# From GIS to Game engines

## Case studies in archaeology from North Greece

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## ABSTRACT

*Over the past two decades, there has been a surge of interest in applying spatial concepts and techniques in archaeology, underscoring the versatility of GIS technology as a crucial asset for humanities. The focus of this paper is to present an overview of GIS applications in the archaeology of North Greece, specifically highlighting the endeavors of the AeGIS Laboratory of Archaeological GIS (http://aegis.athenarc.gr/). The exploration spans from intra-site analysis and data management, exemplified by the Aristotle University excavation in Karabournaki, to macro-scale investigations, such as studying the interplay between environment and settlements in Aegean Thrace. The paper also delves into the integration of GIS data with game engines, such as Unity 3D, for reconstructing and exploring movement and visibility in archaeological landscapes. Emphasizing the theoretical complexity of these spatial tools, the authors argue that, as familiarity with GIS and game engines grows in the archaeological community, these systems, particularly open-source GIS, offer an invaluable and adaptable toolbox. As archaeologists themselves, they contend that platforms like GIS and Unity 3D possess the potential to evolve into heuristic devices, aiding in challenging assumptions and framing insightful archaeological inquiries. The collaborative and open nature of these tools facilitates customization to suit the diverse requirements and preferences of archaeologists.*

## 1. INTRODUCTION: GIS IN ARCHAEOLOGY

Over the past thirty years, since the introduction of GIS in archaeology (Hasenstab 1983; Lock 2003), digital spatial analysis and Geographic Information Systems have evolved into pivotal tools for exploring, analyzing and interpreting spatial data (Verhagen 2018, 11–3). The capacity to operate within a multilayer and multiscalar spatial framework renders GIS technology exceptionally valuable for archaeologists. This utility is evident in various aspects: a) the digitization of vast amounts of data from excavations or surface surveys for subsequent analysis, b) the visualization and measurement of distributions of diverse cultural objects, c) the customization and visualization of landscape surveys, and d) the formulation of analyses and predictions for future surveys.

Despite earlier skepticism within the archaeological community regarding the practical utility of GIS techniques as methodological and analytical tools (Kvamme 1999; Verhagen 2007, 13–25; McCoy and Ladefoged 2009), since the late 2000s, several GIS software packages have emerged as the primary analytical tools for

handling spatial archaeological data (Wheatley and Gillings 2002). This shift reflects a growing recognition of the effectiveness of GIS technology in addressing the challenges posed by the abundance and complexity of spatial data in archaeological research.

Particularly in the last decade, there has been a notable surge in the archaeological community's incorporation of GIS technology into its daily practices (Menéndez-Marsh et al. 2023). Many archaeologists engaged in field-work and landscape reconstruction projects have increasingly recognized the value of geographic databases, digital cartography and spatial analysis. While not always solely for their analytical capabilities, these tools are undeniably appreciated for their heightened effectiveness in managing archaeological information (Llobera 2012; Orengo 2015).

In the following pages, we will present an overview of GIS applications in the archaeology of North Greece, drawing from specific case studies conducted by the GIS Laboratory AeGIS Athena (https://aegis.athenarc.gr/). Simultaneously, we will delve into the epistemological rationale underpinning the application of GIS in our research. This exploration aims to shed light not only on the practical applications of GIS technology, but also the conceptual framework that guides its integration into archaeological inquiries in this region.

## 2. GIS: MAPPING AND RECORDING THE EXCAVATION AT KARABOURNAKI THESSALONIKI

The management of archaeological information holds paramount importance, particularly within the core of the archaeological process itself – the excavation (Neubauer 2004; Levy and Smith 2007). Over the period from 2002 to 2022, the Athena RC-supported project "Karabournaki Recording the Past" extensively explored the multifaceted applications of GIS (Tsiafakis and Evangelidis 2006) for organizing and analyzing excavation data from the Aristotle University excavation in Karabournaki, located in the Thessaloniki area. The site is associated with the ancient Thermi harbor, a pivotal port in North Aegean (Tiverios et al. 2016; Tsiafaki and Manakidou 2021; Tsiafaki 2021).

From the project's early stages in the early 2000s, the utilization of geospatial techniques, particularly GIS, was deemed essential for organizing findings, identifying potential correlations in the spatial distribution of objects, and conducting detailed studies of individual objects (Tsionas et al. 2009; Tsiafakis and Evangelidis 2006). Over time, a geospatial platform took shape, employing various GIS software throughout its implementation. Ultimately, the GIS platform was built on custom versions of QGIS (Orengo 2015), an open-source GIS software designed for use on home or tablet computers and laptops running Windows or Linux.

From the initial design phase, our primary objective was to establish a digital dataset comprising various levels of .shp files and metadata. We aimed to develop a system facilitating rapid and efficient data recording, integrating both vector and raster data sources. The system was designed to enable work with data across multiple scales, expediting the creation of swift mapping and reporting during the excavation period.

