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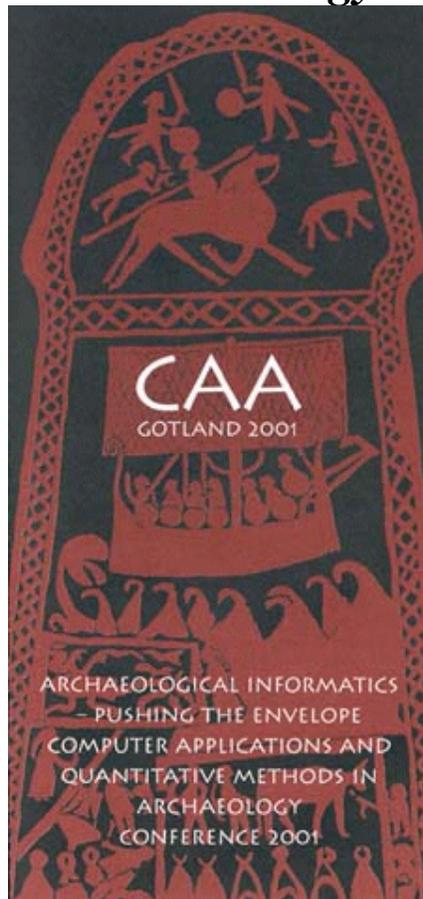
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Ancient Mantineia's Defence Network Reconsidered Through a GIS Approach

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Abstract

Ancient Mantineia, located in the centre of Peloponnese, Greece, consists of an almost 4Km in length elliptical fortification wall containing 10 gates and 126 towers. Since the 19th century, a number of watchtowers have been located at the surrounding slopes of the Mantineian plain and the existence of a defensive network has been suggested.

GIS analysis has been used specifically for studying the defensive network of the ancient settlement and its potential coverage. The gates of the fortification walls and the watchtowers were mapped through high precision GPS units. These data were superimposed on a DEM created by the digitization of 20m elevation lines covering a region of 1000 Km^2. Geological maps, aerial and SPOT satellite imagery were also incorporated to the GIS analysis.

Viewshed analysis was performed in order to determine the extent and degree of intervisibility between the watchtowers situated in the nearby hills and mountains and the gates of the city walls. The data were correlated to the results of previous surface surveys that had located ancient roads and paths. Cumulative viewshed analysis was also employed to suggest the number of the defence constructions that were able to control a specific area. In this way, a thematic map of the potential defensive region has been created, suggesting either possible gaps or candidate archaeological sites that may have been used to complete the defence system of the region. The results of the analysis were superimposed on a SPOT Panchromatic image draped on the 3D DEM. Finally, a fly-over simulation in the area of interest was produced serving as a visual verification of the above analysis.

Keywords: Mantineia, defence network, GIS, GPS, viewshed analysis.

1. Introduction – Aim of the study

The technological advancement of computers has proved to be of great help in Archaeology. New methods and technologies improve and upgrade the traditional approaches in archaeological research. Upgraded computer systems have been systematically used for

image processing, creation of databases, multi-variable analyses of archaeological and environmental data, three-dimensional modeling and virtual reality.

During the last years, Geographic Information Systems, designed to collect, store and analyze objects and phenomena with a geographic variable, have been widely used in archaeological applications. Such an application is the study of the Ancient Mantineia's defence network, in Arcadia, Peloponnese, Greece (Topouzi, et al 2000).

Ancient Mantineia, located in the center of Peloponnese, Greece, consists of an almost 4Km in length elliptical fortification wall containing 10 gates and 126 towers. Since the 19th century, a number of watchtowers have been located at the surrounding slopes of the Mantineian plain (Loring 1895; Fougères 1898; Lattermann H., 1913; Frazer 1965) and the existence of a defensive network has been suggested (Pikoulas 1990-1; 1995).

The term "network" suggests a carefully planned defensive system, consisted of watchtowers with intervisibility between one another. Such intervisibility must also exist between the watchtowers and the city's fortification walls. Previous studies have not been able to identify the effectiveness and extent of this defensive network. Performing a viewshed analysis based on the digital elevation model of the area was considered as the appropriate method to provide some complementary information regarding the type and structure of this network.

