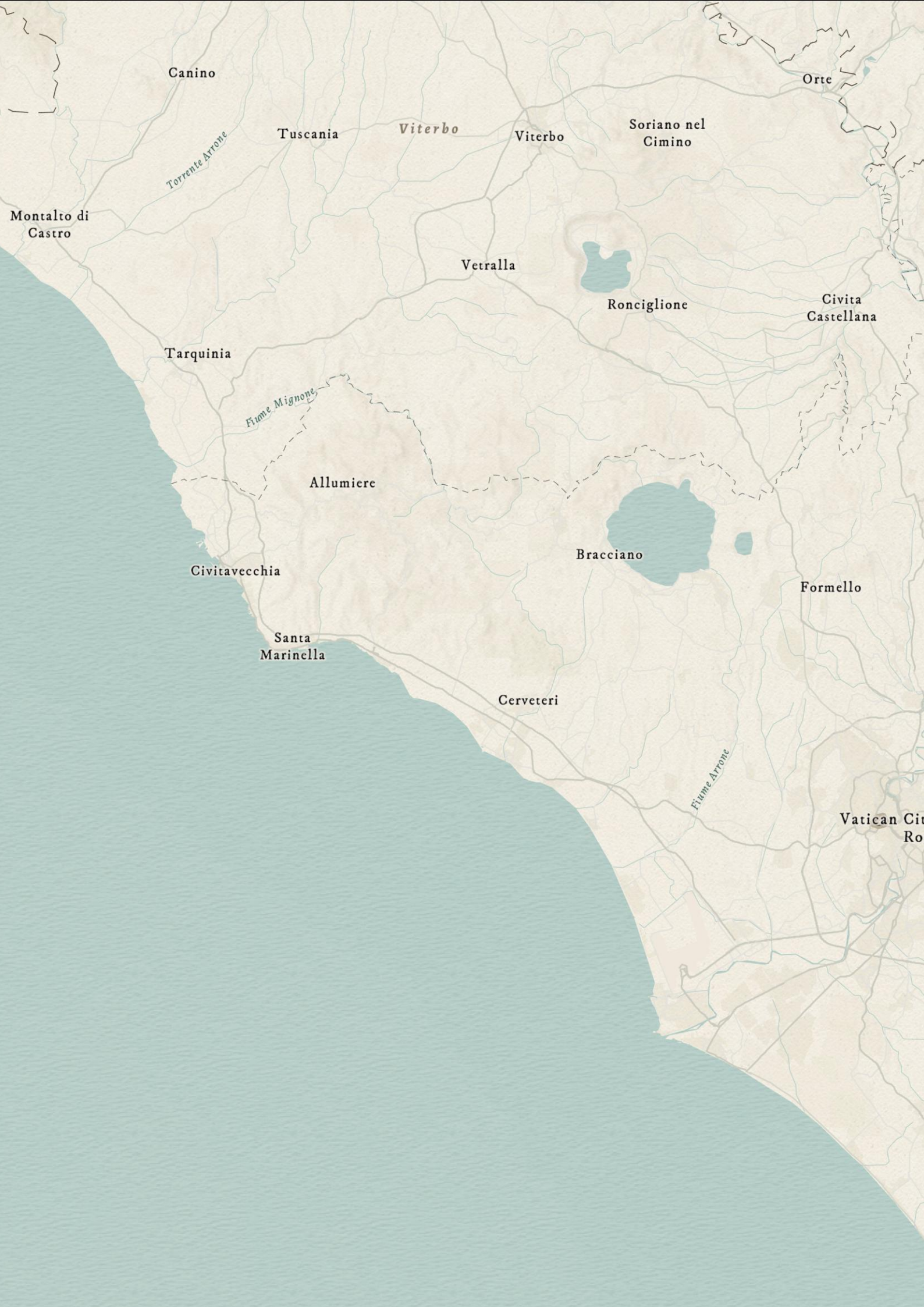






POLITECNICO DI TORINO

Department of Architecture and Design (DAD)

Master's degree in Architecture For Heritage

THESIS TITLE

**3D Survey and WebGIS-Based Methodology for the
Documentation of the Banditaccia Necropolis (Cerveteri)**

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I dedicate

To my parents, Reza and Mahboubeh whose endless love and unwavering support have
always been my greatest strength

To my brother, Danial, whose strength and encouragement have continuously inspired me
all my life and the years spend far from home

To my beloved partner, Alessandro, for always standing by my side throughout this
journey

And

To the brothers and sisters of my homeland,
of those who sacrificed their lives for their homeland, may every drop of blood they shed
for this land become a river for them in heaven.

