

Fuzzy Viewshed Analysis of the Hellenistic City Defence System at Sagalassos, Turkey

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Abstract

This paper presents the results of the interdisciplinary study of the Hellenistic outer defences at the site of Sagalassos. The aim of this study was to analyse the reciprocal relation and intervisibility of a small part of the Hellenistic outer defences, i.e. a fortress and two watchtowers on the mountain tops immediately north and southwest of the city, and the main north and south approaches to the city. This analysis uses a GIS, thus combining archaeology, computer science and geography. Because of the deceptive accuracy of binary viewshed maps, fuzzy viewsheds were calculated. Two types of viewsheds, projective and reflective, were produced. Because of the sensitivity to the positioning of the observation points of the projective viewsheds, it was decided to also calculate reflective viewsheds. Both projective and reflective viewsheds show that the different towers guard a well defined part of the main north and south approaches to the city. It also became clear that the visibility of the different watchtowers interact, and that they can be integrated into a single system, thus indicating a contemporaneous date for all elements of this system of outer defences. The results of the method used in this study, seems promising enough to further develop and apply it. Also the drawbacks of both projective and reflective viewsheds become clear, leading to the conclusion that a combination of these two types of viewshed often offers the best view on the visibility in the study area.

1 Introduction

This paper presents the results of analytical methods applied to geographical data acquired from the region of the ancient site of Sagalassos, Turkey. The city of Sagalassos lies at an altitude between 1490m to 1600m on the lower south slope of a mountain rim (Aglasun Daglari) in the western Taurus mountain range (Paulissen *et al* 1993, 230). It is relatively easily accessible from the steep slopes to the south, east and west which can easily be seen and controlled from the city proper. Towards the north the city is completely dominated by the Aglasun Daglari which form a steep cuesta front. Yet, the more gentle slopes of these mountains, exposed towards the north, are not visible from within the city, making them more difficult to control. This, combined with the many military threats the city was exposed to during its history, made the construction of an extensive defence system necessary. The first serious threat, documented in ancient literature, involved Alexander the Great who besieged and conquered the city in 333 BC (Arrianos, *Anabasis Alexandri* I, 28). After Alexander's death the continuous feuding between the Hellenistic monarchs and the Hellenistic cities often escalated into fierce wars which presumably also affected Pisidia and the city of Sagalassos. It was only after the establishment of Roman rule, with the annexation of the kingdom of Galatia in 25 BC (Levick 1967, 29) that these wars came to an end. For

over four centuries Sagalassos experienced a relatively peaceful and prosperous existence, only to be interrupted towards the end of the fourth and the beginning of the fifth century AD by raids of the Isaurians (Waelkens 1993, 48). For a more detailed survey of the various military threats imposed on Sagalassos in Hellenistic and later times see Loots (in press).

In reply to the military threats during the Hellenistic period the inhabitants of Sagalassos built an extensive defence system comprising of a city wall, two barrier walls to the north of the city, a fortress and two watchtowers on mountain peaks directly overlooking the city, as well as several watchtowers spread throughout the territory of the city (Waelkens 1997, 31 and 39). The latter not only served for defensive purposes and refuges for local peasants, but may also have had a function in controlling the countryside. The Hellenistic date of this defence system has been established by its building face and stone masonry, as well as by the study of archaeological parallels. The fortress and the watchtowers, situated on the mountain peaks in the immediate vicinity of the city, formed a necessary element in the defence of many Hellenistic cities in Asia Minor. Examples of such systems can be found around Ephesus (Jobst 1978, 447-456) and around Herakleia on the Latmos (Krischen 1922, 44). The Hellenistic city wall was built using pseudo-isodemic

masonry with a fill of mortar and rubble. In one preserved stretch of the wall the remains of four rectangular towers are still visible. Two other parts of the wall, a tower and possibly also the main south city gate, are also partially preserved. The Hellenistic defence system of Sagalassos became obsolete in the first three or four centuries AD, during which the Hellenistic city wall was largely dismantled. The fortress and watchtowers on the mountain tops immediately around the city however, most probably stayed in use, or were at least reused in the late-Roman period, indicated by sixth century ceramics found in the fortress and in one of the watchtowers. Towards the end of the fourth and the beginning of the fifth centuries AD, when it became necessary to fortify the city centre again, a wall mainly comprising of reused blocks was built. These defensive structures, with the exception of the watchtowers on the city territory further away from the city, are described by Loots (in press).