A series of decisions and parameters, as will be presented below, were taken into consideration to form the system. The ontological decisions underlying the base design of the project entailed fundamental choices related to the nature and categorization of entities (topographical features, architecture and artifacts) within the digital framework. These decisions, as discussed by Peuquet (2002) and Kai Sun et al. (2019), are pivotal in shaping the project's overall methodology, and are directly linked to fulfilling key objectives. Ontological decisions involve determining the types of entities, their relationships and the essential characteristics that define them in the digital realm. In simpler terms, it involves deciding what kinds of things will be included in the project, how they are connected, and what key features make them unique or identifiable in the digital context. For example, in the base of Karabournaki excavation, defining how archaeological features, artifacts or spatial elements are conceptualized and represented within the digital structure required careful consideration. This is because the chosen ontological approach influences data interoperability, searchability and the overall

effectiveness of analyses conducted on the digital dataset. It serves as the conceptual foundation that guides subsequent data organization, retrieval and interpretation, thus playing a critical role in achieving the project's overarching goals. These decisions regarding Karabournaki were not merely technical choices, but theoretical considerations that significantly impacted the meaningful representation and analysis of archaeological data in the digital domain.

It is worth noting that, despite the perception of data digitization as an automatic or mechanistic process by some (see the discussion in Zubrow 2006, 15), the conversion of spatial data into digital form entails significant risks, which were also taken into account. One prominent risk lies in the potential loss or distortion of nuanced contextual information during the digitization process. Spatial data, when translated into a digital format, may undergo simplifications or generalizations that could compromise the accuracy and richness of the original archaeological context. Another inherent risk is the introduction of errors, whether through the manual input of data or the challenges associated with georeferencing. These errors may propagate throughout the dataset, leading to inaccuracies in subsequent analyses and interpretations. Additionally, issues of data completeness and the loss of three-dimensional information during the conversion process pose further risks, limiting the holistic understanding of archaeological features.

Another important parameter considered for the Karabournaki GIS platform was the role of the archaeologists themselves. This is because the archaeologist overseeing the project plays the most crucial role in recognizing and addressing the challenges associated with the digitization process (Huggett 2017, 2). Their active involvement is essential in fostering a heightened awareness of the intricacies involved in taking the "digital leap" (Mak 2014). This goes beyond a mere technical understanding, encompassing a comprehensive grasp of the implications and consequences of translating spatial data into a digital format.

This heightened awareness is particularly vital during the critical stage of project development. At this juncture, the archaeologist is tasked with making key decisions that extend beyond the digital realm. They must engage in precise design considerations for both the logical and physical structure of the project. The logical structure involves defining the ontological framework, determining how entities are conceptualized and related within the digital space. On the other hand, the physical structure pertains to the practical implementation, including choices of software, hardware and data storage mechanisms.

The concept of the "electronic translation" (Huvila et al. 2018, 143) underscores the transformative nature of digitization and the constraints it may introduce. The archaeologist's role is to mitigate these constraints by carefully designing the project framework, ensuring that the digital representation remains faithful to the complexities of the archaeological context. This process requires meticulous consideration, as decisions made at this stage profoundly impact the project's success in achieving a meaningful and robust transformation of spatial data into a digital format.

From this theoretical and methodological standpoint, the digitization of the Karabournaki excavation within a Geographic Information Systems (GIS) environment has ushered in transformative processes of knowledge production, as illustrated in Figure 1.