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Abstract

The Banditaccia necropolis in Cerveteri is one of the most complex archaeological landscapes of the ancient Mediterranean, the place that funerary architecture, territorial organisation and environmental processes converge into a united cultural system. Despite its outstanding universal value, the site faces different problems such as increasing pressures linked to erosion, vegetation dynamics, climatic variability and visitor impact. Traditional conservation approaches are often focused on individual monuments, struggle to address the spatial and ecological dimensions that shape the long-term vulnerability of the necropolis. This thesis proposes a landscape-based and digitally supported methodology for understanding and managing the archaeological territory of Cerveteri. Through an integrated analysis of archaeological structures, morphological patterns, spatial organisation and ecological behaviour, the research reconstructs the territorial logic that governed the development of the necropolis and continues to influence its preservation. Building on this interpretative framework, the study develops a GIS and WebGIS system designed to map archaeological features, environmental indicators and conservation risks within a unified geospatial environment and on-site 3D survey. The method operates at two different scales of this area: a general scale covering the entire necropolis and a detailed scale which is the most important part of the thesis focused on the Via degli Inferi sector, where drone imagery, orthophotos and on-site observations are used to assess deterioration patterns and environmental pressures. It can be said that the resulting WebGIS platform functions as a decision-support tool for preventive conservation, enabling continuous monitoring, spatial analysis and the integration of archaeological, ecological and administrative data. By combining conservation theory, landscape interpretation and digital spatial technologies, the thesis shows how WebGIS can enhance the management of complex archaeological sites and contribute to sustainable preservation strategies. The work positions Cerveteri as a model for digitally informed conservation of Mediterranean cultural landscapes and outlines future perspectives, including the potential integration of participatory approaches within heritage monitoring frameworks.

Keywords: Archaeological Landscape; Preventive Conservation; 3D Survey; GIS; WebGIS; Spatial Analysis; Cultural Heritage Management; Banditaccia Necropolis; Cerveteri; Landscape-Based Approach; Environmental Vulnerability; Digital Documentation; Territorial Organisation; SLAM; Photogrammetry; GNSS.

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CHAPTER I

INTRODUCTION

1.1 Introduction

The conservation of archaeological landscapes has increasingly shifted from monument-based intervention toward approaches that recognise heritage as a dynamic system shaped by environmental, cultural and territorial processes. Across the Mediterranean, open-air archaeological sites face accelerating pressures linked to climate variability, vegetation growth, erosion, tourism and the long-term fragility of exposed materials. Traditional conservation methods, often focused on individual structures, struggle to address the spatial and ecological dimensions that determine the vulnerability of these landscapes. This gap highlights the need for methodologies capable of integrating archaeological knowledge with environmental observation and spatial analysis. In this broader context, the Banditaccia necropolis in Cerveteri represents an exemplary case. Its monumental tumuli, carved chamber tombs, tufa plateaus and ritual pathways form a complex funerary landscape where human activity and natural processes have interacted for millennia. The site functions simultaneously as a funerary city, an archive of urban memory and a living ecological system. Its spatial organisation, visibility patterns and territorial relationships with the ancient centre of Caere reveal a conception of landscape that is symbolic, political and environmental. Understanding such a landscape requires moving beyond isolated monuments toward an integrated reading of space, morphology and cultural meaning. Digital technologies particularly GIS and WebGIS offer new possibilities for analysing and managing archaeological landscapes at multiple scales. Through geospatial modelling, it becomes possible to map environmental risks, visualise spatial relationships, monitor vegetation dynamics and integrate heterogeneous datasets into a unified platform. These tools do not replace archaeological interpretation but they extend it, making visible the processes that shape preservation over time and enabling preventive conservation strategies rather than reactive interventions. This thesis emerges from the intersection of conservation theory, landscape interpretation and digital spatial analysis. Its aim is twofold, to understand how the Banditaccia necropolis expresses Etruscan identity through spatial organisation and to develop a WebGIS-based methodology capable of supporting conservation through continuous monitoring and spatial evaluation. By approaching Cerveteri as a dynamic territorial system one shaped by geology, ecology, ritual practice and modern pressures the research positions the site as a laboratory for testing digital tools in heritage management.

