out and that the Accessibility value was 0 because of the DEM, overall the results seem to indicate medium to high defensibility of the sample of guard houses. The highest D.I. value belongs to Karoumes – Morther Fort, while the lowest D.I. value belongs to Kokkino Froudi.

Thirdly, Space Syntax and Visibility Graph Analysis were applied to the sample of guard houses. Buildings as a whole, the visibility and the entrance values were interpreted separately, each giving their own results for several measurements. Some guard houses that seemed to have a defensible interior when looking at the Control value of the whole building, while the Control value of the entrance suggested the opposite. All the results were combined into one table, with scale values 1 through 7, from high defensibility to low defensibility, which were given depending on the order per measurement. The final result was that the guard house of Kokkino Froudi, which has the lowest D.I. value, has the highest defensibility rating based on the Space Syntax results.

Kali Elia and Karoumes – Fort of the Sea, of which the latter has a high D.I. value, have the least defensible interior.

The above three methods each have their own results, that on occasion seem to be opposites. As was said already in the previous chapters, it would not be wise to combine the results of all three methods into one extensive table and choose the guard house with the highest overall defensibility value. The reason for this, is that results would be evened out, and it would not be possible to see the sometimes large differences between the methods. Interpreting the results of each method separately, allows for a more honest representation of the defensibility per point of view, interior and exterior.

Although the results presented in this thesis have their flaws, these have more to do with the inaccurate datasets that were used and/or the small sample, than it had to do with the methods themselves. The methods that have been used are unique in their own way. The combination made it possible to study both the outside of guard houses, up to 2 km around them, and the inside. Using these three modern methods it was again confirmed that the Minoan guard houses are defensible buildings, although some are more defensible from the outside, while other are more defensible from the inside. Seeing these defensible guard houses as part of a defensive network that was either watching the hinterland or the territorial borders, adding to their own defensibility as well, it can be understood why they were successful at keeping the territory of Zakros together for such a long time. In the future, a higher resolution DEM, and more accurate and complete datasets may make it possible to get an even more detailed overview of the defensibility of the Minoan guard house of eastern Crete.

Summary

The guard houses of Minoan Crete are often said to be defensible buildings, based on their location and architecture. However, were they really defensible? To answer the question of how defensible these buildings were, three different methods were applied to a sample of guard houses. These methods were Least Cost Path analysis, the calculation of a Defensibility Index value, and Space Syntax with Visibility Graph Analysis. These methods have never been tried before and the results give new insight in how defensible these guard houses actually were. Not only from the outside, but from the inside as well. The results have confirmed that these guard houses are generally defensible buildings, although the defensibility differs per building and per method. In the future, a higher quality DEM and better datasets, that fix most of the flaws in the results presented here, will provide an even more accurate perspective on these guard houses.

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Appendix A: LCP images

The following pages present the GIS images that were used for the Least Cost Path analysis. For all studied sites, for the ranges 300 m, 1 km and 2 km, LCPs were calculated from a 100 points around the sites. These images will be presented here per site.

Also, 3D model images are included, which will come afterwards. These 3D images show the location of every site within the landscape, based on the used DEM, to help visualise how the studied guard houses were placed in the landscape and in relation to each other.

Agio Pnevma

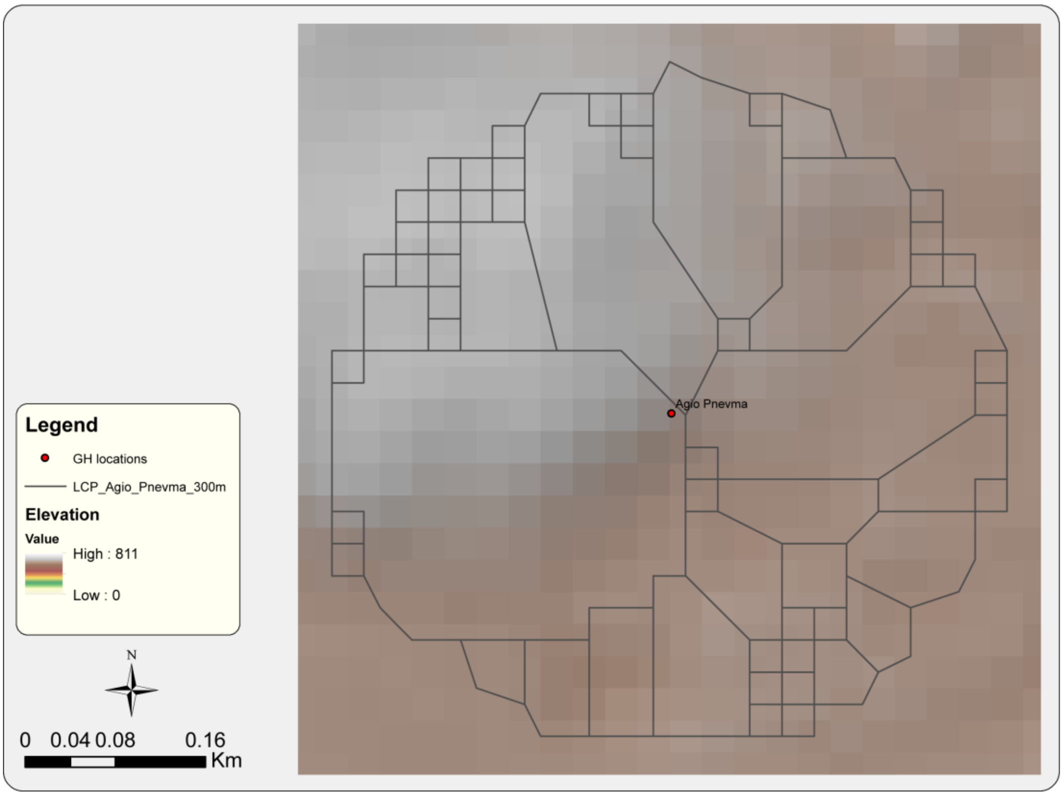

Figure 1: LCPs from 300 m range around the guard house of Agio Pnevma.

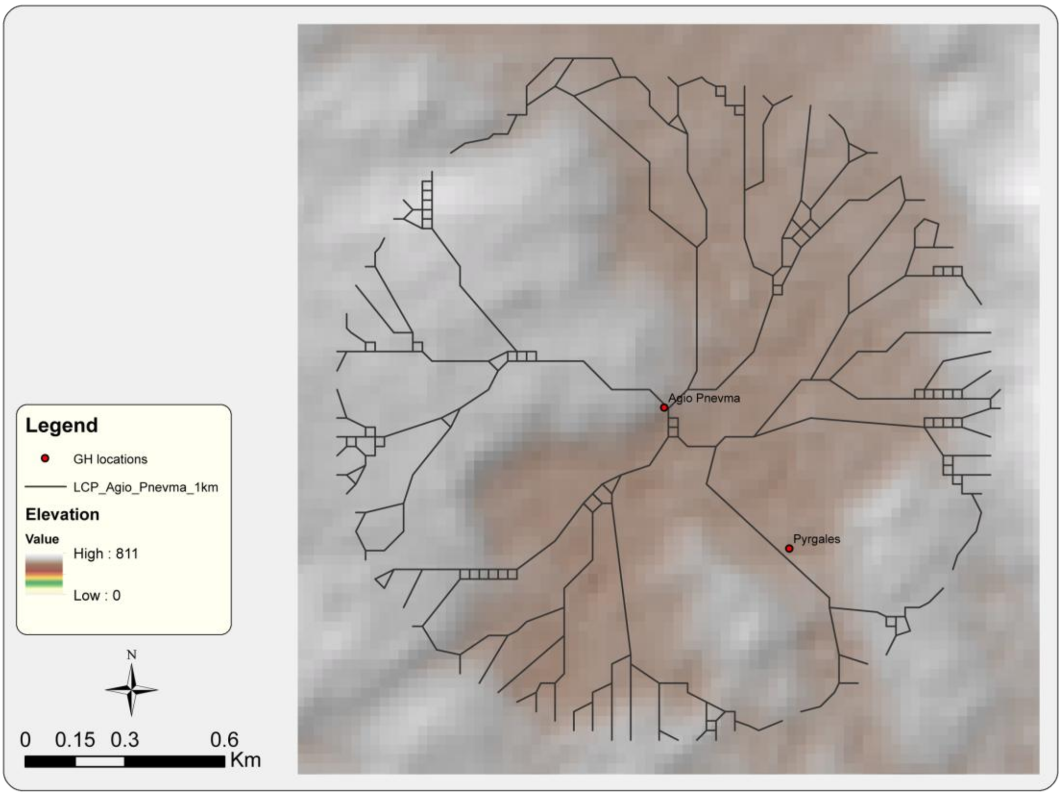

Figure 2: LCPs from 1 km range around the guard house of Agio Pnevma.

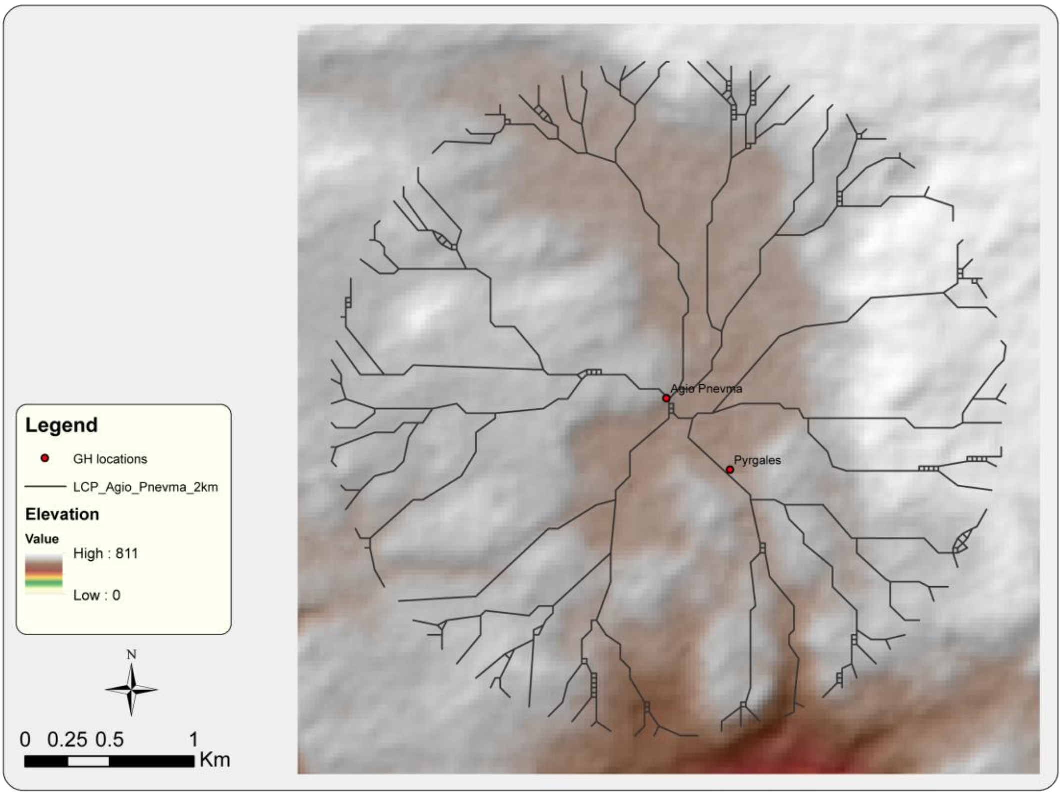

Figure 3: LCPs from 2 km range around the guard house of Agio Pnevma.

Aspres Plakes

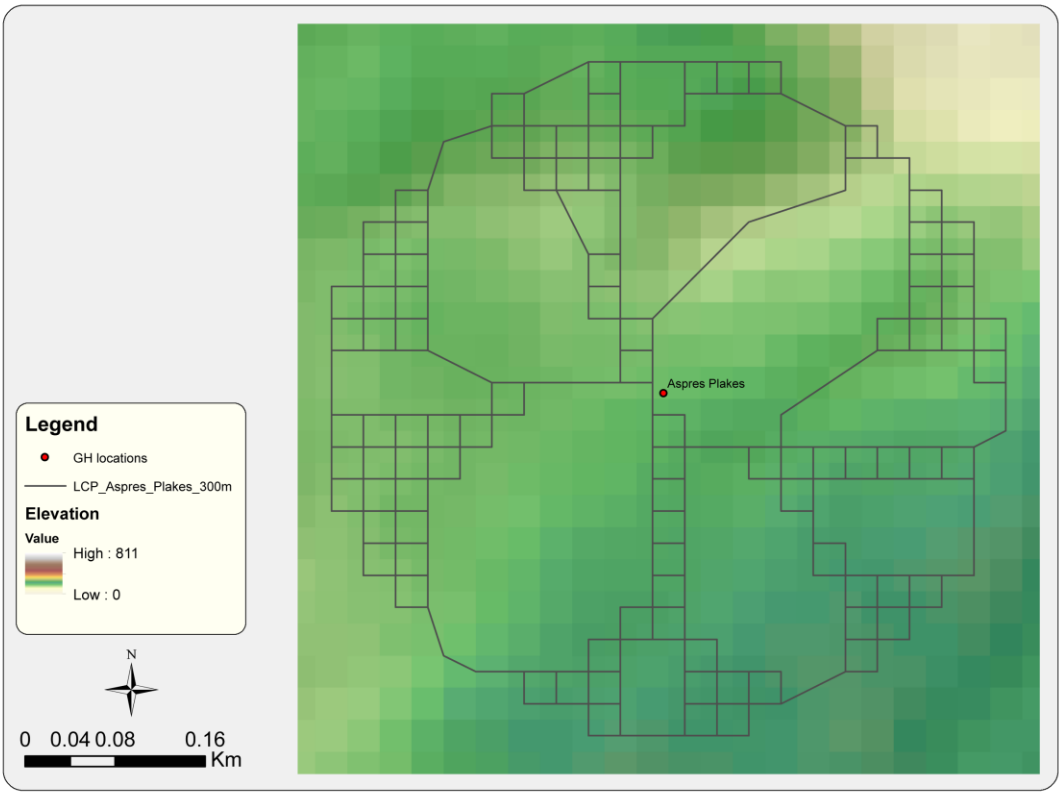

Figure 4: LCPs from 300 m range around the guard house of Aspres Plakes.

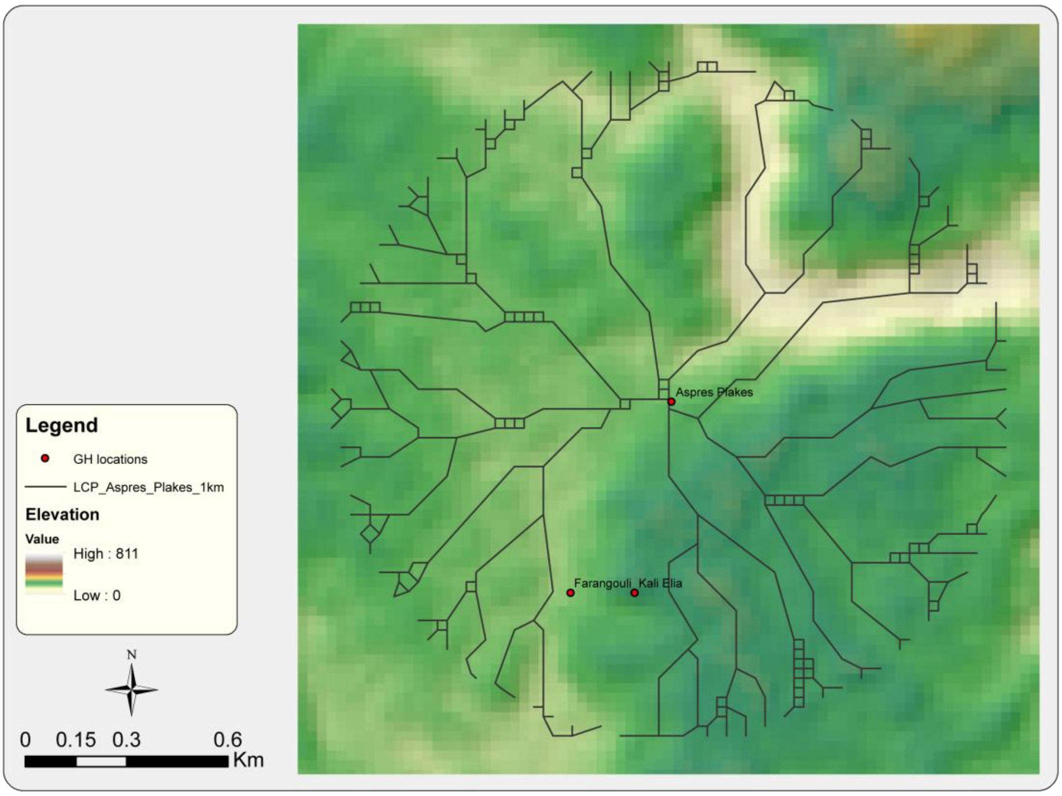

Figure 5: LCPs from 1 km range around the guard house of Aspres Plakes.

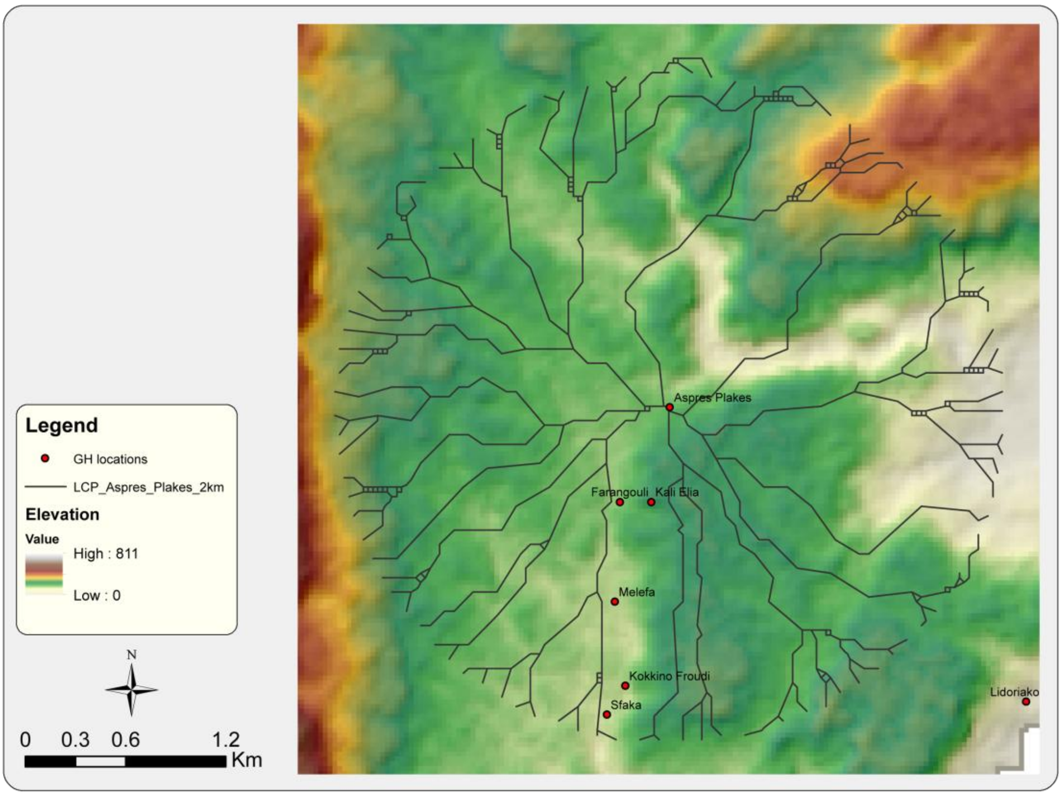

Figure 6: LCPs from 2 km range around the guard house of Aspres Plakes.

Chiromandres

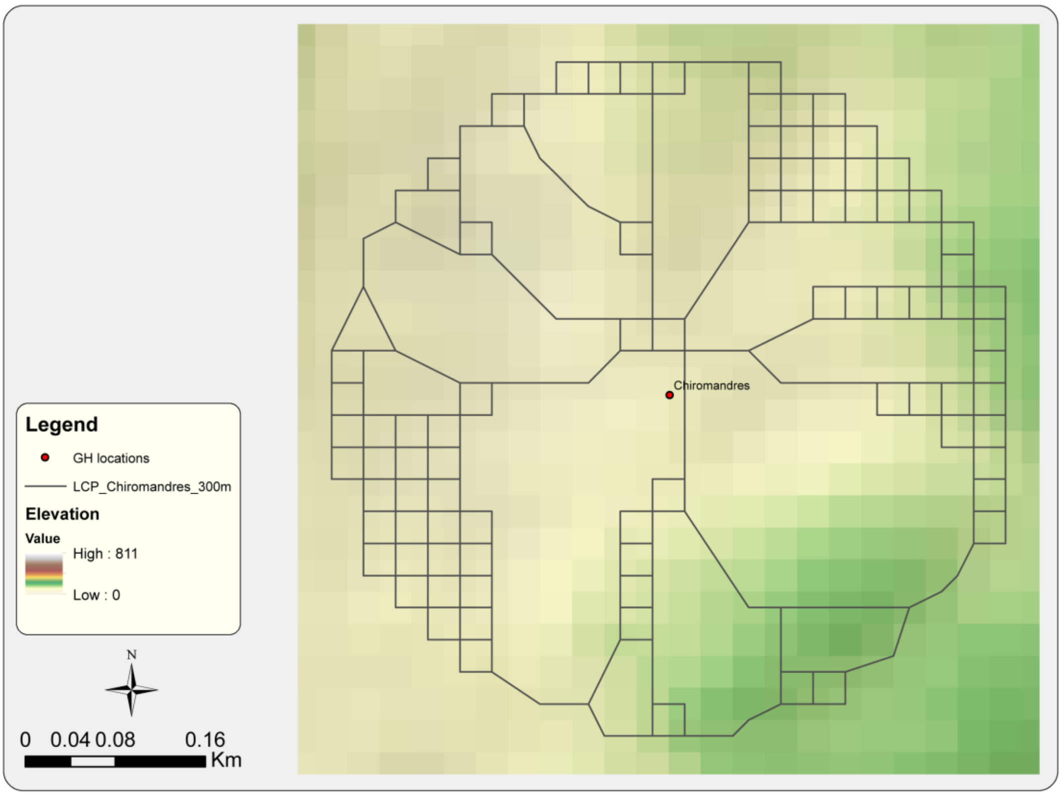

Figure 7: LCPs from 300 m range around the guard house of Chiromandres.

