Antonia Moropoulou · Andreas Georgopoulos · Marinos Ioannides · Anastasios Doulamis · Kyriakos Lampropoulos · Alfredo Ronchi (Eds.)

Communications in Computer and Information Science 2838

Transdisciplinary Multispectral Modeling and Cooperation for the Preservation of Cultural Heritage

4th International Conference, TMM_CH 2025
Athens, Greece, April 7–9, 2025
Revised Selected Papers

Springer

TMM 072 045 CH

Communications in Computer and Information Science 2838

Rationale
The CCIS series is devoted to the publication of proceedings of computer science conferences. Its aim is to efficiently disseminate original research results in informatics in printed and electronic form. While the focus is on publication of peer-reviewed full papers presenting mature work, inclusion of reviewed short papers reporting on work in progress is welcome, too. Besides globally relevant meetings with internationally representative program committees guaranteeing a strict peer-reviewing and paper selection process, conferences run by societies or of high regional or national relevance are also considered for publication.

Topics
The topical scope of CCIS spans the entire spectrum of informatics ranging from foundational topics in the theory of computing to information and communications science and technology and a broad variety of interdisciplinary application fields.

Information for Volume Editors and Authors
Publication in CCIS is free of charge. No royalties are paid, however, we offer registered conference participants temporary free access to the online version of the conference proceedings on SpringerLink (http://link.springer.com) by means of an http referrer from the conference website and/or a number of complimentary printed copies, as specified in the official acceptance email of the event.

CCIS proceedings can be published in time for distribution at conferences or as post-proceedings, and delivered in the form of printed books and/or electronically as USBs and/or e-content licenses for accessing proceedings at SpringerLink. Furthermore, CCIS proceedings are included in the CCIS electronic book series hosted in the SpringerLink digital library at http://link.springer.com/bookseries/7899. Conferences publishing in CCIS are allowed to use Online Conference Service (OCS) for managing the whole proceedings lifecycle (from submission and reviewing to preparing for publication) free of charge.

Publication process
The language of publication is exclusively English. Authors publishing in CCIS have to sign the Springer CCIS copyright transfer form, however, they are free to use their material published in CCIS for substantially changed, more elaborate subsequent publications elsewhere. For the preparation of the camera-ready papers/files, authors have to strictly adhere to the Springer CCIS Authors' Instructions and are strongly encouraged to use the CCIS LaTeX style files or templates.

Abstracting/Indexing
CCIS is abstracted/indexed in DBLP, Google Scholar, EI-Compendex, Mathematical Reviews, SCImago, Scopus. CCIS volumes are also submitted for the inclusion in ISI Proceedings.

How to start
To start the evaluation of your proposal for inclusion in the CCIS series, please send an e-mail to ccis@springer.com.

Toward Understanding an Archaeological Site Using GIS Technology

Zoi Stamati[1], Andreas Georgopoulos[2(✉)], and Emmanouil Stefanakis[1(✉)]

[1] Department of Mediterranean Studies, University of the Aegean, 85100 Rhodes, Greece
stefanakis@rhodes.aegean.gr

[2] Laboratory of Photogrammetry, National Technical University of Athens, 15780 Athens, Greece
drag@central.ntua.gr

Abstract. Geographic Information Systems (GIS) have revolutionized archaeological research by enabling precise spatial analysis, site mapping, and predictive modeling. This study examines the application of GIS at the Kymissala archaeological site on the island of Rhodes, Greece, where GIS technologies have been instrumental in uncovering settlement patterns, burial sites, and ancient trade networks. By integrating remote sensing and geospatial analysis, researchers have successfully identified previously unknown necropoleis and subsurface structures, reconstructed ancient road systems, and assessed environmental factors influencing settlement distribution. The study highlights GIS's role in non-invasive archaeological research, cultural heritage preservation, and landscape reconstruction. Key findings indicate that settlements at Kymissala were strategically positioned near water sources and elevated terrains, reflecting defensive and economic considerations. Additionally, GIS has mapped trade routes connecting Kymissala to other Aegean centers, reinforcing its historical significance. Despite its advantages, GIS-based archaeology at Kymissala faces challenges such as data gaps, preservation threats, and the need for ground-truth verification. Future research should focus on AI-enhanced predictive modeling, advanced 3D site reconstructions, and enhanced remote sensing techniques to further archaeological knowledge while ensuring long-term site conservation. This case study underscores GIS's transformative potential in archaeology, demonstrating how digital spatial technologies can expand historical understanding, optimize excavation strategies, and safeguard cultural heritage sites for future generations.

