CHAPTER 7

GEOGRAPHICAL INFORMATION SYSTEMS (G.I.S.) AND ARCHAEOLOGY: APPLICATION IN FIELD SURVEYS

PERIKLIS CHRYSAFAKOGLOU

PERIKLIS CHRYSAFAKOGLOU

GEOGRAPHICAL INFORMATION SYSTEMS (G.I.S.) AND ARCHAEOLOGY: APPLICATION IN FIELD SURVEYS

Periklis Chrysafakoglou: Geographical Information Systems (G.I.S.) and Archaeology: Application in Field Surveys, in: Yannis Chatzikonstantinou (ed.) (2024): Archaeozooms: Aspects and potential of modern archaeological research. Heidelberg: Propylaeum 2024, 132-153. https://doi.org/10.11588/propylaeum.1319.c19009

Abstract

Geographical Information Systems are digital tools derived from the combination of different technologies in application fields related to data management, digital design, automated cartography, and image processing that enable the creation of new spatial information. The evolution of archaeological thought and the availability of new technologies led to their utilization by the archaeological world. G.I.S. manages spatial properties by using space as the common denominator for connecting the data, thus offering the possibility to connect archaeological data with the spatial features of a map and explore new correlations. The spatial analysis tools of the G.I.S. allow complex spatial and statistical analysis to be carried out, creating new data in terms of exploring spatial relationships between archaeological data and understanding complex archaeological phenomena. The combined approach of landscape, archaeological finds, and geospatial data through the tools and applications of G.I.S. is applied to a case study in a group of Neolithic sites in Thrace focusing on the distribution and density of surface finds.

Introduction

Geographical Information Systems (GIS) are digital tools that derive from the combination of different technologies applied in fields related to data management, digital design, automated cartography, and image processing (Wheatley and Gillings 2002, 9-10). Essentially, a GIS is a database system with specific capabilities for spatially referenced data but can also carry out a set of functions aimed at analyzing the data (Wheatley and

Gillings 2002, 9). Their use extends to different disciplines as their software develops, providing new opportunities for further development (Κατσιάνης 2009, 69) creating new spatial information (Savage 1990, 23).
The operation of GIS is based on the data input mechanisms that transform the raw information into digital form and suitable for processing (map digitization), the information storage units that govern the retrieval and updating of the database, the data management tools that perform the spatial analyzes and essentially produce the new information and in the data visualization environment which allows the visual examination of the analysis through the form of a map (Marble 1990, 12).
Using the GIS, it is possible to link the graphical cartographic representation of each spatial object with additional information related to the object's thematic characteristics or the researcher's observations stored in a database. Specific spatial analysis techniques were developed and integrated into these systems, giving the ability to retrieve spatial relations by formulating spatial and topological queries. The particular needs of specific research fields have caused the development of many different spatial analysis tools. Based on the above, the user of the GIS actively participates in all stages of the cartographic process, from the processing of information to the final use of the digital map (Τσιπίδης 2009, 18-9).

Data and GIS

The data entered into a GIS application is distinguished into attribute, spatial, and graphic data. The attribute data is the information related to the spatial data. In order to use them through the application, the information is stored in a database system connected with the GIS application (Καρανικόλας 2007, 9). This data is usually numbers, words, texts, drawings, and symbols (Figure 1).

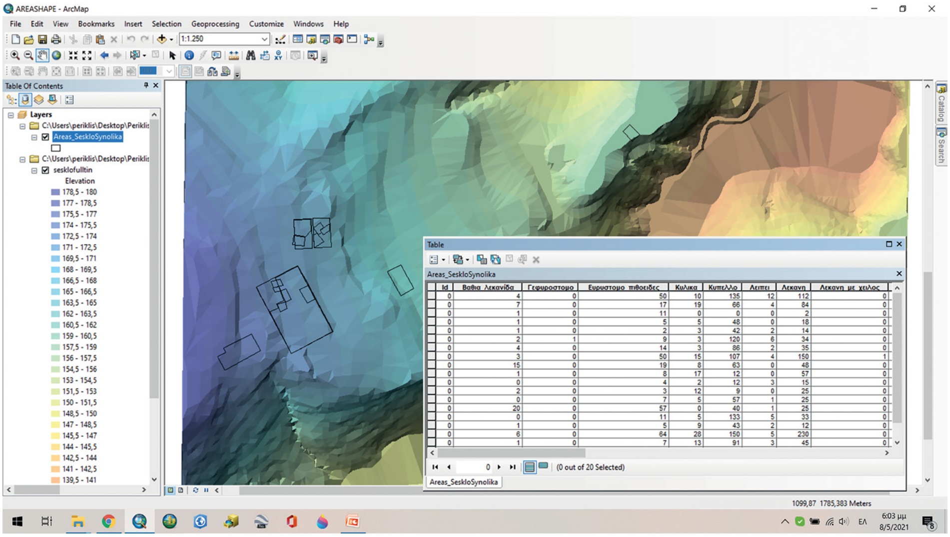

Figure 1 : Attribute table in the digital environment of ArcGIS software. (Chrysafakoglou Periklis)

Spatial data (geometry data) describes geographic features of the real world. The correlation of individual points, lines, or areas in digital form with objects of the real world is usually done through their incorporation into a coordinate reference system (Καρανικόλας 2007, 7). Spatial data imported into a GIS is mapped to a geographic, cartographic, or cartesian coordinate system (Marble 1990, 20).
Spatial data is in the digital form, either in mosaic format (raster) or in vector format as polygons, lines, or points (Figure 2). These two kinds of computer files differ in how they store, process, and display spatial data and the type of data each one represents (Conolly and Lake 2006, 24).