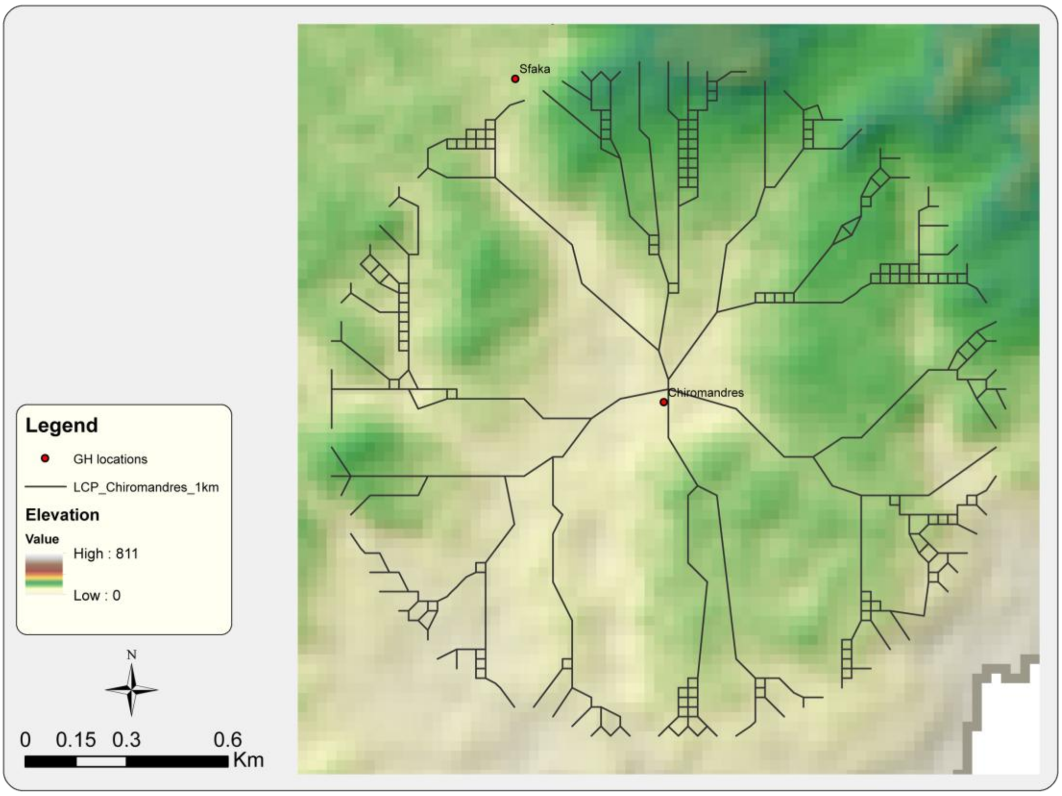

Figure 8: LCPs from 1 km range around the guard house of Chiromandres.

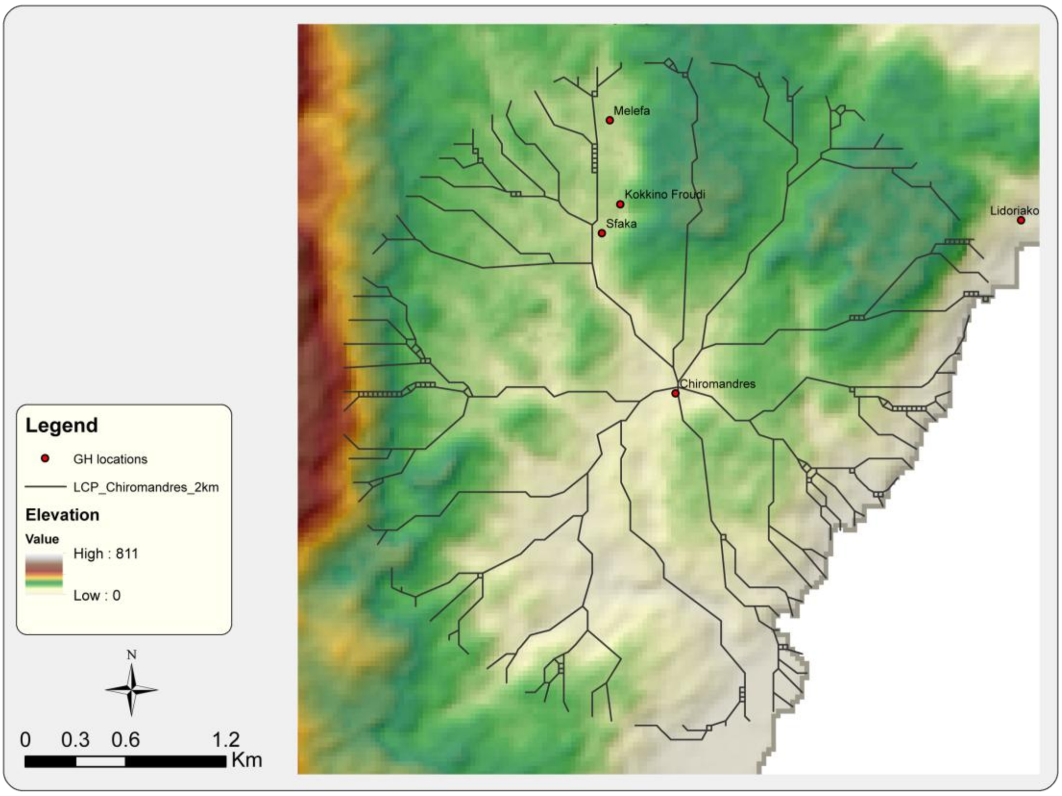

Figure 9: LCPs from 2 km range around the guard house of Chiromandres.

Chochlakies

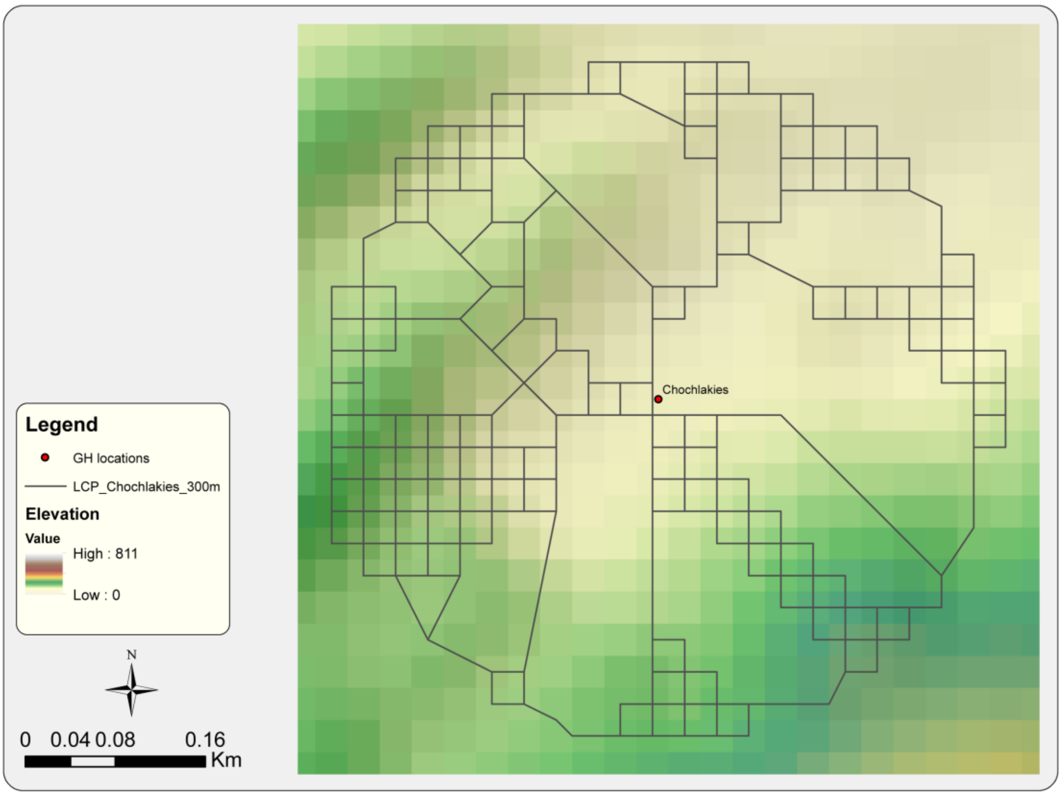

Figure 10: LCPs from 300 m range around the guard house of Chochlakies.

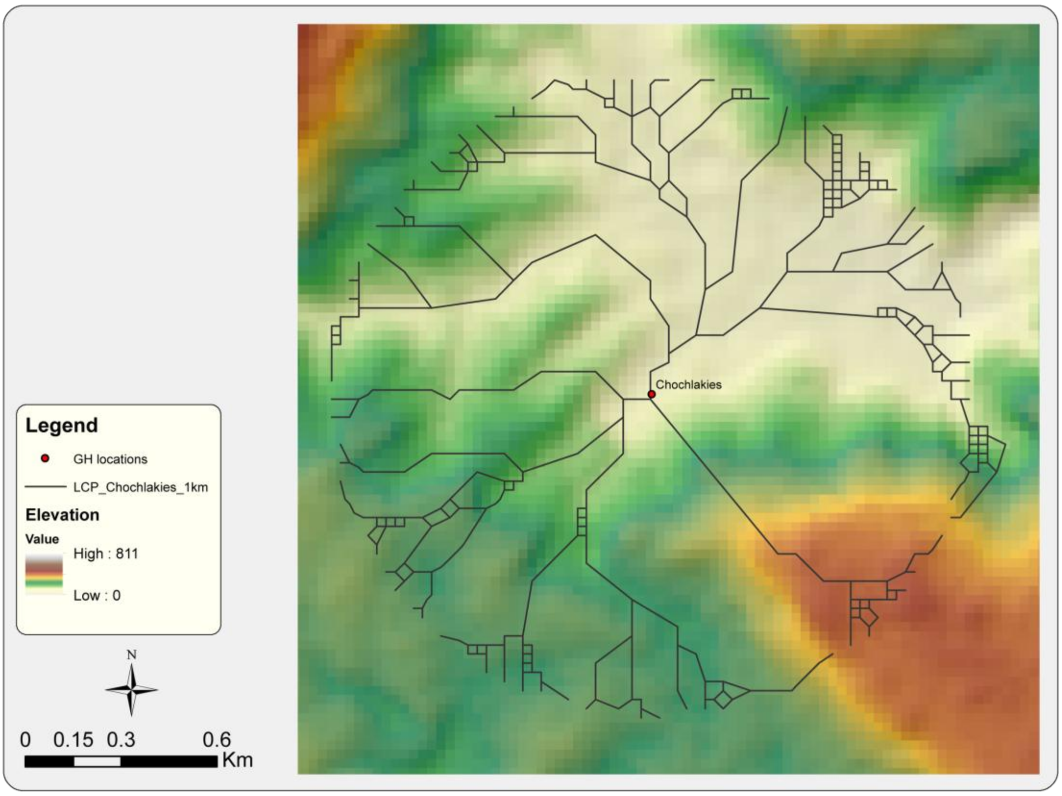

Figure 11: LCPs from 1 km range around the guard house of Chochlakies.

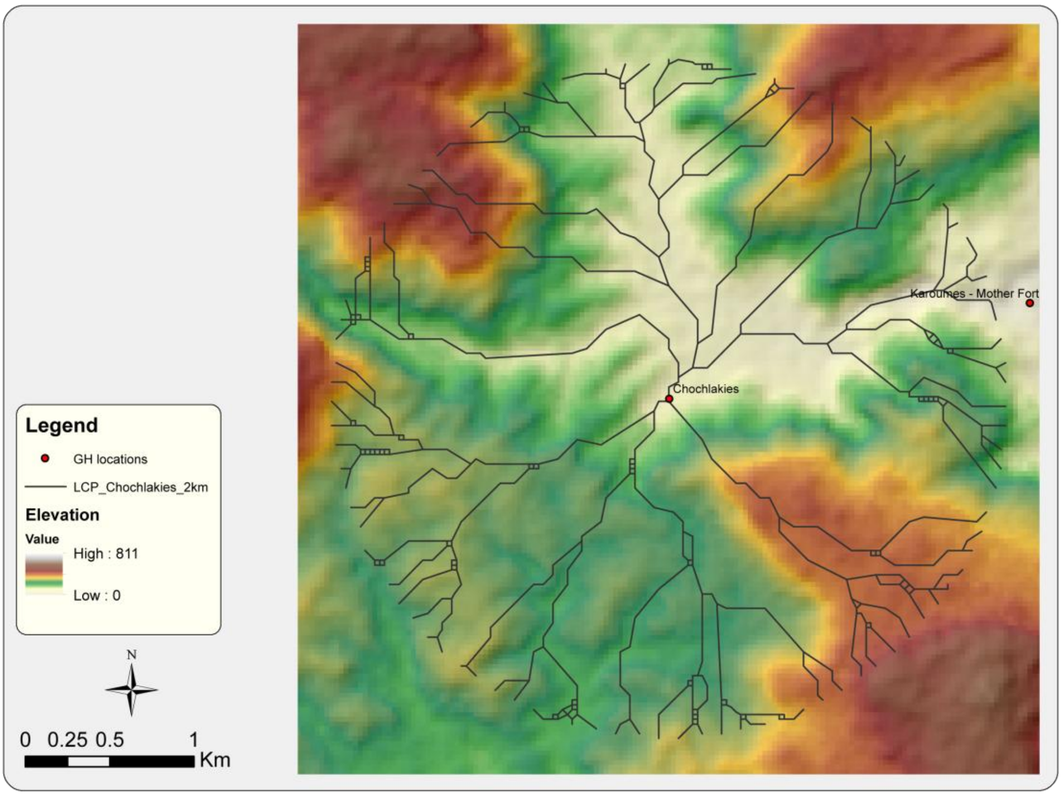

Figure 12: LCPs from 2 km range around the guard house of Chochlakies.

Farangouli

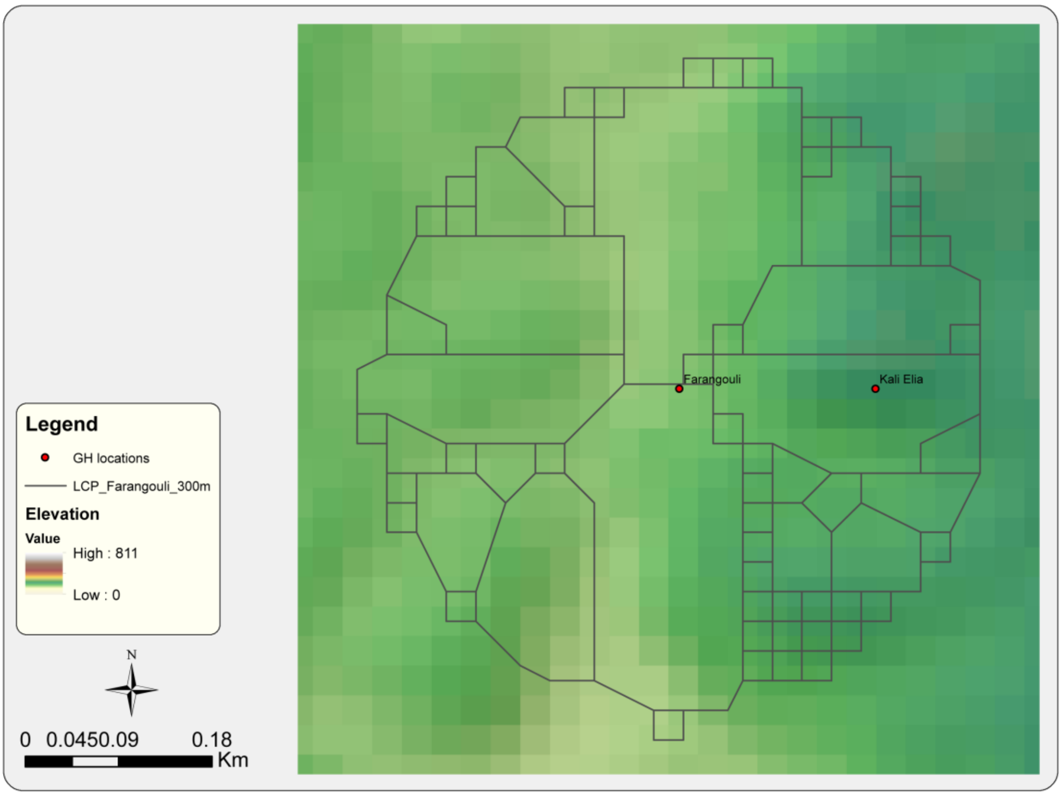

Figure 13: LCPs from 300 m range around the guard house of Farangouli.

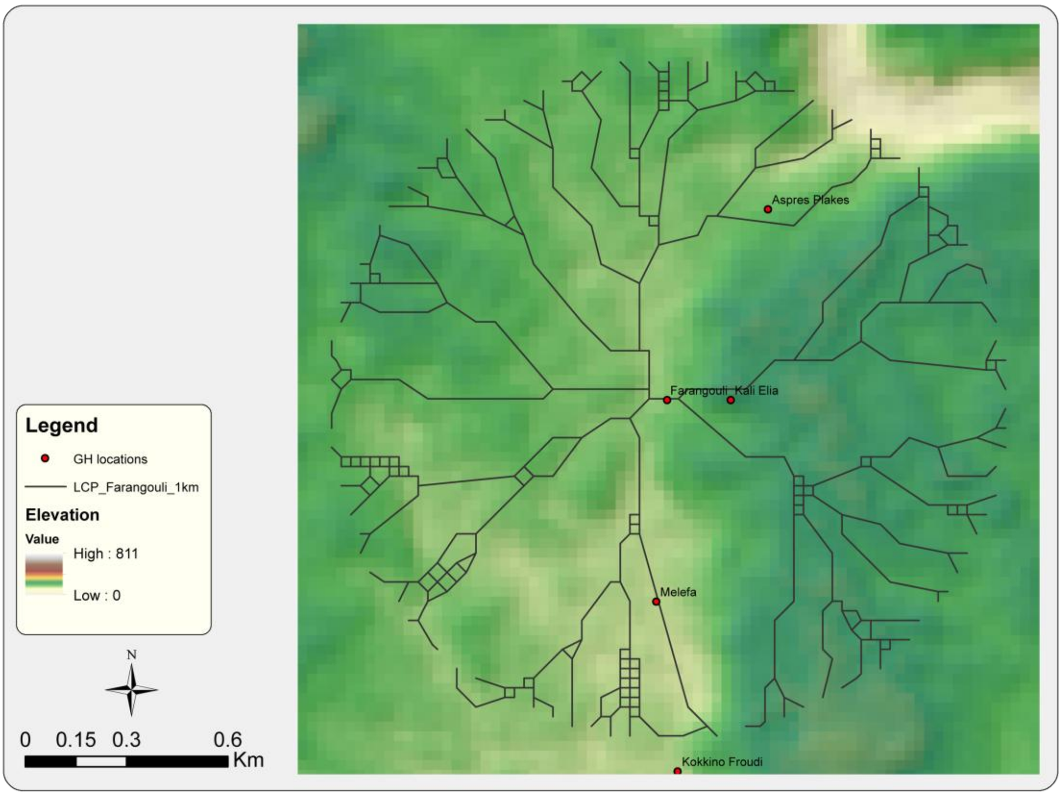

Figure 14: LCPs from 1 km range around the guard house of Farangouli.

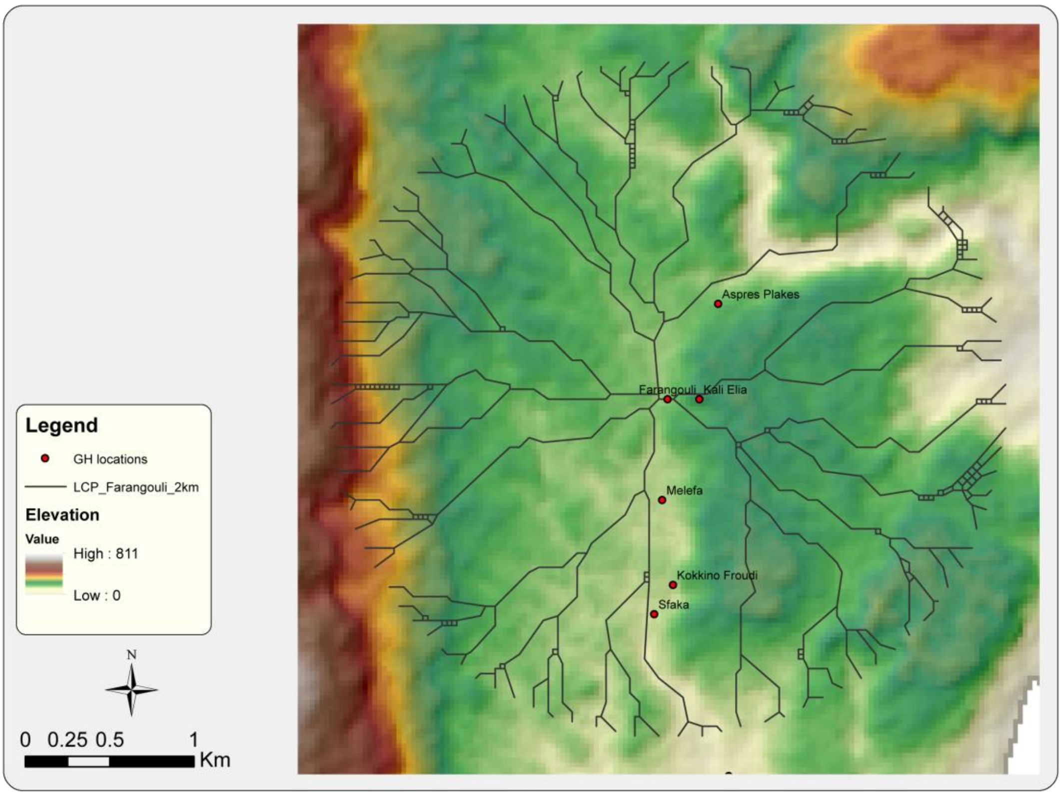

Figure 15: LCPs from 2 km range around the guard house of Farangouli.

Kali Elia

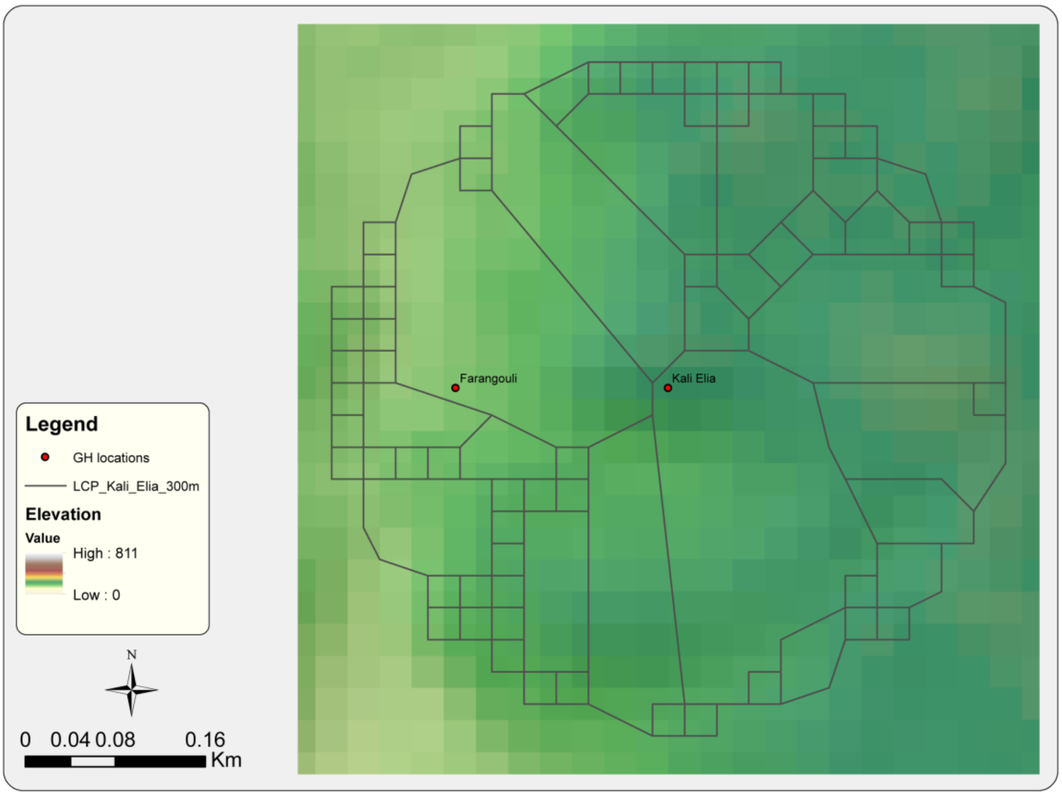

Figure 16: LCPs from 300 m range around the guard house of Kali Elia.