A number of other analyses, such as slope and aspect, were performed in addition to the viewshed analysis. In the future, the corresponding results could be used in order to create a predictive model, capable to suggest new, unknown until now, archaeological sites.

2. The study area – The defensive structures

The ancient city of Mantineia was located within three valleys of central Arcadia, Peloponnese, and was surrounded by mountains. The elevation varies from 624m to 640m.

Habitation in the area begun during the Early Helladic period. During the early historical years, Mantineia is divided in 5 demes (Strabo, VIII 3.2), the names of whom are not known. The classical city bears two chronological phases, one before 385 B.C., when it was destroyed by Agissipolis, king of Sparta, and one after 370 B.C., when it was reconstructed. The remnants of the city's fortification walls belong to the second phase. They consist of a stone foundation, built according to the irregular polygonal masonry system, over which a brick wall, now destroyed, was raised. The walls' shape is elliptical, having a perimeter of 3942m. The N-S axis measures 1349m and the E-W axis measures 1087m.

According to G. Fougères (Fougères 1898), the walls had 126 almost equally spaced towers and 10 gates (fig.1). From each gate a road started, connecting Mantineia with its neighboring cities.

Five watchtowers (fig.1) and a small fortress lie at the surrounding slopes. The watchtowers are similar to one another, built from local limestone according to the irregular polygonal masonry system. Their dimensions are almost 5×5m and it has been suggested that they should have been about 8m in height (Pikoulas 1990 – 1). The small fortress of the town Nestani is built of the same material and masonry system. All of them control important road passes.

Figure 1 : One of the gates of Mantineia's walls (left) and the watchtower of St. Tryphon (right)

3. Methodology of the GIS construction

The methodology used to create the specific GIS project consisted of the following steps : Digitization, GPS positioning, Digital Elevation Model Construction, Remote Sensing, Georeference and Database Construction.

3.1 Digitization

The 20m elevation contours, datum points, roads, rivers, wells, modern settlements and the railroad network were digitized from 84 topographic maps of the Greek Army Geographic Service (scale 1:5000). The Root Mean Square (RMS) error was kept under 0.005, providing a very good accuracy in the digital transformation of the maps. The total area covered by the topographic maps was nearly 1000 km^2. In addition two geological maps (scale 1: 50000) were digitized and a database containing the geological formations was constructed. A geological formation (attribute), represented by a different color and pattern, was assigned to every closed polygon.

3.2 GPS positioning

All the defensive constructions were accurately positioned using two sub-cm accuracy Global Positioning System units. During the five days of fieldwork, static relative geodetic

positioning was used for mapping the architectural monuments of the region. The technique involved the placement of a continuous tracking receiver at a fixed and known position and the use of a second rover receiver for measuring at the sites of interest. The coordinates of the base receiver were determined with high accuracy by measuring to GPS satellites for a period of one hour at a nearby army datum point. The data from the roving receiver were corrected by comparing computed pseudoranges of the base station with the measured pseudoranges from the rover receiver.

The coordinates of the four corners of each watchtower were determined (fig.2). One point was chosen for each gate of the city's walls in order to position them on the walls' digitized plan (fig.3). A total of 38 points were established, including the army datum points. Processing of the GPS data was conducted daily, so as to evaluate the coordinates and their accuracy. Point coordinates were determined in both the satellite reference system (i.e. the World Geodetic Reference System-84, WGS'84) and the national system of EGSA'87 (Greek Geodetic System 1987) used by the National Cadastre of Greece. After completing the processing, the coordinates were exported and stored in a spreadsheet (excel format) in order to import and use them in the database of the Geographic Information System. The accuracy of the measurements was kept below 10 centimeters.
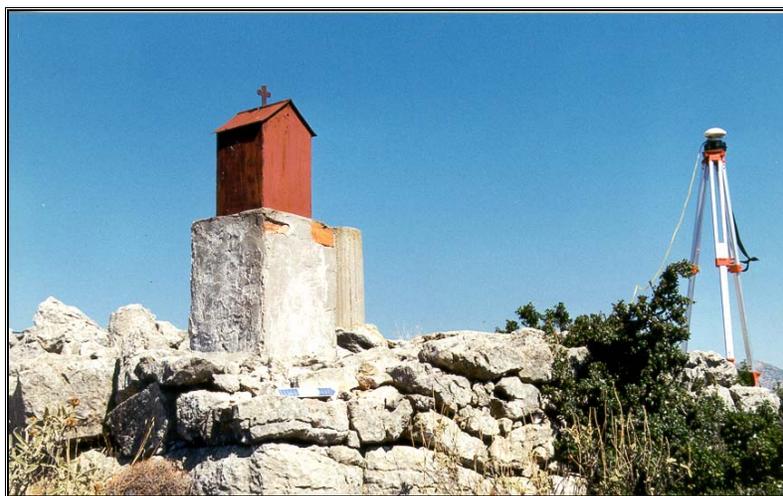
Figure 2 : Positioning the NE corner of the watchtower at St. Tryphon