Ultimately, the thesis addresses a central question:

How can archaeological landscapes be conserved as dynamic living systems?

1.2 Problem Statement and Research Questions

The archaeological landscape of Cerveteri and particularly the Banditaccia necropolis, shows one of the most extensive and historically layered funerary complexes of the ancient Mediterranean. Despite its outstanding universal value, the site faces increasing pressures linked to environmental decay, vegetation dynamics, climate variability, tourism impact and the limitations of traditional conservation approaches. While extensive archaeological scholarship has focused on tomb typologies, chronology and material culture, the landscape itself understood as a spatial, ecological and cultural system is still insufficiently analysed in a management-oriented perspective. This gap becomes evident when confronting practical conservation issues: root infiltration damaging tufa walls, erosion destabilising tumuli, seasonal vegetation growth altering micro-climates, and the lack of integration between archaeological knowledge, maintenance records and environmental monitoring. Existing documentation is often descriptive, fragmented or not spatially referenced, meaning that much of the knowledge produced about the necropolis does not translate into preventive conservation policies. The problem is not the absence of research but the absence of an integrated, spatial, decision-support approach. Digital technologies particularly GIS and WebGIS offer the possibility to connect archaeological data, environmental parameters, conservation history and risk indicators within a single geospatial environment. Yet their application in Cerveteri remains limited, locally implemented or not exploited at landscape scale. For a site whose identity is inseparable from terrain morphology, ecological processes and territorial continuity, a spatial-based methodology is not optional; it is necessary.

So, the central research problem of this thesis can be formulated as follows:

How can the Cerveteri necropolis be documented, analysed and managed not only as a collection of monuments, but as a cultural landscape system whose preservation depends on environmental processes, territorial organisation and digital spatial analysis?

According to this challenge, the study develops a structured set of research questions, guiding the analytical path of the dissertation these research questions include:

Research Questions:

- How has the landscape of Southern Etruria and Cerveteri evolved historically and what territorial logics shaped the Banditaccia necropolis?
- How do geological characteristics, Architectural patterns, vegetation patterns and spatial configuration influence the identity and conservation vulnerability of the funerary landscape?
- What forms of degradation currently affect the necropolis, and which environmental or human-induced factors accelerate deterioration?
- How can 3D Survey, GIS/WebGIS be used to map, analyse and monitoring archaeological features, environmental risks and conservation needs?
- How can a spatial-based methodology support decision-make for preventive conservation and long-term management?

These questions show the bridge between historical-archaeological understanding and digital conservation strategies, transforming the thesis from a descriptive study into a method-driven investigation in which digital tools form the core interpretive and operational framework.

1.3 Aims, Objective and Expected Outcomes

The present research aims to investigate the conservation problems affecting the archaeological landscape of Cerveteri, with particular attention to the Banditaccia necropolis, to develop an integrated methodology for documentation, vulnerability assessment and decision-making support. The study approaches the site not as an isolated monumental complex but also as part of a broader territorial system which is shaped by geology, vegetation, ritual space and historical urban development. According to this framework, the research seeks to analyse how landscape processes, human activity, and environmental factors intersect and influence the long-term preservation of the necropolis. A primary goal of the thesis is to build a digital spatial framework using GIS and WebGIS tools Based on 3D survey which is capable of storing archaeological, environmental and conservation-related information in a structured and continuously updatable platform. By mapping tomb types, landscape morphology, vegetation behaviour and conservation risks, the research intends to establish a foundation for long-term monitoring rather than episodic intervention. This objective aligns with contemporary conservation approaches