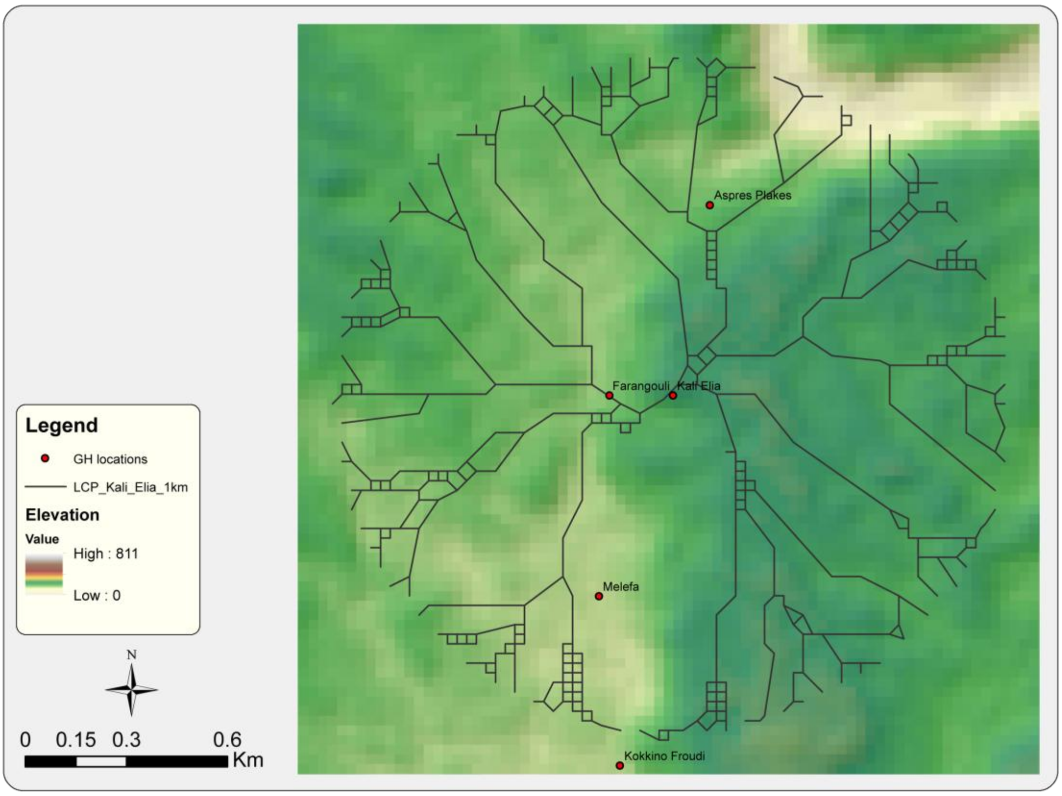

Figure 17: LCPs from 1 km range around the guard house of Kali Elia.

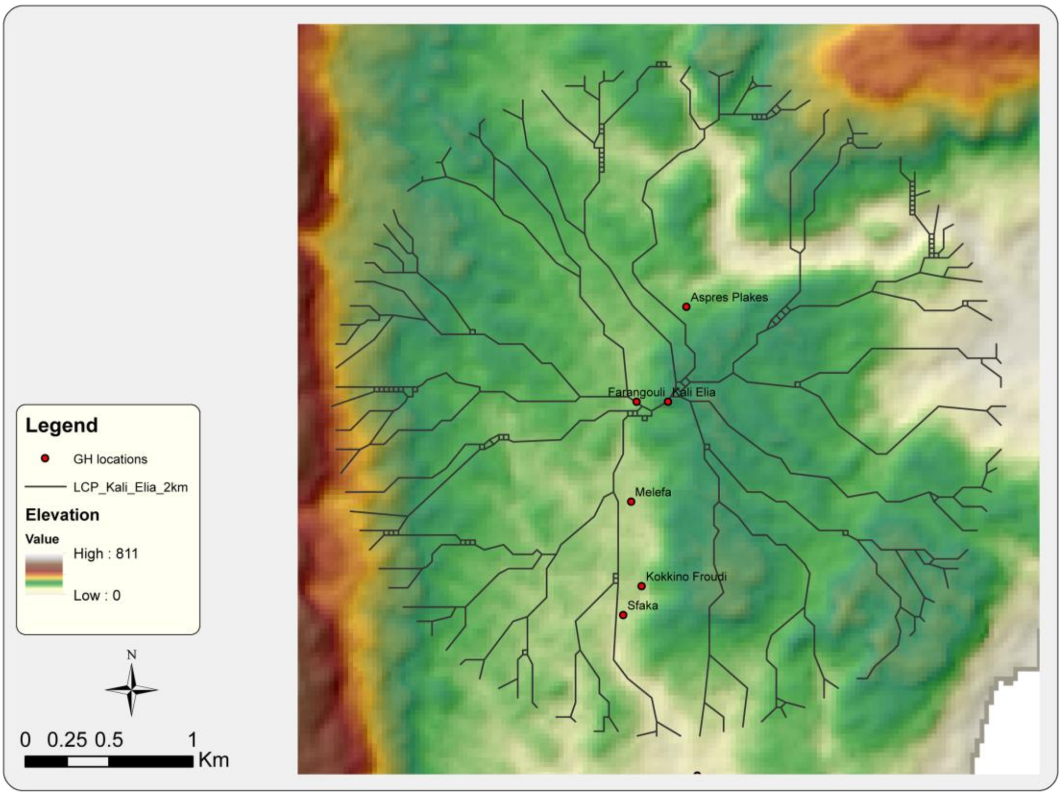

Figure 18: LCPs from 2 km range around the guard house of Kali Elia.

Karoumes – Fort of the Sea

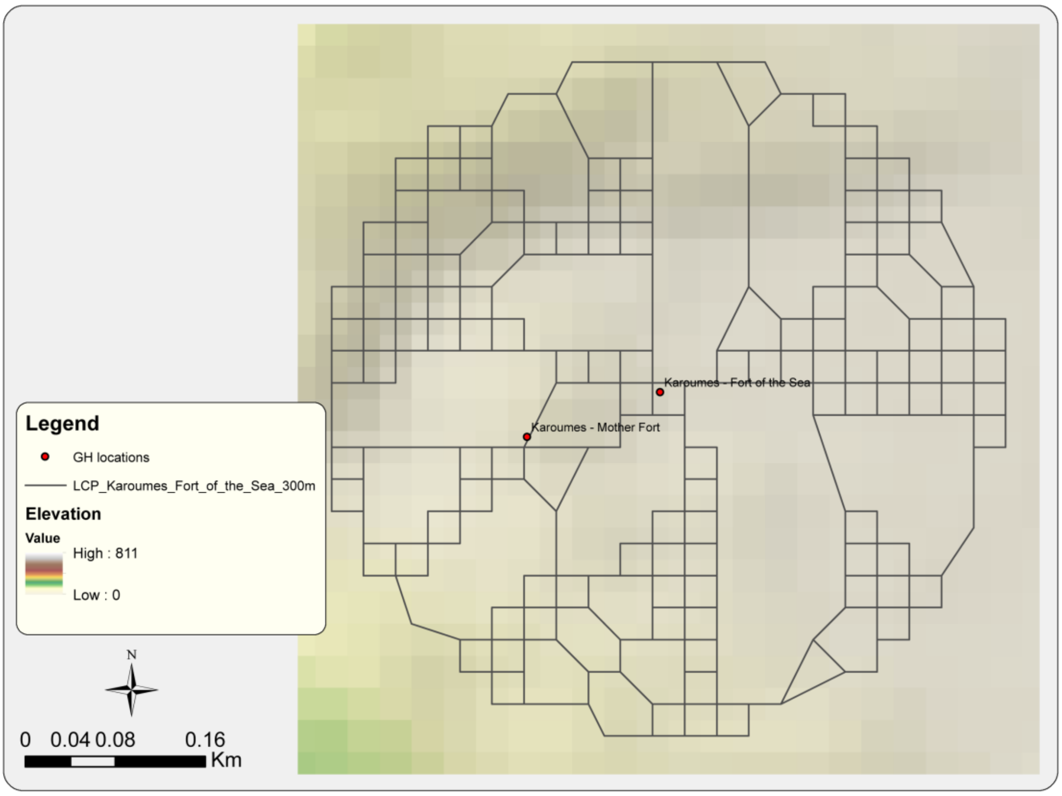

Figure 19: LCPs from 300 m range around the guard house of Karoumes – Fort of the Sea.

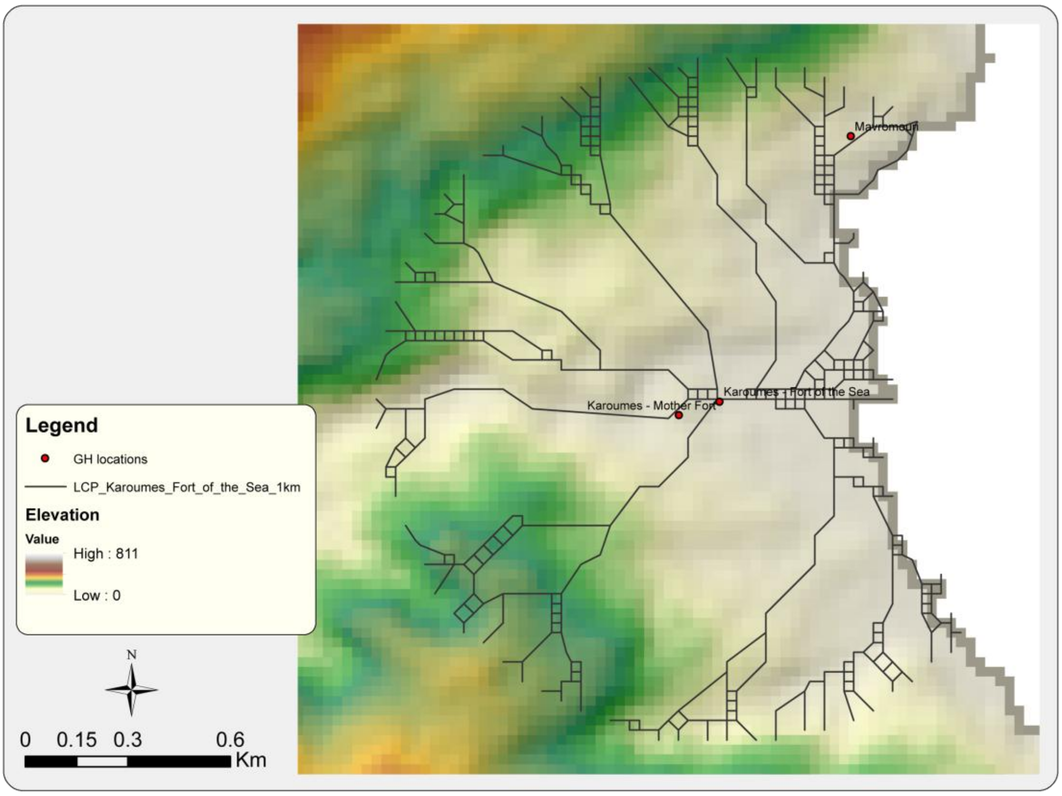

Figure 20: LCPs from 1 km range around the guard house of Karoumes – Fort of the Sea.

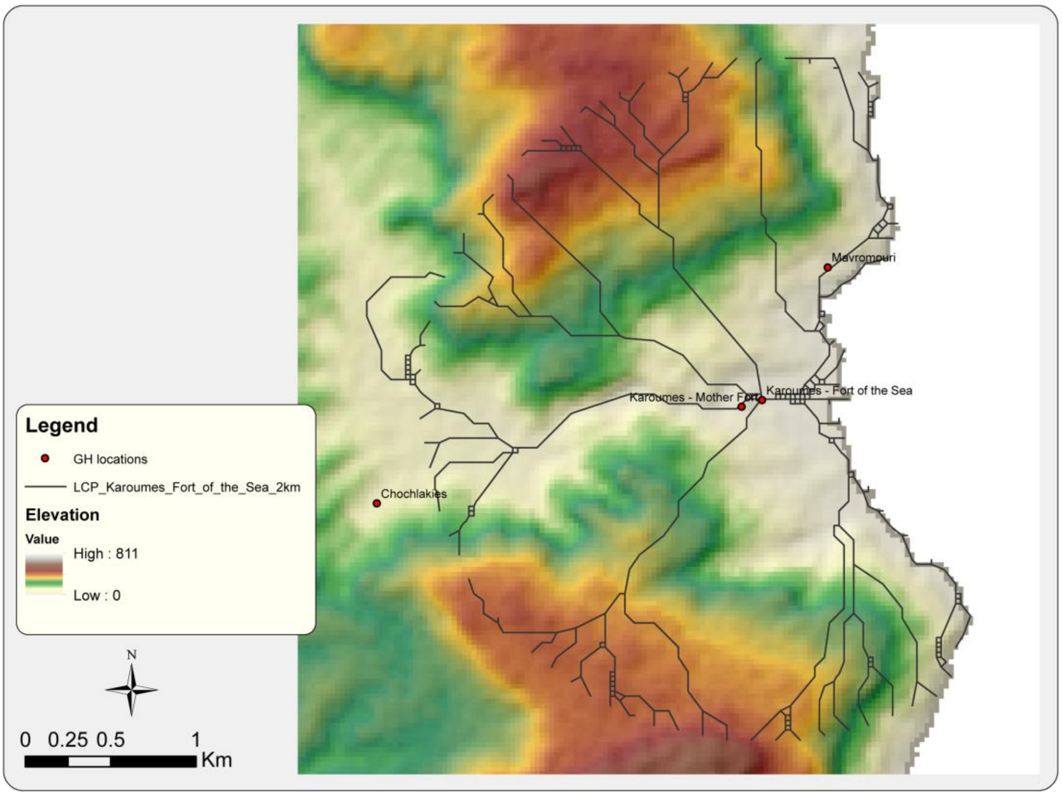

Figure 21: LCPs from 2 km range around the guard house of Karoumes – Fort of the Sea.

Karoumes – Mother Fort

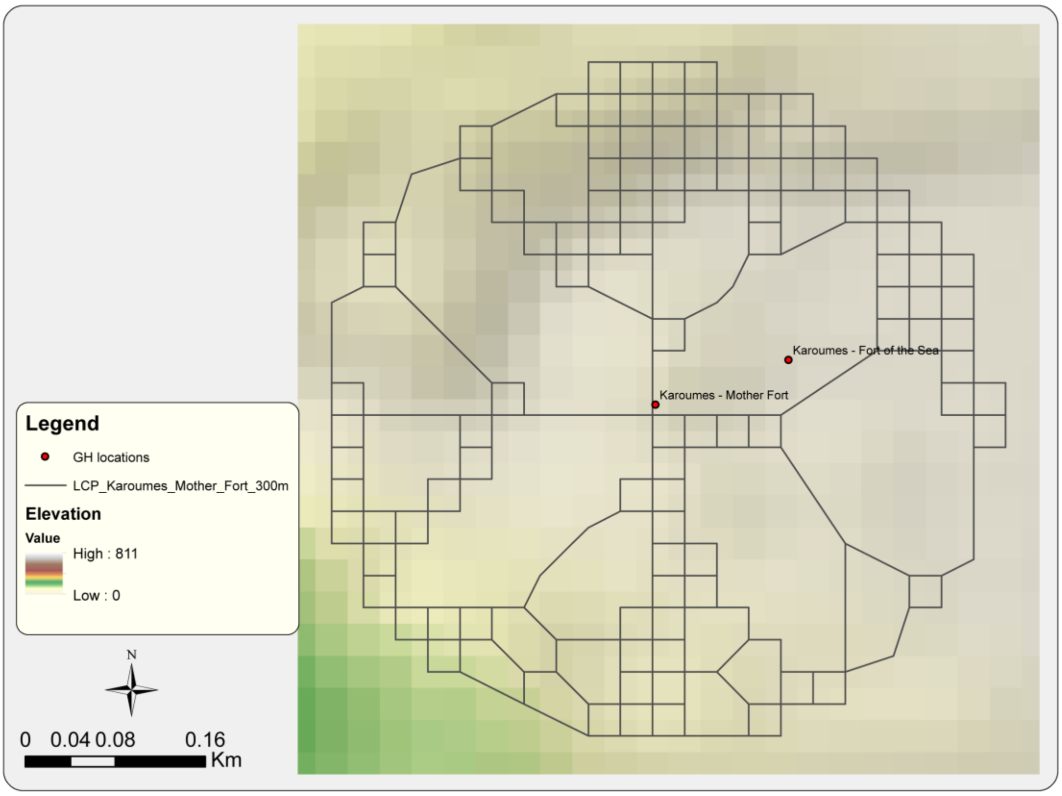

Figure 22: LCPs from 300 m range around the guard house of Karoumes – Mother Fort.

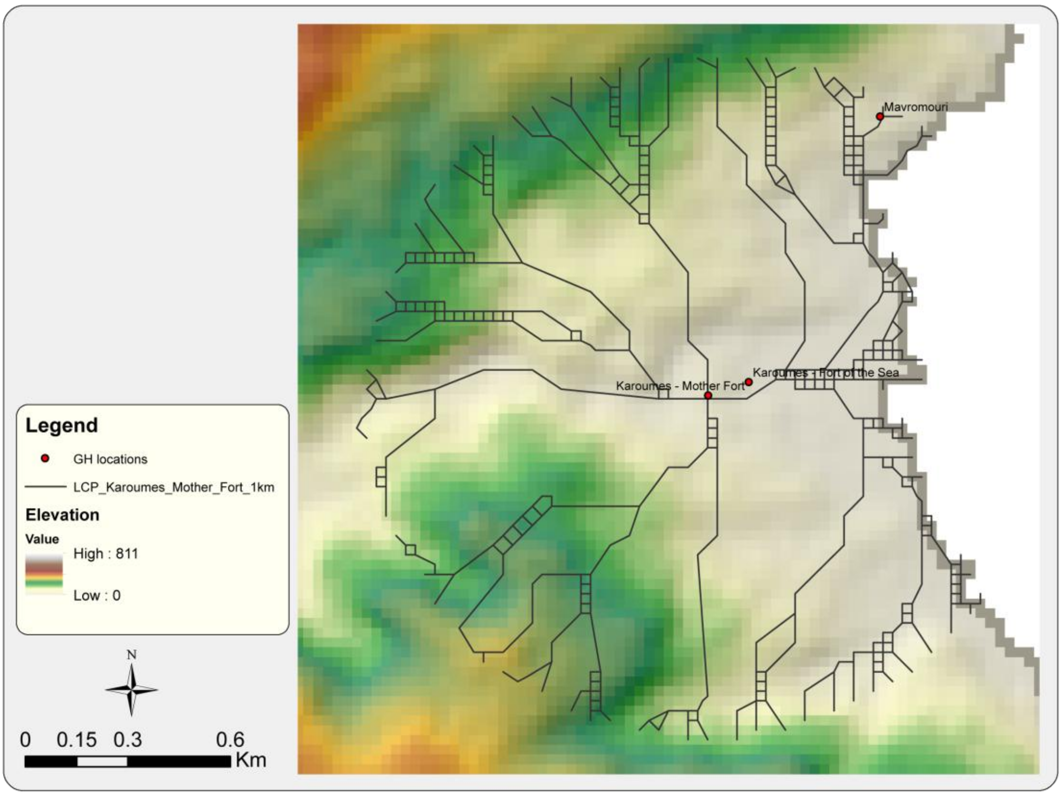

Figure 23: LCPs from 1 km range around the guard house of

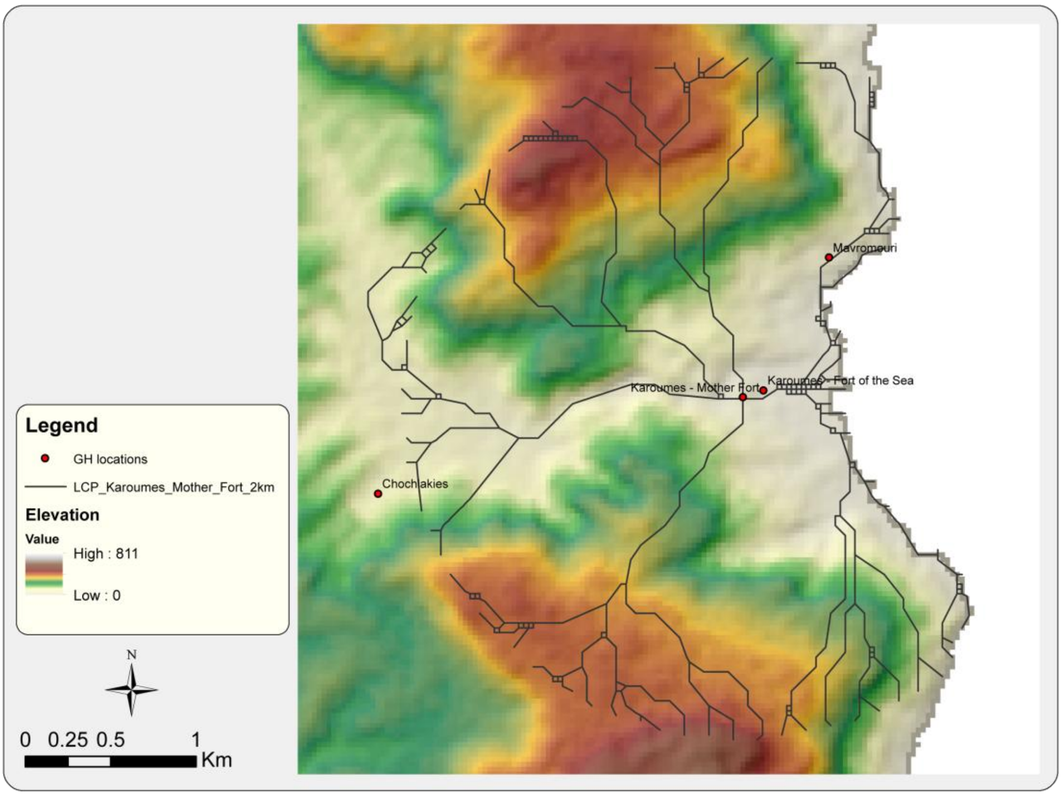

Figure 24: LCPs from 2 km range around the guard house of Karoumes – Mother Fort.