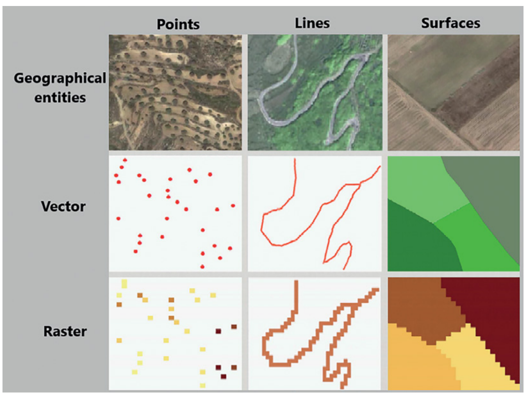

Figure 2: Discrete and continuous display of geographic entities in GIS (Κατσιάνης 2009, 156).

The digital data in raster format depicts an area on the ground, structured in a table as tiles. Each tile has a value that represents some feature (color, temperature value). The setup of raster spatial data in a mosaic format allows the application and analysis of remote sensing data of aerial photographs and satellite images. This structure is advantageous over vector models as it is more suitable for computer calculations. The user can perform complex analysis relatively quickly and with high accuracy, limiting computational errors (Conolly and Lake 2006, 28). Disadvantages of the raster digital data are the large memory and computing power requirements for their processing, but also the inability to render proximity correlations between the geographic features attributed (Καρανικόλας 2007, 7-8).

Digital data in vector format is used to render geographic features using points for point features, lines for linear features, and polygons for surfaces. The spatial information that makes up the points, lines, and polygons is registered in the vector digital file with their coordinates in a particular geographic reference system (Καρανικόλας 2007, 8). Thanks to cartesian coordinates, the features are depicted with great precision in space (Conolly and Lake 2006, 25). Each object in vector format representing a geographic feature can be associated with attribute information (Καρανικόλας 2007, 8). With this capability, vector files can be associated with object properties that contain qualitative and quantitative information (Conolly and Lake 2006, 25). Vector files are characterized by low memory requirements and lower computing power for their processing compared to raster digital files. In contrast to digital raster data, vector data is registered information on the proximity correlations between the rendered geographic features (Καρανικόλας 2007, 8-9).

The spatial and attribute data combination is based on the relational or object-oriented data model. In the relational model, attribute data is organized into tables and later associated with spatial data through unique values common to both data types. In the object-oriented model, spatial and attribute data are merged into objects that model some other objects or natural features with a spatial dimension (Kim 1990, 327-39).

GIS Software

The first commercial software of GIS was created at the end of the 1980s (Κατσιάνηs 2009, 135). The available GIS software sets are divided into closed-source and open-source or free software.

Closed Source Software is a commercial package published by specific companies and marketed as executable files. The software user cannot intervene, format, or develop them further. The Closed Source Software is advantageous in terms of support from the company by ensuring a level certified to international standards. On the contrary, the high cost and the inflexibility in matters of development act as a deterrent to their choice (Καρανικόλαs 2007, 1). The most common of this type is the ArcGIS software of the ESRI Company.

Open Source Software or Free Software is software that anyone can use, distribute, copy, and modify according to specific needs without requiring the acquisition of a license. Through the free availability and source code of the Open Source Software, the user is provided with the possibility of changes and improvements. The disadvantages of this type of GIS are the lack of certification by a global standard as well as the absence of support from a provider (Καρανικόλαs 2007, 1-3). More known Open Source Software is GRASSGIS and QUANTUMGIS (Καρανικόλαs 2007, 5).

GIS in Archaeology

The GIS was initially applied to archaeological research in the mid-1980s (Κατσιάνηs 2009, 135), with the first attempts being made in North America and Europe (Kvamme 1983; Harris 1986; Wansleeben 1988; Murray 1995). In Greek projects, the use of the GIS became more popular in archaeological research in recent years, which were undertaken by universities, research institutions, and state agencies (Αλεξάκηs 2009, 95). The interest of the archaeologist in the use and application of the GIS was also expressed by the writing of manuals on their use in archaeology (Wheatley and Gillings 2002; Conolly and Lake 2006).

Advances in spatial technologies have offered new opportunities to upgrade archaeological records from earlier research. Therefore, the GIS contributed to geometric modeling processes, integrating and managing spatial data produced using different techniques and transcribing information in conventional or digital documentation. At the same time, the user can use a set of ancillary spatial data, such as the topography of the site, aerial photographs or satellite images of an area, geoarchaeological information, data from archaeological surface surveys, test sections, or even past excavations (Pessina 2001, 179-84), evidence from geophysical survey and soil analyses (Neubauer 2004, 159-66). New dynamic ways of interacting with the content of an archaeological archive in the context of a cartographic environment are thus formed, making it possible to understand the correlations and differences at the level of space and time. At the same time, the grouping of the data and the quantitative analysis facilitate the extraction of additional results (Katsianis et al. 2014, 46).