The aim of our study was to analyse the reciprocal relation and intervisibility of a small part of the Hellenistic defence system, i.e. the fortress and the two watchtowers on the mountain tops north and south-west of the city, and the main north and south approaches to the city of Sagalassos. This analysis uses a Geographical Information System (GIS). The restriction of our research to the fortress, the two watchtowers and the approaches was chosen in order to simplify the necessary computations, as well as to obtain a straightforward example of what is possible using a GIS to answer specific archaeological questions. The choice of the aforementioned problem was inspired by the hypothesis that the watchtowers might be directly related to these approaches, therefore controlling those stretches that were not visible from the city itself. Secondly, other questions concerning the mutual intervisibility between the watchtowers proper, the watchtowers and the city, and the watchtowers and other defensive structures, as well as the relative dating of the defence system may also be answered. Some of these questions, however, can easily be answered by observations on the terrain and need not be analysed any further.

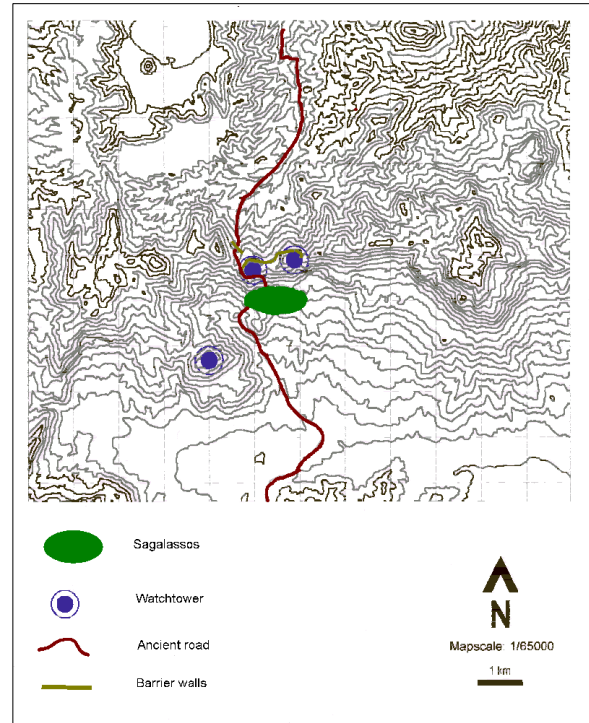


Figure 1. Map of the study area.

2 Description of the archaeological remains (see Fig.1)

The fortress on the Tekne Tepe (1885m) located to the north-west of the city measures approximately 41m by 58m and has a slightly oval form, predetermined by the topography of the mountain top (see Fig. 2). It is composed of a double wall made up of roughly cut polygonal stones and rubble fill. In some places the remaining walls still stand 1.20m high, incorporating bedrock in the south and in the north-west corner. There are two, 1.25m wide entrances; one in the east, built into the wall and one in the west, cut into the bedrock. Within this wall other structures are visible, including five rooms of which the function is not clear, measuring 4.5m by 5m to 6m by 10m. A rock-cut cistern of 1.25m by 4m lies next to rock-cut stairs which probably lead towards the parapet of the fortress wall. To the north of the fortress the remains of a watchtower (7.5m by 9m) with a southern entrance can be seen. Its double walls consist of roughly cut polygonal stones with rubble fill. The location of this watchtower, in the north of the fortress, points to its function, i.e. the control of the northern approaches towards the city. Indeed, from the watchtower Sagalassos itself was not visible, although one could easily see the city from the south wall of the fortress.