Kokkino Froudi

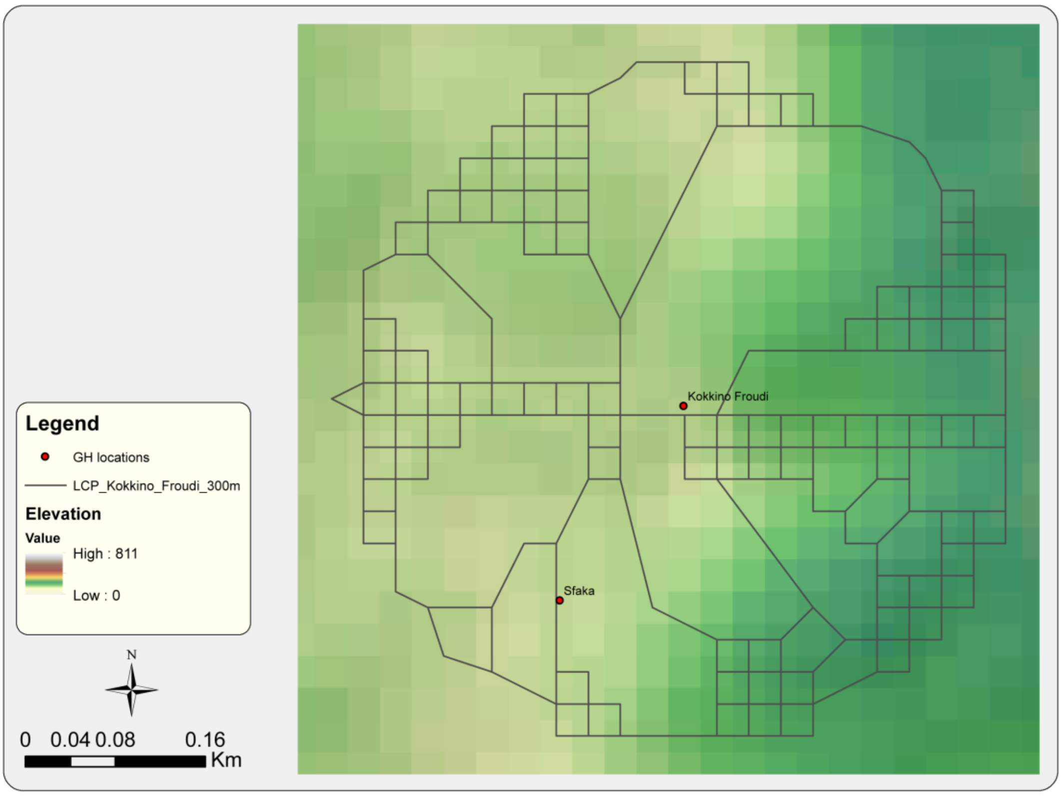

Figure 25: LCPs from 300 m range around the guard house of Kokkino Froudi.

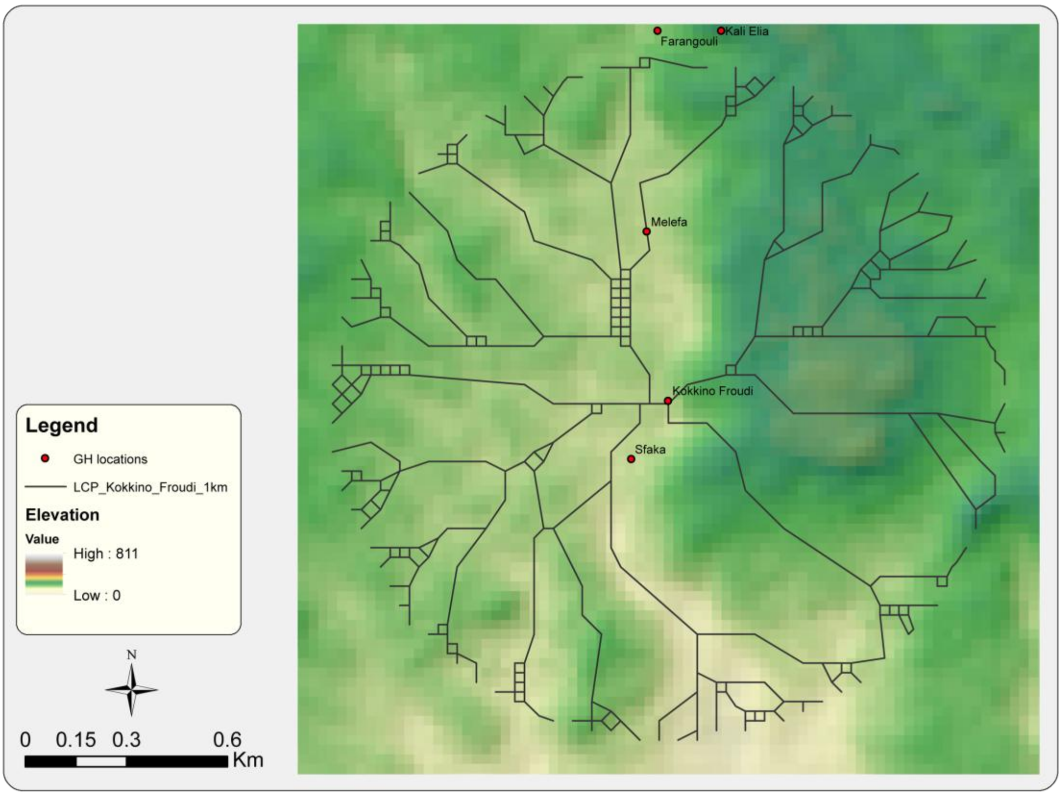

Figure 26: LCPs from 1 km range around the guard house of Kokkino Froudi.

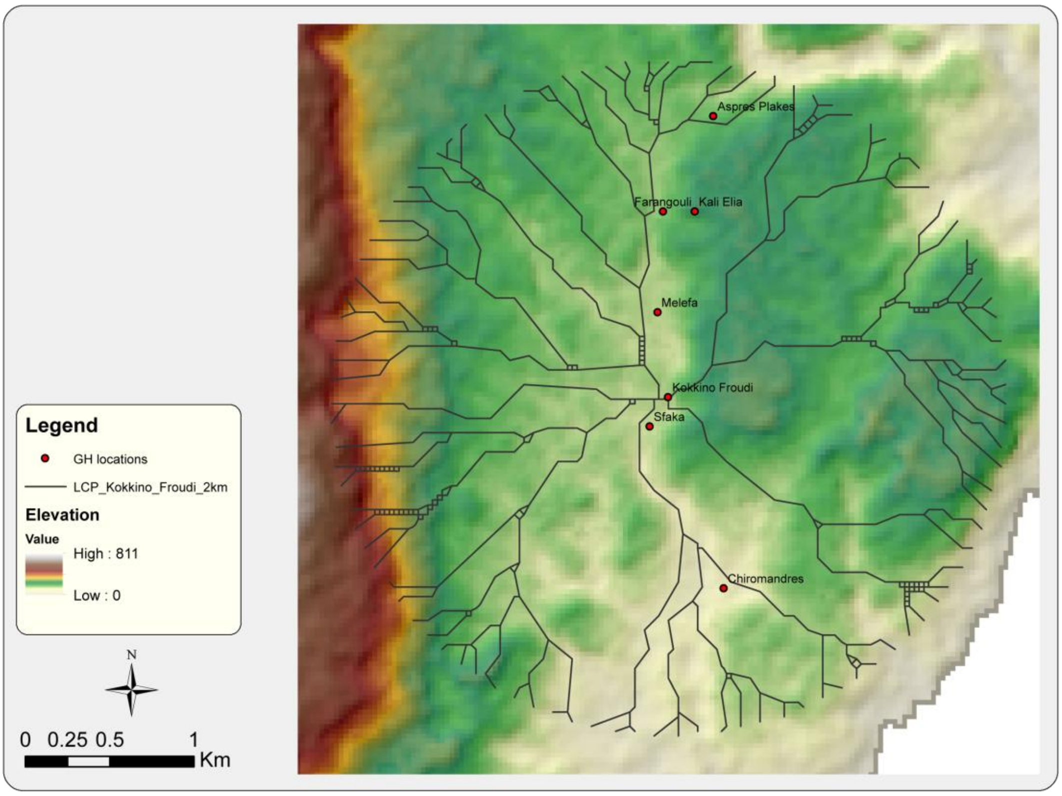

Figure 27: LCPs from 2 km range around the guard house of Kokkino Froudi.

Lidoriako

Figure 28: LCPs from 300 m range around the guard house of Lidoriako.

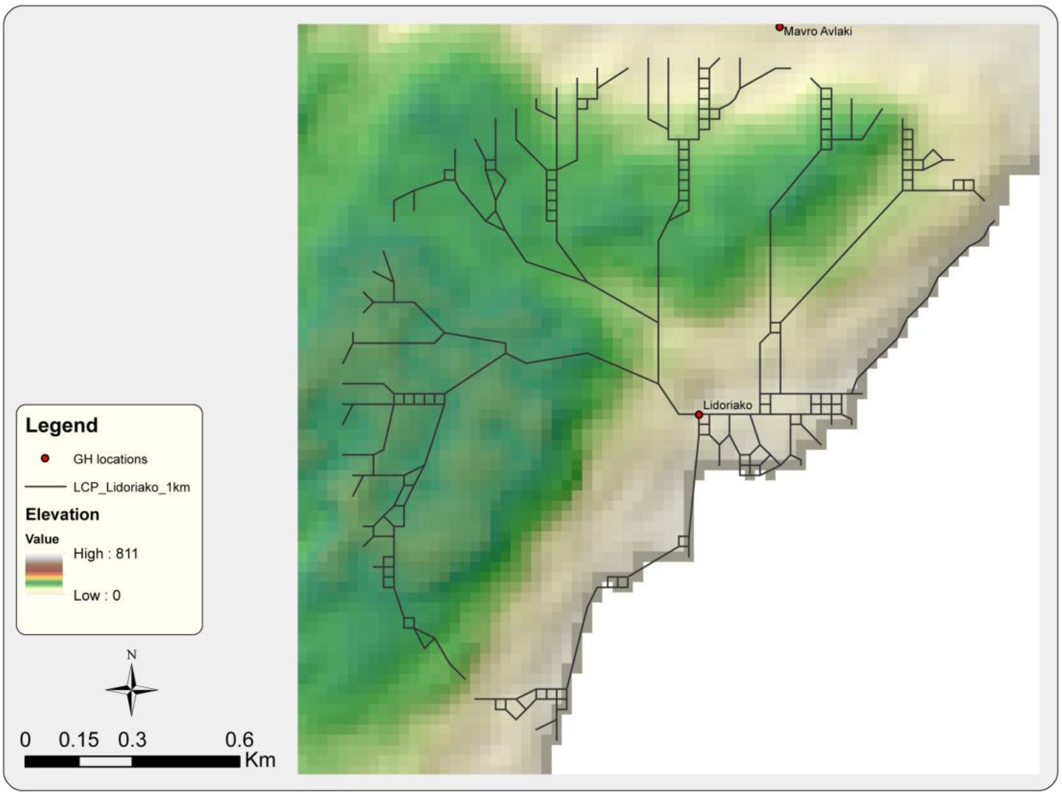

Figure 29: LCPs from 1 km range around the guard house of Lidoriako.

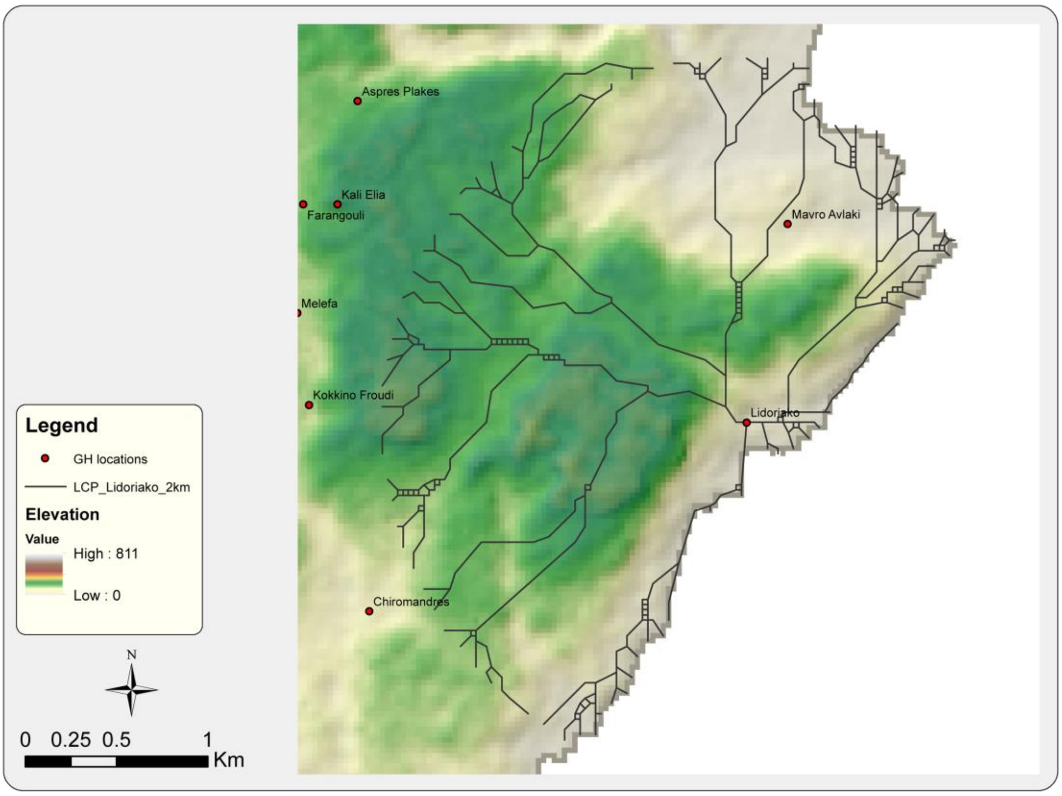

Figure 30: LCPs from 2 km range around the guard house of Lidoriako.

Mavro Avlaki

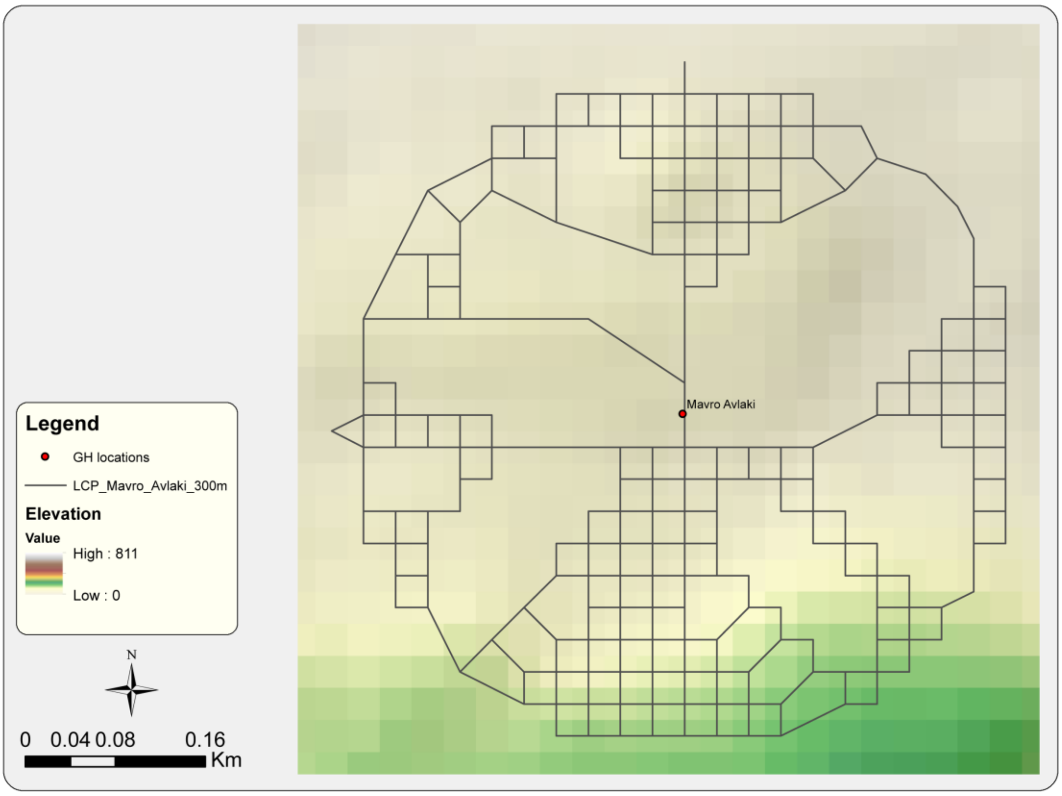

Figure 31: LCPs from 300 m range around the guard house of Mavro Avlaki.

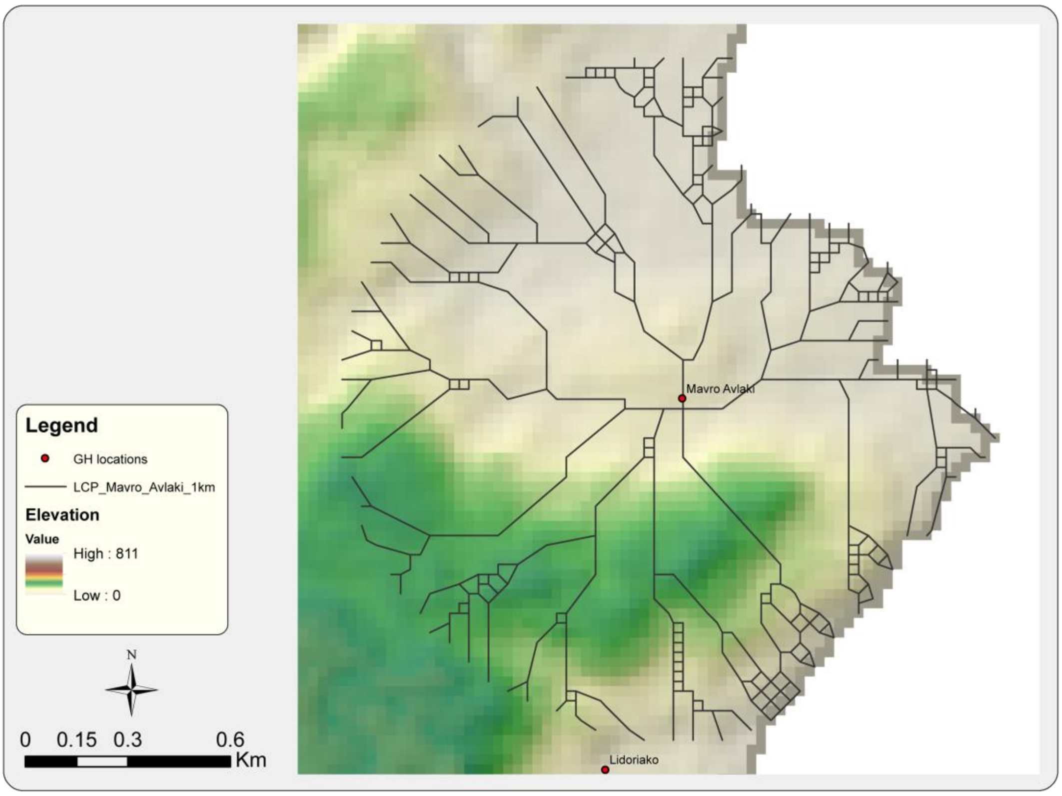

Figure 32: LCPs from 1 km range around the guard house of Mavro Avlaki.

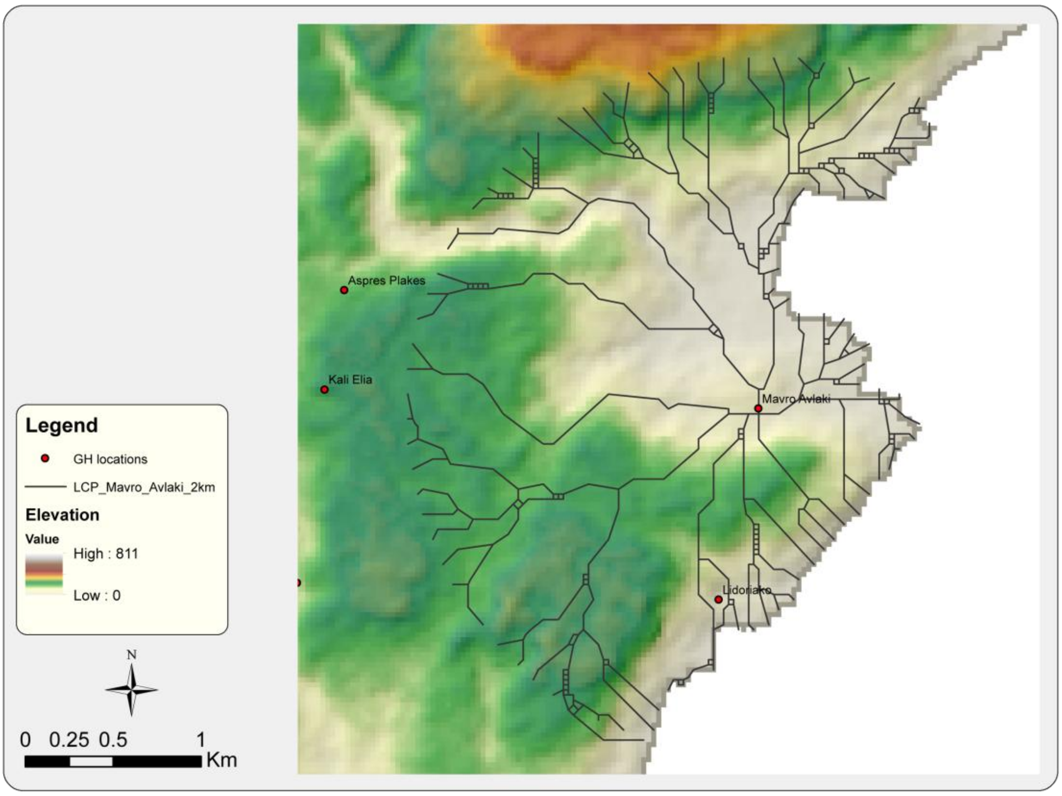

Figure 33: LCPs from 2 km range around the guard house of Mavro Avlaki.

Mavromouri

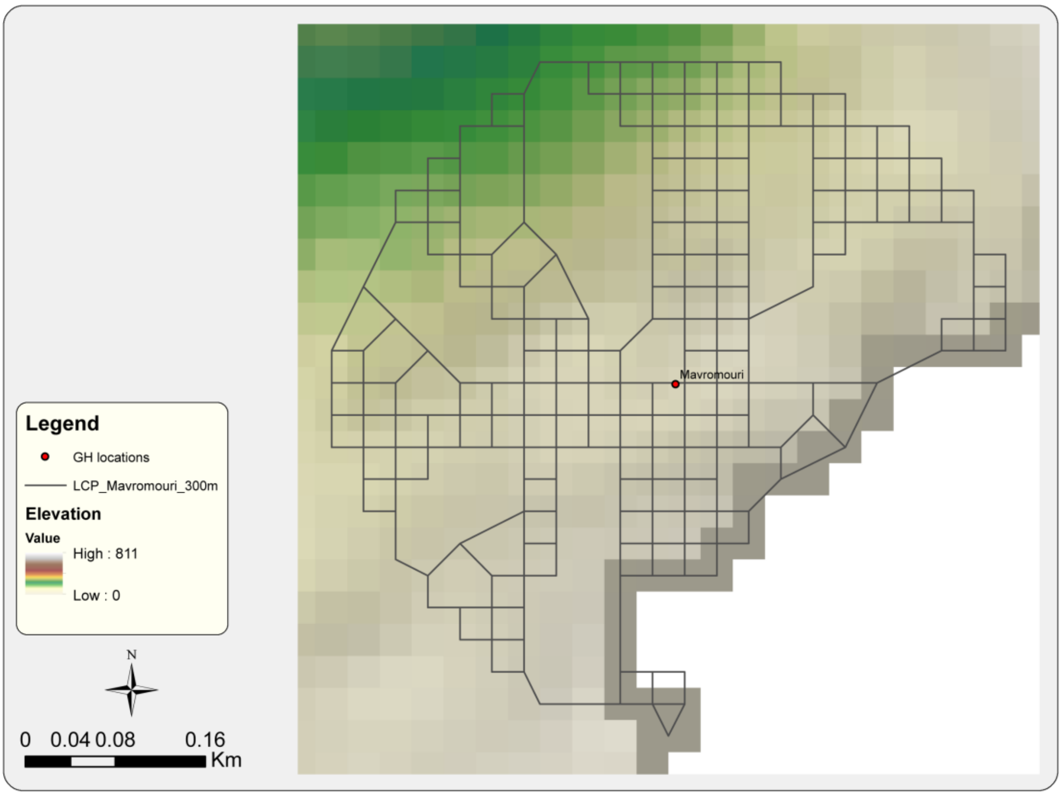

Figure 34: LCPs from 300 m range around the guard house of Mavromouri.