This digitization has introduced efficiencies that have significantly enhanced the interpretation of archaeological data. Firstly, it has expedited the interpretation process, enabling archaeologists to analyze and understand the archaeological data more rapidly and efficiently. The architectural remains have been meticulously mapped and correlated with other findings, facilitating a comprehensive understanding of their spatial relationships and contextual significance. Additionally, the digitization allowed for a thematic organization of the excavation data, categorized by period or type of feature (e.g. different types of pottery or other small finds). This approach enables the presentation of specific features or findings individually, providing clarity amid a multitude of complex and visually overlapping objects. The utilization of layers in the GIS environment has proven instrumental in organizing intricate data systematically. This system supports diverse ways of visually presenting information, enhancing accessibility and comprehension. The stratification of data layers also facilitates the execution of complex spatial queries, enabling the identification of correlations and connections
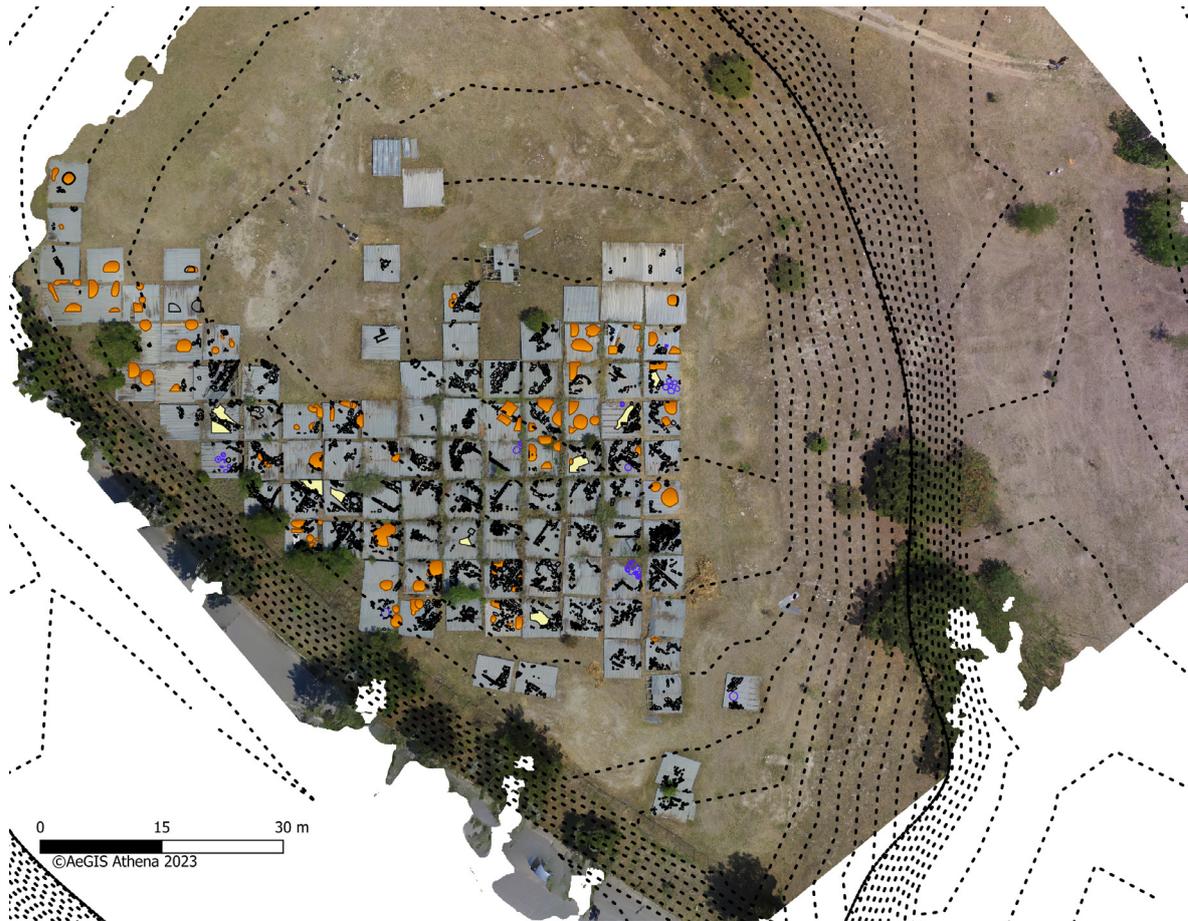
Fig. 1. Architectural remains in Karabournaki. GIS data overlayed on orthophoto, depicting the trenches.

between specific categories of materials. This, in turn, serves as a valuable tool for identifying potential indicators of the presence of functional areas within the archaeological site (like, for instance, residential areas, workshops, storage facilities, communal gathering spaces and other specialized zones). In essence, the digitization process within the GIS environment has not only streamlined the handling and interpretation of archaeological data, but has also empowered archaeologists with tools for in-depth spatial analysis and meaningful visualization, contributing to a more nuanced understanding of the site's complexity.

At Karabournaki, GIS primarily served as an organizational and data handling tool, significantly improving the management of materials, particularly the extensive ceramic finds (Tsiafakis et al. 2006) (Fig. 2). Initially utilized for its capacity to enhance the efficiency of handling and categorizing archaeological data within the excavation, GIS's spatial capabilities became increasingly apparent as familiarity with the geospatial tools grew. As expertise in using these tools deepened, it became evident that GIS's spatial functionalities, especially the ability to transition from the micro-scale of the excavation to the macro-scale of the broader environment, presented an opportunity to address a broader spectrum of questions. Specifically, it enabled the exploration of the settlement's position within the network of surrounding settlements and its visual relationships with them.

