Dimitris Alexakis – Theodoros Astaras – Apostolos Sarris – Kostas Vouzaxakis – Lia Karimali

Reconstructing the Neolithic Landscape of Thessaly through a GIS and Geological Approach

Abstract: Neolithic Thessaly has been traditionally studied to understand human partitioning and territoriality of the landscape by non-hierarchical human groups. Thessaly is a region of low relief with extensive coastline and a great alluvial plain, where hundreds of Neolithic settlements/tells called *magoules* were established from the Early Neolithic period until the Bronze Age. Archaeological data was collected forming a corpus of surveyed and excavated sites and settlements, differentiated by type, size or time-scale of occupation. Reconstruction of the Neolithic landscape was based on synthesis of geological maps, records of stratigraphic data collected from a total of 400 boreholes and the indexing of past studies relative to the geomorphological changes that have affected Neolithic Thessaly from Holocene until today. These were spatially and statistically processed to estimate the amount of alluvial deposits and their distribution on the Thessalian plain from the Early Neolithic period to the present.

Introduction

Due to reasons pertaining to the peculiar geomorphological features of the Thessaly landscape which formed a closed geographical unity with well-defined limits and sub-divisions (see below), Thessaly is ideal for reconstructing the major settlement patterns of the first Neolithic farming groups of Greece, in direct relation to the features of the natural (hydrology, geology) and the human landscape (distance of sites, inter-communication patterns etc.). Thessaly is a relatively closed geographic unit, with definite mountainous borders (Mt. Antichasia and Olympus to the north, Mt. Ossa, Mavrovouni and Pelion to the east, Mt. Othris to the south, and Mt. Pindus to the west, reaching an altitude of 2000 m) with two accesses to the sea, one through the Tempe gorge (NE) and another between the Othrys and Mavrovouni mountains to the gulf of Volos. In the interior of Thessaly due to several tectonic episodes of the past, two localized major basins of different altitude have been formed: the Karditsa and Trikala plain to the SW and the plain of Larisa to the NE.

The goal of the current project is the construction of a model describing the settlement patterns of the Neolithic period in Eastern Thessaly through the reconstruction of Neolithic landscape, and an extensive spatial analysis and multivariate statistical processing of topographic, environmental, satellite and archaeological data.

Research Methods and Materials

The study involved 3D detailed modeling of the Thessaly landscape by incorporating the following modules:

- Topographic mapping through the use of Global Positioning Systems (GPS). The particular task was carried out to map a large percentage (more than 342 settlements) of the existing archaeological sites *(Fig. 1)*. These measurements were used for the GIS analysis as well as for the identification of their spectral signatures to be used in the predictive modeling stage of research.
- Digitization of 1 : 50,000 scale topographic and geological maps of the Geographic Service of the Hellenic Army and of the Institute of Geological and Mineral Exploration. The Digital Elevation Model (DEM) of the study area with a cell size of 20 m was based on the digitized 20 m elevation lines. Geological formations were reclassified to form a unified geological map. Further details of the above maps, such as rivers, lakes, faults and modern villages were also included.
- An archaeological information inventory was also constructed in SQL to include the basic information regarding the archaeological settlements (type of site, chronological phases, type of raw materials present in the sites, etc.) *(Fig. 1)*. Data was collected from previously published gazetteers and recent fieldwork and excavation reports, representing a better and more complete