that privilege preventive strategies, multidisciplinary collaboration and data-driven evaluation. A further goal is to examine the historical evolution of Caere within the broader context of Southern Etruria, showing how patterns of settlement, funerary architecture and political organisation shaped the configuration of sacred and urban landscapes. Understanding these dynamics is necessary for translating the necropolis not only as a funeral ground but as a material expression of identity, memory and social hierarchy. The expected outcome of this work is the production of a digital management model capable of supporting future conservation strategies. The final WebGIS environment should function as an analytical and operational tool, allowing heritage authorities to visualise risk, document deterioration, and plan targeted interventions based on spatial evidence. According to all this the thesis aims to contribute to the broader discourse on conservation of archaeological landscapes by showing how digital methods can strengthen interpretation, improve planning efficiency and keep the integrity of complex heritage systems. Ultimately, this research intends to bridge theoretical conservation principles with on-site practical needs, producing a framework that is scientifically grounded, operationally useful and adaptable for future studies on similar Mediterranean archaeological landscapes.

1.4 Research Methodology and Thesis Structure

This research adopts a multidisciplinary methodology that combines archaeological interpretation, landscape analysis and digital spatial technologies to investigate the archaeological landscape of Cerveteri. The study develops progressively from theoretical concepts to practical applications, with each phase contributing to the construction of the overall analytical framework.

The first stage is based on a review of the literature concerning conservation theory, cultural landscapes, archaeological heritage management and digital approaches to heritage documentation. This theoretical background provides the conceptual foundations necessary for understanding archaeological landscapes as dynamic systems shaped by the interaction of cultural, environmental and territorial processes. The second stage focuses on the historical and archaeological context of Southern Etruria and Cerveteri. Through the analysis of archaeological studies, historical sources and previous research, the territorial development of the region is reconstructed, highlighting the processes that contributed to the formation and evolution of the Banditaccia necropolis. The third stage adopts a landscape perspective, examining the necropolis not as an isolated group of monuments but as part of a wider territorial system. Particular attention is given to spatial organisation, topography, environmental conditions, visibility patterns and the relationship between funerary architecture and the surrounding landscape. This approach allows the necropolis to be understood as a cultural landscape shaped by the continuous interaction between human activity and natural processes. The methodological framework is further supported by the use of GIS and WebGIS technologies. These tools provide an effective environment for integrating archaeological, environmental and conservation-related information into a

single spatial database. Through mapping, spatial analysis and visualisation, GIS and WebGIS facilitate the interpretation of relationships between monuments, landscape features and conservation conditions.

Finally, the methodology is applied to the Via degli Inferi sector, which serves as the case study of the research. The resulting GIS and WebGIS environment functions both as a documentation platform and as an analytical tool for organising archaeological information, supporting conservation assessment and enhancing the communication of knowledge related to the archaeological landscape.

Workflow of the Thesis Structure

Chapter I

Introduction and Research Framework

Establishes the research background, defines the research problem and objectives, and presents the methodological structure of the thesis.

Chapter II

Conservation and Heritage Management Framework

Introduces conservation theory, archaeological heritage management and the role of digital technologies in cultural heritage documentation and preservation.

Chapter III

Historical and Territorial Context

Reconstructs the historical development of Southern Etruria and Cerveteri, providing the archaeological and territorial context of the Banditaccia necropolis.

Chapter IV

Landscape Analysis of the Banditaccia Necropolis

Examines the necropolis as a cultural landscape through the analysis of spatial organisation, morphology, environmental conditions and landscape dynamics.

Chapter V

3D Survey, GIS and WebGIS Methodology for the Via degli Inferi

Develops the GIS database structure and WebGIS environment through the classification of tombs, spatial data organisation, conservation-related attributes and digital visualisation tools.

Chapter VI

Future Perspective And General Conclusion

Synthesises the results and evaluates the contribution of GIS and WebGIS technologies to the documentation, interpretation and management of archaeological landscapes.