This shift allowed for a more comprehensive, macro-scale perspective on the development of the site. It provided a means for multiscalar analysis, offering insights into diachronic trends and spatial dynamics across the broader area of the Thermaic Gulf. By extending the analysis beyond the immediate excavation site, researchers gained a holistic understanding of how Karabournaki fit into the larger regional context. This approach not only enriched the interpretation of the site's development, but also facilitated a nuanced exploration of the broader historical and spatial trends within the Thermaic Gulf area.
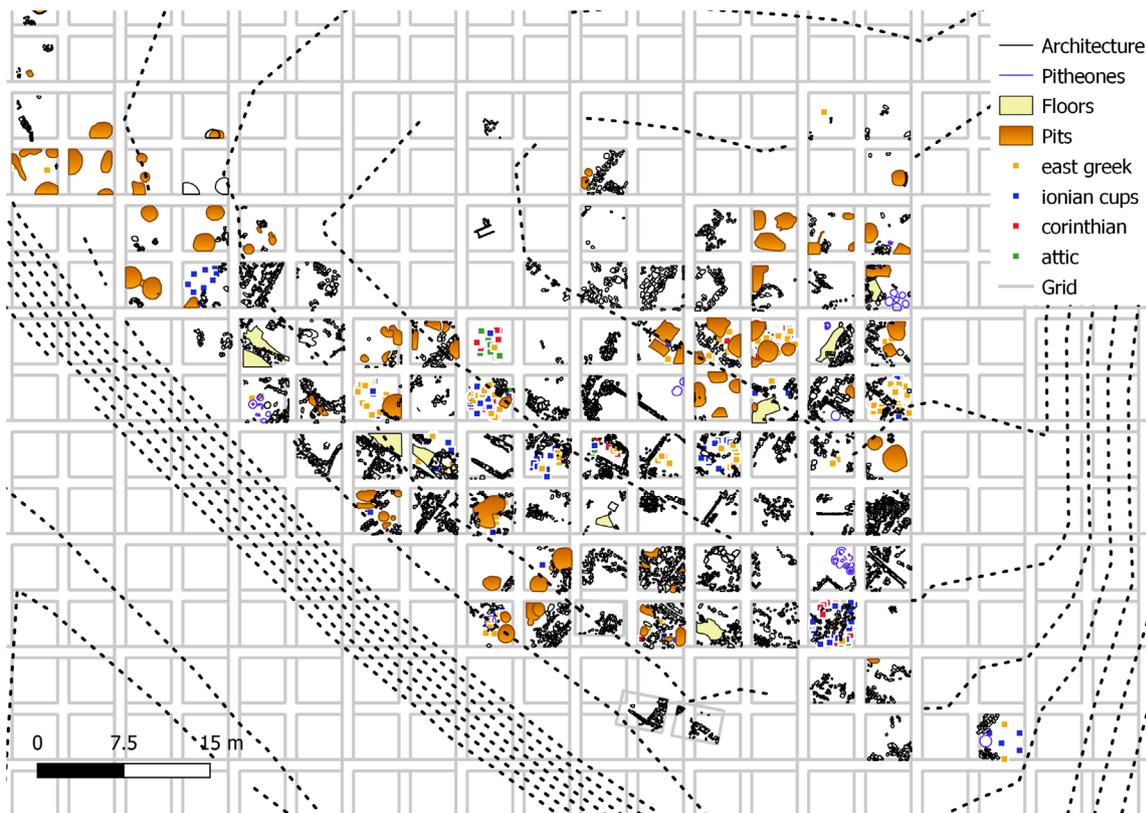
Fig. 2. Features, remains and pottery in Karabournaki.

# 3. ANALYSIS BASED GIS APPROACHES: ENVIRONMENT AND SETTLEMENT IN AEGEAN THRACE

Building upon the groundwork laid in Karabournaki, subsequent research initiatives at Athena RC, including the newly established GIS laboratory, AeGIS Athena, have expanded upon GIS methodologies for more in-depth analyses. In these projects, the focus has shifted towards mapping and investigating the intricate geographies of the Aegean Thrace region. The research specifically delves into understanding the impact of environmental factors on human settlement, with a keen emphasis on elucidating the foundations of Greek colonies during the Archaic period.

Conducted between 2018 and 2020, a landscape archaeological project sought to explore various zones related to landscape, settlement and economy within the Aegean Thrace region (Tsiafaki and Evangelidis 202 2). By integrating information and evidence from diverse scientific disciplines and sources, the investigation focused on specific elements of the physical environment, particularly fluvial landscapes and soils, to gain insights into the dynamics of the region.