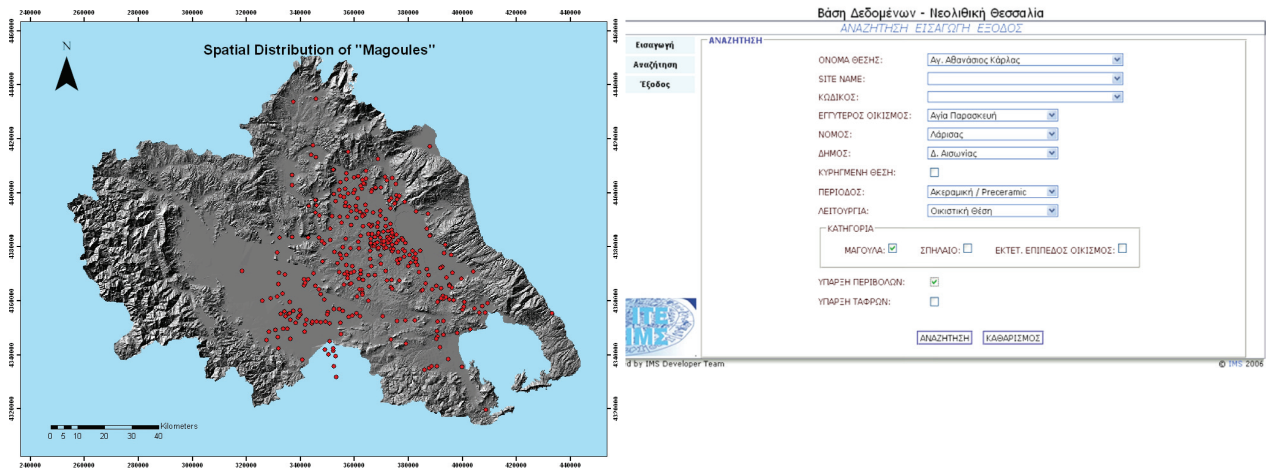

Fig. 1. Left: Spatial distribution of the magoula sites in eastern Thessaly. Right: A sample from the inquiry form of the archaeological database.

distribution of sites than ever before. At the same time, cultural attributes and environmental information that may have played a significant role in the patterning and location of sites accompany the archaeological records.

Following a common geo-referencing of the available data to the local projection system of Greece (GGRS ′87 – Greek Geodetic Reference System), all the data were implemented into a GIS environment.

Landscape Reconstruction

The reconstruction of the Neolithic Thessaly landscape was based on the study of two major regimes, namely the tectonic and the geomorphologic regime. The details of the analysis are provided in the following paragraphs.

Tectonic Regime

In our effort to understand the landscape evolution of Thessaly, we first considered the tectonic regime evolution of the area during the last million years. At Middle Pleistocene, Thessaly was subsided into two grabens which formed the Larisa and Karditsa basins/plains. From a structural point of view, during this period there was a NE–SW tensile trend within Larisa (and Karditsa as well) basin that still dominates the morphology of Thessaly. This was followed by another N–S to NNE–SSW tensile phase during the Middle – Late Pleistocene, which is still active today (Caputo / Bravard / Helly 1994). These were the most significant processes as over the last 10,000 years tectonic processes did not affect the Thessaly landscape on a regional scale.

Regarding subsidence, Demitrack (1986) referred to a rate of subsidence of 1.5 m/1000 years for the Larisa basin, although she has argued that such a subsidence rate should have caused some of the alluvial deposits that nowadays are on the surface to be buried. Other local scale trends and/or fluctuating rates of subsidence may be the answer to this question.

Geomorphologic Regime

Three distinct geomorphologic topics, namely alluvial basins, coast line and lake Karla, were included in the investigations of the geomorphologic regime of Thessaly.

Alluvial Basins

Thessaly consists of two major basins, Larisa Plain with an area of 1020 km^2 and Karditsa Plain with an area of 2210 km^2 which currently contain 181 out of the 342 registered “magoules”. This proves the crucial importance of the reconstruction of the two alluvial basins during the Neolithic period. The reconstruction of the particular alluvial basins was based on the synthesis of the geological maps, the archives of stratigraphic data from boreholes and indexing of past geomorphologic studies.

From a geological point of view, Thessaly belongs to the Internal Hellenides and specifically to Pelago-