The use of GIS in a wide range of archaeological applications and the functionality they have demonstrated are primarily related to how spatial data is managed. Their purpose is not only the organization of data but also the creation of new information through questions and correlations (Κατσιάνης 2009, 75). GIS manages spatial properties using space as the common point in connecting the data, thus offering the possibility of linking archaeological data with the spatial features of a map and exploring new correlations (Neubauer 2004, 161). The spatial analysis tools of the software allow complex spatial and statistical analysis to be carried out, creating new data in terms of investigating spatial relations between the archaeological data that lead to the understanding of complex archaeological phenomena (Τσιπίδης 2009, 40). The different applications of GIS in archeology rely on their software's ability to perform specific processes in dealing with particular issues.

Forms of application and use of GIS

SITE PREDICTION MODELS

One of the first applications of GIS was its use as a tool for creating site prediction models, mainly in North America (Kvamme 1995). The creation of a prediction model is applied to the attempt to locate archaeological sites in a region through the similarities of the characteristics already present in known archaeological sites in another similar region (Conolly and Lake 2006, 179). The site prediction model approach has been criticized, and archaeologists gradually reduced its use quite a bit (Conolly and Lake 2006, 180). In recent years, however, a new approach has been attempted due to the availability of new data, such as satellite images.

ARCHAEOLOGICAL SITES MANAGEMENT

The application of GIS has also found productive ground in the management of cultural heritage. The basic principle of their use is the creation of databases with features of interest to the user (e.g., archaeological sites, cultural monuments) and their integration into the applications and tools of the GIS. As a result, the spatial rendering of cultural heritage features occurs in a cartographic environment without losing their attribute information. It thus becomes possible to create correlative questions about archaeological sites, enabling them to be studied within a broader social context (Conolly and Lake 2006, 33-4).

FIELD RESEARCH

In field archaeology, the use of the GIS is separated into two categories depending on the scale of the analysis. The first category is related to investigations of an area at a large scale, such as an archaeological surface survey, the extent of which can vary according to each research subject and aims, while the second is to investigations of a limited scope, such as excavations. In the former, using GIS proved very useful from an early use stage. On the contrary, in the latter, the GIS application was initially characterized as insufficient but has gradually been applied more often as techniques and technology advance (Katsianis and Tsipidis 2005).

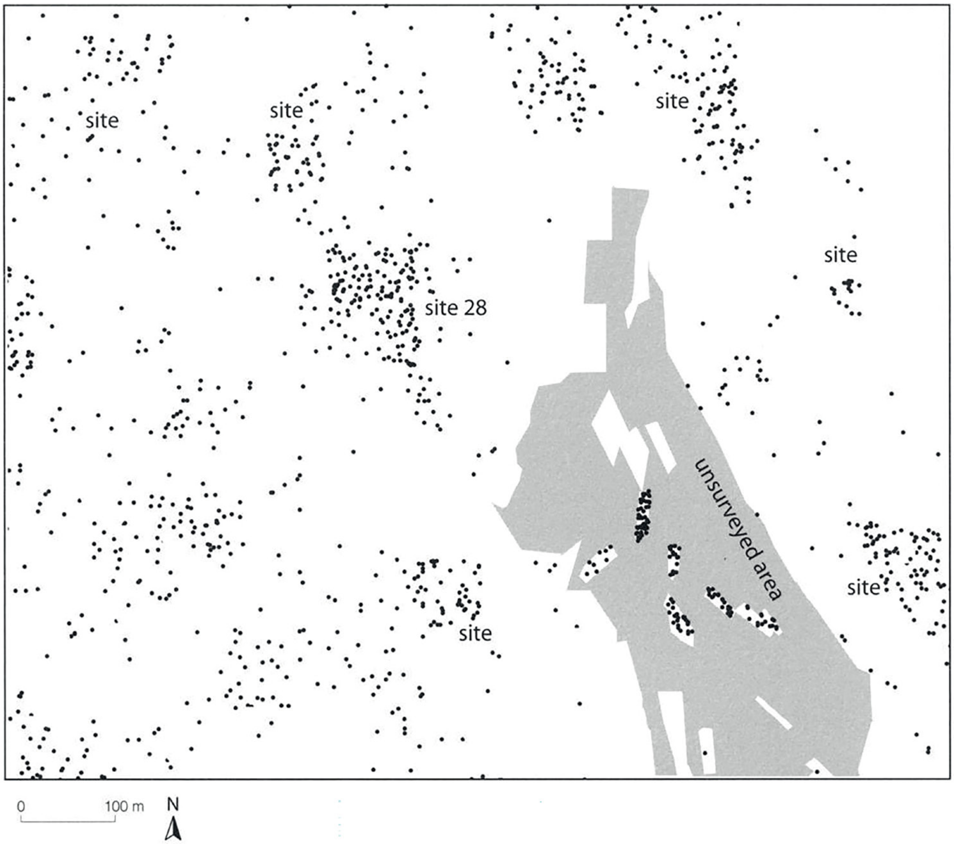

Figure 3: Distribution of pottery finds from a surface survey on the island of Kithira (Bevan and Colony 2004, 130).