Utilizing integrated data in a comprehensive GIS synthesis offers a notable advantage by enabling the assessment and utilization of a significantly more extensive array of environmental attributes (Siart et al. 2018). This approach enhances the depth and richness of the analysis, allowing for a more nuanced understanding of the interconnected environmental factors that influence the studied region. By incorporating diverse datasets from various sources and scientific disciplines, the synthesis provides a holistic view, facilitating a more comprehensive evaluation of the complex relationships and dynamics within the environment under investigation.
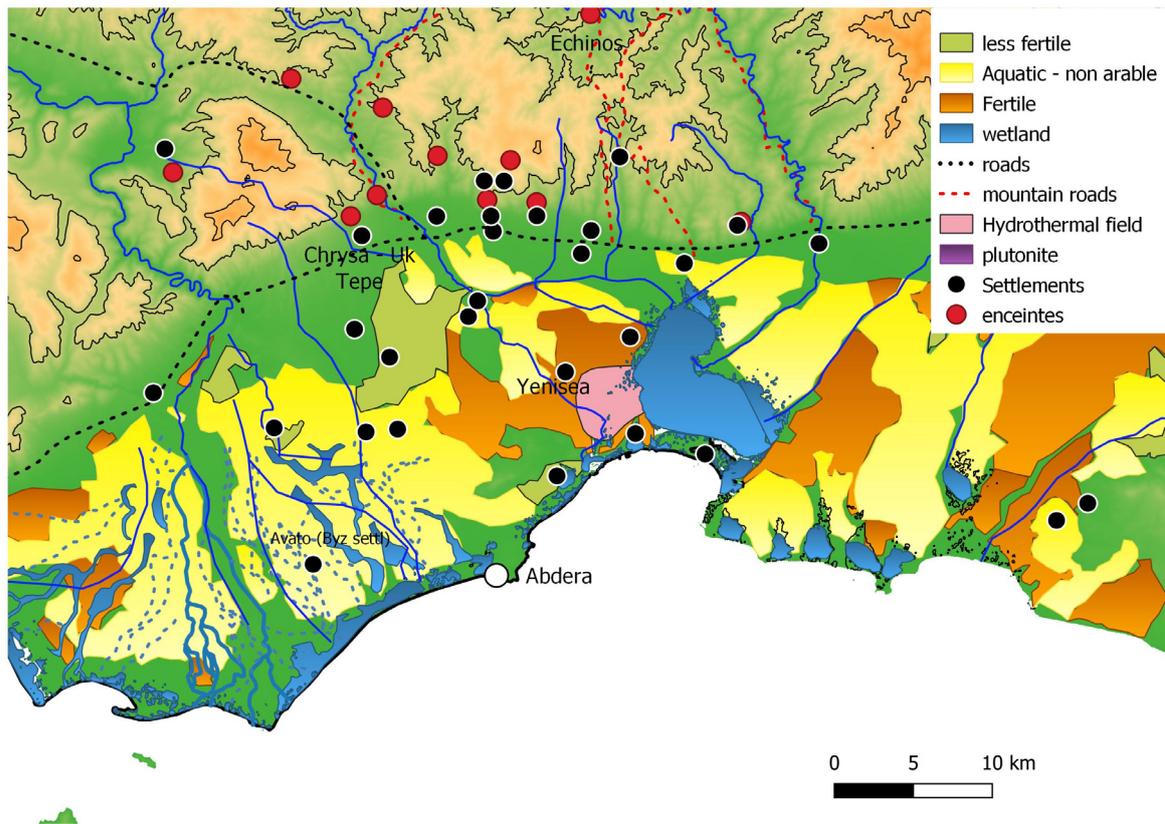
Fig. 3. Fluvial landscapes, soil classification and distribution of sites in Aegean Thrace.

This, in turn, enhances the capacity to draw informed conclusions and make nuanced interpretations based on the broader and more intricate set of environmental attributes at play.

The research project, along with other similar initiatives mapping the topography of Roman-period Thrace (Evangelidis 2021), has significantly enhanced our comprehension of specific landscapes and underscored the potential of geospatial technologies, notably GIS, as invaluable tools for archaeological investigation. Specifically, our approach involved synthesizing information from literary sources and integrating it with a diverse array of archaeological and geological data collected systematically over the past century in the region. By consolidating this wealth of information and processing it through integrated, autonomous digital platforms like QGIS, we aspire to construct an environmental history of the region. This historical narrative aims to consider the various means of utilization of natural resources, the transformation of landscapes, and, crucially, the intricate interconnections characterizing human activities in the area.

Central to our research was the establishment of a GIS platform, a pivotal tool designed to streamline the integration of a diverse range of hydrological, geological and meteorological data from various sources, including other databases and field tests, presented in different formats such as digital data and maps. The primary objective of this platform was to create a coherent and logical structure that could accommodate the amalgamation of information critical to our study. Within this framework, the GIS platform facilitated the analysis and visualization of various environmental data and field test results conducted in the research area. Customized queries were employed to generate contour maps and perform spatial operations, particularly concerning soil productivity and site distribution (Fig. 3). These tailored queries allowed for the extraction of specific insights and patterns from the integrated data.

Furthermore, the platform incorporated multi-criteria query forms, offering a versatile tool for the analysis and visualization of different datasets. This approach not only enabled a more nuanced examination of the

available data, but also provided a means to scrutinize and validate existing interpretations derived from the integrated evidence. The GIS platform, through its functionality, played a crucial role in enhancing the depth and accuracy of our environmental analysis in the studied area.

The findings substantiate a novel ecological hypothesis regarding the settlement patterns and economy of the area, offering an alternative perspective to the previously established narrative derived solely from literary sources. While earlier accounts portrayed the region primarily as an agricultural hub attracting Greek settlers (Isaac 1997, 75; Loukopoulou et al. 2005, 172; Tiverios 2008; Kallintzi 2011), the environmental evidence, filtered and analyzed through geospatial tools, paints a different and distinctive picture.