Keywords: Geographic Information Systems (GIS) · Archaeology · Kymissala · Rhodes · Remote Sensing · Spatial Analysis · Cultural Heritage Preservation

1 Introduction

Geographic Information Systems (GIS) have revolutionized archaeological research by providing tools for spatial analysis, site documentation, and heritage management. GIS facilitates the integration of topograph.ancient landscapes, analyze settlement patterns, and monitor site preservation (Wheatley & Gillings, 2019). In recent years, GIS has become essential in digital archaeology, allowing for high-precision mapping, predictive modeling, and remote sensing applications (Verhagen, 2018).

A. Moropoulou et al. (Eds.): TMM_CH 2025, CCIS 2838, pp. 223–230, 2026.
https://doi.org/10.1007/978-3-032-15069-1_17

Kymissala, located approximately 70 km southwest of Rhodes city, encompasses an area exceeding 10 km^2. The region is characterized by semi-mountainous, forested terrain and includes the acropolis atop Agios Fokas hill, overseeing several subsidiary settlements such as Vassilika, Napes, and Charakas. Systematic archaeological endeavors commenced in the late 19th century, with notable contributions from Italian archaeologists in the early 20th century. These efforts unveiled a plethora of artifacts and structures, underscoring the region's historical significance. The presence of Mycenaean cemeteries and Classical-era fortifications suggests continuous habitation and strategic importance throughout various historical periods (Stefanakis et al., 2015). Notably, this environment is recognized as a NATURA 2000 protected rural landscape, highlighting its ecological significance (Georgopoulos et al., 2017). The region presents unique challenges for traditional archaeological methods due to its rugged terrain and dense vegetation (Stamati et al., 2022). The application of GIS has been instrumental in overcoming these challenges, facilitating comprehensive mapping and analysis of Kymissala's historical and environmental context (Stefanakis et al., 2015).

This study explores the role of GIS in surveying, mapping, and analyzing the Kymissala archaeological landscape. By integrating spatial data, remote sensing, and predictive modeling, researchers can reconstruct past human activities and gain insights into settlement patterns. Additionally, GIS supports cultural heritage preservation by monitoring environmental threats and planning excavation strategies (Wheatley and Gillings 2002).

This paper will first discuss the theoretical framework of GIS in archaeology, followed by an examination of its application to Kymissala. The study highlights key findings derived from GIS-based analysis and evaluates its impact on archaeological interpretations. Finally, the paper will address the limitations of GIS in archaeology and propose future research directions.

2 Historical Overview of Kymissala

2.1 Historical Significance

The ancient site of Kymissala is situated approximately 70 km southwest of Rhodes city, within the modern boundaries of the Municipality of Atavyros. This region encompasses the coastal areas of the Monolithos and Sianna communities. The terrain is characterized by a rugged, mountainous landscape, rich in dense forests, which has historically rendered the area relatively inaccessible. Notably, this environment is recognized as a NATURA 2000 protected rural landscape, highlighting its ecological significance (Stefanakis & Patsiada, 2009–2011).

2.2 Historical Significance

Kymissala stands as one of the most significant archaeological sites in the Rhodian countryside, with evidence of continuous habitation from the Mycenaean period through Late Antiquity. During the Hellenistic era, the area was part of the Demos of Kymissaleis and was administratively linked to the city of Kameiros (Stefanakis & Patsiada, 2009–2011).

The site encompasses a wealth of archaeological features, including an acropolis, extensive necropolises, and remnants of ancient settlements, offering profound insights into the region's historical and cultural development (Stefanakis et al., 2015).

2.3 Previous Archaeological Studies

The archaeological significance of Kymissala was first documented in the late 19th century. Initial surveys and excavations were conducted by E. Billioti and L'Abbé Cottret in 1881, focusing on the site's necropolises. Subsequent explorations by Italian archaeologists in 1915 provided detailed studies of the acropolis, including the ancient temple and surrounding settlements. These early investigations laid the groundwork for future research endeavors (Stefanakis & Patsiada, 2009–2011).