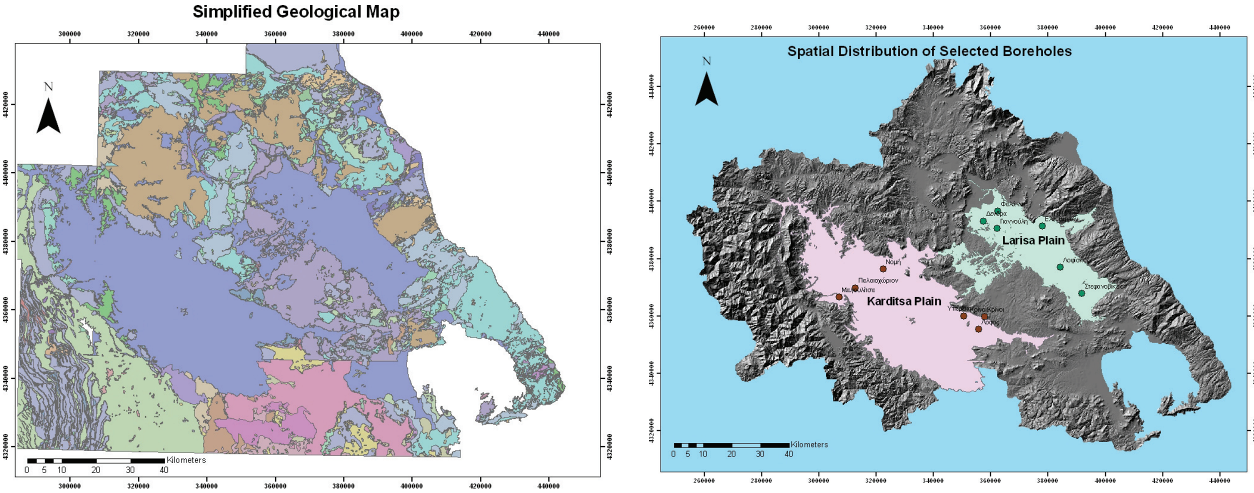

Fig. 2. Left: Generalized geological map of eastern Thessaly. Right: Spatial distribution of the selected boreholes from the basins of Larisa and Trikala, which were used for the reconstruction of the Neolithic landscape.

nian massif to the east and the Pindos range to the west. The known geological formations generalized for homogeneity purposes and a simplified geological map of Thessaly *(Fig. 2)* was created by considering main geological formations: a) Paleozoic to Triassic metamorphics (gneiss, schist, phylitte) – Mesozoic granite, b) Mesozoic limestone, c) Late Cretaceous Flysch, d) Ophiolites (diabase, peridotite, dunite, pyroxenite, serpentinite), e) Oligocene to Miocene conglomerates, sandstones, f) Neogene lacustrine and fluvial deposits, and g) Quaternary alluvium.

Similarly, a geological data base of 50 selected drill cores (based on the quality of data presented) out of a total of more than 400 drill cores collected and reported by the Prefectures of Karditsa, Larissa, Volos, and Trikala was constructed. The depth to the alluvial deposits was estimated based on the most credited drill cores (6 from Karditsa basin and 6 from Larisa basin) *(Fig. 2)*. Provision of the local relief was taken into account for a more accurate and absolute estimation of the alluvium deposits depth.

Finally, estimates of the depth of the deposits (for the alluvial basins) for the three main Neolithic periods can be obtained following Demitrack's assumption (for Larisa basin) about deposition rates (Demitrack 1986): 5.5 m for Late Neolithic, 6.5 m for Middle Neolithic and 8.5 m for Early Neolithic.

Based on the above, the reduction of the drill core data concerning the alluvial deposits for the particular periods can be based on the following algorithm:

$$X = (\mathrm{d}y - y_{\min}/(y_{\max} - y_{\min})) + y_{\min'}$$

where X is the reduced depth of deposits (for the particular drill holes), dy is the current depth of deposits (from drill cores), $y_{\min}$ is the minimum depth of deposits (within the basin from drill cores), $y_{\max}$ is the maximum depth of deposits (within the basin from drill cores) and $y_{\min'}$ is the minimum depth of deposits according to Demitrack (1986).

Although the Quaternary of Trikala-Karditsa basin is less well known than that of the Larisa basin, a similar procedure was followed, due to the fact that depositional processes in the area reflect a parallel history of floodplain deposition and incision, closely related to that of the Larisa basin.

The above estimates were used for calculating (through a best fit line) a much more general equation for converting from the current elevation (namely current DEM of alluvial basins) to the corresponding alluvial depths (reconstructed depths) for each one of the three major Neolithic sub-periods. Six linear equations were approximated to define the depth of the deposits for the three periods of Neolithic for Karditsa and Larisa basins independently *(Fig. 3)*.