In the cases of the first category, the researchers take advantage of the analytical possibilities of the GIS to create applications that cover different issues related to the interaction between humans and landscapes (Figure 3). The user/archaeologist has the ability and flexibility to adapt the digital cartographic data and shape its structural elements (scale, symbolism) by constructing thematic maps that respond to research questions (Τσιπίδης 2009, 40). By mapping the under-study areas by creating multi-level spatial data and suitable visualizations, it becomes possible to display the complexity of spatial information in a modern and comprehensible way. The connection of the archaeological monuments with a small or medium-scale geographical relief highlights the relation of the ancient constructions with their natural environment, the geographical relief, as well as the natural or artificial formation of the surface (Παπακωνσταντίνου et al. 2014, 11). Attempts were made to approach the landscape from different theoretical perspectives with various analytical methods from other fields of application. However, the inability to guide the use of GIS in a more theoretical and cultural direction led to a partial questioning of their appropriateness in such cases (Katsianis and Tsipidis 2005). In the intra-excavation application, the GIS was initially utilized to store and manage the information produced by an excavation and its presentation. Through the digital environment, the spatial analysis of various uncovered finds, including stable features, is also possible (Katsianis and Tsipidis 2005; Katsianis et al. 2008). Essentially, the GIS was initially used as a mapping tool that allows better management of the excavation design file at discrete levels of relevant information (Κατσιάνης 2009, 70). According to the latest studies, it appears that by applying different configuration processes and utilizing existing information, it is possible to integrate spatial data and the process of creating standards. The combination of the above with post-excavation studies of stratigraphy and finds and their depiction in a three-dimensional cartographic environment leads to the understanding of stratigraphic sequence and spatiotemporal patterns (Figure 4). Data clustering and quantitative analytical techniques enhance information extraction processes (Katsianis et al. 2014, 47).

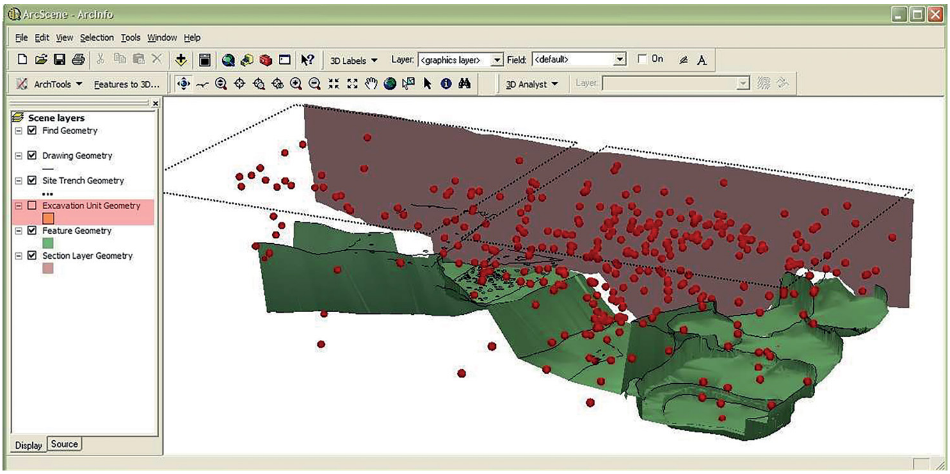

Figure 4: 3D distribution model of excavation finds (Κατσιάνης 2009, 259).

Advantages and disadvantages of the GIS

Using GIS applications, the creation of two-dimensional and three-dimensional maps becomes more accessible and less expensive. After the maps are completed, correcting and adding new data and viewing the map information at different levels and scales is possible. At the level of the digital map, it is possible to accurately calculate a series of questions (e.g., the density and the distance of finds), which in a conventional form of visualization would be difficult or even impossible. Perhaps the most essential advantage is the accuracy of the geographic information provided through applications and georeferencing systems. At the same time, the interaction with databases provides data entry reliability and thus avoids errors. In more practical matters, the storage and transfer of digital data used by the GIS is much easier and faster than the corresponding conventional methods.
The main disadvantage of the GIS is the high cost of acquiring and maintaining equipment support. At the same time, the need for specialized staff makes their access and use problematic for the general public.

Case study: Prehistoric Thrace

The interest in the systematic study of prehistoric Thrace has dramatically increased in recent decades (Ευστρατίου and Καλλιντζή 1994, 7). However, specific references to the region of Thrace are lacking in the literature, despite the pivotal geographical position of the Rhodope plain and the Evros valley between the Aegean, the Balkans, and Anatolia during the significant changes of prehistory (Andreou et al. 1996, 591). Among the research carried out during the last century, those of G. Bakalakis, D. Theoharis, D. French, and D. Triantafyllos stand out. From the first studies, it was realized that the prehistoric communities, which developed in Aegean Thrace from the end of the 6th millennium B.C., had close cultural relations with the settlements of southern Bulgaria and eastern Macedonia, having nevertheless formed cultural characteristics indicative of a separate geographical area. Prehistoric sites were identified in all three regional units (R.U.) of the Aegean Thrace (Xanthi, Rodopi, Evros), with most of them located on low hills, along the rivers and in coastal areas, but also in two caves (Ευστρατίου and Καλλιντζή 1994, 7-11). Few were investigated by excavation or with geophysical methods: Paradimi, Krovili and Proskinites (Rodopi R.U.), Makri (Evros R.U.), Lafrouda and Diomedia (Xanthi R.U.) (Ammerman et al. 2008; Andreou et al. 1996, 591-3; Bakalakis and Sakellariou 1981; Καλλιντζή and Παπαδόπουλος 2007).