CHAPTER II

CONTEXT

2.1 Theoretical and Administrative Premises of Conservation

The field of conservation, as we see today, is the outcome of a gradual transition from traditional craftsmanship to a discipline grounded in theory, method and institutional regulation. This transition did not occur suddenly; it developed through an increasing awareness that cultural heritage embodies meanings that go far beyond its physical presence. In general, conserving an object, a monument or an archaeological site is not simply an act of repairing a damaged surface in fact it is an act of interpretation, because each intervention mentions a judgement about what should be preserved, what can be altered and what must be transmitted to future generations.¹ In this sense, conservation is a cultural responsibility before it becomes a technical operation. During the twentieth century, the need to establish shared principles for conservation became increasingly evident. Quick expansion of restoration activities, together with the emergence of heritage as a public value, highlighted the limitations of interventions guided solely by tradition or personal sensitivity. One of the most influential attempts to provide a solid theoretical foundation for conservation was the work of Cesare Brandi. In *Teoria del Restauro*, Brandi suggested an important conceptual framework and structure which defined conservation as the moment in which the material integrity of a work and the perception of its aesthetic unity converge.² His theory identifies between the historical dimension of an artwork linked to the passage of time and its aesthetic dimension, which relates to the experience of the object as a coherent whole. Brandi argued that interventions should respect both dimensions equally, avoiding actions that clarify the historical evidence or interrupt the aesthetic reading of the work.³ These rules, however formulated within the Italian context, became reference and more important points for broader international debate. Their influence and effect are clearly reflected in the Venice Charter (1964), one of the most important and foundational documents of modern conservation theory. Scientific methodologies, documentation, and authenticity were emphasized. A unified approach should be adopted to conserve monuments and sites.⁴ It also introduced the idea that monuments cannot be separated from their surroundings, the relationships between architecture, landscape and environment form part of the heritage and must be preserved as well. Over time, the Charter has been revisited and reinterpreted, as new understandings of heritage and new societal expectations emerged.⁵ The conversation around it sheds light on how conservation has evolved from an emphasis on monuments to understanding of a wider range of cultural, social, and territorial values. Subsequent global documents, most clearly the Nara Document on Authenticity (1994), expanded the meaning of authenticity and adapted it to cultural diversity. Nara explicitly acknowledged that heritage values and concepts may differ cross-culturally and authenticity is not only a matter of material fabric but also of traditions, uses, memories, and community relations.⁶

¹ Jukka Jokilehto, *A History of Architectural Conservation* (London: Routledge, 1999).

² Cesare Brandi, *Teoria del Restauro* (Torino: Einaudi, 1963).

³ ICOMOS, *The Venice Charter* (1964).

⁴ Herb Stovel (ed.), *The Venice Charter Revisited* (Rome: ICCROM, 2006).

⁵ UNESCO, *The Nara Document on Authenticity* (1994).

⁶ Giovanna Caneva, *Memoria, percezione, vegetazione: Il paesaggio archeologico mediterraneo* (2021).

This broader concept is especially relevant for archaeological landscapes, where the identity of a site often depends on the interaction between natural processes, historical stratifications and the ways in which communities have engaged with the place over time.⁷ In this scenario, understanding heritage requires a combination of archaeological knowledge, environmental observation and cultural interpretation. Beside theoretical developments, conservation is also shaped by administrative and legal frameworks that regulate the responsibilities and procedures associated with heritage protection. In Italy, the primary reference is the *Codice dei Beni Culturali e del Paesaggio* (Legislative Decree 42/2004), which describes a cultural heritage as a public good and establishes the legal mechanisms through which it must be safeguarded.⁸ According to the Code, the state through the *Soprintendenze* has the authority to supervise conservation activities, authorise interventions, ensure compliance with standards and coordinate with other public institutions. This system ensures that conservation follows recognised criteria rather than all ideal decisions, and that heritage remains accessible, interpretable and integrated within territorial planning. The Code also provides a specific definition of archaeological parks as complex territorial systems that include monuments, landscape elements, vegetation, infrastructure and all components necessary to interpret the archaeological context.⁹ In recent decades, the notion of preventive conservation has become increasingly important within this administrative structure. Preventive conservation focuses on understanding the environmental, biological and structural processes that affect heritage, in order to reduce risks before deterioration becomes irreversible.¹⁰ This is particularly crucial for open-air archaeological sites, where factors such as climate, vegetation growth, humidity and erosion continuously interact with archaeological remains. Studies on the management of archaeological resources highlight that long-term preservation requires not only interventions on the material but also systems for monitoring, documentation and planning.¹¹ So, conservation becomes a multidisciplinary practice in which archaeologists, conservators, botanists, geologists and administrators must collaborate with each other for conservation and preservation. The integration of digital tools, especially GIS and WebGIS systems, represents one of the most significant recent developments in the field. These tools enable the collection, visualisation, and analysis of spatial data, making it possible to understand how environmental conditions, structural vulnerabilities and human activities interact across a site.¹²