The above estimates were applied to all elevations of the two basins and a reconstructed DEM of the basins was formed for each one of the periods of Neolithic. The rest of the altitudes for the mountainous regions remain unaltered. Based on Boolean operations, the reconstructed DEM for the whole region of Thessaly was formed by subtracting the reconstructive alluvial deposits DEM of the Larisa and Karditsa basins (only) from the current DEM of the whole region of Thessaly. An overlay of the magoules on the reconstructed DEM pro-

	Number of sites	Percentage%	Reconstructed depths to alluvial deposits (m)
Early Neolithic Settlements	67	37	<8
	108	59.6	8–10
	6	3.31	>10
Middle Neolithic Settlements	21	11.6	<5
	123	67.95	5–7
	37	20.44	>7
Late Neolithic Settlements	58	32	<4
	97	53.59	4–6
	26	14.36	>6

Tab. 1. Statistical results of the location of the Neolithic settlements (for the three major periods of Neolithic) in terms of the reconstructed depth of alluvial deposits for each period of interest. The classification of the depths is based on the concentration of the data within certain depth limits by taking in account the standard deviation of the samples.

vided valuable information regarding the location of the Neolithic settlements in terms of the altitude *(Tab. 1)*.

After reconstructing the large scale topography of the Thessalian landscape, emphasis was given to the reconstruction of the micro-topography around the settlements. Two factors were taken into consideration: the height of the settlements, (estimated through fieldwork activities) and the excavation information provided for Platia Magoula Zarkou (Van Andel / Gallis / Toufexis 1992). The particular data were statistically processed following a classification of magoules to 14 categories according to their duration of habitation. The reduction of the corresponding heights was based to the cross-section plan of Platia Magoula Zarkou provided by Van Andel / Gallis / Toufexis (1992). Taking into account the mean diameter of magoules (approximately 150 m), three buffer zones of 50 m each around each magoula were also created. The first (central) buffer zone kept the height of each magoula as mentioned above, whereas in the second (middle) and third (outer) zones the height was gradually reduced by 50% and 25% of the initial height correspondingly *(Fig. 4)*. In this way, the final estimate that was used for the reconstruction of the DEM within the vicinity of the magoulas was given through the sum of the landscape reconstructed DEM, the 0–50 m DEM zone, the 50–100 m DEM zone and the 100–150 m DEM zone.

Coastline

A rise in the sea level by 100–120 m has been noticed after the last glacial period of Wurm all over the Aegean Sea. This melt affected the coastline of Thessaly especially towards the coastal zone of Volos and Almyros plains within areas consisting of Holocene alluvium deposits. In order to examine the changes to the coastline during the Early Neolithic to the Late Neolithic period, the results of the study of Kampouroglou (1994) were adopted. Kampouroglou made approximate plans of the Neolithic coastline of Volos plain based on a number of drill holes within the Volos basin. The particular plans were geo-referenced with the help of multispectral imagery (ASTER) and compared to the current coastline. According to the spatial measurements carried out in different sections of the coastline, it was noticed that in the Early Neolithic period the coastline was about 650 m seawards, whereas during the Late Neolithic period the coastline has moved 300 m inland in comparison to the current coastline *(Fig. 5)*.

Lake Karla

The extent of ancient lakes is considered to be a crucial factor for the reconstruction of the Neolithic landscape. Lake Karla to the SE of Larisa plain has been known to exist in antiquity, although its extent was extremely variable due to the different climatic conditions in different periods. Nowadays