Figure 3 : GPS positioning of a gate of the Mantineia's fortification walls

3.3 Digital Elevation Model Construction

The digital elevation model (DEM) of the area was created in TNTmips software, using the 20m contours combined with digitized topographic points. The processing method used was that of the Minimum Curvature, a method with the optimum result when combining contours and points. The vector format elevation values produced a 60m pixel size DEM. The two-dimensional and three-dimensional DEM (fig. 4) were further enhanced through the processing of the histogram.
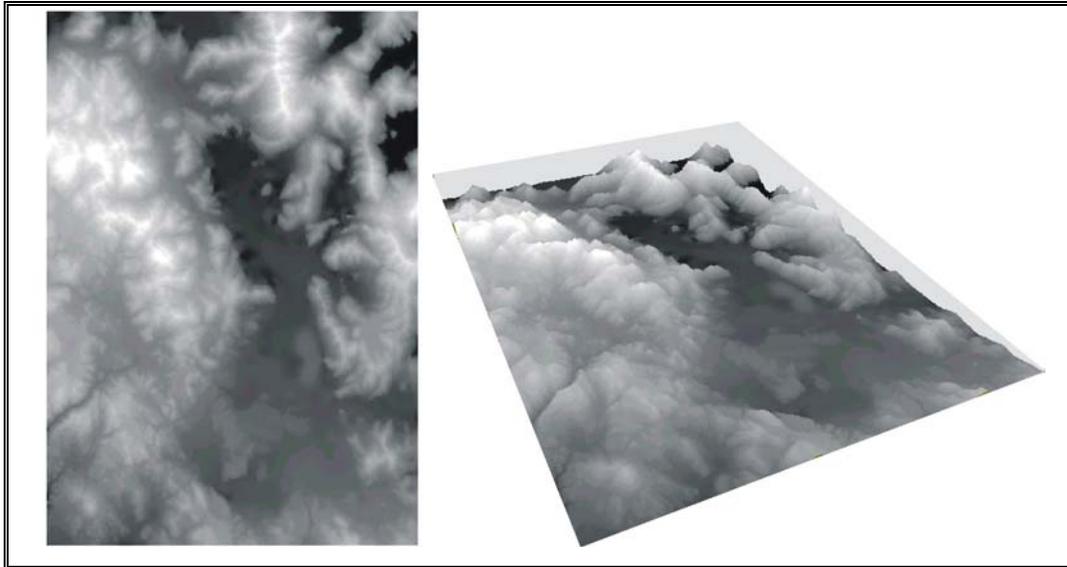
Figure 4 : 2D (left) and 3D (right) Digital Elevation Model (DEM) of the Mantineia plain
(auto normalize contrast)