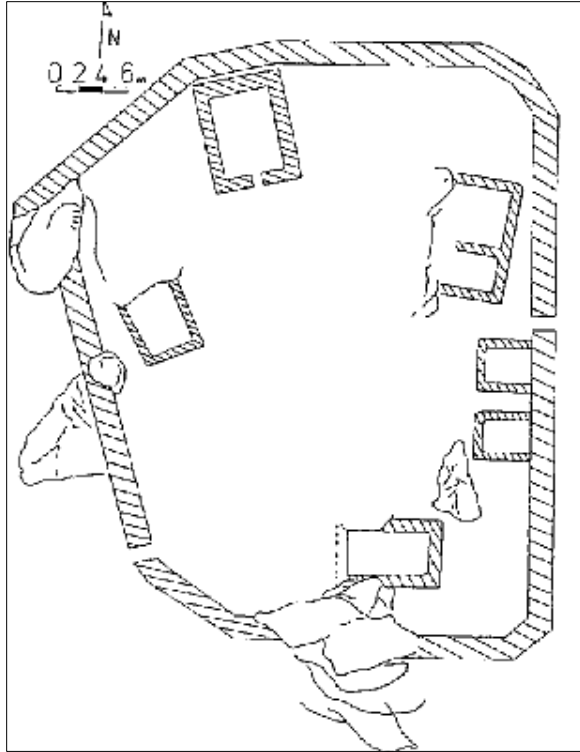


Figure 2. Plan of the fortress on the Tekne Tepe.

Of the watchtower on top of the Çiñçinkirik Tepe (2045m) located immediately north-east of the city, only a few stretches of wall, and a 1.20m wide entrance in the west remain. The polygonal shaped watchtower measures approximately 6m by 18.5m by 10.5m by 20m. Its walls consist of a double ashlar casing filled with rubble. The watchtower is located on a rock outcrop on the northern section of a small plateau which covers the mountain top and, as such, does not offer any view on Sagalassos. The main function of this watchtower is also to control the area north of the city.

The watchtower on top of the Zencirükin Tepe (1666m) located immediately south-west of Sagalassos, is very poorly preserved. Few roughly cut polygonal stones are still visible, but from these stones it was possible to reconstruct the polygonal plan of the watchtower (9.20m by 10.30m by 10.20m). Observations in the field revealed that this watchtower offered a very good view of the mountain pass west of the Zencirükin Tepe, and of the valleys just south and south-east of Sagalassos.

3 Methodology

The foundation of this study rests on a Digital Elevation Model (DEM) of the local landscape,

produced using elevation data gathered during several field campaigns. The data exist as contour lines at 50m intervals and individual elevation points. The analogue data were digitised with the ARC Digitising System (ADS) module of ARC/INFO_{pc} (ESRI 1986) with a Calcomp 9100 digitiser table. A digital map of contour lines and elevation points was produced.

The position of the different observation points used in this study were manually surveyed using a hand held TRIMBLE ENSIGN GPS. To obtain a maximum accuracy, connections with seven or eight satellites were established. The coordinates were manually inserted into the DEM and geocoded with the GENERATE command in ARC/INFO_{pc} (ESRI 1986). Minor displacements of the observation points could be corrected using an overlay of the elevation information and a thorough knowledge of the topography of the study area. The complete digital dataset was then converted to Idrisi for Windows using the UNGENERATE command in ARC/INFO_{pc} and the ARCIDRIS command of Idrisi for Windows.

The next step was the calculation of the viewsheds themselves. Because of the deceptive accuracy of binary viewshed maps, we decided to produce fuzzy viewsheds (Nackaerts 1997, 3-11). Fuzzy viewsheds indicate the probability, expressed in percentages, that a cell lies within or outside the viewshed, thus making shaded decisions possible. Two types of viewsheds, which constitute two distinct mapping approaches, projective and reflective viewsheds, were produced (Fels 1992, 266).

The projective viewsheds were calculated from the observation points that were studied (i.e. the watchtowers themselves) (see Fig. 3). They reveal the extent of visibility from the observation points towards the surrounding area. Because of their sensitivity to the positioning of the observation point, the results of the projective viewsheds did not always correspond completely with the observations that were made on the terrain (see below section 4.2). Therefore, it was decided to calculate reflective viewsheds.

Reflective viewsheds are less sensitive to the positioning of the observation points. They show whether, and to what extent, the different observation points are visible from their surroundings. When calculating the reflective viewsheds a multiple viewpoint approach was applied in order to produce a cumulative intervisibility map. Thus, the visibility of the different observation points from several specific points in the surrounding landscape was calculated.