In 2006, the Kymissala Archaeological Research Project (KARP) was initiated as a collaborative effort between the Department of Mediterranean Studies at the University of the Aegean and the Ephorate of Antiquities of the Dodecanese. This multidisciplinary project has employed modern methodologies, including digital geometric documentation and GIS technologies, to systematically study and preserve the site's extensive archaeological features (Georgopoulos et al., 2017).

3 GIS and Archaeology: a Theoretical Framework

3.1 Introduction to GIS in Archaeology

Geographic Information Systems (GIS) have significantly transformed the field of archaeology by providing powerful tools for spatial data analysis, visualization, and predictive modeling. Originally developed for geographical and environmental sciences, GIS has since been adapted to archaeology, offering researchers the ability to digitally reconstruct landscapes, analyze settlement patterns, and assess environmental factors that influenced past human activities (Conolly and Lake 2006).

3.2 Key Applications of GIS in Archaeology Spatial Analysis and Site Distribution

One of the primary uses of GIS in archaeology is spatial analysis, which helps researchers identify patterns of settlement distribution, trade routes, and land-use practices. By integrating topographic, hydrological, and environmental data, archaeologists can determine why certain locations were chosen for habitation or ritual purposes. For example, studies in the Mediterranean have used GIS to correlate ancient site distributions with water sources, soil fertility, and defensive advantages (Verhagen 2018).

A practical example is the study of Neolithic and Bronze Age settlements in Greece, where GIS spatial modeling revealed a strong correlation between settlement locations and proximity to arable land (Bevan and Conolly 2004). Similar approaches can be applied to Kymissala, where GIS can help reconstruct ancient settlement networks and their interaction with natural resources.

Predictive Modeling in Archaeology
GIS-based predictive modeling is another critical application that helps archaeologists forecast the likelihood of discovering unknown sites. This technique involves analyzing known archaeological sites and their environmental variables to create models that predict where other sites might exist. Machine learning algorithms and statistical analysis are increasingly integrated into GIS software to refine predictive models (Lake 2014).

For instance, a GIS-based predictive model for Mycenaean (16^{th} - 11^{th} c. BC) settlements in Messenia successfully identified high-probability zones for Bronze Age settlements by considering terrain ruggedness, proximity to water, and historical trade routes (Wheatley and Gillings, 2002). A similar approach could be applied to Kymissala, identifying potential excavation areas that align with historical settlement patterns

3.3 Challenges and Limitations of GIS in Archaeology

Despite its advantages, GIS in archaeology faces several challenges:

- Data Accuracy and Resolution – Many archaeological datasets are incomplete or based on uncertain historical records, affecting GIS analysis reliability (Scianna and Villa 2011).
- Cost and Technical Expertise – Advanced GIS tools require technical skills and expensive software, limiting access for smaller research projects. However, open-source alternatives like QGIS are increasingly popular (Hacıgüzeller, 2012).
- Ethical Considerations – Publicly sharing spatial data of archaeological sites can lead to the risk of looting or unauthorized excavations, necessitating careful data management policies (Evans and Daly, 2006).

4 GIS Applications at Kymissala

4.1 Introduction

The Kymissala archaeological site, located on the western part of Rhodes, Greece, is an area of historical and cultural significance. Known for its Classical, Hellenistic and Byzantine remains, Kymissala contains temples, necropoleis, fortifications, and settlements (Stefanakis & Patsiada, 2009–2011), making it an ideal site for archaeological exploration using GIS technologies. Given the rugged terrain and dense vegetation (Stefanakis & Patsiada, 2009–2011), traditional archaeological methods face limitations, which GIS and remote sensing can overcome by enabling non-invasive site detection, spatial analysis and digital reconstruction.

4.2 GIS-Based Surveying and Mapping

The application of Geographic Information Systems (GIS) in the Kymissala archaeological site has significantly improved surveying and mapping techniques. The provided dataset, visualized as a satellite-based route map with kilometer markers, represents a structured survey of the region. By using GPS tracking, remote sensing, and digital cartography, researchers have been able to map the rugged landscape of Kymissala efficiently (Fig. 1).