3.4 Remote Sensing

One SPOT 4 panchromatic and four multi-spectral (XS) images were also used to create pseudochromatic images of the region (fig.5). Supervised image classification techniques were applied in an effort to identify areas of archaeological interest, together with other environmental characteristics, with unsatisfactory results. In addition, the panchromatic image has been used as a background layer, over which all other data have been superimposed. Besides satellite images, forty-eight air photos (scale 1: 15000) taken in 1980, have been used to create a photo mosaic (fig.6).
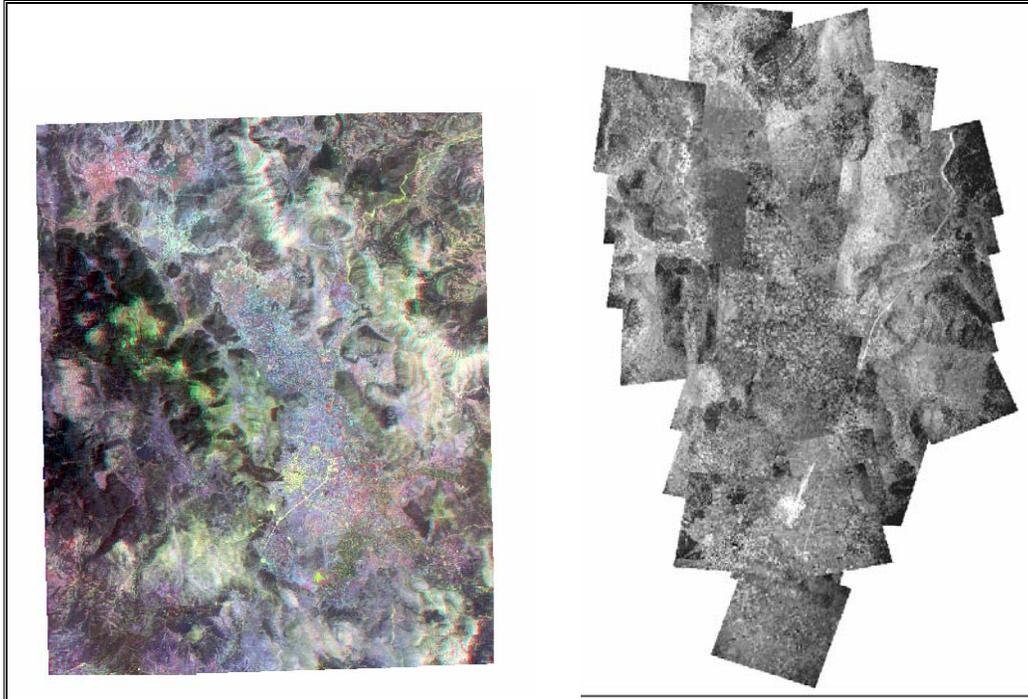
Figure 5 : Pseudochromatic image of the
wider Mantineia area. Combination of SPOT
panchromatic, XS1 and XS4 images

Figure 6 : Aerial image mosaic

3.5 Georeference

Since the aforementioned data (GPS coordinates, satellite images, aerial photo and topographic maps) were in different reference systems, it was necessary to proceed with the registration of them to a common system. The Greek Geodetic Reference System 1987 (EGSA '87 was chosen for the specific purpose. A polynomial transformation was used for transforming the topographic maps from HATT (a previously used reference system in Greece) to EGSA '87. Afterwards, the transformed road cross-sections were used in order to georeference the satellite images, the aerial photos and the geological map.

3.6 Database construction

Microsoft Access was used for the design and the construction of the database to be used for the registration, storing and searching of the archaeological information. It consisted of 12

tables which included various types of information, such as the name and the type of the sites, chronology, information regarding excavations and surveys in the area, photos, plans and bibliography. The database was later exported in DBF format to be implemented in the GIS analysis.

4. GIS analysis and results

After completing the construction of the GIS it was possible to perform a number of analyses in order to determine the existence of a defensive network in the Mantineia area.

4.1 Viewshed analysis

Viewshed analysis was considered as the appropriate method to provide some complementary information regarding the level and structure of the defense network. As it was mentioned above, the digital elevation model (DEM) of the wider area of interest was created by digitizing 84 topographic maps (scale 1:5000 and 20m elevation contours). A DBF containing the GPS coordinates of the watchtowers and the gates of the city's walls was superimposed on it. An additional height of 8m for the elevation data was allowed for each one of the gates of the wall of the ancient city of Mantineia, as well as for the watchtowers, in order to take into account the height of the structures. Visibility parameters were set from -90^0 to 90^0 for the vertical field of view and 0^0 to 360^0 for the horizontal field of view, defining visibility control towards every direction (Smith 2000). Similarly, the view distance was set to a maximum value, in order to cover the entire DEM. The results, for each site, were encoded as a binary raster in which visible cells have a value of 1 and those without visible contact have a value of 0. The synthesis of the binary viewshed maps was made either in form a logical union (multiple viewshed) (fig.7) or in form of cumulative viewshed maps (Wheatley 1995) (fig.8). A cumulative binary raster was created to represent the visibility of the wall gates, the visibility of the watchtowers and the intervisibility between both of them.