In this study the points chosen within the surrounding landscape form the trajectory of the ancient road (see Fig. 4).

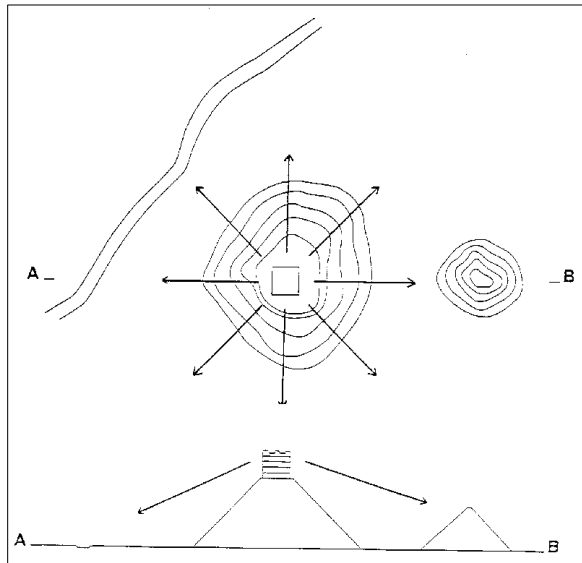


Figure 3. View direction of the projective viewsheds.

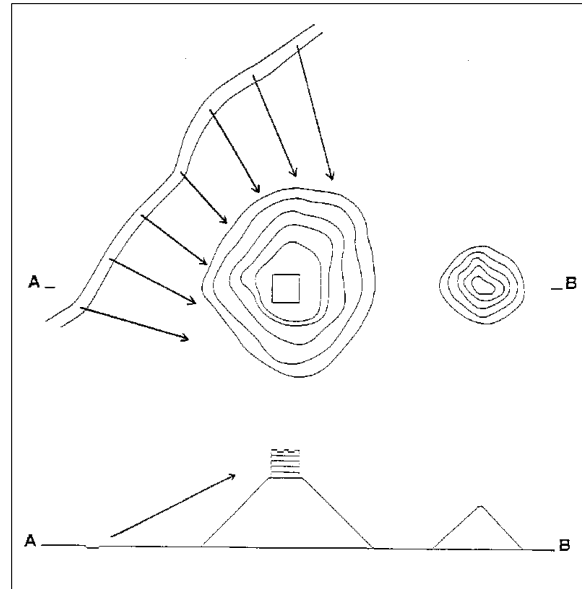


Figure 4. View direction of the reflective viewsheds.

4 Results

4.1 Remarks

The area for which the viewsheds have been produced was restricted to a circle with a radius of 5km due to the fact that in the mountainous terrain around Sagalassos, the overall visibility will not readily extend beyond this radius. This restriction also simplifies the calculation of the viewsheds and thus the time needed to produce them. However, a comparison between the viewsheds of the watchtowers on the Tekne Tepe and on the Çinçinkirik Tepe shows that in particular areas this radius may not be wide enough (see below section 4.2).

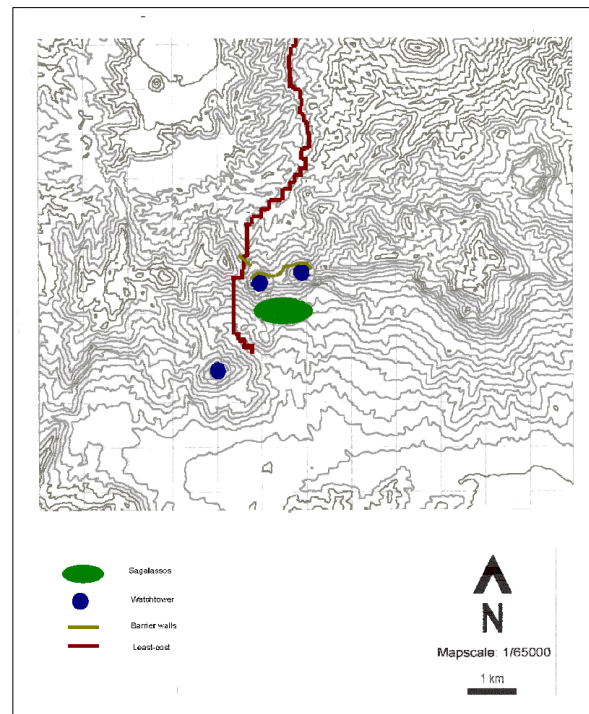


Figure 5. Least-cost analysis.