But the use of GIS does not replace theoretical principles, it provides an operational platform that helps translate those principles into concrete management strategies. The ability to connect administrative information, conservation records, environmental monitoring and archaeological documentation within a single digital environment supports the type of informed decision-making required by both international charters and national

⁷ Italia, *Codice dei Beni Culturali e del Paesaggio*, D.Lgs.42/2004

⁸ Giovanna Caneva, *Plant Biology for Cultural Heritage* (Los Angeles: Getty Conservation Institute, 2014).

⁹ Timothy Darvill, *The Management of Archaeological Resources* (London: Routledge, 1995).

¹⁰ Herb Stovel, *From Monuments to Living Heritage* (Rome: ICCROM, 2008).

¹¹ Paolo Torsello, *Restauro Architettonico: Padri, Teorie, Immagini* (Milano: Franco Angeli, 1988).

¹² UNESCO World Heritage Centre, *Operational Guidelines for the Implementation of the World Heritage Convention* (2019).

legislation. The evolution of conservation theory in Italy has also been analysed by Paolo Torsello, whose work emphasises restoration as an interpretative and architectural act grounded in transparency, recognisability and responsibility toward historical fabric. His perspective reinforces the idea that conservation is not merely technical but intellectual, requiring awareness of the cultural significance embedded in material form.¹³ According to all these approaches, it can be concluded that the theoretical and administrative premises of conservation establish the cultural, ethical and regulatory framework that guides every decision related to heritage. Understanding these foundations is essential and important before approaching and describing any specific case study, because they define the criteria through which significance is recognised, interventions are evaluated and long-term strategies are developed. Conservation today stands at the intersection of theory, law and technology, and it is within this integrated framework that methodologies such as WebGIS-based systems can contribute effectively to the preservation and interpretation of archaeological sites.

¹³ UNESCO, *Etruscan Necropolises of Cerveteri and Tarquinia – Nomination Dossier* (2004).

2.2 The Cultural and Archaeological Setting of Southern Etruria

It is more important to Understand the cultural and territorial background of heritage sites in conservation practice and it is one of the most important step. Theoretical principles and administrative frameworks provide the criteria for intervention, but the effective application of these principles requires a full knowledge of the historical, environmental and archaeological context in which a site developed. For this reason, before addressing the specific case of Cerveteri, it is necessary to outline the broader cultural and archaeological setting of Southern Etruria. (Fig.1)



Figure 1. Historical map of central Italy showing key Etruscan cities and territorial features relevant to the study of funerary landscapes, including Cerveteri, Tarquinia, Veii, and Vulci. The spatial distribution of rivers, lakes, and settlements provides essential context for understanding environmental and cultural dynamics in ancient Etruria.

Source: <https://weirditaly.com>

Southern Etruria represents one of the most historically rich and archaeologically complex regions of pre-Roman Italy. Situated between the Tyrrhenian coastline, the Tiber Valley and the volcanic plateaus of northern Lazio, this area developed as a dynamic intersection of territories where natural morphology and human activity evolved in close relationship. The region's distinctive landscape characterised by tufa plateaus, deep ravines, fertile plains and coastal corridors shaped both the distribution of settlements and the cultural practices that emerged within them.¹⁴ Throughout the first millennium BCE, Southern Etruria hosted several of the most influential Etruscan city-states, including Veii, Tarquinia, Vulci and Caere (modern Cerveteri). These centers were not isolated entities but formed an interconnected territorial network based on political alliances, economic exchange and shared religious structures. Urban areas, sacred spaces, cemeteries and rural hinterlands developed as components of a coherent system that reflected the social organisation and cultural values of Etruscan communities.¹⁵ (Fig. 2)



Figure 2. Map of ancient Tuscia by Abraham Ortelius. *Theatrum Orbis Terrarum*. London, 1606

Source: [L'Etruria e le Città-Stato - WCI](#)

Their position was usually intentional, settlements were strategically located to control communication routes, access water, manage agricultural production and exploit the defensive advantages offered by volcanic plateaus.¹⁶ The landscape itself played an integral role in shaping Etruscan identity. The topography of ridges, valleys and natural thresholds influenced the organisation of space, the placement of ritual areas and the structuring of territorial boundaries. Religious activity was deeply embedded in the natural environment, sanctuaries often occupied liminal positions near springs, crossroads or elevated promontories, reinforcing the symbolic relationship between human presence and the surrounding environment.¹⁷ Cemeteries, rather than being peripheral spaces, were deliberately positioned at urban limitation and one a main roads the situation that they

¹⁴ Jokilehto, *A History of Architectural Conservation*.