The analysis reveals a landscape characterized by unique features, distinguishing it from an environmental standpoint. Key factors, such as environmental variability in fluvial landscapes and soil workability, emerge as prominent contributors to the differentiation in settlement patterns and economic strategies, with lasting effects on the livelihoods of local groups situated along the foot of Rodope mountains or along the coast. Notably, the majority of areas within the wheat belt region (see Fig. 3) exhibit relatively poor soil fertility and lower productivity due to their periaquatic substance.

The spatial database, coupled with subsequent data analysis, addresses the exploitation of the plain of the Nestos River, shedding light on the significant role that fluvial landscapes and alluvial processes played in shaping the distinctive agropastoral economy of the area. Furthermore, these findings contribute to an enhanced understanding of the motives behind the establishment of Greek coastal colonies or *apoikiai* (Tiverios 2008; Tsiafaki 2020). In this context, the utilization of geospatial computing tools seeks to strike a balance between historically contextualized archaeology of the region and hard environmental data, offering an approach suited to specific questions and datasets.

## 4. THE NEXT STEP: GAME ENGINES AND ANCIENT LANDSCAPE RECONSTRUCTIONS

Taking a broader perspective of the larger landscapes prompted us to explore methods for enriching spatial information, aiming not only to enhance visualization, but also to facilitate a more immersive approach.

Recent advancements in digital technology have introduced intriguing possibilities for the collection, analysis, interpretation and visualization of archaeological data. Techniques like image-based modeling, the utilization of unmanned aerial vehicles, and the incorporation of 3D gameplay, particularly through platforms like Unity 3D, have significantly transformed archaeological practices. These developments prompt us to reconsider how GIS can bolster interpretive frameworks by embracing novel modes of representation. The goal is not merely to replace reality, but to establish a more suitable backdrop for the creation of archaeological interpretations, aligning with the broader exploration of enhancing spatial information and fostering a more immersive approach in archaeological research.

Researchers have often have articulated the limitations of GIS as a comprehensive tool for recreating and simulating the conditions that defined past human experiences (Landeschi 2019, 19–20). While GIS excels in spatial analysis and data representation, its traditional framework may fall short in capturing the nuanced and multi-sensory aspects of historical contexts. The richness of past human experiences involves intricate layers of social, cultural and environmental dynamics that extend beyond the spatial dimensions typically addressed by GIS.

Landeschi (2019) emphasizes the need to go beyond the constraints of GIS in archaeological research. The conventional use of GIS may struggle to convey the immersive and contextual intricacies of historical settings. Therefore, researchers advocate for a more integrative approach that combines GIS with other technologies and methodologies, such as 3D modeling and virtual reality, to offer a more holistic and experiential understanding

of the past. This recognition of GIS limitations underscores the ongoing exploration of innovative tools and methods to enhance the depth and accuracy of archaeological reconstructions.

In a 2012 article, Llobera (2012) underscores the challenge of comprehending the complexity of a landscape through conventional spatial representations, as they often offer a simplistic and monolithic depiction of reality. Traditional point-based maps and cartographic representations are effective for modeling quantitative data, such as the distribution of ceramics, and conveying information related to proximity and scale. However, when it comes to exploring more intricate human phenomena –like the experience of visiting a place, navigating from one location to another, or assessing landscape visibility– these representations prove less adequate (see generally Forte 2003).

This inadequacy poses a significant hurdle for researchers aiming to analyze landscape experiences and the nuanced spatial relationships between various elements. To address this limitation, there is a pressing need to propose environments, in which archaeologists can immerse themselves, relying on their own perceptions to contextualize and understand the intricacies of the landscape (Eve 2012). This perspective encourages a shift towards more immersive and experiential methodologies that extend beyond traditional spatial representations, allowing for a more nuanced exploration of the complex interplay between humans and their surroundings in archaeological research.

One potential solution to this challenge lies in leveraging game engines and integrating them with GIS data to construct cohesive spatial models. The infusion of gamification elements into archaeology provides an innovative avenue for exploring dynamic aspects of the environment that prove challenging to grasp through traditional two-dimensional maps (Lulof 2020). Gamification, as conceptualized by Seaborn and Fells (2015), involves reconstructing ancient landscapes to represent various hypotheses related to landscape experiences. Recognizing that gamification techniques foster engagement, involvement and problem-solving (Brigham 2015), archaeologists are increasingly exploring the synergy between GIS and gaming technology.

This 'marriage' of GIS and gaming technology holds the potential to produce simulations and visualizations of ancient landscapes that surpass conventional 3D applications. Importantly, these reconstructions are grounded in accurate archaeological information and narrative. By incorporating simulation, the reconstruction and visualization of historical landscapes gain a heightened level of interactivity between users and their virtual environment. Elements such as terrain scale, spatial components, a sense of presence, and visual perception become pivotal in crafting the dynamics of exploring a historical landscape, defining the interaction between users and their digitally recreated environment.