In order to produce the reflective viewsheds used in this study the main southern and northern approaches to the city had to be converted into a 'road' with a fixed trajectory. From this 'road' reflective viewsheds could then be calculated. A description of the roads leading towards Sagalassos from the north and from the south, has been given by F.V.J. Arundell (1828, 136) and other travellers (Waelkens 1997, 11-18). It is possible to plot the roads on a map using these descriptions (see Fig.1), but caution must be applied because the accuracy of these descriptions is uncertain. To the south of the mountain rim the

ancient road was still partially visible only decades ago. To the north, however, no visible traces remain. The trajectory can only be reconstructed based on the descriptions of Arundell and others and our taking into account the topography of the terrain. To obtain a more objective reconstruction, a least-cost analysis was conducted in Idrisi for Windows. This involved calculating the most economical way to get from point A (the probable entry of the road into the area of the viewshed) towards point B (the pass west of the Tekne Tepe, where the road crossed the mountain rim). Although this least-cost analysis differs in respect to the previous reconstruction of the trajectory of the road, the similarity between them is large enough to clarify that our identification of the trajectory of the road represents its most probable position (compare Figs. 1 and 5).

Because this study uses fuzzy viewsheds which give the probability of visibility, it was necessary to determine the extent something can be considered very well visible or less visible. Considering the size of the armies that could have been provided by rivalling cities and those of the Hellenistic kings (Bar-Kochva 1976, 7), i.e. some hundred to several thousands of men, a probability between 50% and 75% can be considered most probably visible, and a probability of 75% and higher as almost certainly visible. Under 50% too many unknown factors hinder any reliable predictions. These limits, however, are not absolute, since visibility is also function of other factors such as weather and vegetation.

4.2 Projective fuzzy viewsheds

Projective viewsheds were produced from the observation points corresponding to the different watchtowers on the mountain tops around the city. If the trajectory of the road is plotted on such a viewshed it is possible to determine which areas of the road are visible from each watchtower (see Figs 6, 7, 8).

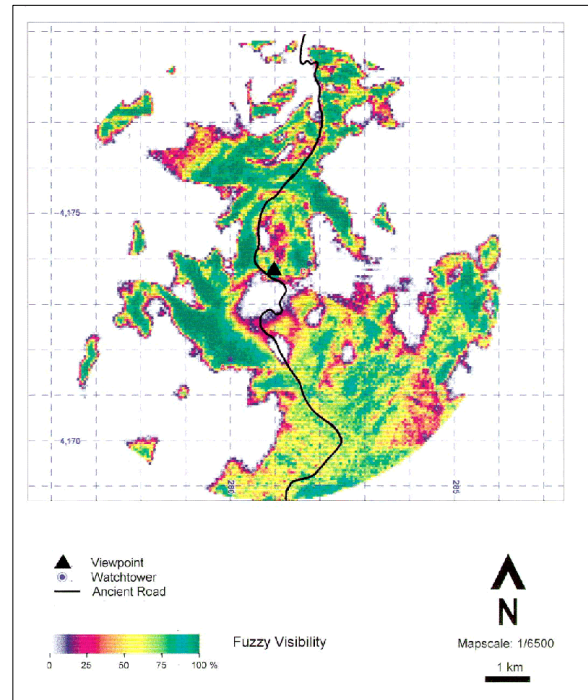


Figure 6. Projective viewshed of the Tekne Tepe.