In the rest of this article, I'll present the application of GIS in a systematic archaeological surface survey of selected prehistoric settlements, which was carried out within the Mapfarm project. The settlements included are Diomedeia, Paradimi, Yfantes, Krovili, Nea Santa, and Mylon Mana. Most included sites have not been excavated or were investigated by trial trenches of a limited extent, which didn't provide information on the spatial organization of the settlements or for other aspects of their residents' lives except for some attributes of their material culture.

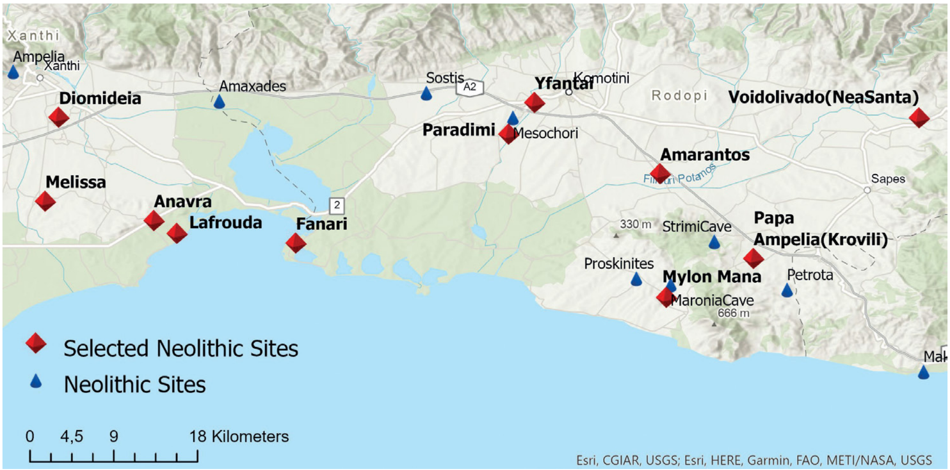

Figure 5: Selected sites in Thrace examined by the Mapfarm program (https://mapfarm.he.duth.gr/node/55).

METHODOLOGY

Research of selected prehistoric settlements in the area of Aegean Thrace included the collection of available published information for those settlements from the literature, alongside the utilization of the results of an intensive field survey carried out on each of them (Urem-Kotsou et al. 2022, Σγουρόπουλος et al. 2022). Information collected from literature and fieldwork concerns the topography of the settlements, the distribution of the archaeological finds on the ground surface, and their chronology. A key detail in the process of recording findings in the field is the use of a highly precise Global Positioning System (GPS) (Urem-Kotsou et al. 2022, Σγουρόπουλος et al. 2022). All data collected during the archaeological surface survey were stored and organized in a single digital database, processed, and studied using GIS applications. The archaeological and geospatial information was imported into the digital environment of the software, allowing the combined observation and study of the data, giving evidence related to the size and the extent of the settlements, the use of space, the distribution, and the density of archaeological finds.

FINDS DENSITY

Basic questions that concern a large part of archaeological studies, especially research that focuses on prehistoric settlements, are related to identifying and determining the size of the settlements and human activities outside the residential areas. The identification of human activity in the natural landscape is mainly achieved through the archaeological remains found during field research in an area, either through an excavation or a surface survey. It is generally accepted that the quantitative and qualitative distribution of archaeological finds on the surface has the potential to define the extent of the site and the type of activities that took place in the past (Renfrew and Bahn 2001, 85-7). Using GIS in conjunction with the archaeological record can significantly assist in answering the questions related to the settlements' identification and extent. Visualization of the distribution pattern of surface finds analytical methods for identifying concentrations of characteristic archaeological finds and their clustering, which indicate the use of space and thus define the sites, and "interpolation methods to help understand off- and on-site distributions" are some of the methods that have been applied (Bevan and Conolly 2004, 129-30).

In the case of the selected prehistoric settlements in Thrace investigated within the MapFarm project, a new approach in the recording of surface finds in the field was applied, which is based on the digital recording that ensures the high accuracy of their distribution and thus of the results of the surface survey (Urem-Kotsou et al. 2022, Σγουρόπουλος et al. 2022). Through the variety of GIS applications and tools, specifically the ArcGIS Pro software, digital files were created in raster format, indicating the degree of density of archaeological finds in the areas under study. The calculation of the density of archaeological finds results from the relationship of the location of each individual recorded find compared to the other recorded in the field, comparing the distance between them and their position in the field.