This high-resolution spatial dataset allows for:

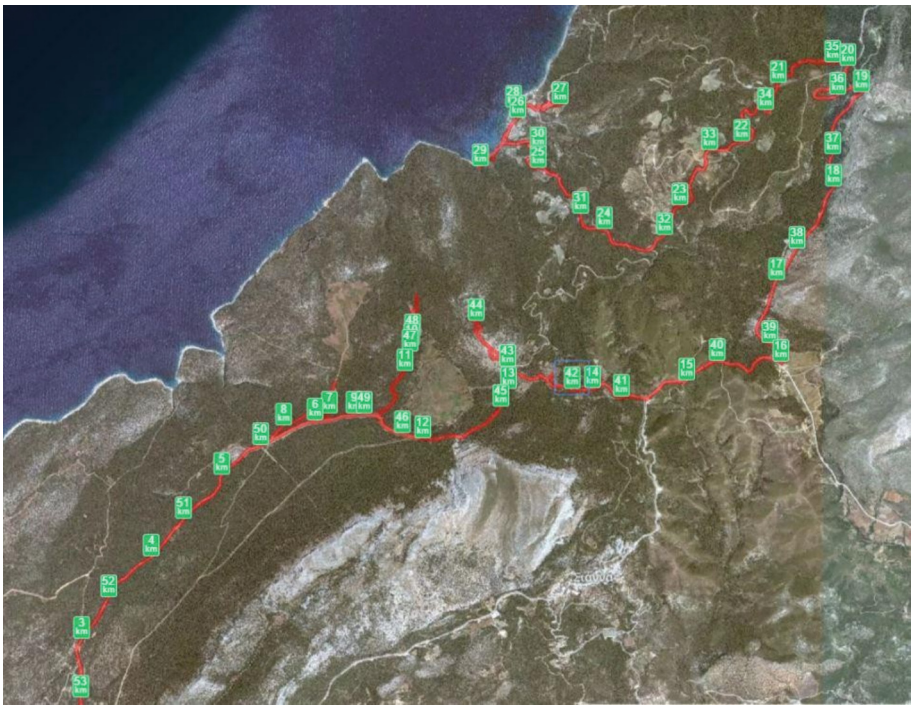

Fig. 1. A route map with kilometer marker

- Accurate geolocation of archaeological features, such as necropolises, ancient settlements, and pathways.
- Topographical modeling to assess terrain elevation, slopes, and accessibility.
- Route optimization for field surveys and excavation teams, ensuring systematic exploration.

The marked distance points in the dataset help in spatial referencing, allowing archaeologists to correlate artifact distribution with geographical features. This methodology minimizes errors in site documentation and enhances historical landscape reconstruction.

4.3 Spatial Distribution of Settlements and Site Management

Using GIS-based georeferencing, archaeologists in Kymissala can document the precise location of settlements and excavation sites. The dataset allows for:

- Predictive modeling to identify potential excavation zones.
- Heritage site monitoring to prevent illegal excavations.
- Tourism planning by designing guided routes for cultural heritage trails.

By integrating the surveyed route data with archaeological site markers, researchers can create a spatially interactive database for Kymissala, ensuring better site management, conservation planning and historical analysis.

4.4 3D Modeling and Predictive Analysis in Kymissala 3D Modeling for Archaeological Reconstruction

One of the most advanced applications of GIS in Kymissala is the creation of 3D models based on digital elevation models (DEMs) and GPS data. These models provide a realistic representation of the ancient landscape, offering valuable insights into how past civilizations adapted to their environment. Using high-resolution elevation data from the provided GIS dataset, archaeologists can:

- Reconstruct historical settlements, mapping ancient structures in their original geographic context.
- Simulate past landscapes, understanding how environmental changes influenced settlement patterns.
- Virtually restore ancient roads and pathways, integrating the surveyed route map to visualize historical connectivity.

For example, if the kilometer markers in the dataset align with known excavation sites, archaeologists can overlay excavation data onto the 3D terrain model, helping them assess site accessibility and preservation challenges.

Predictive Modeling for Site Discovery
GIS-based predictive modeling is a powerful technique that uses spatial data to identify potential archaeological sites. By analyzing environmental factors, terrain features, and artifact distributions, researchers can estimate high-probability excavation zones. In the case of Kymissala, predictive models leverage:

- Topographical features (elevation, slope, proximity to water sources).
- Known settlement locations and their spatial relationships.
- Accessibility patterns derived from the GIS-mapped route data.