### 4.1. Case studies: reconstruction of archaeological landscapes through Unity 3D

In our pursuit of incorporating gamification into archaeology, we harnessed the capabilities provided by the popular open source platform Unity 3D to reconstruct and investigate a range of archaeological landscapes, drawing on data from various GIS projects conducted in preceding years. The features of Unity 3D enable simulations that empower researchers to navigate the landscape as an 'open environment', moving beyond a singular reconstruction or a static snapshot of the past. This approach fosters a dynamic and immersive exploration of historical landscapes, allowing for a more interactive and experiential engagement with the archaeological data.

The incorporation of Unity 3D into our projects serves a dual purpose. Firstly, it aims to advance possible reconstructions of landscapes in the Northern Aegean region. Secondly, it seeks to experiment with the concept of digital presence, drawing on insights from studies like Riva et al. (2004) and Epstein (2006). Regarding the latter objective, our intent is to delve into aspects of the landscape related to viewpoints, visibility, movement and the perception of environmental elements, both from a macro perspective (Fig. 4) and the standpoint of individual agents (see Fig. 5). These simulations, embodying the essence of simulation as outlined by Whitley (2016), span various scales – from expansive kilometer-long areas like the Nestos paleo delta (a crucial zone for our research on the interplay between environment and settlement, as depicted in Fig. 4) to micro-landscapes such as the segment of the via Egnatia passing through the villages of Xanthi (Fig. 5). Moreover, our simulations

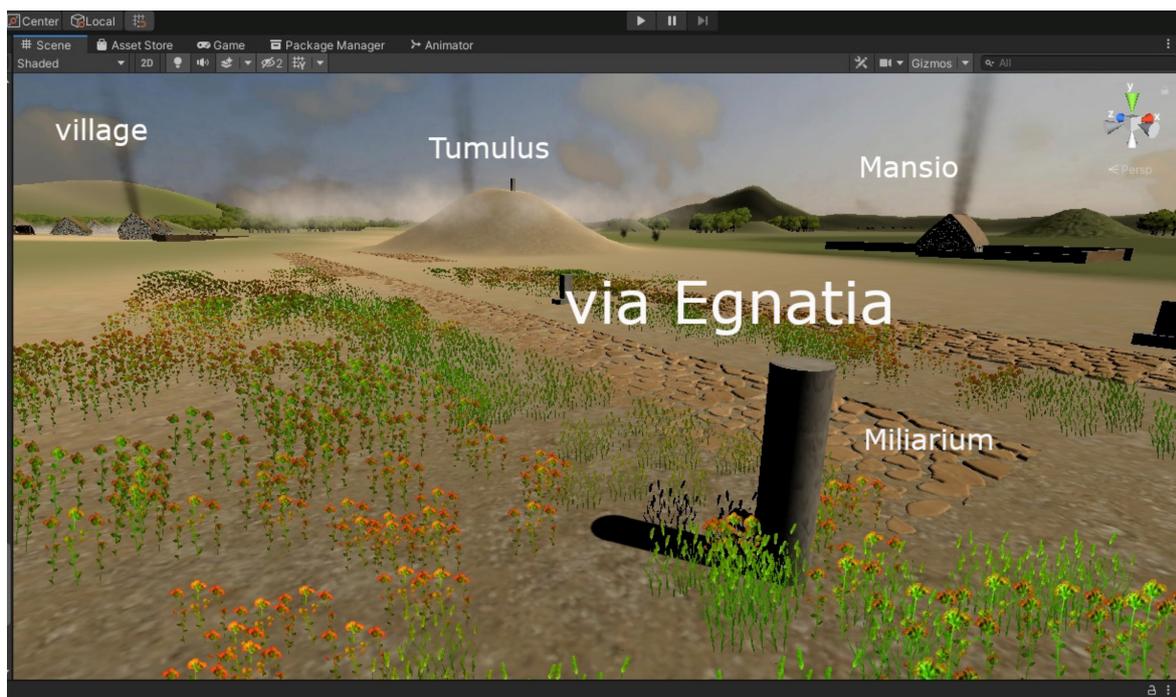Fig. 4. Reconstruction in Unity 3D of the PaleoDelta of Nestos.



Fig. 5. The idea of presence. Landscapes along via Egnatia.

go beyond mere reconstruction, aiming to provide an immersive experience of settlements inspired by our extensive work at the ancient site of Karabournaki (Fig. 6).