**DEFENCE SYSTEM OF THE WIDER MANTINEIA REGION – PELOPONNESE
VIEWSHED ANALYSIS**

| INTEGRATED VIEWSHED ANALYSIS OF THE WALLGATES OF THE ANCIENT CITY OF MANTINEIA | INTEGRATED VIEWSHED ANALYSIS OF THE WATCHTOWERS IN THE WIDER AREA OF ANCIENT MANTINEIA | MULTIPLE VIEWSHED ANALYSIS OF THE DEFENCE SYSTEM IN THE AREA OF ANCIENT MANTINEIA |
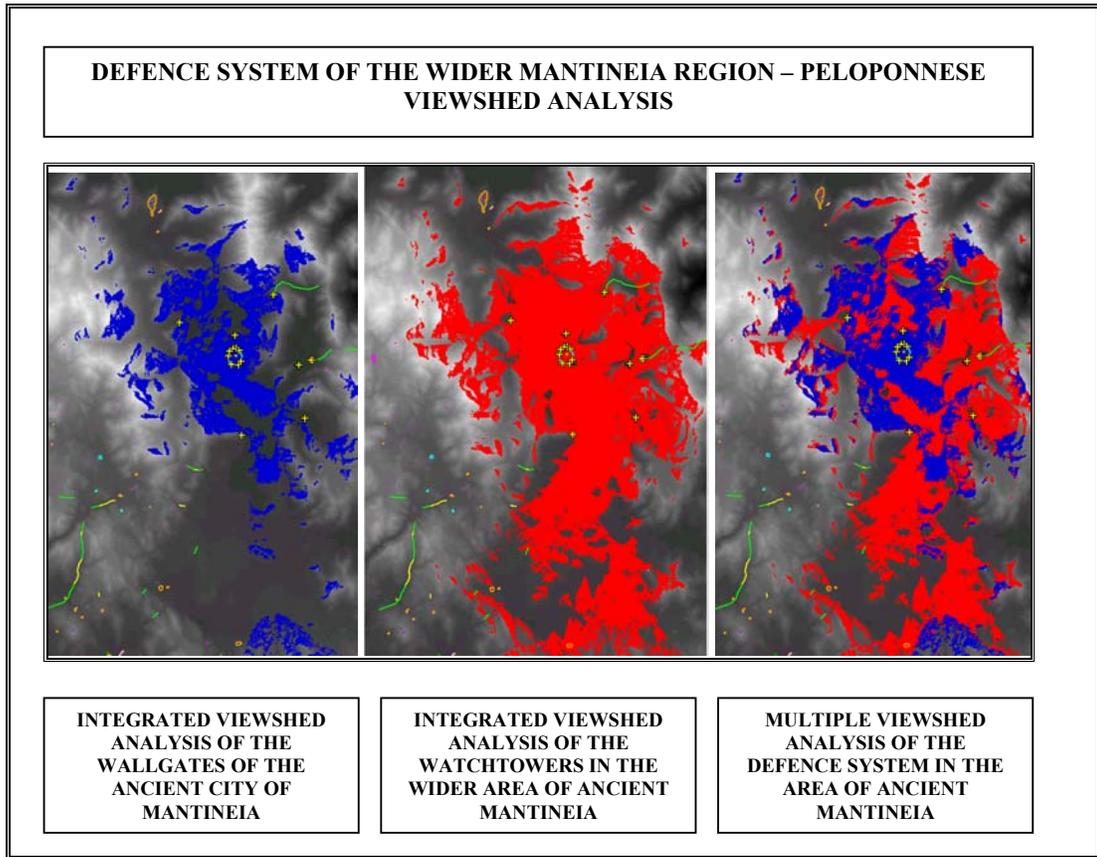
Figure 7: Single and multiple viewshed analysis of the defensive network of the Mantineia plain.