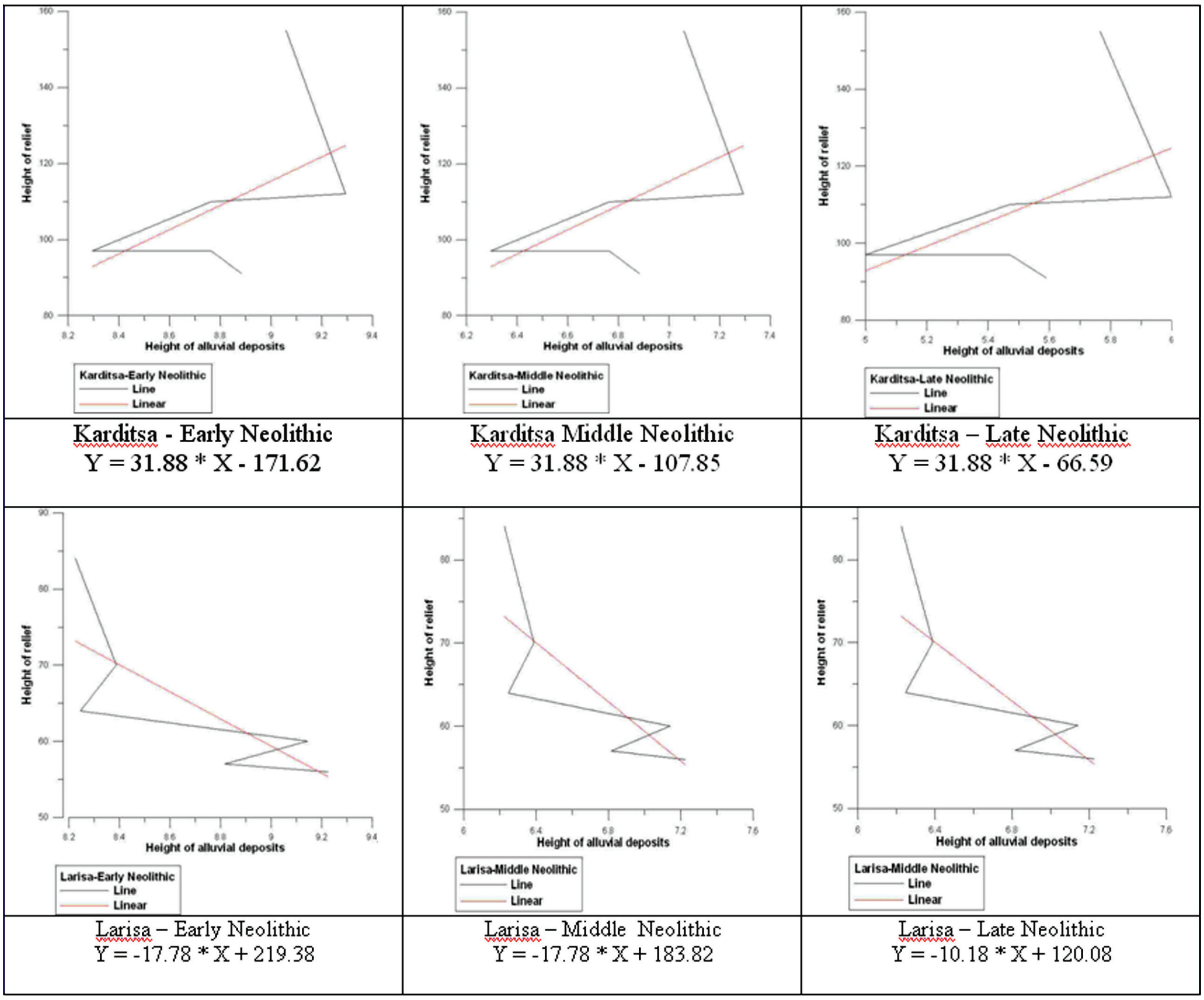

Fig. 3. Linear equations estimating the reconstructed depths to the alluvial deposits of the three Neolithic periods (early, middle and late) for each one of the major basins of Thessaly (Karditsa and Larisa). In the above formulas, Y is the current elevation and X is the reconstructed alluvial deposits depth.

lake Karla has dried out although there are plans for its re-creation.