¹⁵ Brandi, *Teoria del Restauro*.

¹⁶ ICOMOS, *Venice Charter*.

¹⁷ Stovel, *Venice Charter Revisited*.

were people lived, forming monumental markers of ancestry, memory and social hierarchy.¹⁸ It is interesting to say that One of the most distinctive features of Etruria culture was their religion. The Etruria's believed in a pantheon of gods and goddesses, later partly assimilated by the Roman pantheon, each of whom was responsible for a particular aspect of life or nature. They also believed in an afterlife and built elaborate tombs for their deceased loved ones, many of which have been discovered by archaeologists. Archaeological evidence from Southern Etruria reveals a remarkable continuity of occupation, allowing the reconstruction of territorial development from the Early Iron Age through Roman expansion. The region preserves domestic districts, funerary complexes, sanctuaries, hydraulic systems and agricultural infrastructures, offering a comprehensive picture of how Etruscan society organised everyday life, managed resources and structured political authority.¹⁹ These interrelated contexts demonstrate the tight relationship between urban centres and their landscapes, a relationship essential for understanding sites such as Cerveteri and the Banditaccia necropolis.

Southern Etruria also played a central role in long-distance exchange networks. From the Orientalising period onward, the region shows strong Mediterranean connections, visible in imported ceramics, artistic styles and technological innovations linked to Phoenician traders and Greek colonies of southern Italy.²⁰ These exchanges stimulated the development of local elites, who expressed their identity through monumental tombs, decorated architecture and increasingly elaborate funerary rituals.²¹ Environmental diversity is another defining characteristic of the region. Volcanic soils supported intensive agriculture, while wooded ravines and coastal zones created varied ecosystems that influenced settlement strategies and resource exploitation. Recent studies highlight how soil composition, vegetation growth and microclimatic conditions affected not only ancient land use but also the present-day preservation of archaeological structures.²² Understanding these environmental processes is fundamental for developing sustainable conservation approaches, particularly in extensive open-air landscapes. In conclusion, Southern Etruria constitutes a cultural and territorial framework shaped by the interaction of natural morphology, long-term human activity and symbolic practices. Analysing this broader setting provides the necessary foundation for approaching the specific case of Cerveteri, situating the Banditaccia necropolis within the larger network of Etruscan landscapes and explaining the historical and environmental conditions that contributed to its development.²³

¹⁸ UNESCO, Nara Document.

¹⁹ Caneva, Memoria, percezione, vegetazione.

²⁰ Italia, Codice dei Beni Culturali.

²¹ Caneva, Plant Biology for Cultural Heritage.

²² Darvill, Management of Archaeological Resources.

²³ Stovel, From Monuments to Living Heritage.

2.3 Landscape, Environment and Territorial Structure

As Mentioned before , the landscape of Southern Etruria is the product of a long interaction and relationship between natural processes and human settlement strategies. Its geomorphological configuration, dominated by volcanic plateaus, deep ravines and wide fertile plains, conditioned the ways in which communities organised their territories from prehistory through the Etruscan period and into the Roman era. The environment cannot be separated from the cultural evolution of the region like soils, vegetation, hydrology and topography which all together created a framework that shaped settlement choices, economic activities and ritual practices. according to Understanding these environmental dynamics is essential and more important for any interpretation of the archaeological landscape of Cerveteri and its surroundings. Southern Etruria is basically a volcanic area created by eruptions from the Monti Sabatini and Monti della Tolfa mountains. These eruptions produced extensive layers of tufa, the soft volcanic stone that defines much of the region's architectural and funerary landscapes. Tufa plateaus provided defensible high grounds for urban centres, while their edges cut by erosion into deep ravines created natural boundaries that structured territorial divisions. These geomorphological formations also facilitated the excavation of tombs, storage spaces and road cuttings, giving the region its characteristic carved landscapes. The distinctive morphology of tufa environments made them both strategic and symbolically charged, influencing the spatial logic that would later characterise major Etruscan sites such as Caere.^{24 25} (Fig .3)