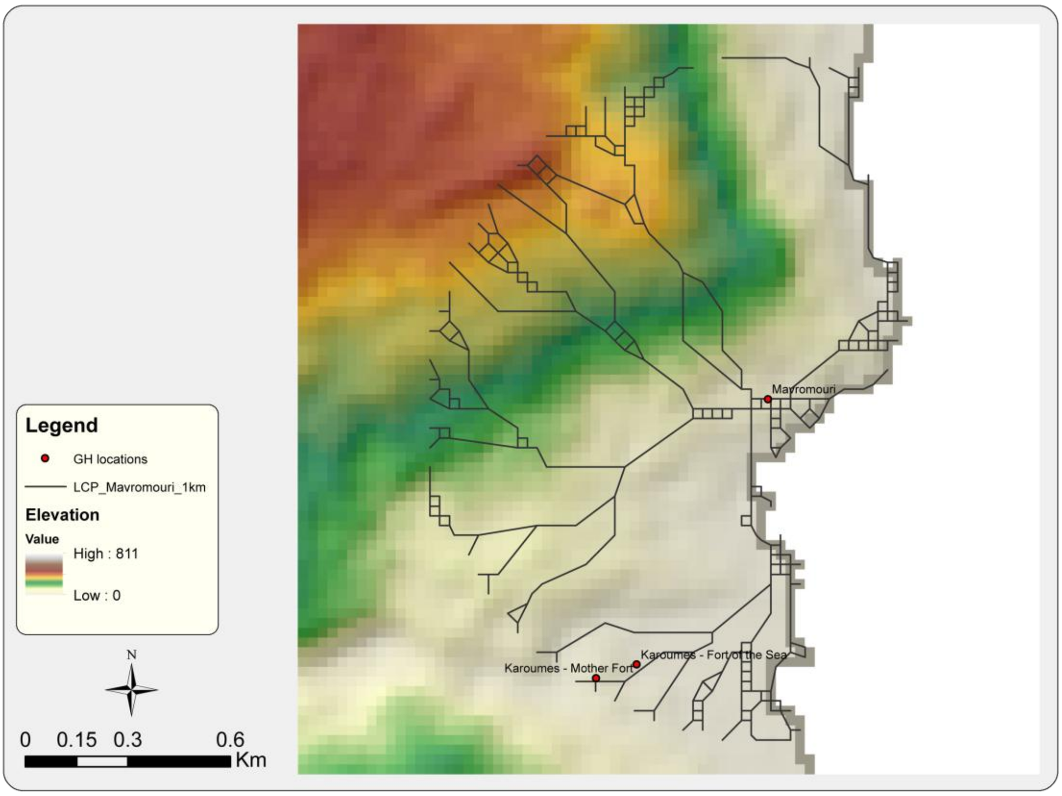

Figure 35: LCPs from 1 km range around the guard house of Mavromouri.

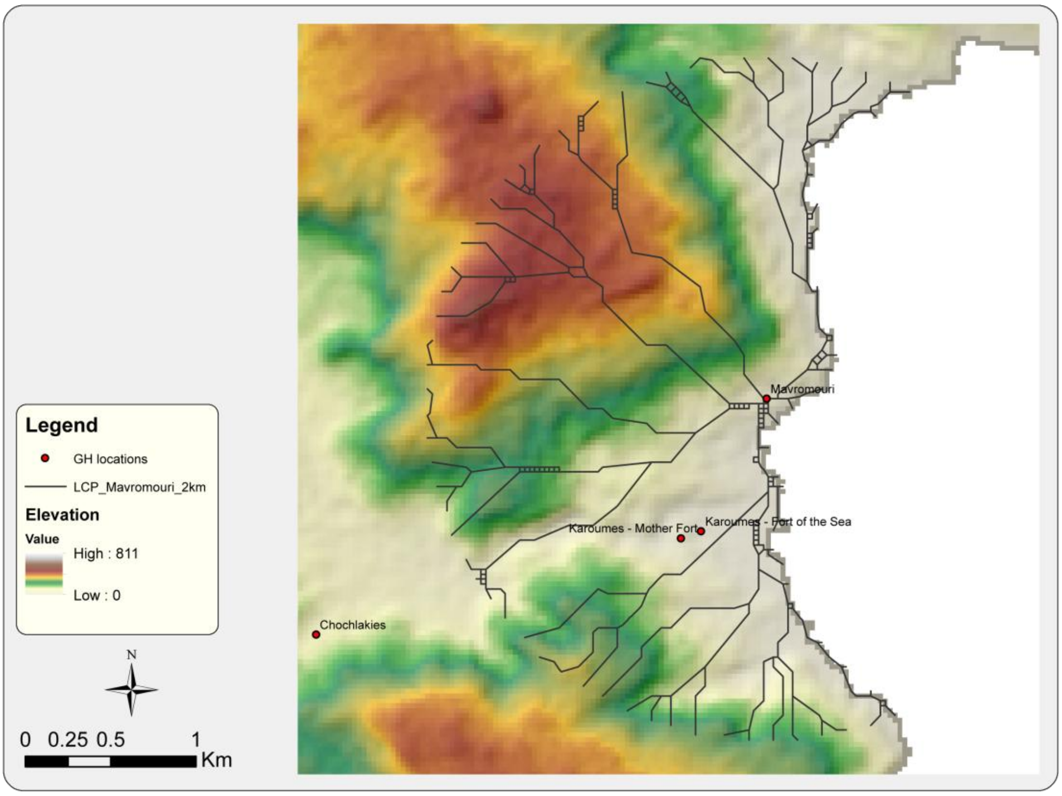

Figure 36: LCPs from 2 km range around the guard house of Mavromouri.

Melefa

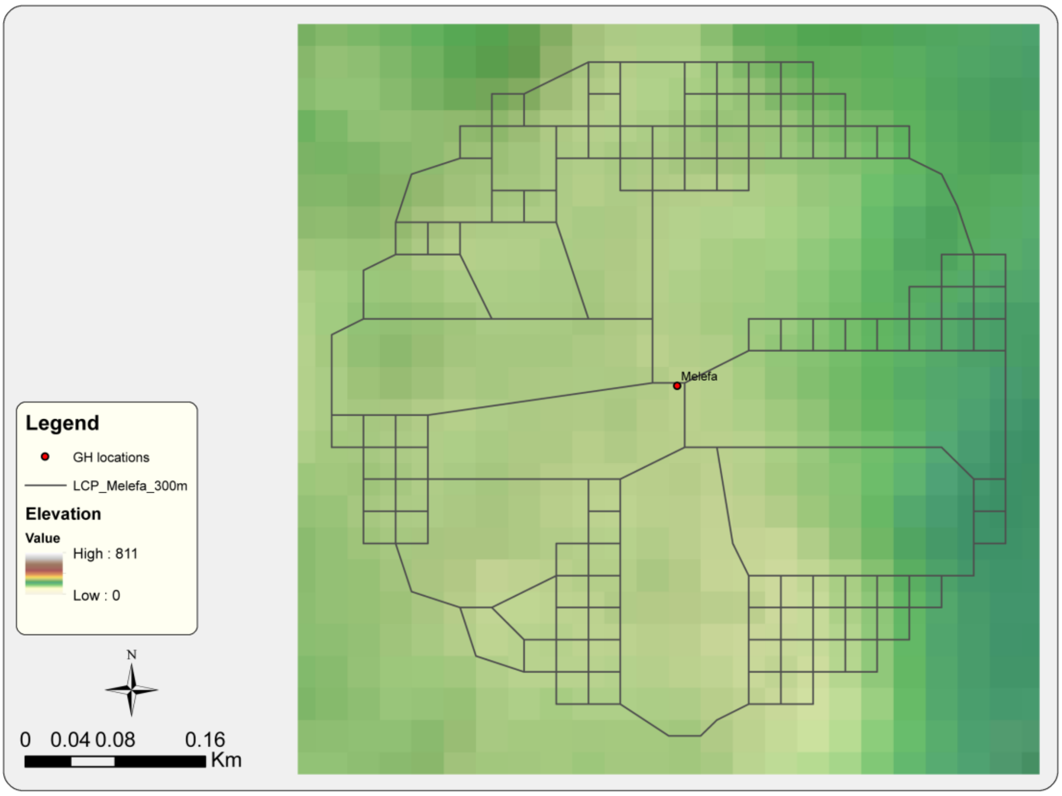

Figure 37: LCPs from 300 m range around the guard house of Melefa.

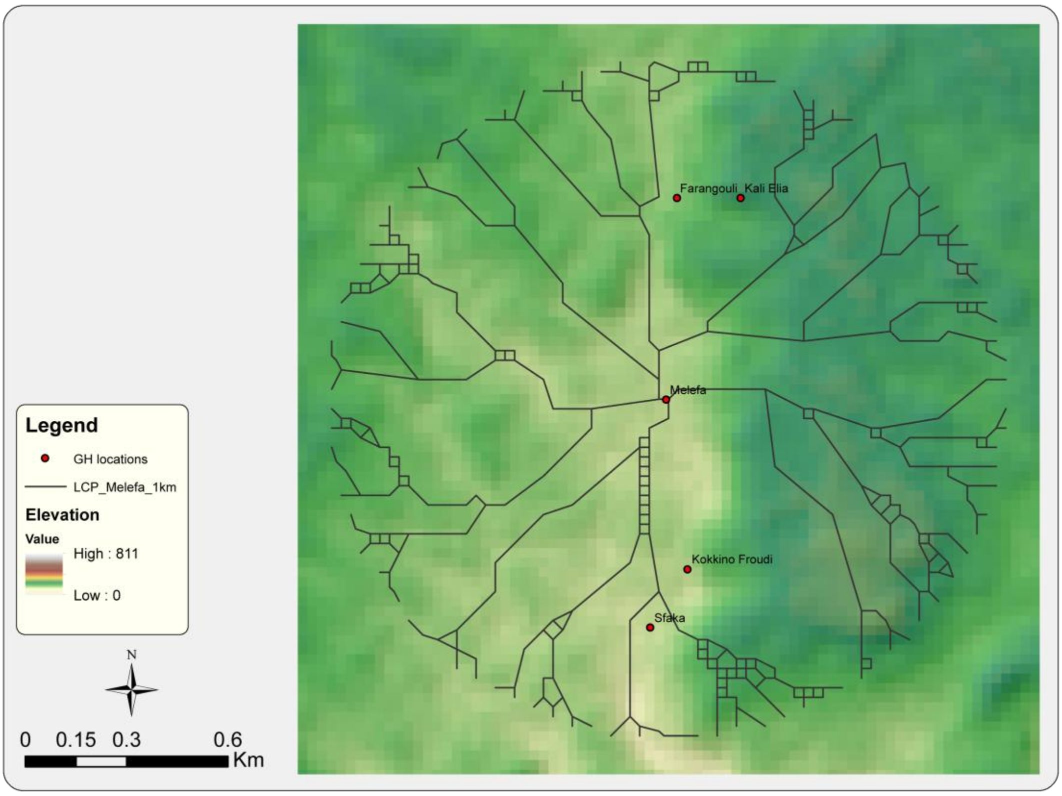

Figure 38: LCPs from 1 km range around the guard house of Melefa.

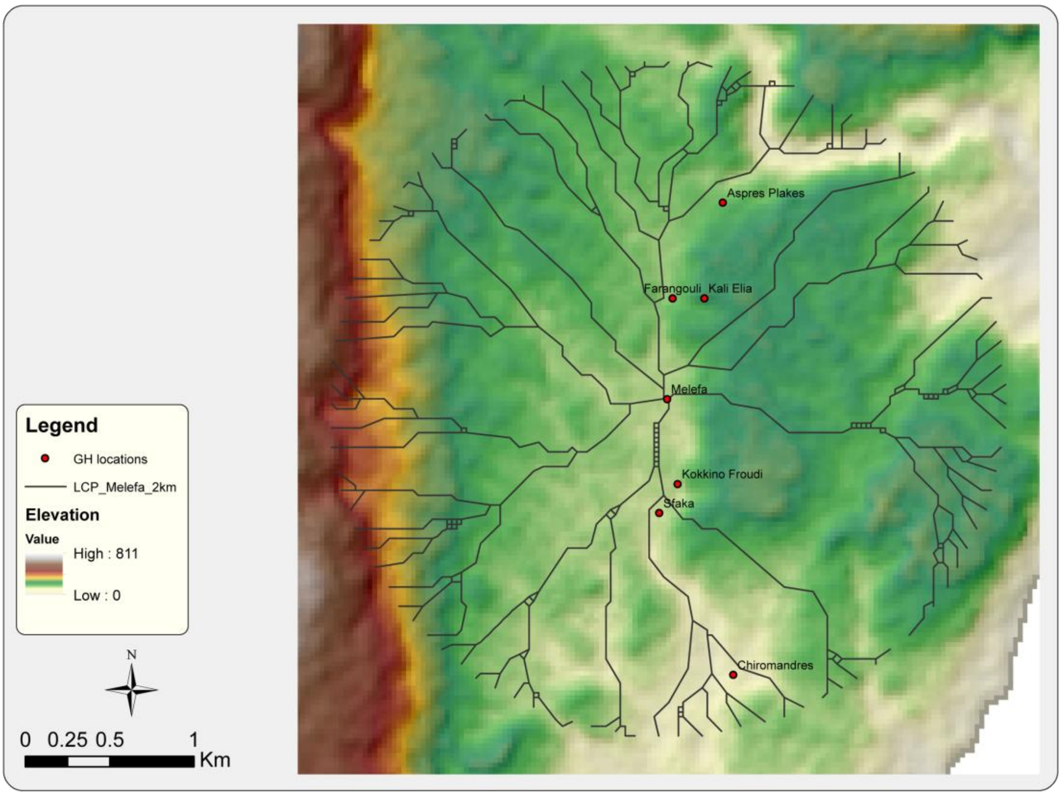

Figure 39: LCPs from 2 km range around the guard house of Melefa.

Plakalona

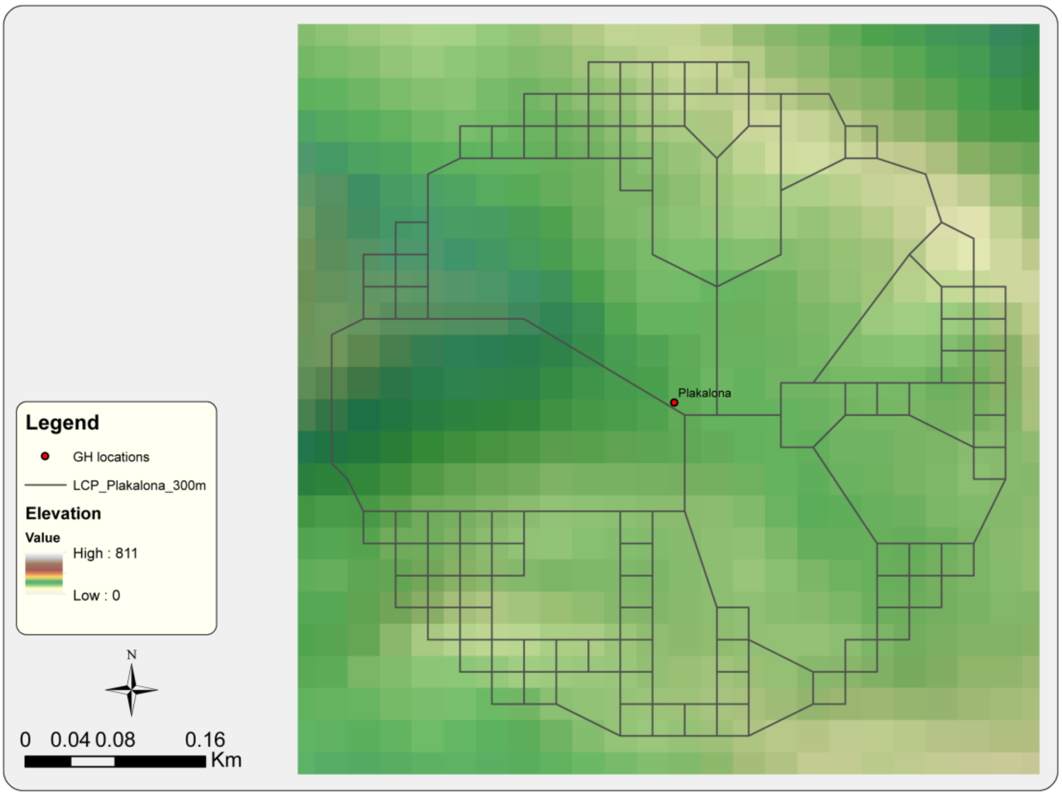

Figure 40: LCPs from 300 m range around the guard house of Plakalona.

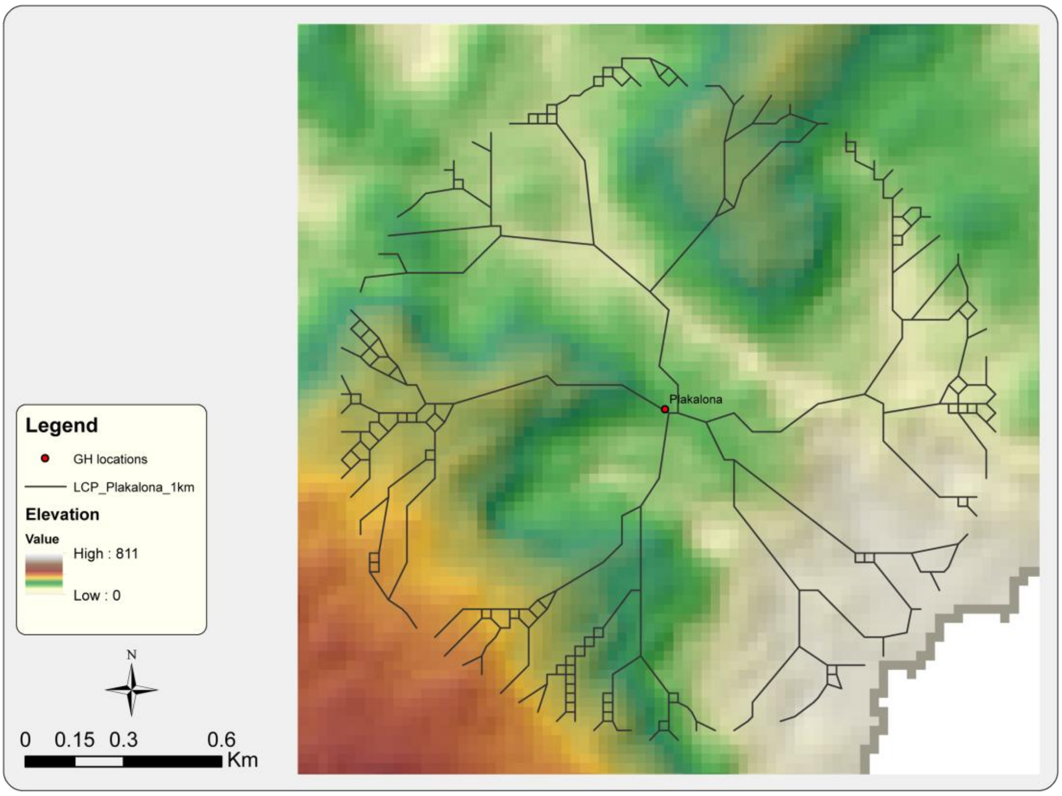

Figure 41: LCPs from 1 km range around the guard house of Plakalona.

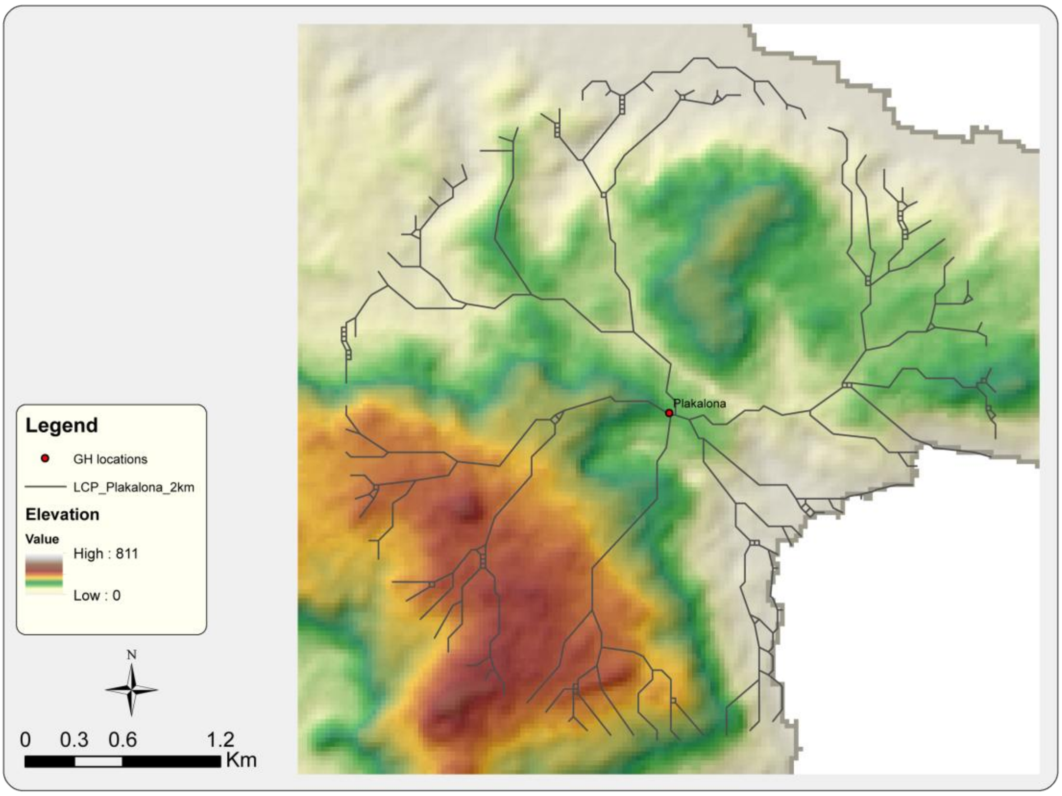

Figure 42: LCPs from 2 km range around the guard house of Plakalona.