Due to its distinct settings, a completely different alluvial deposit model was used for the reconstruction of lake Karla during the Neolithic. The model was based on the outline of its prehistoric extent provided by Grundmann (1937) and the spatial distribution of magoules around its shoreline, as they have been recorded by the latest GPS survey. The data suggested the lake level (during the Neolithic

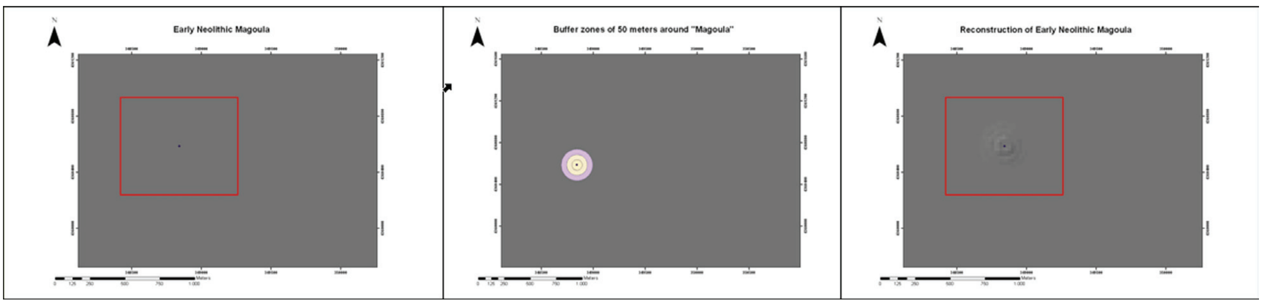

Fig. 4. Reconstruction of the micro-topography around the Neolithic Magoules. Left: Point location of the magoula. Middle: buffer zones created around the magoula. Right: reconstructed DEM around the magoula.