The application of the GIS in the density calculation of surface finds and the approach briefly described above was carried out on the sites of Paradimi, Krovili, Nea Santa, Mylon Mana, and Yfantes in the Regional Unit of Rodopi and the site of Diomedia in the Regional Unit of Xanthi (Figure 5). Of the above sites, Nea Santa and Mylon Mana do not have morphological features that characterize tell settlements and, for this reason, are considered flat-extended settlements. The other four belong to tell-type sites. The study's first results indicate differences in the distribution pattern and the density of surface finds between different types of settlements, but also some common characteristics. The common feature observed at all sites is the absence of a high density of finds at the peripheral areas of the sites, regardless of the type of settlement. However, some settlements like Yfantes were affected by natural changes in the landscape where the nearby river had cut off part of the settlement. In such cases, the finds from the settlement's periphery are missing. On tell-type sites that include Krovili, Yfantes, Paradimi, and Diomedeia, two different patterns are observed in the distribution of archaeological finds. Investigations at Krovili (Figure 6: C) and Yfantes (Figure 6: F) show an increased density of finds in the higher altitude areas. At the same time, gradually, as we move away from the top of the tell, it decreases.

On the contrary, at Paradimi (Figure 6: B) and Diomedeia (Figure 6: A), the concentrations of archaeological finds cluster in different areas without having a smooth fluctuation. Especially at Diomedia, a site with a reasonably large area with surface finds, and the most extensive set of recorded finds, the highest density of finds is observed in the southwestern and northeastern parts of the site without corresponding values in the center of the tell. Finally, at Nea Santa (Figure 6: D) and Mylon Mana (Figure 6: E), a high frequency of recorded finds is observed in patchy form in areas of small extent, which could be related to the different intra-site distribution of activities at these two flat-extended sites than may have been at tells.

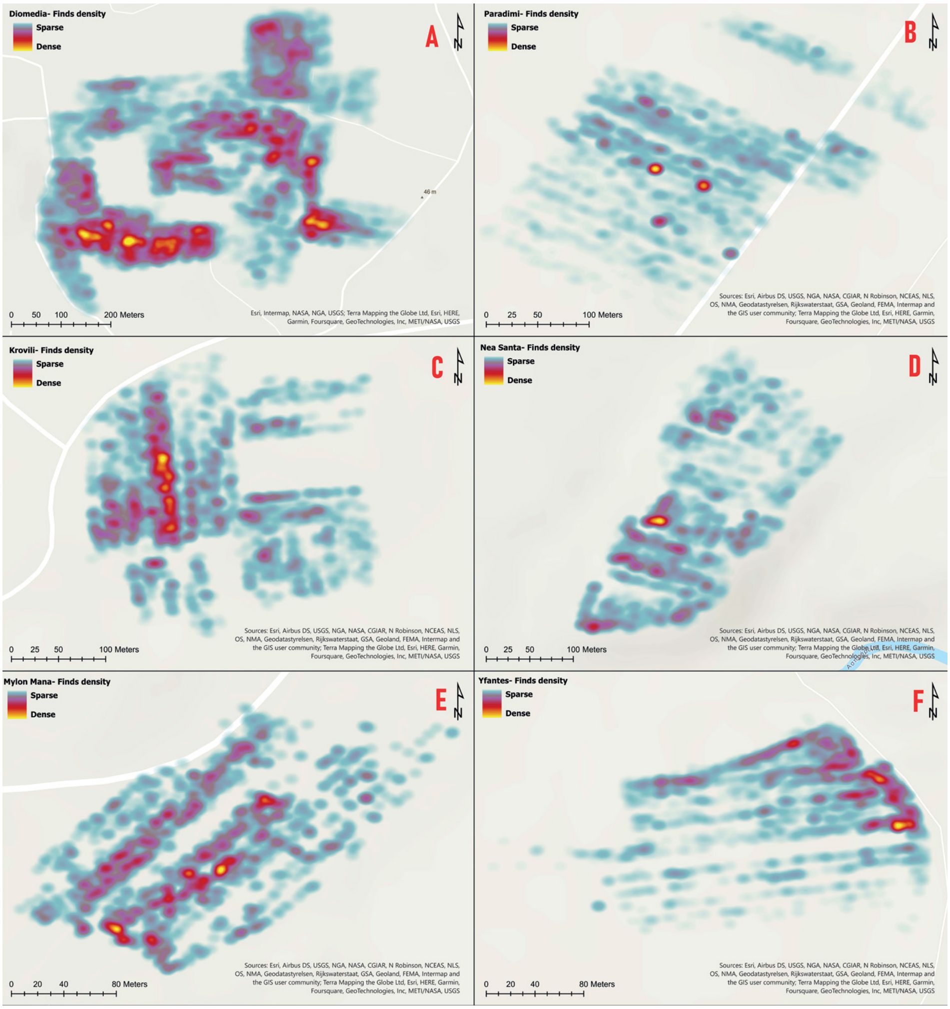

Figure 6: Density distribution of surface finds from A) Diomedeia, B) Paradimi, C) Krovili, D) Nea Santa, E) Mylon Mana and F) Yfantes. (Mapfarm, Chrysafakoglou Periklis)

Discussion-Conclusions

The use of GIS in recording and processing surface finds applied in archaeological surface surveys at the selected Neolithic settlements in Aegean Thrace allowed fast and precise recording of surface finds distribution and data processing. The immediate visualization of the surface finds' distribution is realized through the combined use of satellite photos and the creation of different digital backgrounds from high-resolution orthophotos and 3D models of the archeological sites using an uncrewed aircraft (drone) and Ground Control Points, whose coordinates were measured with high accuracy RTK GPS receiver (Urem-Kotsou et al. 2022). These offered a more straightforward reading of the diversity in the density of surface finds recorded during the field survey and have indicated some differences between the settlements of different types. The distribution and density of finds tend to be higher in the center of the tell sites and gradually decrease as we move away from the top of the tell, though some, like Diomedeia, deviate. At the two flat-extended sites, the concentration of finds was patchier than at tells. Observed differences between tell and flat-extended sites could reflect the diversity in the spatial organization of activities in the most recent phases of habitation of the two different site types.