13

DEFENCE SYSTEM OF THE WIDER MANTINEIA REGIO – PELOPONNESE CUMULATIVE VIEWSHED ANALYSIS

AREAS VISIBLE FROM WATCHTOWERS

AREAS VISIBLE FROM WALLGATES

AREAS VISIBLE FROM ALL SITES
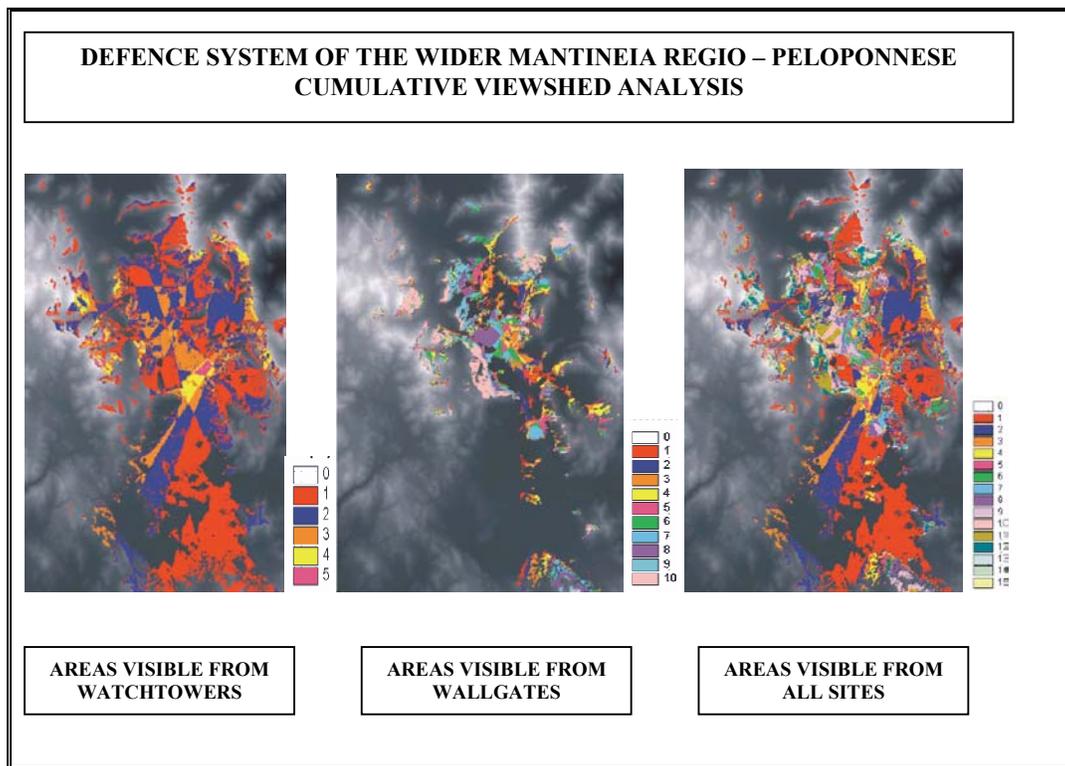
Figure 8 : Cumulative viewshed analysis of the defensive network of the Mantineia plain

The results of the viewshed analysis confirmed the previous assumption that the defensive constructions in the Mantineian plain formed a defence network in combination with the city's fortification walls. It is suggested that the location of the structures was chosen according to their intervisibility, in order to cover possible gaps in their visual communication (fig.9).
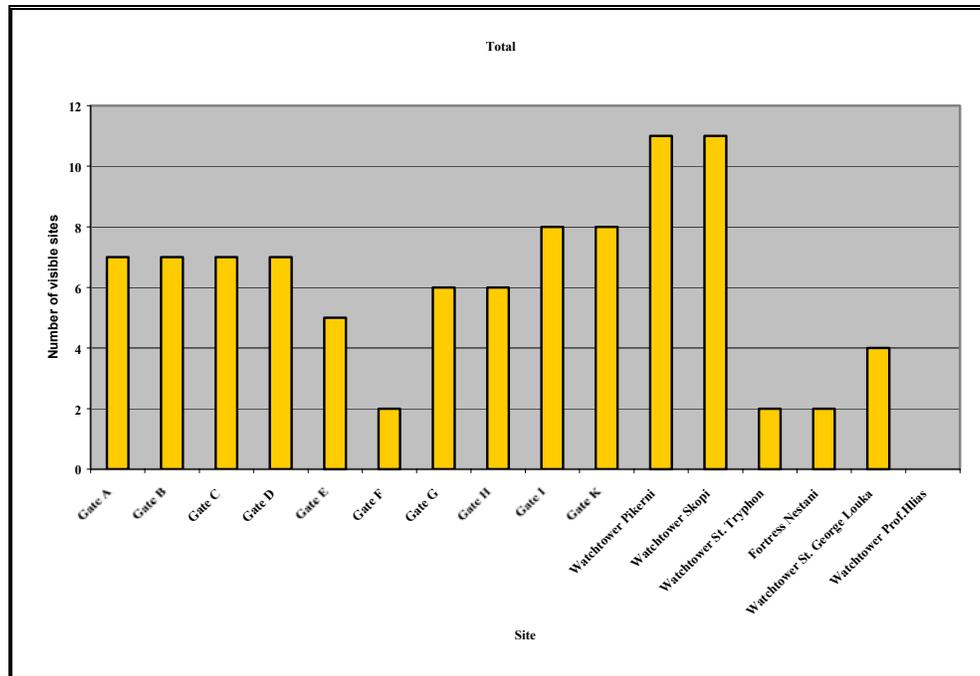
Figure 9 : Chart representing the total number of the visible sites from each defensive construction