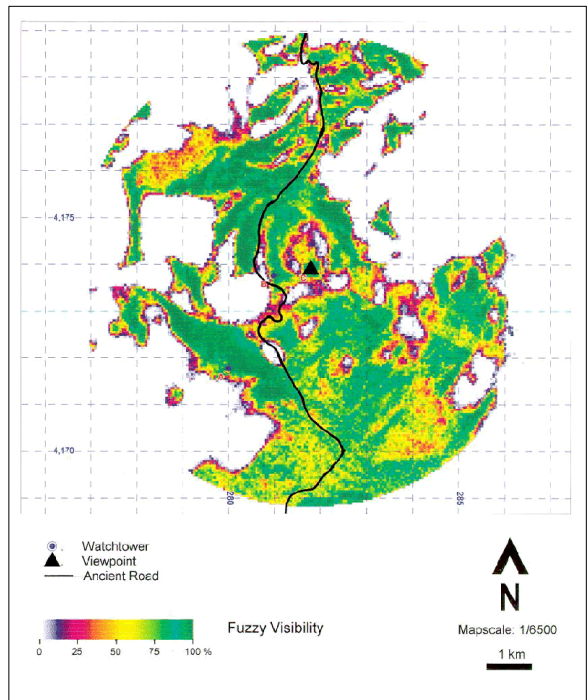


Figure 7. Projective viewshed of the Çinçinkirik Tepe.

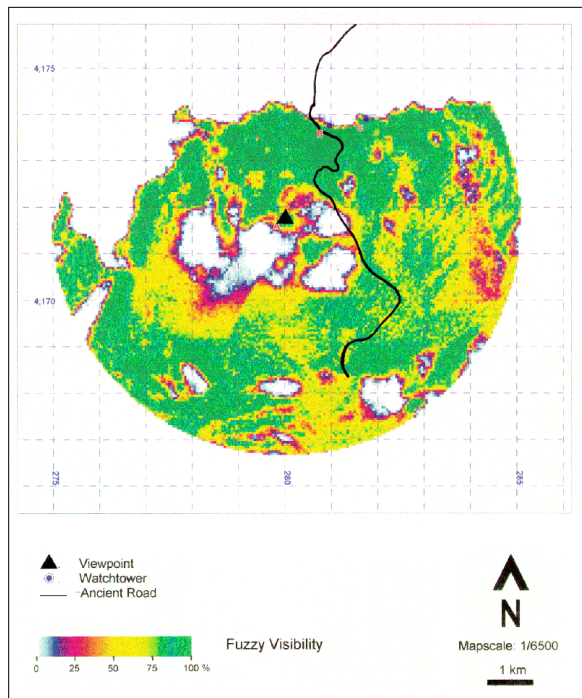


Figure 8. Projective viewshed of the Zencirükin Tepe

From the projective viewsheds it is clear that both the watchtower on the Tekne Tepe (see Fig. 6) and on the Çiñçinkirik Tepe (see Fig. 7) guard the north part of the road. The two viewsheds show similar results towards the north, leading one to question why two watchtowers were built this close to one another to guard the north. Observations on the terrain revealed that from the higher Çiñçinkirik Tepe parts of the approach to the city from the north that fall outside the radius of 5 km can be seen, which are not visible from the Tekne Tepe. The projective viewshed of the Çiñçinkirik Tepe also clarifies that this mountain peak offers a broader view towards the north than does the Tekne Tepe. This offers a reasonable explanation as to why a second watchtower was built on the Çiñçinkirik Tepe. From the Çiñçinkirik Tepe it would also have been possible to guard the small steep pass east of this mountain. Thus, the main function of the fortress on the Tekne Tepe may not have been control of the northern part of the road, but rather the housing of the men who's task it was to defend the long barrier wall north of the mountain rim (Loots in press). The watchtower on the Tekne Tepe does not offer an extensive view towards the south. However, since the watchtower is located in the north of the fortress, the viewshed does not offer an accurate image. One can see the southern part of the road and the city very well when standing at the southern edge of the fortress. The watchtower on the

Çiñçinkirik Tepe offers a better view towards the south than the watchtower on the Tekne Tepe, but this tower is also orientated mainly to the north. The ancient road passes the mountain rim through the mountain pass immediately west of the Tekne Tepe. This pass forms an important strategic point in the control of the northern approach towards the city. Yet, the projective viewshed from the Tekne Tepe shows that the mountain pass has only a probability of visibility of 25% or less. Observations in the terrain also show that from within the fortress on the Tekne Tepe it is not possible to overlook the pass itself. This was most probably the reason for building a barrier wall blocking the road some 100m north of the mountain pass (Loots in press).