However, additional factors could influence the reliability of the results to a certain degree. One of these is the variability in the visibility of investigated fields at the time of the surface survey, which may have affected the recording rate of the findings. Also, the particular morphology of the landscape of each site is a factor that may have affected the interpretation of the finds' distribution. These factors will be checked in the next stage of this research, which will include a surface survey of the same areas in different seasons that GIS will further process to enrich the information on the distribution and the density of finds.

Acknowledgments

I would like to thank the director of the Mapfarm program warmly, Dr. Duska Urem Kotsou, Associate Professor at the Department of History and Ethnology of the Democritus University of Thrace, for both providing part of the data under study and for her valuable advice for the completion of this specific work. I would also like to thank Dr Kyriakos Sgouropoulos, a member of the Mapfram project and Laboratory Teaching Staff of the Department of History and Ethnology, for his significant assistance in technical and research issues. The study under the Mapfarm project was supported by the Hellenic Foundation for Research and Innovation in the framework of the Action "1st Announcement of research projects of H.F.R.I. for the support of faculty members and researchers and the supply of research equipment of big value" (Project Number: HFRI-FM17-2187).

Bibliography

Αλεξάκης, Δ. 2009. Η συμβολή της γεωμορφολογίας με τη βοήθεια της τηλεπισκόπησης και των γεωγραφικών συστημάτων πληροφοριών στη χαρτογράφηση αρχαιολογικών θέσεων. Διδ. Διατρ. Τομέας Φυσικής και Περιβαλλοντικής Γεωγραφίας. Τμήμα Γεωλογίας. Α.Π.Θ.

Ammerman, J. A., Efstratiou, N., Ntinou, M., Pavlopoulos, K., Gabrielli, R., Thomas K. D. and Mannino, M. A. 2008. Finding the early Neolithic in Aegean Thrace: the use of cores, *Antiquity* 82, 139-50.

Andreou, S., Fotiadis, M. and Kotsakis, K. 1996. Review of Aegean Prehistory V: The Neolithic and Bronze Age of Northern Greece, *American Journal of Archaeology* 100, 537-97.

Bakalakis, G. και Sakellariou, A. 1981. *Paradimi*. Meinz am Rhein: Verlag Philipp von Zabern.

Bevan, A, Conolly, J. 2004. GIS and archaeological survey data: four case studies in landscape archaeology from the island of Kythera (Greece). J. *Field Archaeol.* 29, 123–38.

Conolly J., Lake M. 2006. *Geographical Information Systems in Archaeology.* Cambridge: Cambridge University Press.

Ευστρατίου, Ν. και Καλλιντζή, Ν. 1994. *Μάκρη Έβρου. Ανασκαφές* 1988-1993. Θεσσαλονίκη: Βάνιας

Gillings, M. and Sbonias, K. 1999. Regional survey and GIS: The Boeotia Project in In *Geographical Information Systems and Landscape Archaeology,* ed. M. Gillings, D. Mattingly, J. Van Dalen 55-64. Oxford, Oxbow Books.

Harris, T. 1986. Geographic Information System design for archaeological site information retrieval, Computer Applications in *Archaeology* 1986, 148-61. Birmingham, Centre for Computing and Computer Science, University of Birmingham.

Καλλιντζή, Κ. and Παπαδόπουλος,Στ., 2007. Ο αρχαιολογικός χώρος Διομήδειας Ν. Ξάνθης, *Αρχαιολογικό Έργο στη Μακεδονία και Θράκη* 21, Θεσσαλονίκη 2010, 443– 54.

Καρανικόλας, Ν. 2007. Ελεύθερα λογισμικά GIS. GRASS και QGIS. Εγχειρίδια χρήσης. Σέρρες: Τμήμα Εκδόσεων ΤΕΙ Σερρών.

Katsianis, M., Tsipidis, S. and Kalisperakis, I. 2014. ENHANCING EXCAVATION ARCHIVES USING 3D SPATIAL TECHNOLOGIES in *Archaeological Research in the Digital Age: Proceedings of the 1st Conference on Computer Applications and Quantitative Methods in Archaeology Greek Chapter (CAA-GR),* ed. Papadopoulos C., Paliou E., Chrysanthi A., Kotoula E., Sarris A.

Κατσιάνης, Μ. 2009. Ανασκαφική Μεθοδολογία και σχεδιασμός συστήματος για τη διαχείριση αρχαιολογικών τεκμηρίων. Διδ. Διατρ. Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης.

Katsianis, M., Tsipidis, S., Kotsakis, K. and Koussoulakou, A. 2008. “A 3D Digital Workflow for Archaeological Intra-Site Research Using GIS”, *Journal of Archaeological Science* 35(3), 655-67.