After completing the viewshed analysis and having generated the three-dimensional DEM, it was possible to overlay the georeferenced SPOT panchromatic image (10m resolution), the corresponding viewshed analysis results and the location of the archaeological sites (fig.10). It was concluded that the watchtowers were built in order to control areas with ancient road passes, covering gaps in places, which were not directly visible from the city's wall gates. Finally, using the above-mentioned data and serving as visual verification, a three-dimensional fly-simulation was created by setting a route, passing over the defensive structures.

WIDER AREA OF ANCIENT MANTINEIA - PELOPENNESE
OVERLAY OF PANCHROMATIC SPOT IMAGE ON THE 3D DEM (20m contours)
MULTIPLE VIEWSHED ANALYSIS
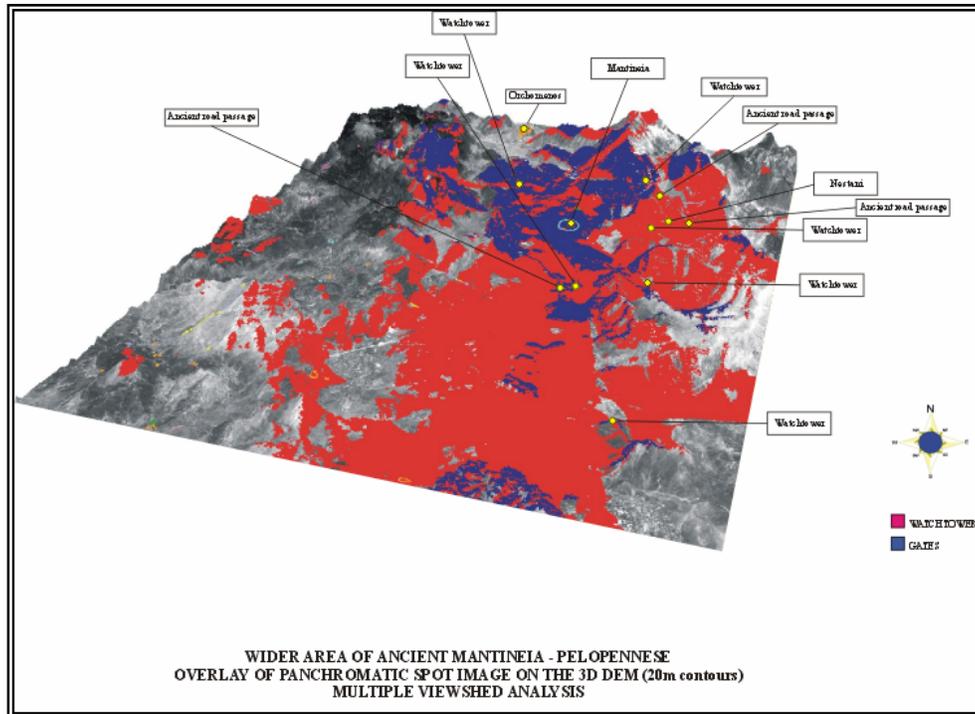
Figure 10 : Overlay of the results of the multiple viewshed analysis of the defensive network of the Mantineia plain, the outline of archaeological features and the SPOT PAN imagery on the 3D DEM.