Although it is not entirely evident from the projective viewshed, the southern part of the road is largely controlled by the watchtower on the Zencirükin Tepe, which also offers an excellent view on the pass west of this mountain (see Fig. 8). The reflective viewshed of the southern part of the road however, offers a clearer view on the function of this watchtower (see below section 4.3).

As is clear from the above mentioned examples, especially when discussing the Tekne Tepe and the Zencirükin Tepe, the projective viewsheds are rather sensitive to the positioning of the observation points. A slight alteration of these points can cause large changes in the viewshed. Therefore, reflective viewsheds from the road itself were produced.

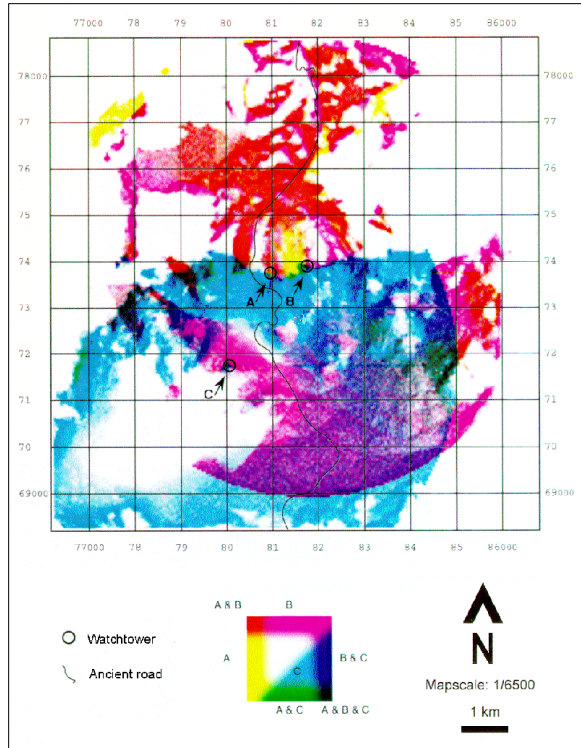


Figure 9. Reflective viewshed of the north part of the road.

4.3 Reflective fuzzy viewsheds

The reflective viewsheds clearly indicate the most important strategic positions for the surveillance of the road. The reflective viewshed for the northern part of the road (see Fig. 9) shows that both the watchtower on the Tekne Tepe and especially the one on the Çinçinkirik Tepe are two of the best places to overlook the north part of the road. Additional strategic positions can be identified towards the north, but they are not visibly connected to the city. In this context, it is interesting that the Koyaklinin Tepe (D), west of the pass, is the most suitable place to overlook the road towards the north. This is also confirmed by a projective fuzzy viewshed which was calculated for the top of this mountain (see Fig. 10). Indeed, from this mountain peak one can overlook the pass west of the Tekne Tepe extremely well. Thus, this mountain top may have formed an integral part of the Hellenistic defence system of the city. The Zencirükin Tepe, south of the mountain rim, seems to be placed well enough to overlook at least a part of the road north of the mountain rim (50% probability).