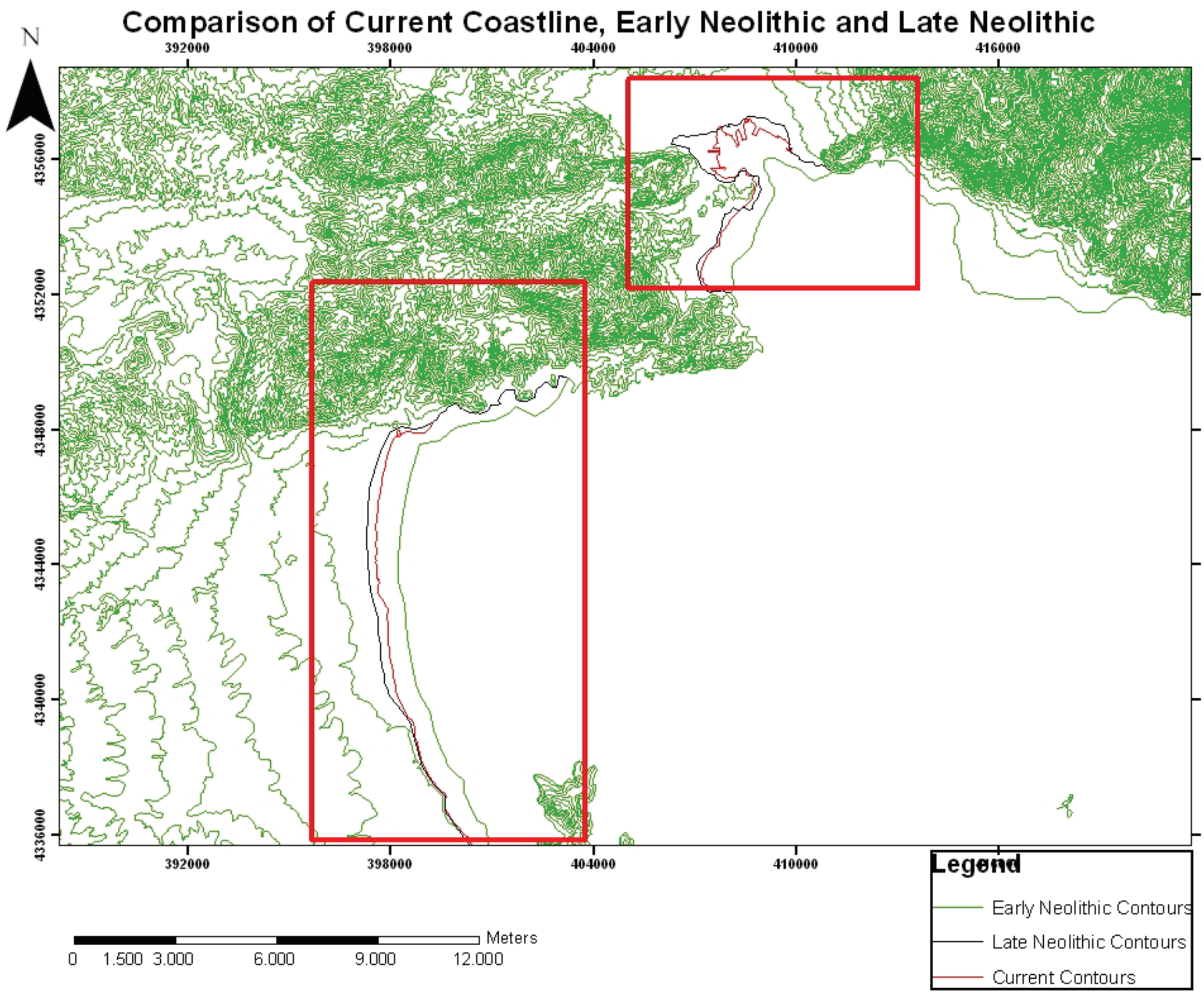

Fig. 5. Comparison of the current coastline with the reconstructed coastlines for the Early and Late Neolithic periods.

period) extended to the 40 m contour line in agreement to Halstead (1984), who considered the lake levels to exist below the 44 m.

Conclusions

Geological studies and archaeological evidence contributed to the reconstruction of the landscape of Neolithic Thessaly. Each one of the local environments of the Thessalian plain was approached in a very different way to model the macro-topography of the Neolithic period. The micro-scale relief changes around the magoules were also taken into account through the existing archaeological evidence. A total area of approximately 3250 km², corresponding to 24% of the total relief, has been affected by the modeling process. In the end, 181 "magoules" out of 342 were laid onto a modified relief terrain. The results of the project are expected to contribute to a better and much more accurate analysis (through GIS spatial analysis) of the settlement patterns of Neolithic Thessaly than those carried out until now.

References

Van Andel / Gallis / Toufexis 1992
T. Van Andel / K. Gallis / G. Toufexis, Early Neolithic farming in a Thessalian river landscape, Greece. In: Mediterranean Quaternary River Environments Proceedings (Cambridge 1992).

Caputo / Bravard / Helly 1994
R. Caputo / J.-P. Bravard / B. Helly, The Pliocene-Quaternary tecto-sedimentary evolution of the Larissa Plain (Eastern Thessaly, Greece). Geodinamica Acta 7, 1994, 57–85.

Demitrack 1986
A. Demitrack, The Late Quaternary Geologic History of the Larisa Plain, Thessaly, Greece: Tectonic, Climatic