4.2 Slope and Aspect Analyses

The slope analysis is the measure of surface steepness and it can be calculated in either degrees or percentage values, with the option to rescale the resulting values to span the full 8-bit data value range (0-255). The aspect analysis is a measure of slope orientation and it refers to the direction that the slope faces (Smith 2000). Both analyses were conducted using the DEM. The raster cell size was identical to the DEM cell size (60m.) and the direction of the sun was set to 90° (vertical), being tested to have the best visual result. The slope values are represented in degrees. A value of 0° represents a surface with no slope and 90° represents a vertical plane. Aspect output cell values describe the direction that the slope inclines relative to north. The TNTmips software, which was used to perform the slope and aspect analysis, can create an 8-bit output raster by scaling the 0 to 360 degree range of a compass to the 8-bit data space, using 0 to 240 for the compass direction (0 = north, 60 = east, 120 = south, 180 = west) and 254 indicating no slope (i.e. a flat region).

16

In this was, it was calculated that the city's wall gates are built in an almost flat ground (slope 0-6°), a result that was expected since the city is in the middle of a plain. The watchtowers and the small fortress are built on the top of hills with maximum slope value 39°, surrounded by much steeper slopes, indicating the defensive nature of the sites (fig.11).
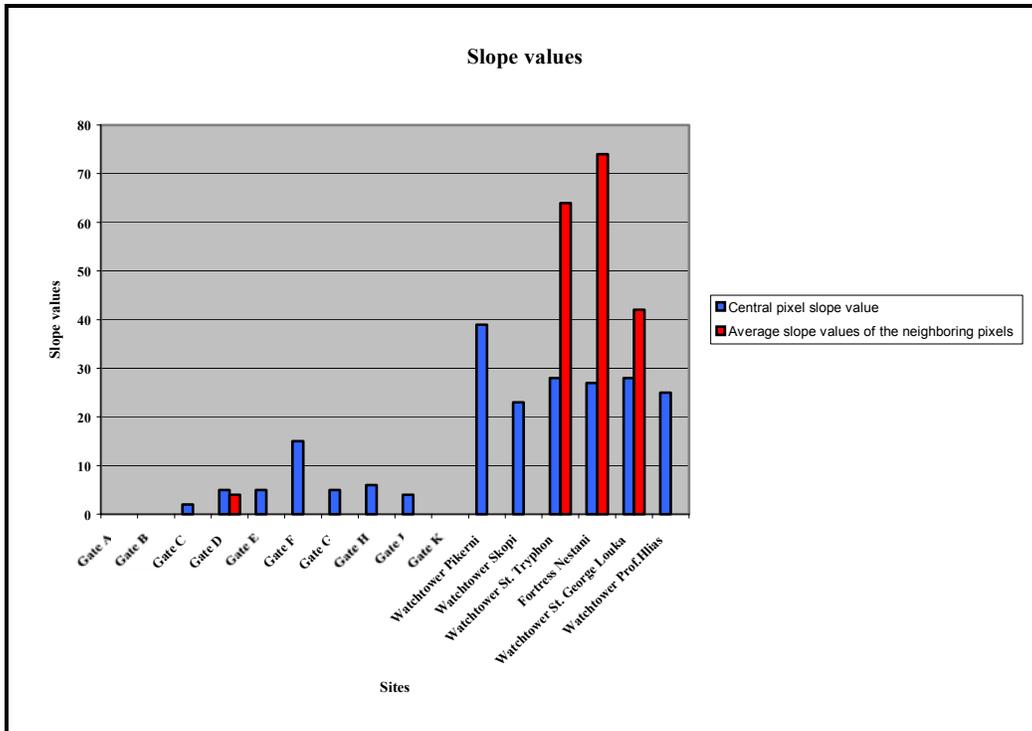
Figure 11: Chart representing the slope values for all the defensive sites

5. Conclusions

The GIS has served as a tool to validate the existence of the defence network in the plain of Mantineia and the extent of its control. It was made obvious that the defensive structures in the area were constructed following a careful planning from the city of Mantineia, in order to control passes and roads, critical for its defence in an eventful chronological period.

Further exploitation of the above results, combined with environmental and archaeological data, could produce a predictive model, for detecting sites of potential archeological interest and a useful tool for the management of the cultural resources of the region.

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