Polla Kladia

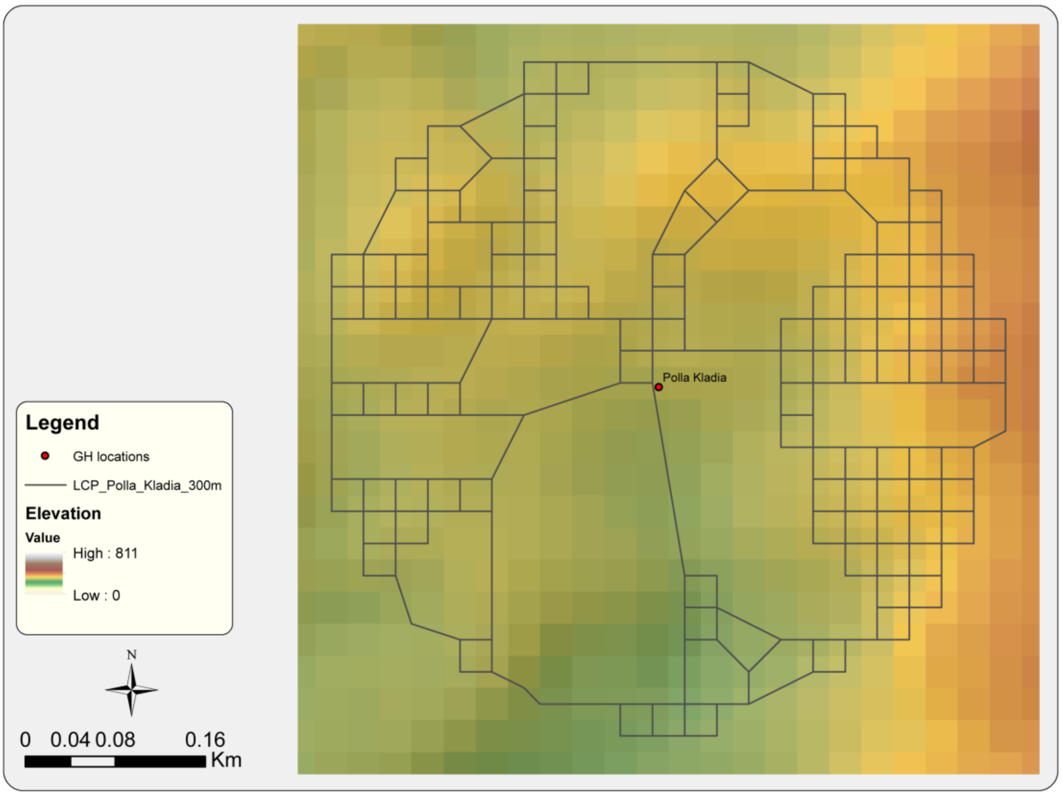

Figure 43: LCPs from 300 m range around the guard house of Polla Kladia.

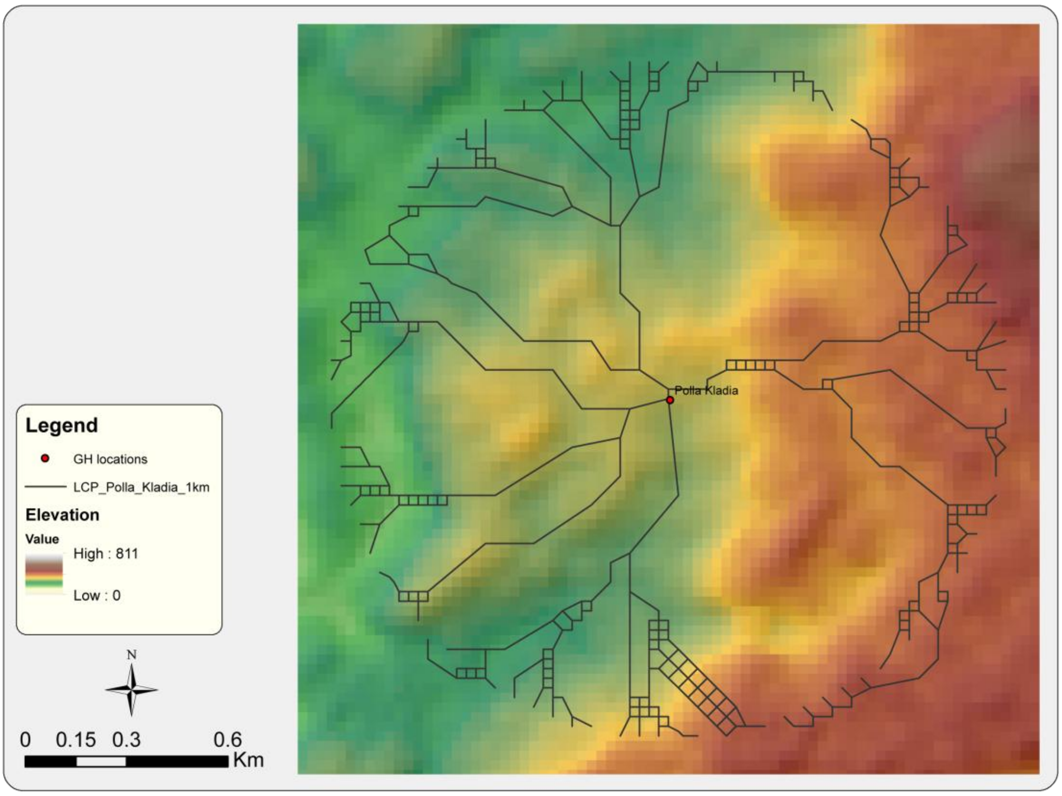

Figure 44: LCPs from 1 km range around the guard house of Polla Kladia.

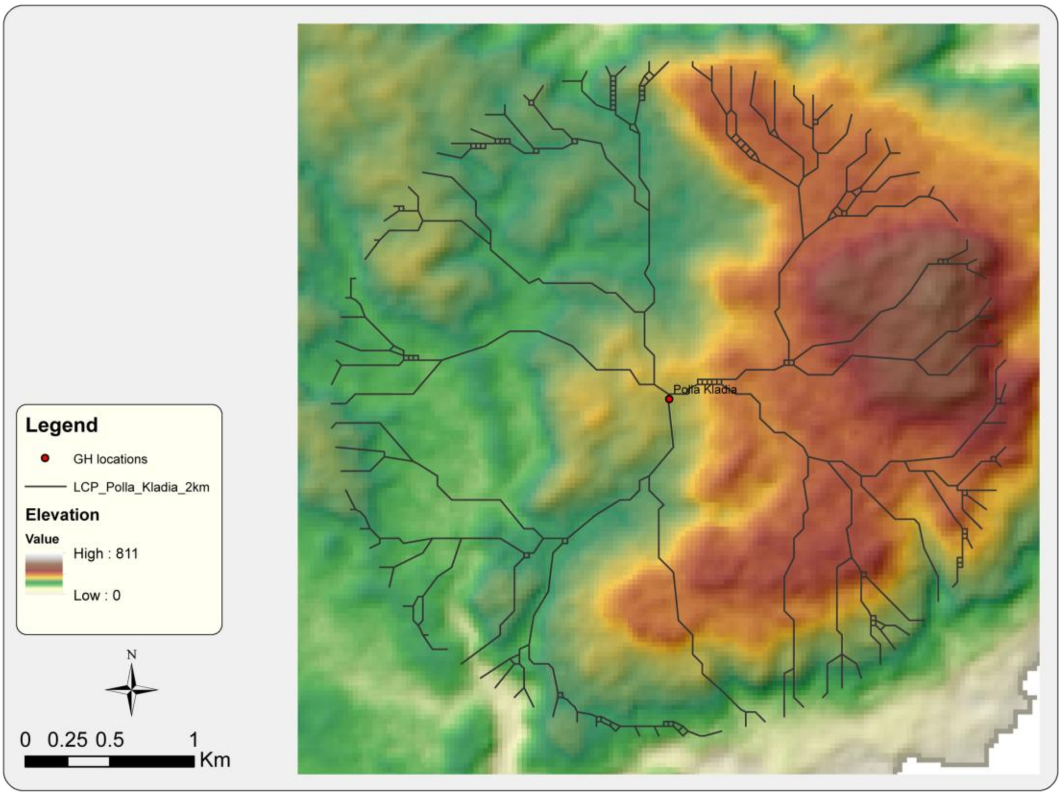

Figure 45: LCPs from 2 km range around the guard house of Polla Kladia.

Pyrgales

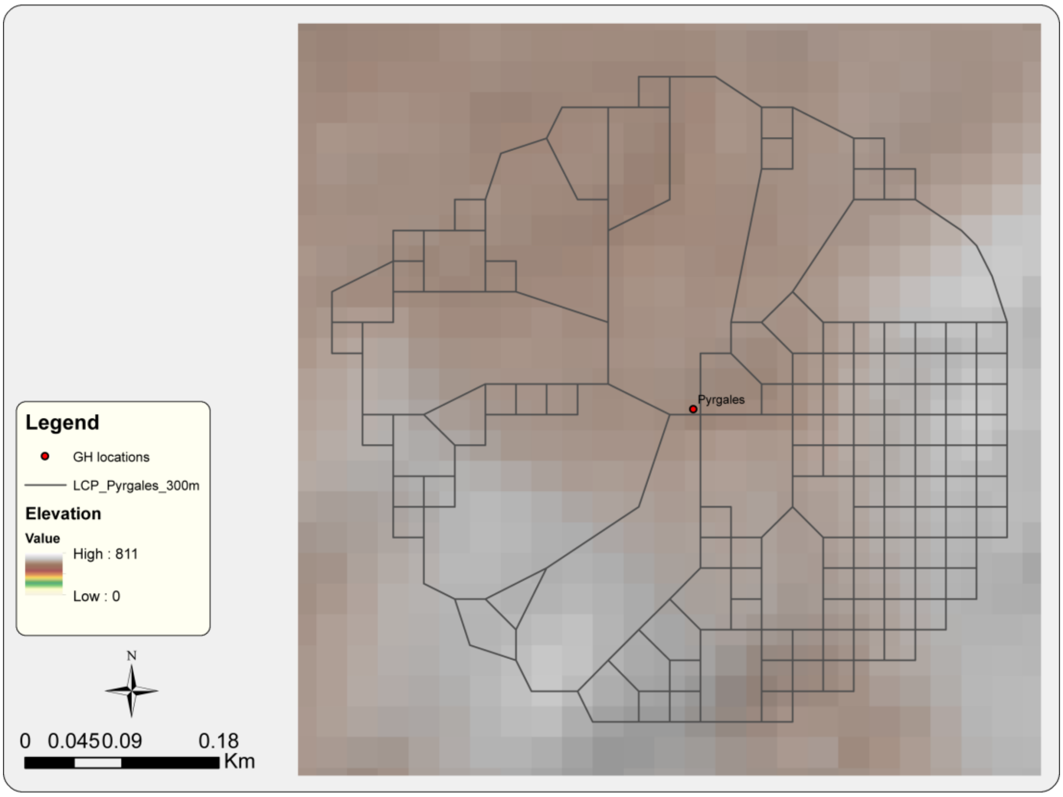

Figure 46: LCPs from 300 m range around the guard house of Pyrgales.

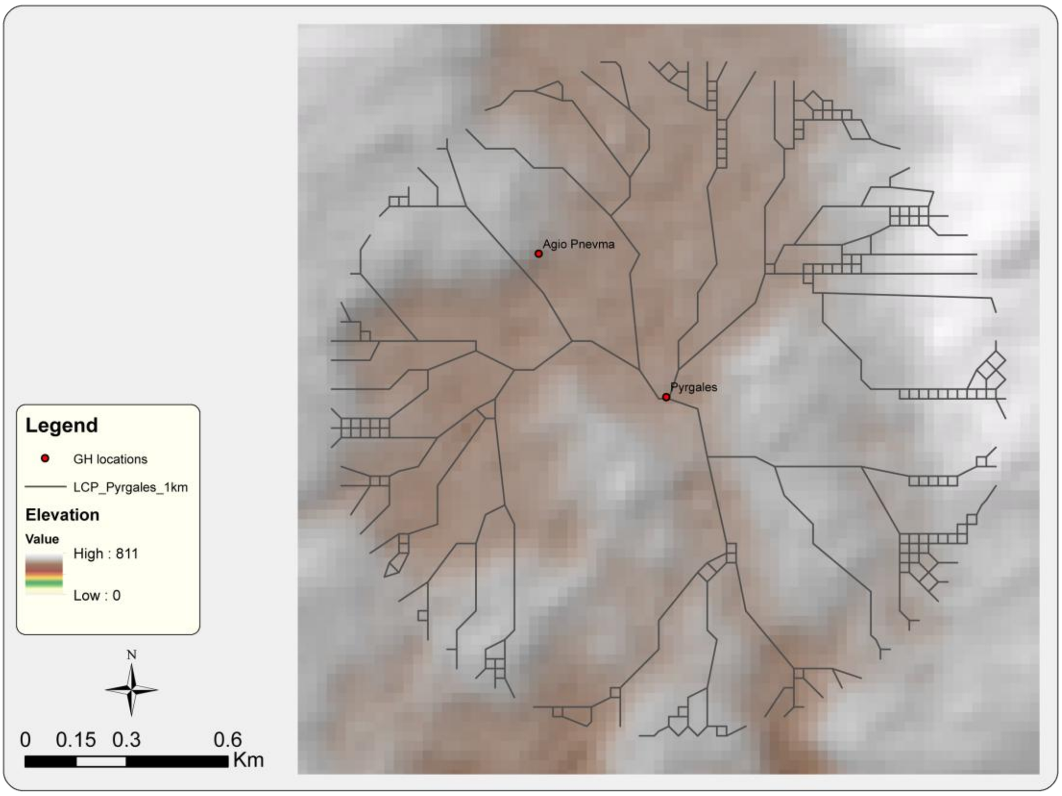

Figure 47: LCPs from 1 km range around the guard house of Pyrgales.

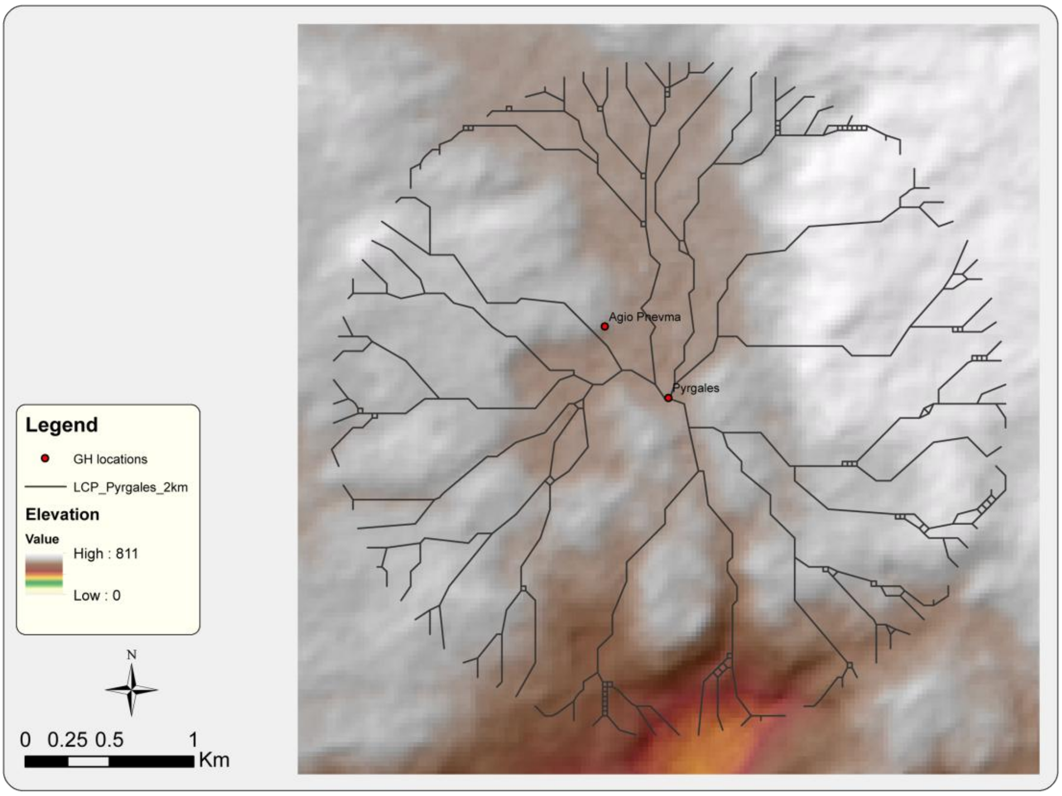

Figure 48: LCPs from 2 km range around the guard house of Pyrgales.

Sfaka

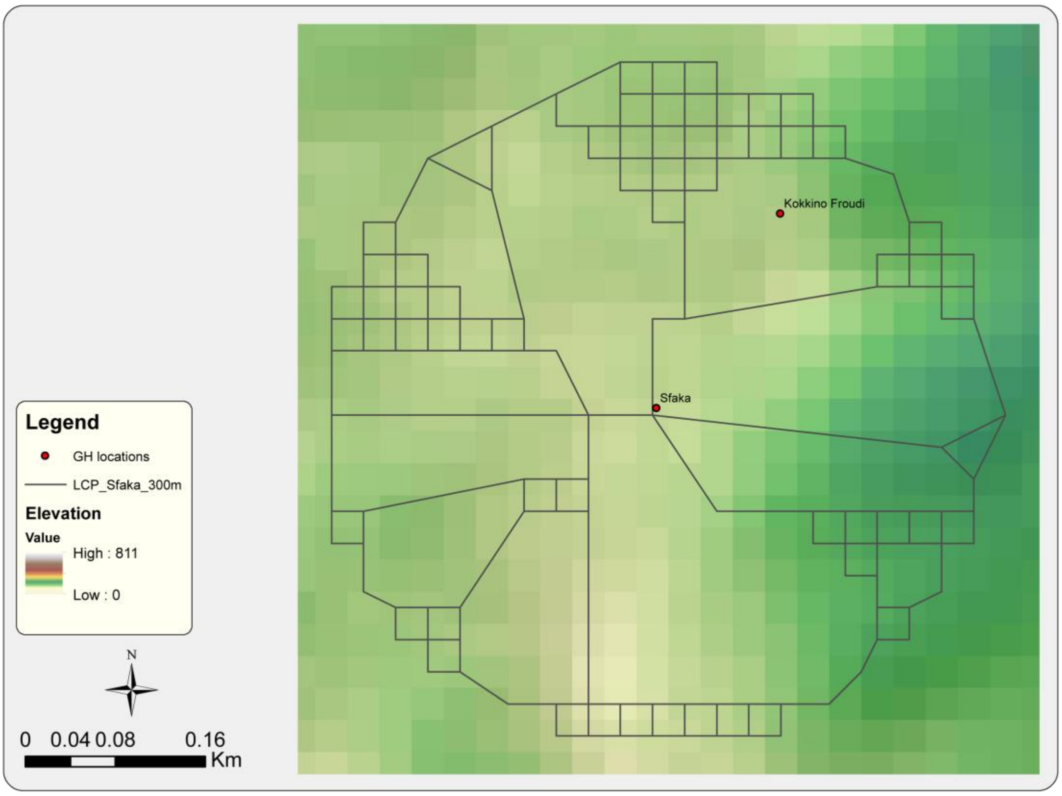

Figure 49: LCPs from 300 m range around the guard house of Sfaka.

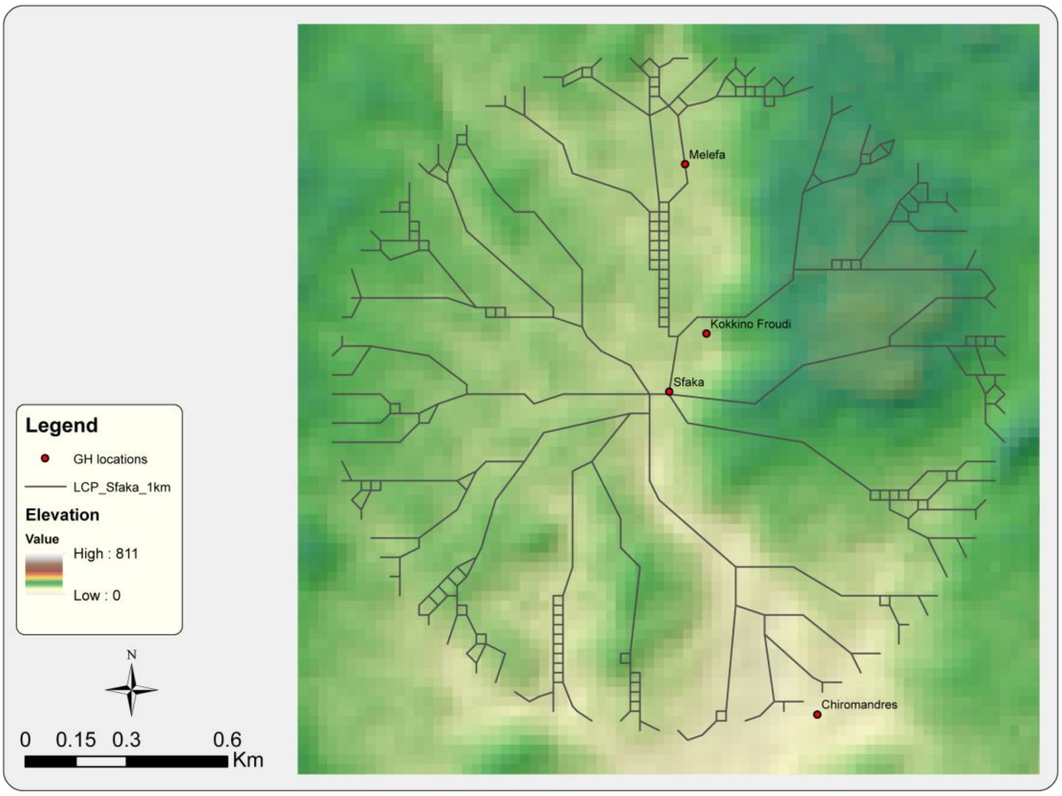

Figure 50: LCPs from 1 km range around the guard house of Sfaka.

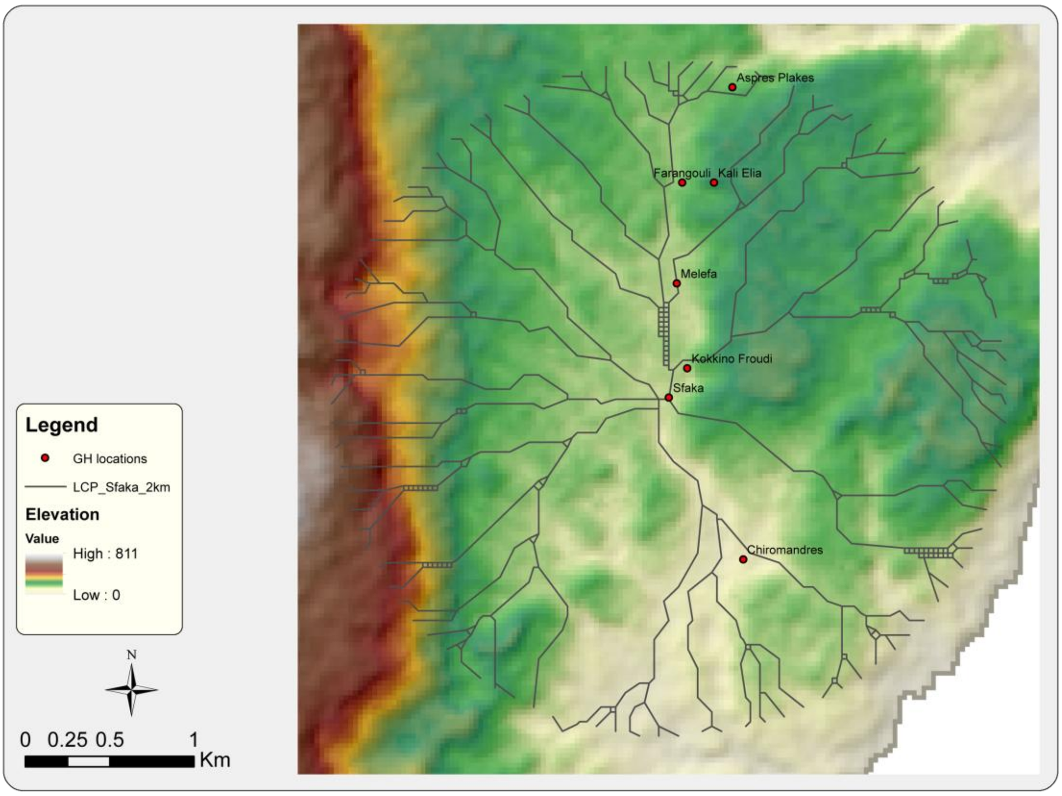

Figure 51: LCPs from 2 km range around the guard house of Sfaka.