4.5 GIS Techniques in Kymissala: Mapping and Analysis

Spatial Analysis Techniques
The use of GIS spatial analysis in Kymissala enables archaeologists to interpret site distribution patterns, predict new archaeological sites and assess environmental impact. Key techniques include:

– Georeferencing and Digital Mapping
– Georeferencing historical maps allows researchers to compare past and present landscapes (Wheatley & Gillings, 2002).
– Topographical Analysis with Digital Elevation Models (DEMs)
– LiDAR-derived DEMs reveal hidden structures, such as buried foundations or ancient road networks.
– Slope and aspect analysis helps determine preferred settlement locations in antiquity.
– Site Predictive Modeling

Archaeologists use weighted overlay models to combine factors such as:

- Proximity to water sources (ancient settlements often located near springs) (Stefanakis, 2017).

- Slope suitability (gentle slopes favored for construction).
- Artifact density clusters (areas with a high probability of containing new sites).

– Network Analysis and Ancient Route Mapping.

- Using GIS network analysis tools, researchers reconstruct possible ancient pathways, correlating them with documented burial sites and settlements.
- The route map surveyed (provided dataset) serves as a modern reference to assess historical travel and trade routes.

4.6 Pathway and Route Analysis

Mapping Ancient Roads
GIS-based analysis of ancient pathways at Kymissala can provide crucial insights into historical movement patterns and trade connectivity and reconstruct a network of roads and pathways using GPS tracking, topographic models, and historical records. Key findings include:

- The route follows natural terrain contours, suggesting optimization for travel efficiency in antiquity.
- Several nodes align with archaeological remains, supporting the hypothesis that this was a major trade corridor.
- Proximity to coastal areas indicates a maritime connection.

5 Conclusion

The integration of GIS technologies in the archaeological study of Kymissala has provided groundbreaking insights into site distribution, landscape evolution, and cultural heritage preservation. By combining spatial analysis, remote sensing, and predictive modeling, GIS has enabled the discovery of previously unknown archaeological features while ensuring long-term digital documentation. Future research should focus on enhanced AI-driven predictive models, expanded LiDAR surveys, and interactive virtual reconstructions to further refine archaeological methodologies and heritage management.

References

Bevan, A., Conolly, J.: GIS, archaeological survey, and landscape archaeology on the Island of Kythera. J. Field Archaeol. **29**(1–2), 123–138. Greece (2004)

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

Evans, T., Daly, P.: Digital Archaeology: Bridging Method and Theory. Routledge, London (2006)

Georgopoulos, A., Tapinaki, S., Stefanakis, M.I.: Innovative methods for digital heritage documentation: the archaeological site of Kymissala in Rhodes. In: ICOMOS 19th General Assembly and Scientific Symposium “Heritage and Democracy”, 13–14th December 2017, New Delhi, India (2017)

Hacıgüzeller, P.: GIS, Critique, Representation and Beyond. J. Archaeol. Sci. **39**(2), 449–460 (2012)
Lake, M.: Trends in archaeological GIS. Geogr. J. **180**(1), 34–46 (2014)
Scianna, A., Villa, L.: GIS and archaeology: a complex relationship. Int. J. Herit. Digit. Era. **1**(1), 127–144 (2011)
Stamati, Z., Stefanakis, M.I., Kontogianni, G., Georgopoulos, A.: Virtual reconstruction of the temple on the acropolis of Kymissala in Rhodes. Digital. **2**(2), 296–319 (2022)
Stefanakis, M.I.: Kymissaleis: archaeology and landscape of an ancient deme in the rhodian countryside. In: Stefanakis, M.I. (ed.) KYMISSALA. Archaeology – Education – Sustainability, pp. 9–34. Archeaopress, Oxford (2017)
Stefanakis, M.I., Patsiada, V.: The archaeological research in the ancient deme of Kymissaleis (Rhodes) in the years 2006-2010: a preliminary report. Eulimene, 10–12, 63–134 (2009–2011).
Stefanakis, M.I., Kalogeropoulos, K., Georgopoulos, A., Bourbou, C.: Exploring the ancient demos of Kymissaleis on Rhodes: multidisciplinary experimental research and theoretical issues. In: de Gruyter, W., Haggis, D.C., Antonaccio, C.M. (eds.) Classical Archaeology in Context: Theory and Practice in Excavation in the Greek World, pp. 219–315. Walter de Gruyter Inc., Berlin, Germany (2015)
Verhagen, P.: Spatial Analysis in Archaeology: Moving into New Territories. Springer (2018)
Wheatley, D., Gillings, M.: Spatial Technology and Archaeology: the Archaeological Applications of GIS, 2nd edn. Routledge (2002)