Katsianis, M. and Tsipidis, S. 2005. *Trends and Problems in Archaeological GIS Applications.*

Kim, W. 1990. Object-oriented Databases. Definition and research directions. *IEEE transactions on Knowledge and Data Engineering* 2(3), 327-41.

Kvamme, K. L. 1983. Computer processing techniques for regional modelling of archaeological site locations. *Advances in Computer Archaeology* 1, 22-6.

Kvamme, K. L. 1995. A view from across the water: the North American experience in archaeological GIS. In *Archaeology and Geographical Information Systems: A European Perspective,* ed. G. R. Lock and Z. Stancic, 1-14. London, Taylor & Francis.

Kvamme, K. L. 1999. Recent Directions and Developments in Geographical Information Systems. *Journal of Archaeological Research*, 7, 153-201.

Lock, G.,Bell, T.,Lloyd J. 1999. Toward a methodology for modeling surface survey data: the Sangro Valley Project. In *Geographical Information Systems and Landscape Archaeology*, ed. M. Gillings, D. Mattingly, J. Van Dalen 55-64. Oxford, Oxbow Books.

Marble D. F. 1990. The Potential Methodological Impact of Geographic Information Systems on the Social Sciences. In *Interpreting Space: GIS and Archaeology,* ed. K.M.S. Allen, S. W. Green and E.B.W. Zubrow, 9-21. London: Taylor and Francis.

Murray, D.M., 1995. The management of archaeological information- a strategy. In *Computer Applications and Quantitative Methods in Archaeology* 1993, ed. J. Wilcock and K. Lockyear, 83-7. Oxford: Tempus Reparatum, British Archaeological Reports International Series S598, Great Britain.

Neubauer, W. 2004. GIS in Archaeology- the interface between Prospection and Excavation. *Archaeological Prospection,* 11, 159-66.

Παπακωνσταντίνου, Α., Κουρτζέλλns,Ι., Παππά, Μ. and Κακές, Γ. 2014. "ΕΦΑΡΜΟΣΜΕΝΗ ΓΕΩΠΛΗΡΟΦΟΡΙΚΗ ΚΑΙ ΓΕΩΟΠΤΙΚΟΠΟΙΗΣΗ ΣΤΗΝ ΑΡΧΑΙΟΛΟΓΙΑ. ΜΕΛΕΤΗ ΤΗΣ ΠΟΡΕΙΑΣ ΤΟΥ ΡΩΜΑΙΚΟΥ ΥΔΡΑΓΩΓΕΙΟΥ ΜΥΤΙΛΗΝΗΣ" in *Archaeological Research in the Digital Age: Proceedings of the 1st Conference on Computer Applications and Quantitative Methods in Archaeology Greek Chapter(CAA-GR),* ed. C. Papadopoulos, E. Paliou, A. Chrysanthi, E. Kotoula and A. Sarris.

Renfrew, C. and Bahn, P. 2001. *Αρχαιολογία, Θεωρίες, Μεθοδολογία και Πρακτικές Εφαρμογές.* Αθήνα: Καρδαμίτσα.

Robinson, J. M. and Zubrow, E. 1999. Between Spaces: Interpolation in Archaeology. In Geographical Information Systems and Landscape Archaeology, ed. M. Gillings, D. Mattingly, J. Van Dalen 55-64. Oxford, Oxbow Books.Savage, S. H. 1990. GIS in archaeological research. In *Interpreting Space: GIS and Archaeology,* ed. K. M. S. Allen, S. W. Green, and E. B. W. Zubrow, 23-32. London, Taylor & Francis.

Σγουρόπουλος, Κ., Χρυσαφάκογλου, Π. and Ούρεμ-Κώτσου Ν. 2022. Σύγχρονη τεχνική καταγραφής επιφανειακών ευρημάτων στην αρχαιολογική έρευνα βασισμένη σε κινητές συσκευές. In *Ιστορία, Κοινωνία, Πολιτισμός. Ερευνητικά ζητήματα και προκλήσεις. Αφιερωματικός τόμος για τα 30 χρόνια του Τμήματος Ιστορίας και Εθνολογίας* ed. Α. Μάρκου, Ι. Μπακιρτζής, Α. Παληκίδης and Χ. Παπαγεωργοπούλου, 433-50. Θεσσαλονίκη: Σταμούλη.

Τσιπίδης, Σ. 2009. Γεω-ΟπτικοποίησηΧωροχρονικών Αρχαιολογικών δεδομένων. Διδ. Διατρ.. Τμήμα Αγρονόμων Τοπογράφων Μηχανικών. Α.Π.Θ.

Urem-Kotsou, D., Sgouropoulos, K., Kotsos, S., Chrysafakoglou, P., Chrysaphi, M., and Skoulariki, D. 2022. Surveying the Neolithic farmers in Aegean Thrace with digital technologies. In *Studia Praehistorica,* 16, 117-132.

Wansleeben, M. 1988. Applications in geographical information systems in archaeological research. In *Computer and Quantitative Methods in Archaeology* 1988 Vol. 2, ed. S.P.Q. Rahtz , 435-51. British Archaeological Reports International Series 446. Oxford, Tempus Reparatum.

Wheatley, D. and Gillings, M. 2002. Spatial Technology and Archaeology. *The Archaeological Applications of GIS.* London & New York: Taylor and Francis.