Appendix B: 3D model images

The 3D model images that are presented on the following pages, show the location of every site within the landscape, based on the used DEM, to help visualise how the studied guard houses were placed in the landscape and in relation to each other.

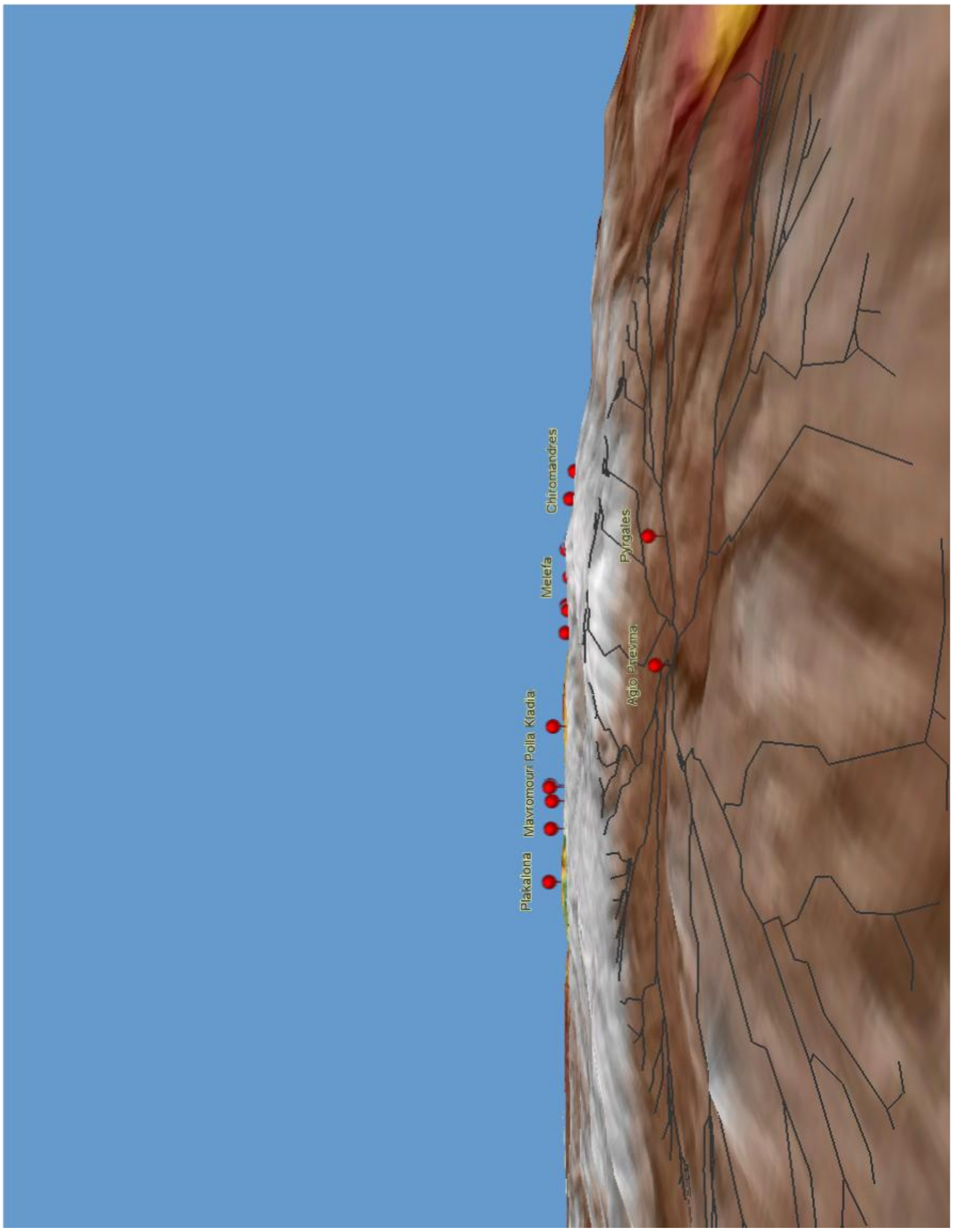

Figure 1: Location of the guard house of Agio Pnevma in the 3D model, looking towards the east.

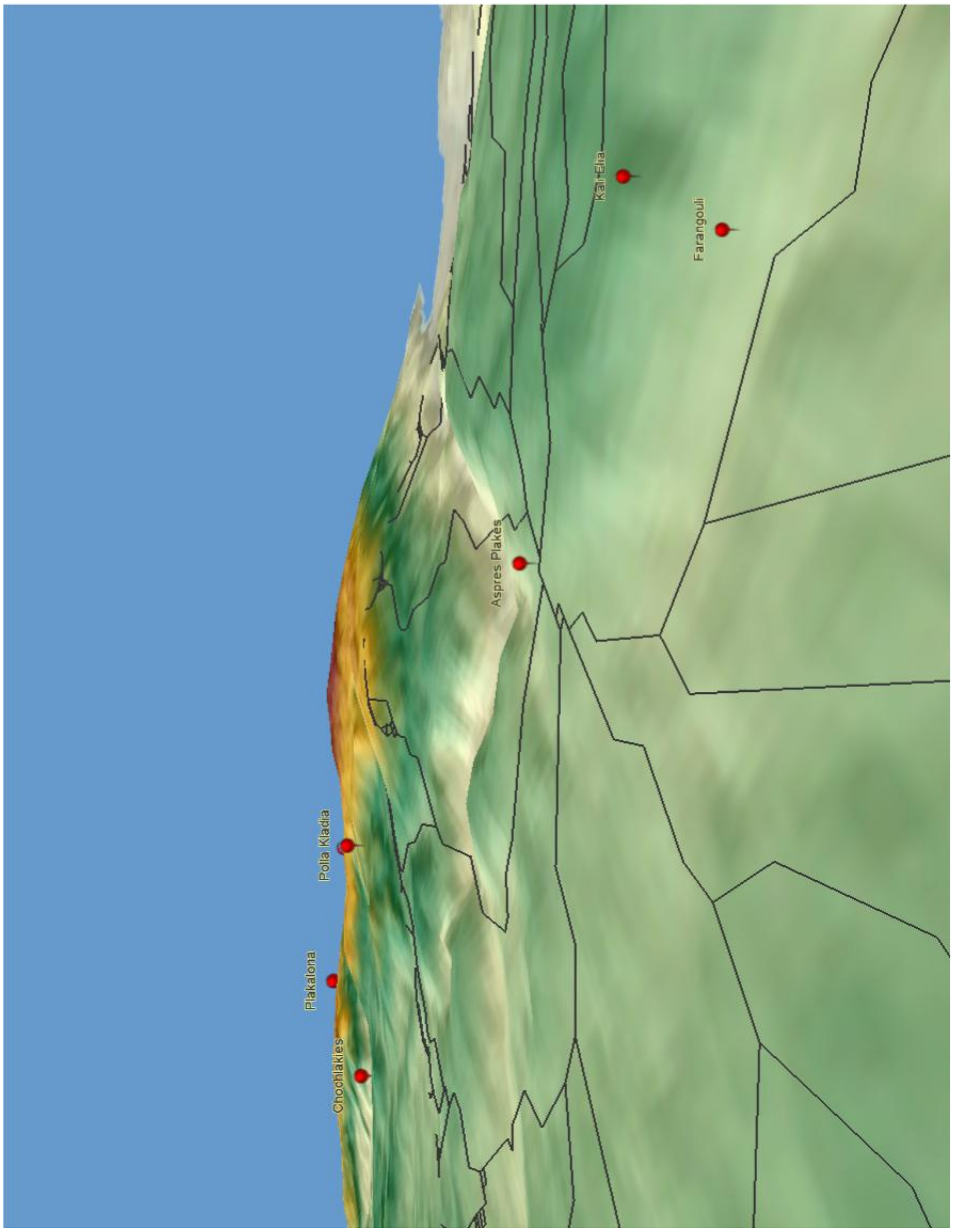

Figure 2: Location of the guard house of Aspres Plakes in the 3D model, looking towards the northeast.

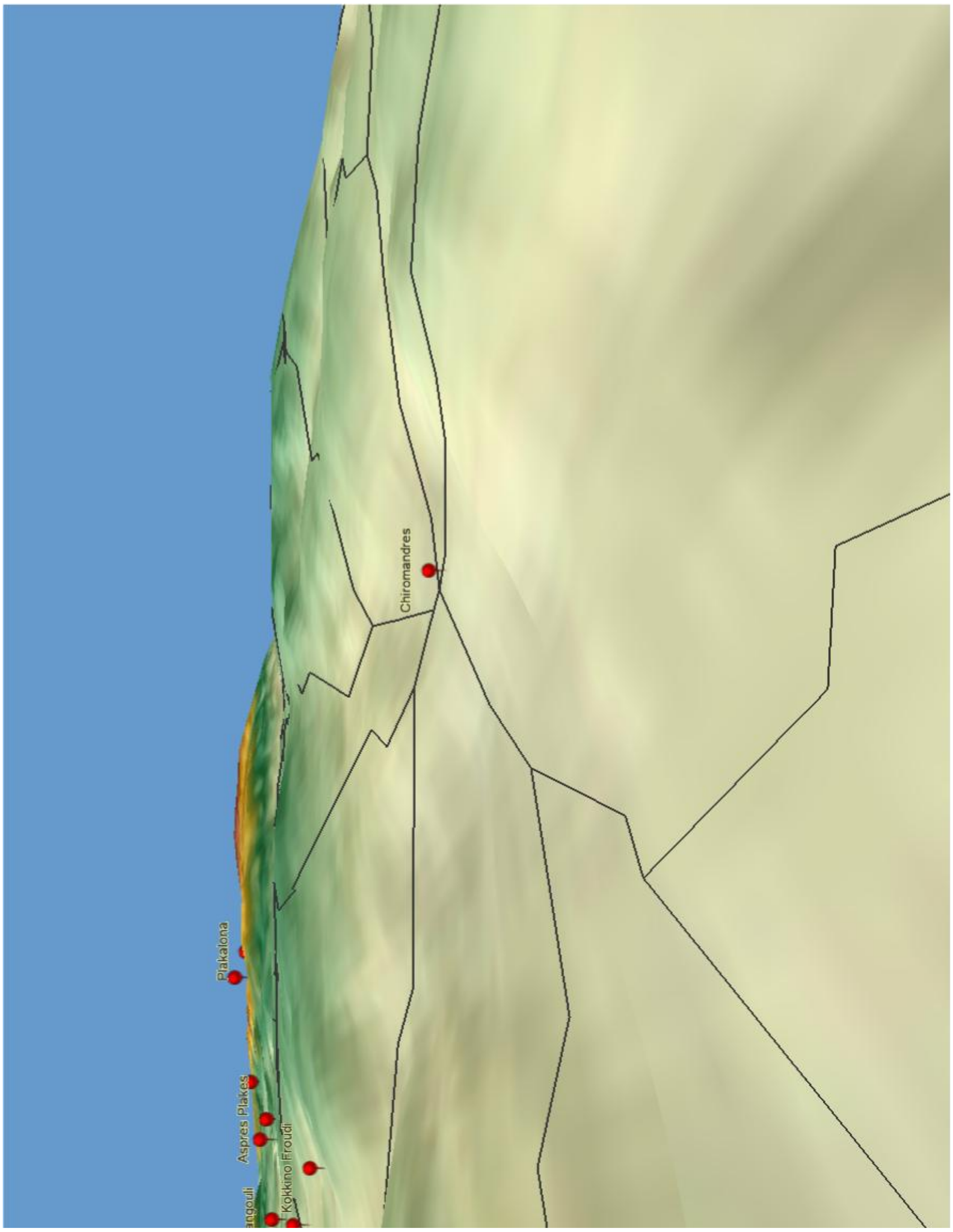

Figure 3: Location of the guard house of Chiromandres in the 3D model, looking towards the northeast.

Figure 4: Location of the guard house of Chochlakies in the 3D model, looking towards the northeast.

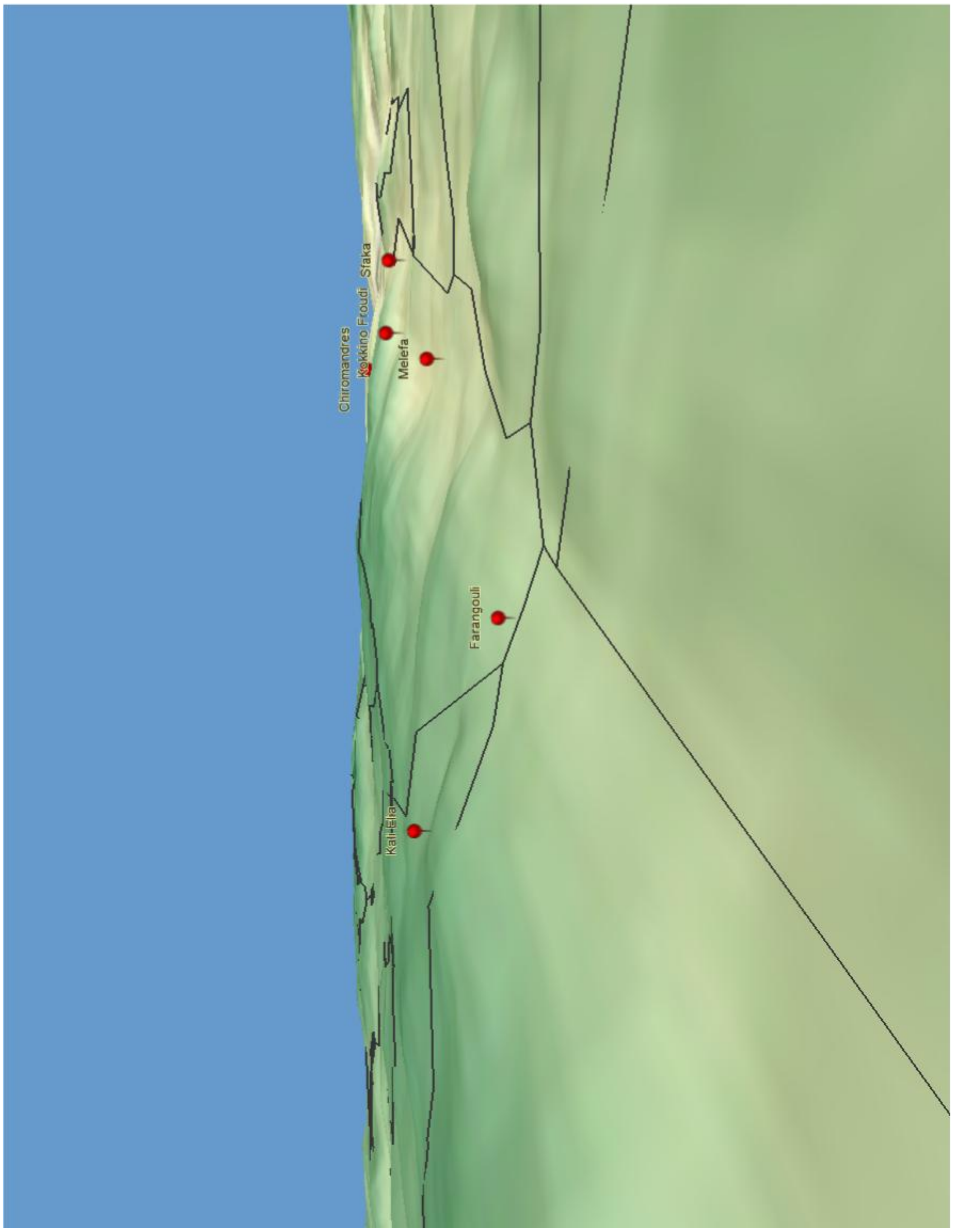

Figure 5: Location of the guard house of Farangouli in the 3D model, looking towards the southeast.

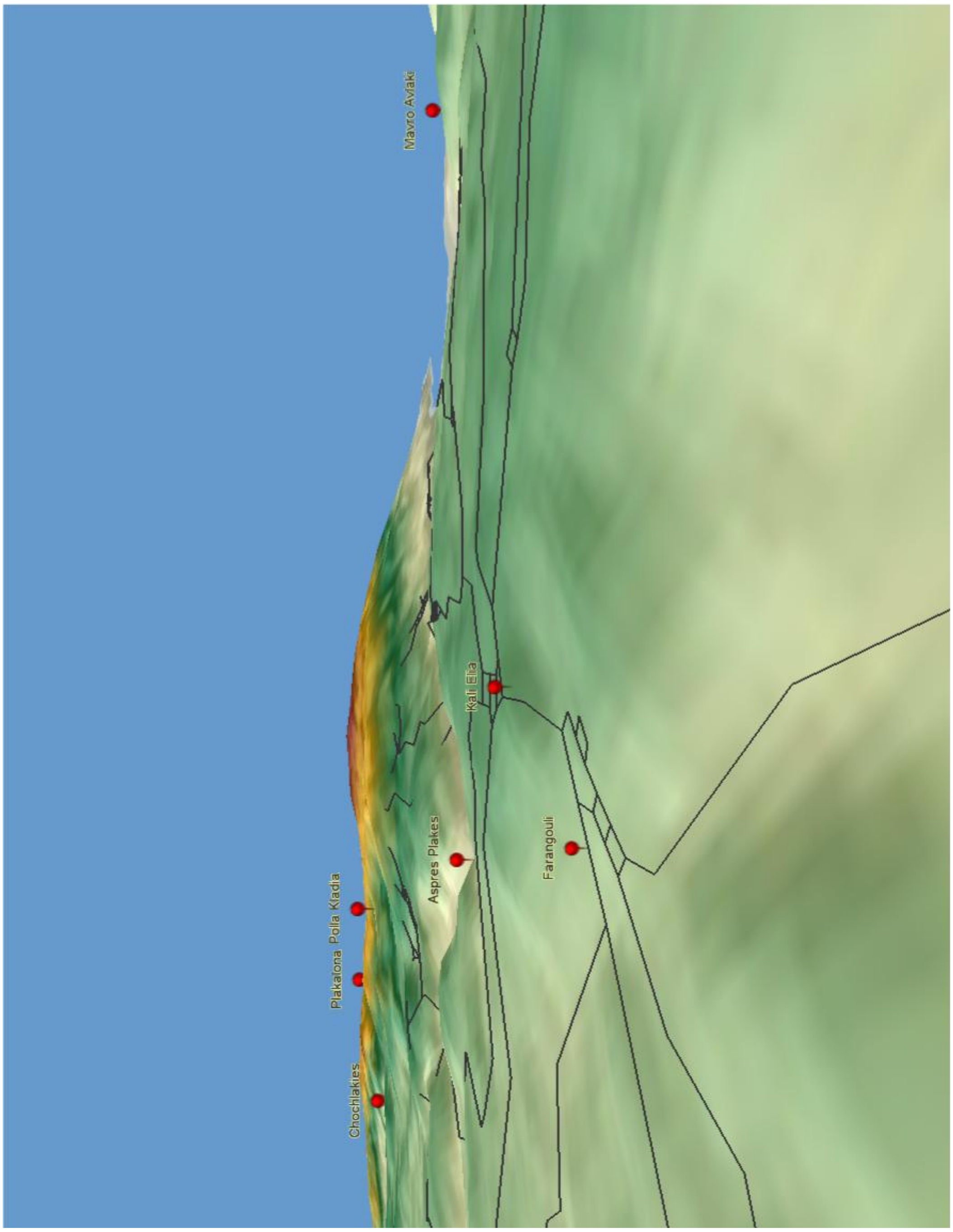

Figure 6: Location of the guard house of Kali Elia in the 3D model, looking towards the northeast.

Figure 7: Location of the guard house of Karoumes – Fort of the Sea in the 3D model, looking towards the west.

Figure 8: Location of the guard house of Karoumes – Mother Fort in the 3D model, looking towards the west.

Figure 9: Location of the guard house of Kokkino Froudi in the 3D model, looking towards the southeast.

Figure 10: Location of the guard house of Lidoriako in the 3D model, looking towards the northwest.

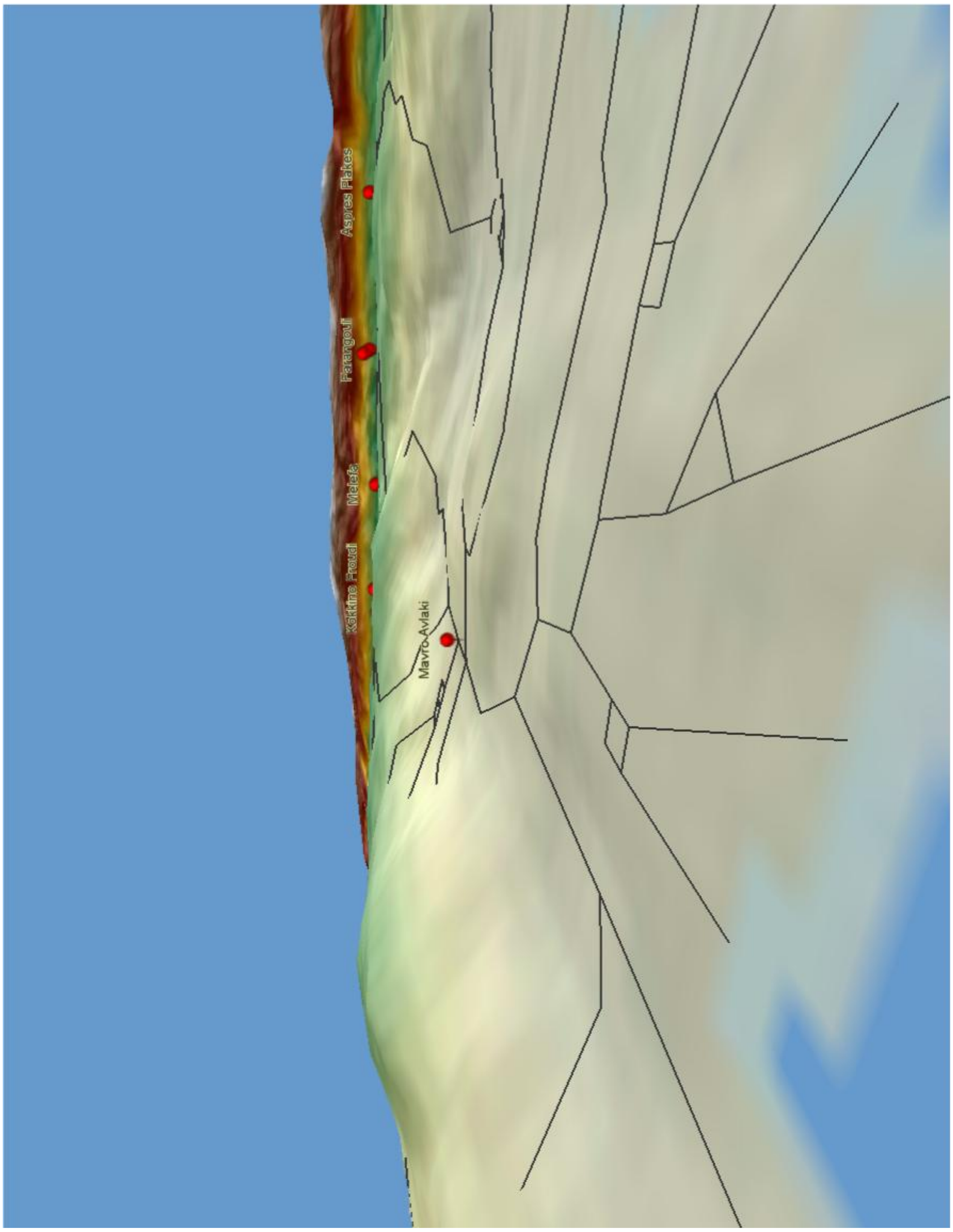

Figure 11: Location of the guard house of Mavro Avlaki in the 3D model, looking towards the west.