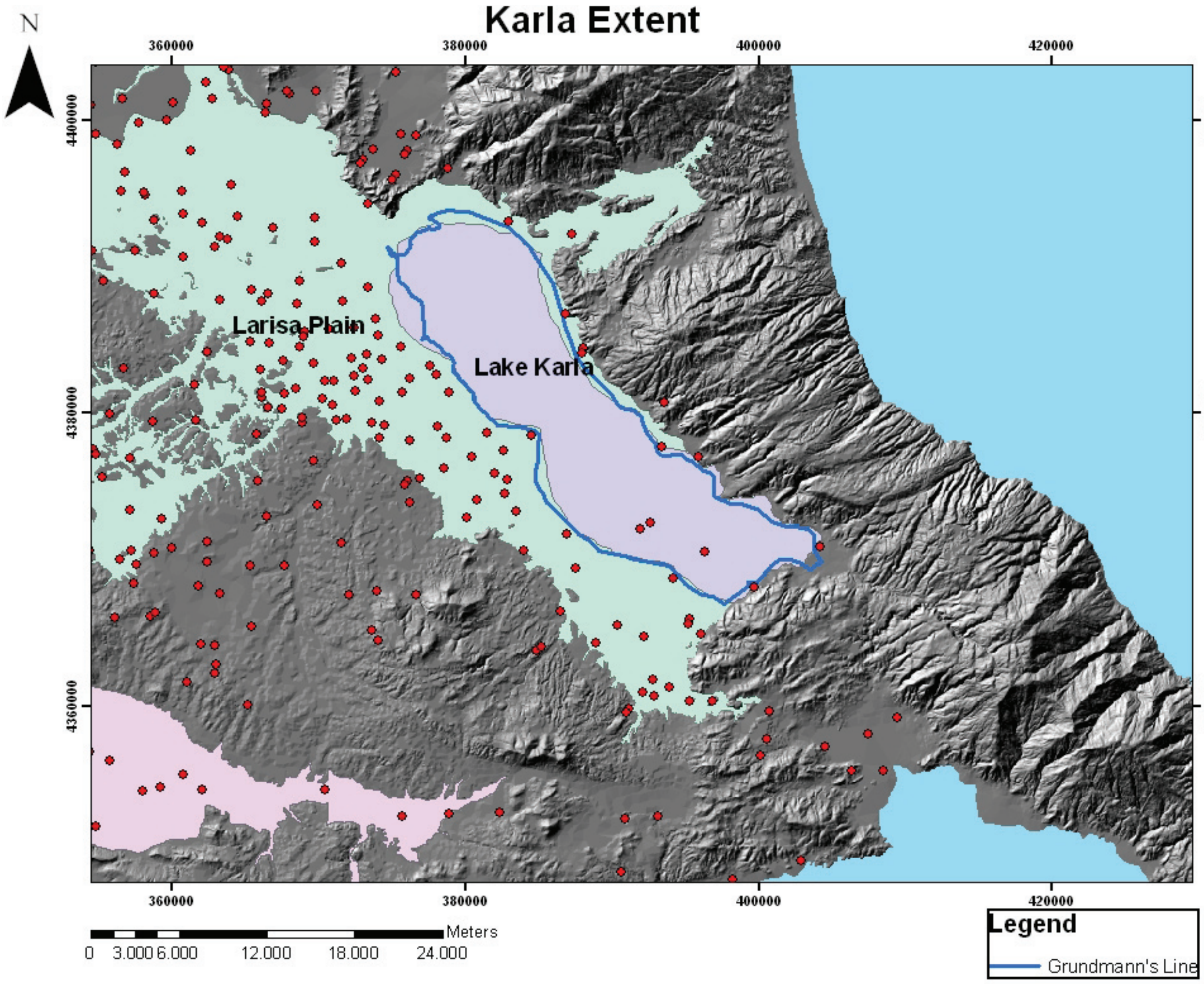

Fig. 6. The area of lake Karla. The red dots represent the Neolithic magoules around the lake. The blue line is the suggested lake level according to Grundmann (1937). The purple color is the suggested extent of the lake according to the recent study. The green color represents the Larisa plain.

and Human Impact on the Landscape. PhD Thesis (Stanford 1986).

Grundmann 1937
K. Grundmann, Magoula Hadzimissiotiki. American Antiquity 62, 1937, 56–69.

Halstead 1984
J. Halstead, Strategies for Survival: An ecological Approach to social and economic change in the early farming communitites of Thessaly, N. Greece. PhD Thesis (Cambridge 1984).

Kampouroglou 1994
E. Kampouroglou, H Geomorphologiki Exelixi toy Kolpou toy Volou apo tin Neolithiki Epochi mexri Simera. In: J.-C. Decourt / B. Helly / K. Gallis (eds.), La Thessalie – Quinze anees de recherches archeologiques, 1975–1990: Bilans Et Perspectives. Actes du Colloque International Lyon, France, April 17–22 1990 (Athen 1994) 41–52.

Dimitris Alexakis
Theodoros Astaras

Aristotle University of Thessaloniki
Department of Physical and Environmental Geography
School of Geology
Remote Sensing and GIS Applications Laboratory
Thessaloniki 54124
Greece
alexakis@chania.teicrete.gr
astaras@geo.auth.gr

Apostolos Sarris
Lia Karimali

Foundation for Research & Technology, Hellas
(F.O.R.T.H.)

Institute for Mediterranean Studies
Laboratory of Geophysical – Satellite Remote Sensing & Archaeo-Environment
Rethymno 74100
Crete
Greece
asaris@ret.forthnet.gr

Kostas Vouzaxakis

Archaeological Museum of Volos
13th Ephorate of Prehistoric and Classical Antiquities (Volos)
Athanassaki 1
38001, Volos
Greece
kvouz@hol.gr