In all these landscapes, our objective was to map movement and visibility in real-time, addressing pertinent archaeological questions. Specifically, we utilized the game engine to analyze landscape visibility, the density of the built environment, proximity, physical volume of buildings, and overall how individuals perceived the landscape, considering both its physical and aesthetic values. For instance, in the reconstruction of the stretch of via Egnatia near Xanthi, we sought to investigate the impression created by the large mounds next to the road for Roman road travelers. We explored the visibility range of the Thracian fortresses crowning the hilltops
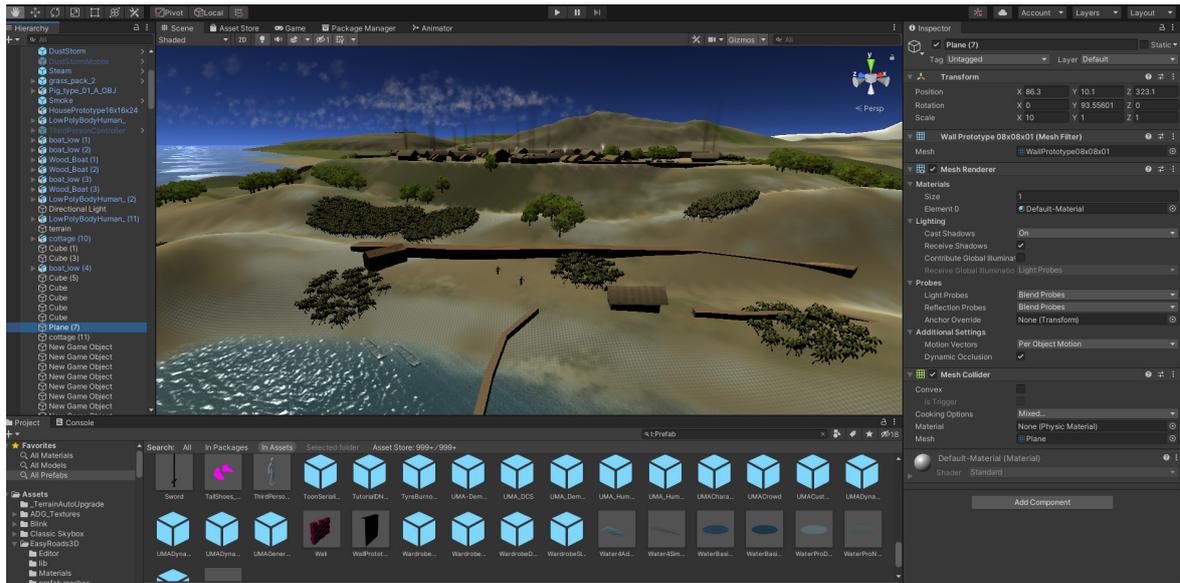
Fig. 6. Unity 3D. A settlement inspired by the archaic period site in Karabournaki.

along the Egnatia route and examined how pedestrians perceived the landscape (Fig. 5). Conversely, concerning the exploration of a settlement, our focus was on exploring issues related to settlement density and its visual relationship with other settlements (see Fig. 6).

## 4.2. Methodology

Addressing the challenges of integrating a comprehensive level of information, the creation of a historical landscape emerges as a particularly demanding task. Within this intricate process, the inclusion of natural and architectural features defining a historical landscape becomes pivotal, as they significantly influence the efficacy of the reconstruction and the user's immersive experience. Leveraging Unity 3D as our primary reconstruction tool, we sought optimal sources of information for generating virtual terrains and landscapes, encompassing elevation data, heightmaps, architectural drawings, and other datasets produced in preceding years across various archaeological projects. Our approach involved integrating diverse data from different platforms and sources, such as GIS, AutoCAD and Blender, to craft a faithful representation of the historical landscape. In our pursuit of the most authentic 'presence', the environment is not simulated with fabricated virtual data; rather, real data is employed, ensuring the precise placement of objects and monuments to bring the digital environment closer to reality. For the broader landscape reconstruction and exploration of movement and visibility, we opted for a cost-effective strategy, relying on low-polygon modeling of environmental and cultural features extracted from historical sources, and archaeological and geological information instead of resorting to more expensive multi-view 3D reconstruction techniques.

## 5. EPILOGUE

The examples highlighted above were carefully selected to showcase the diverse applications of spatial tools in our archaeological research. The transformation of archaeological information into points, lines, themes or textual data within a GIS system opens new possibilities for detecting, analyzing and interpreting spatial patterns. The inherent implication of this utilization is that even seemingly straightforward spatial tasks, such as digitizing the architectural remains of an archaeological site, necessitate a methodological understanding of their application, ultimately leading to substantial interpretation.

As new research questions emerge, requiring spatial methodologies, there will be an increasing demand for systems and platforms like Unity 3D, offering archaeologists the opportunity to play and experiment with spatial models and archaeological hypotheses tailored to the analysis and interpretation of their data. While the benefits of employing GIS techniques for data handling and analysis in archaeology are numerous and diverse, our contention is that integrating them with game engines like Unity 3D can revolutionize the construction of archaeological landscape models and provide a novel means to assess the validity of conventional archaeological assumptions. This combined approach allows for a dynamic engagement with spatial data, fostering innovation and expanding the methodological toolkit available to archaeologists.

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