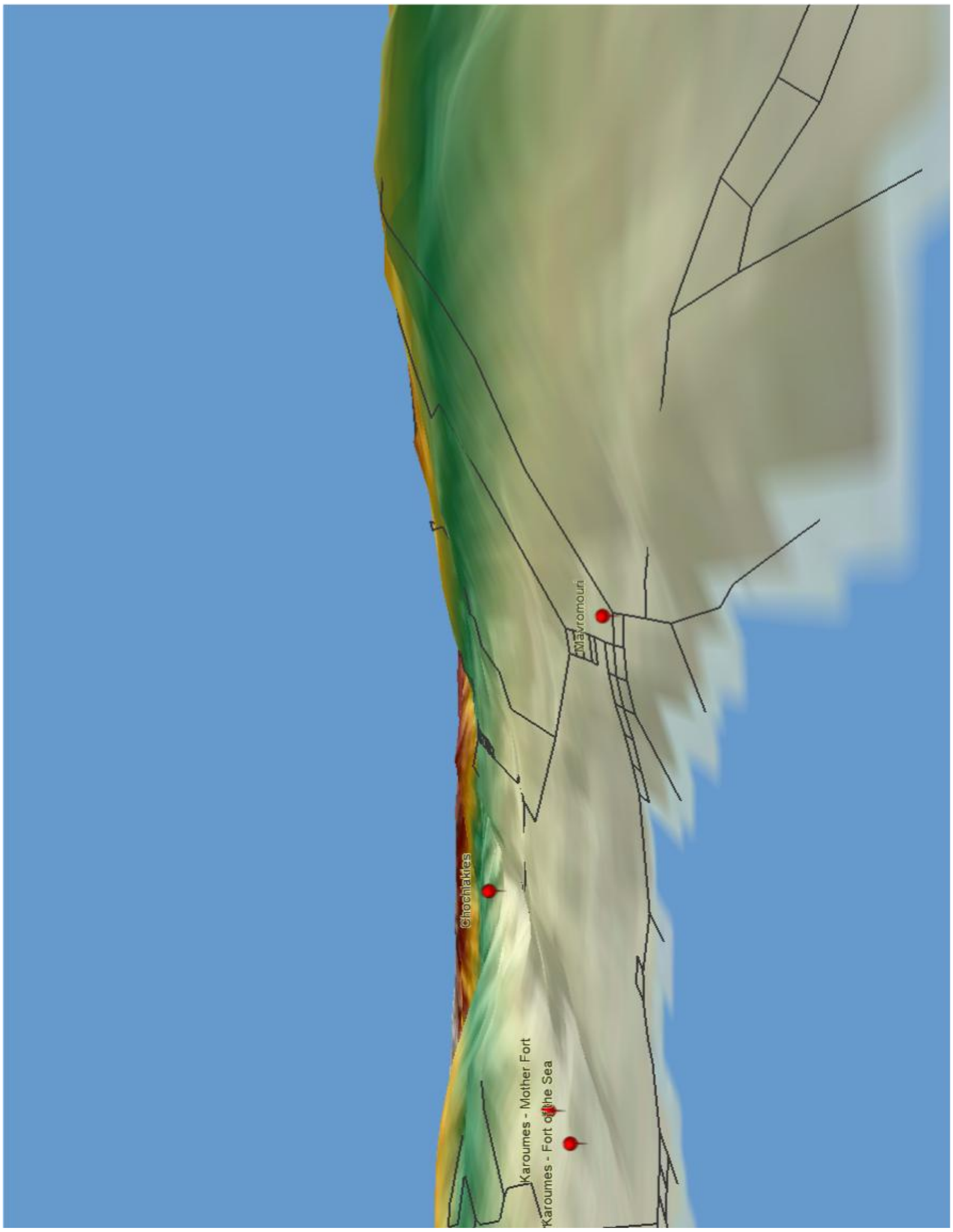

Figure 12: Location of the guard house of Mavromouri in the 3D model, looking towards the west.

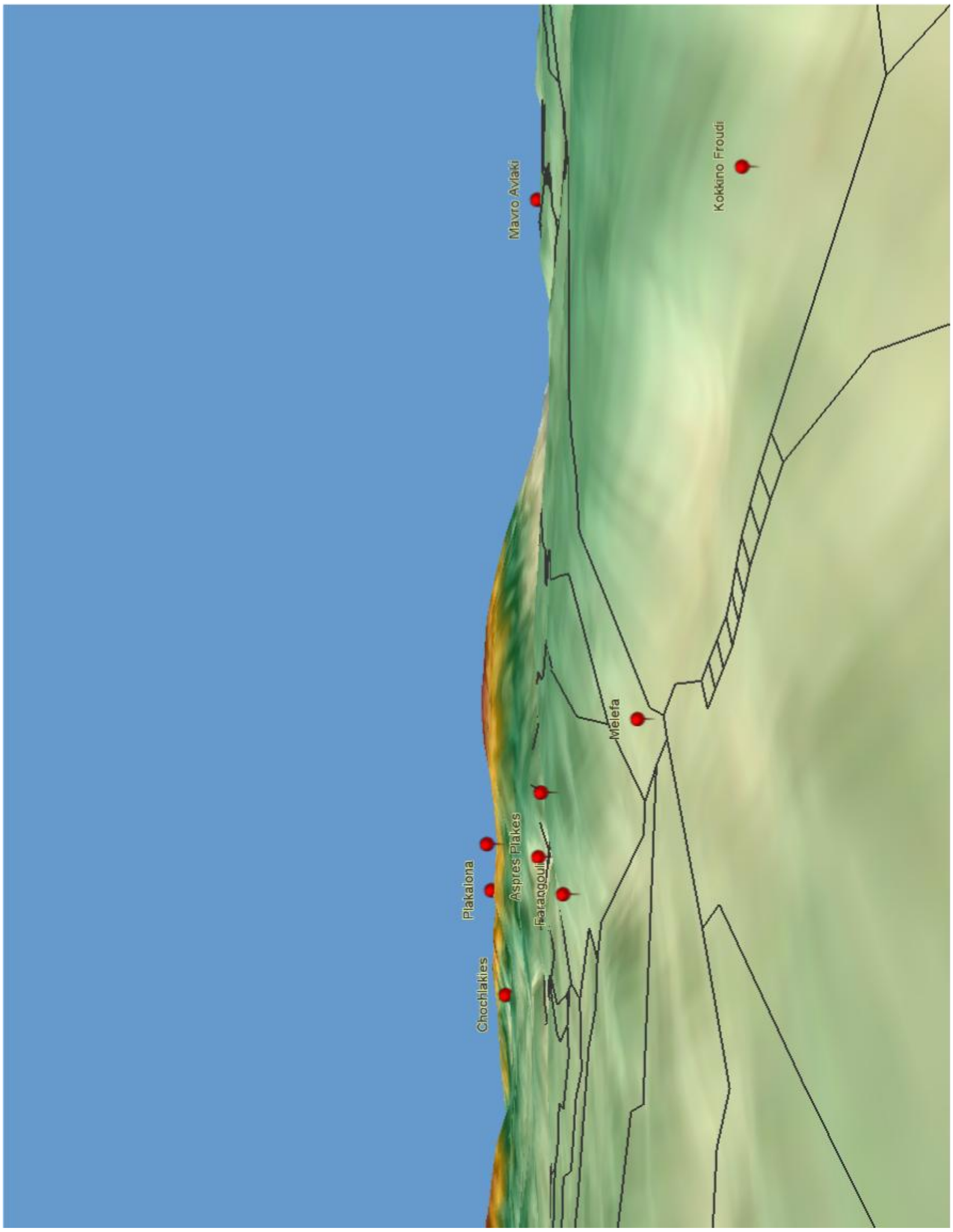

Figure 13: Location of the guard house of Melefa in the 3D model, looking towards the northeast.

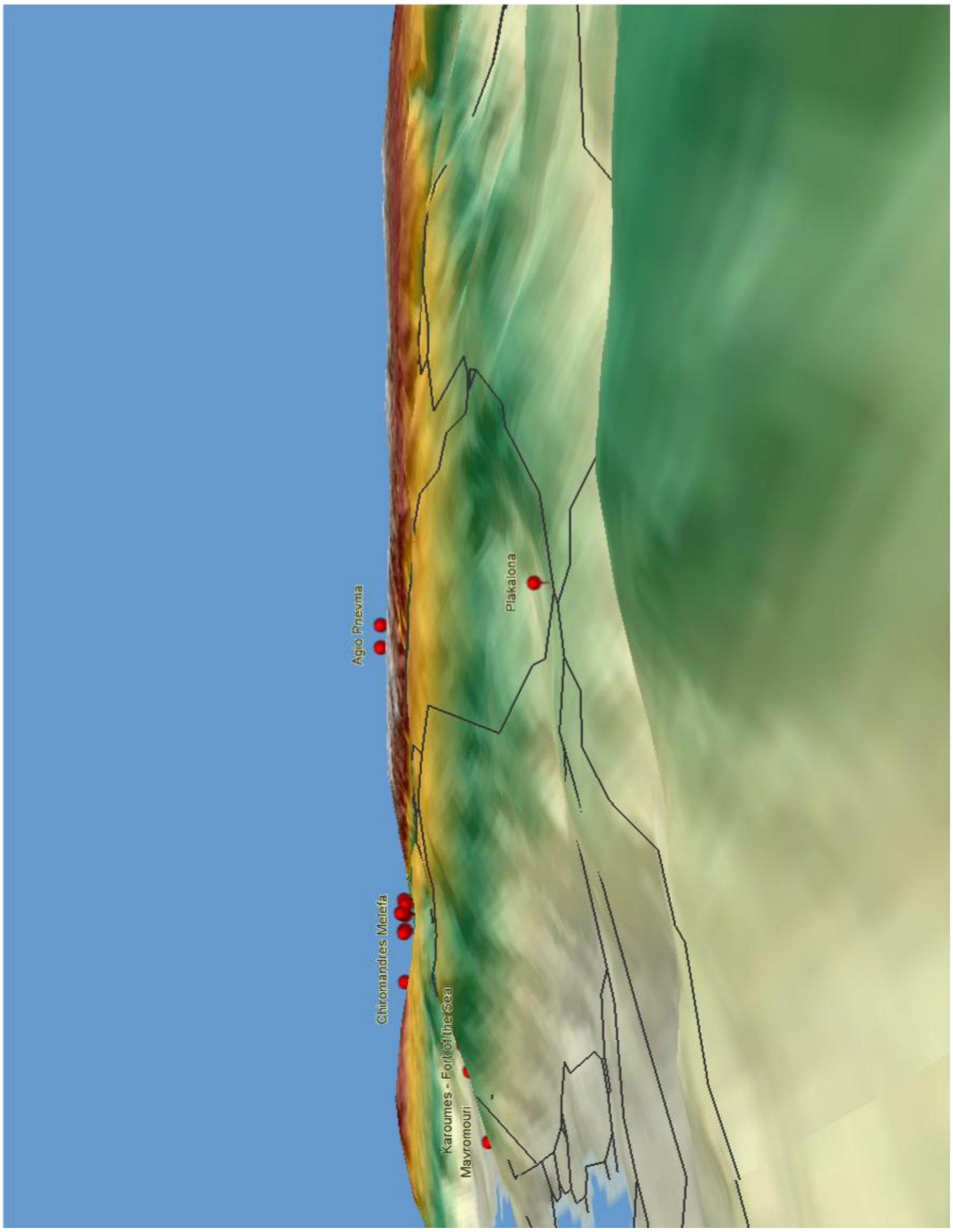

Figure 14: Location of the guard house of Plakalona in the 3D model, looking towards the southwest.

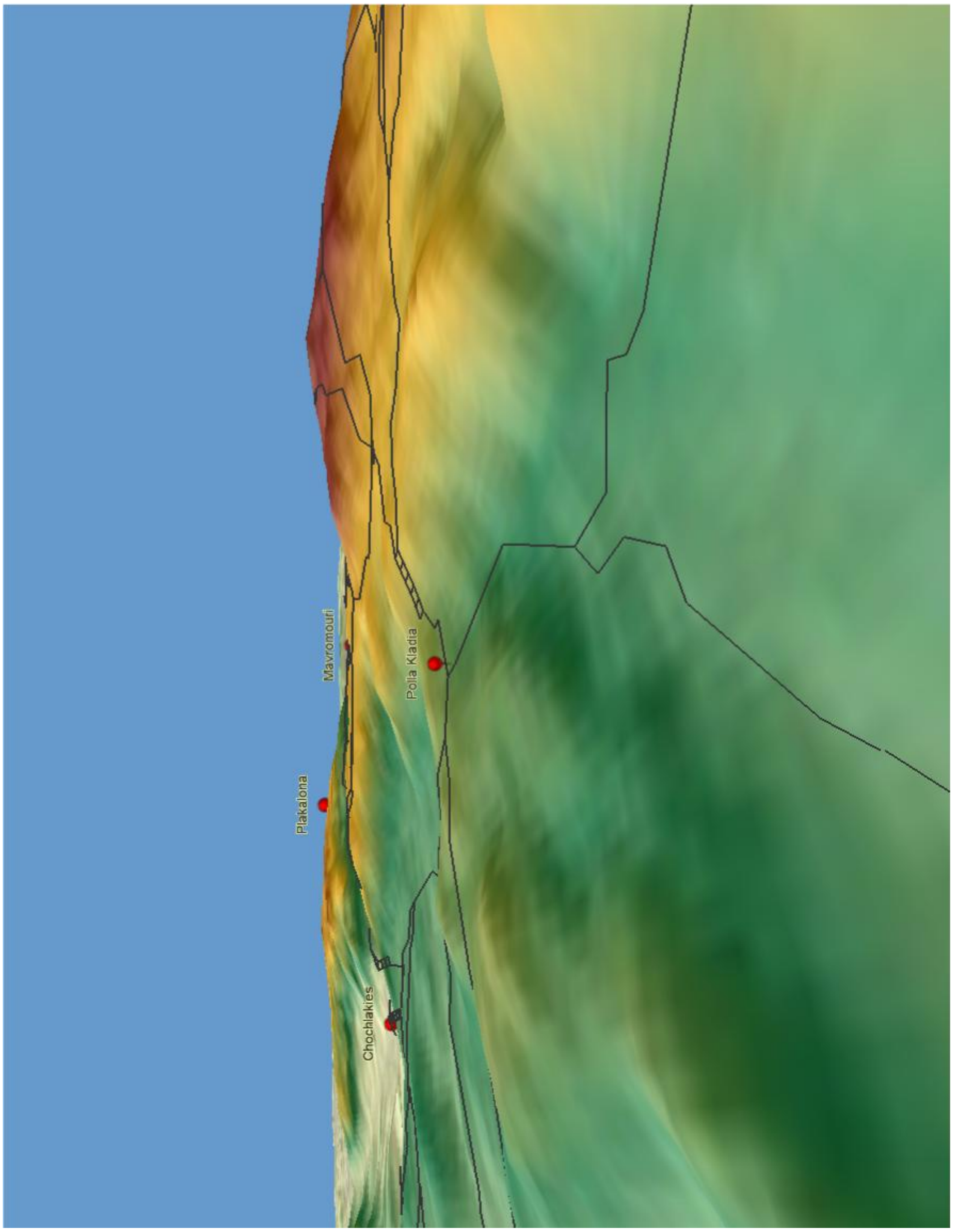

Figure 15: Location of the guard house of Polla Kladia in the 3D model, looking towards the northeast.

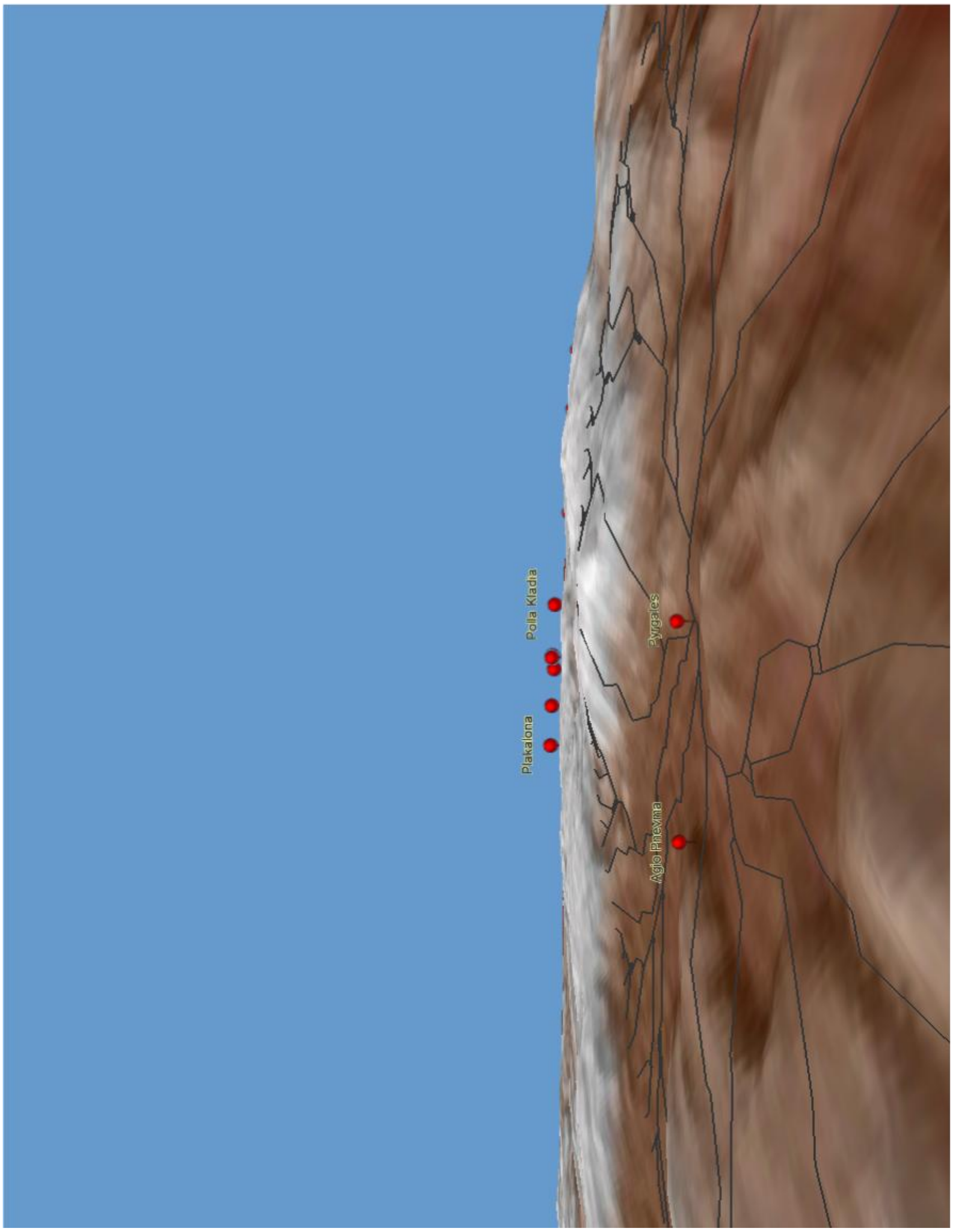

Figure 16: Location of the guard house of Pyrgales in the 3D model, looking towards the northeast.

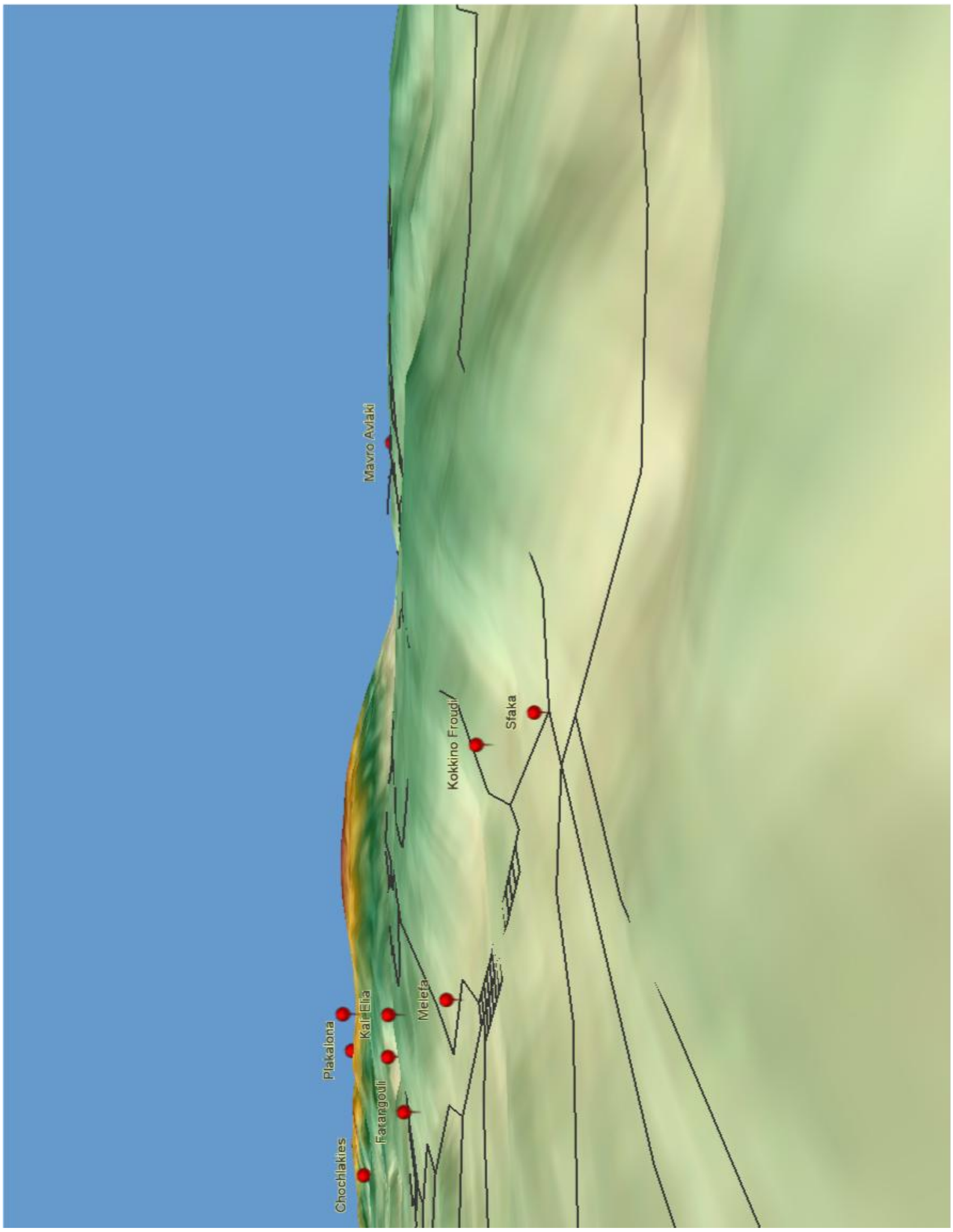

Figure 17: Location of the guard house of Sfaka in the 3D model, looking towards the northeast.