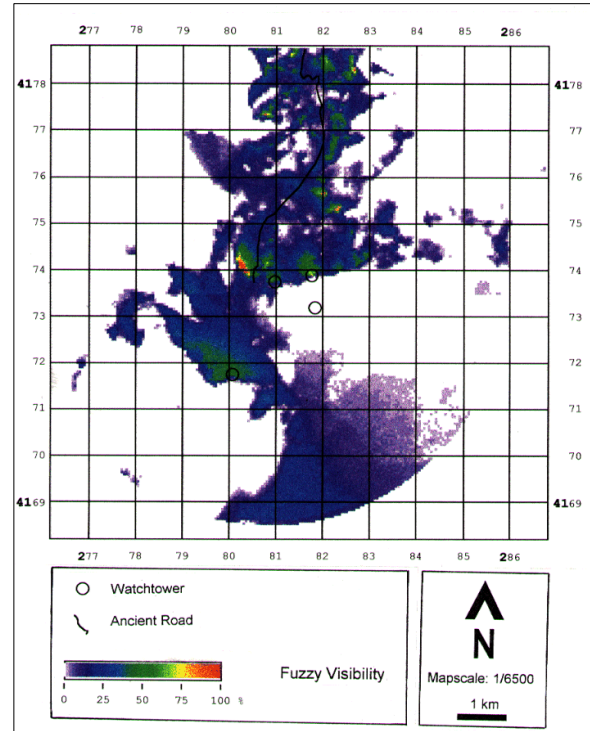


Figure 10. Projective viewshed of the Koyaklinin Tepe.

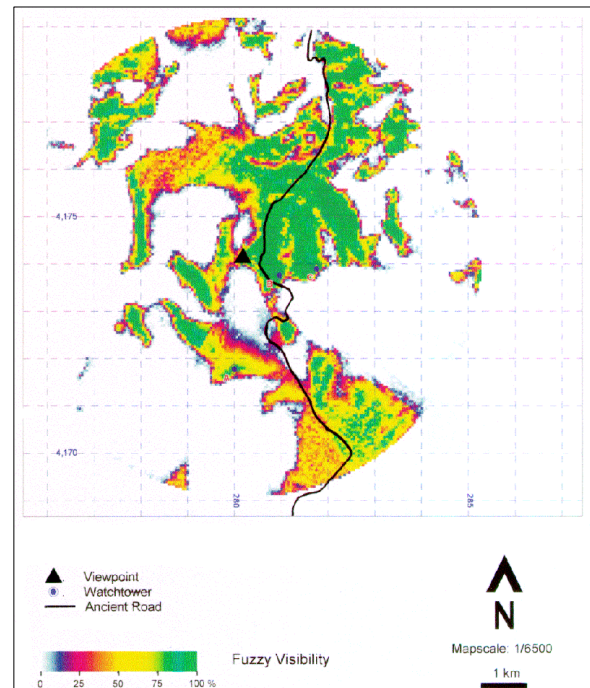


Figure 11. Reflective viewshed of the south part of the road.

The reflective viewshed of the southern part of the road (see Fig. 11) offers a different view on the visibility of the road compared to the projective viewsheds. Not only does the Zencirükin Tepe seem very well suited to control the southern part of the road, in contradiction with its projective viewshed where a large part of the road is indicated as less visible (compare Figs. 8 and 11), but additionally the southern edges of the Tekne Tepe and of the Çinçinkirik Tepe offer a very good view of this part of the road. A further position with rather good visibility, is the top of Alexander's hill, a hill that guarded part of the road south of the mountain rim and that probably formed an important part of the Hellenistic defence system of the city (Loots In press).

5 Conclusion

The relation between the watchtowers on the mountain tops immediately around Sagalassos and the main north and south approaches towards the city has clearly been indicated. Each watchtower guards a well defined part of the approaches, either to the north or to the south of the mountain rim. It also became clear that the visibility from the different watchtowers interact, and that they can be integrated into a single system. Ideally such systems can also be found elsewhere in Asia Minor, but no research using GIS technology has been conducted on this topic thus far. The results of this method seem promising enough to further develop and apply it.

Projective viewsheds often give a slightly misleading view by not incorporating particular parts of the area

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that are indeed visible. By reversing the view direction the reflective viewsheds offer a correct picture of the visibility. They also indicate all places for which the visibility is good, making it an excellent tool for archaeological surveys. While the projective viewsheds ask for a rather elaborate interpretation by the archaeologist, this is much less the case with the reflective viewsheds. Thus, they constitute a more objective instrument in visibility studies. Therefore it seems appropriate, at least in regards to this study, to use mainly reflective viewsheds. This, however, can not be said for every visibility study. According to the aims of a study, one should start by calculating projective viewsheds and if possible combine these with reflective viewsheds in order to obtain a clearer view on the visibility in the study area. Only then can it be decided which of the two viewsheds are the most suitable to answer the specific questions asked. Almost certainly a combination of the two types of viewsheds will offer the clearest view on the visibility in the study area.

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