Hydrological systems also played a decisive role in shaping territorial structure. The region is characterised by a network of seasonal streams, springs, and underground water channels, many of which originate from volcanic aquifers. obviously all These water resources supported agricultural activities for all the people on that time, enabled long-term settlement, and often took on ritual significance. In several areas of Southern Etruria, sacred springs and water sanctuaries functioned as focal points for community identity and territorial cohesion. Rivers and natural corridors also served as communication routes linking inland centres with the Tyrrhenian coast, integrating the region into Mediterranean trade networks.²⁶ (Fig.4)

²⁴ Proietti, Cerveteri.

²⁵ Darvill, Management of Archaeological Resources.

²⁶ Darvill, Management of Archaeological Resources.

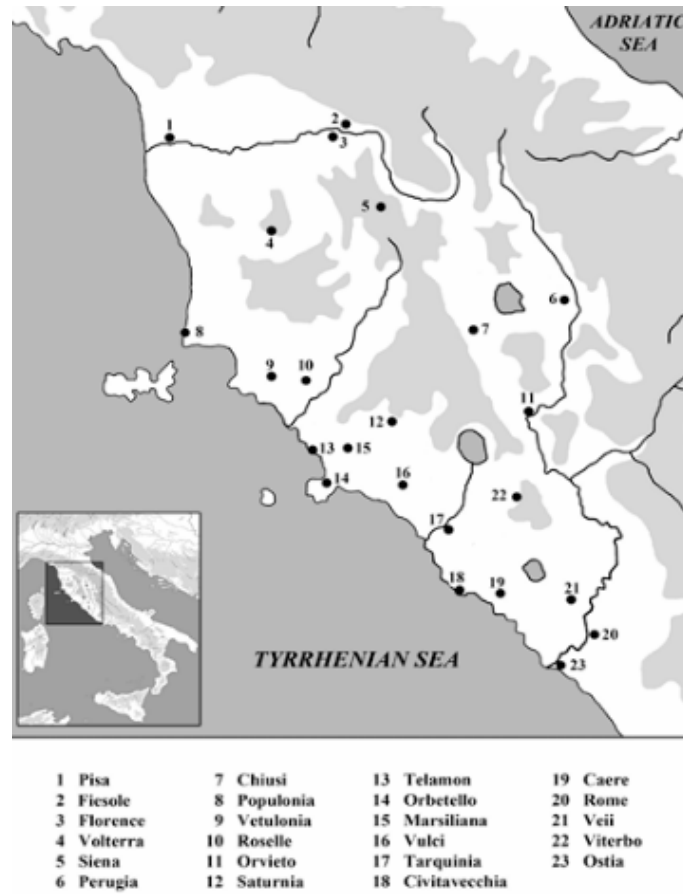


Figure 3. Major sites in Etruria (drawing A. Blaickner).

Source: Blasi, C. et al. 1999; Bartolini, G. et al. 2008.



Figure 4. Drainage basins in Etruria (drawing A. Blaickner).

Source: Blasi, C. et al. 1999; Bartolini, G. et al. 2008

Vegetation is another fact which is more important part of their culture , these patterns in Southern Etruria reflect the ecological diversity of the area. Based on the documents the region consisted of mixed woodlands, Mediterranean shrubs and broad agricultural zones. On the other hand, the volcanic soils of Southern Etruria were highly fertile, supporting cereals, vineyards and olive cultivation, while the surrounding woodlands supplied timber, fuel and hunting resources. In the ancient time vegetation played an active role in shaping land use practices sacred groves defined ritual areas, terraced slopes were created for cultivation, and forest clearing opened new agricultural zones. Today, environmental studies show that vegetation continues to influence the preservation of archaeological remains, as roots, moisture cycles and plant growth can accelerate the decay of tufa structures.²⁷In the following that it is interesting that to take a look at this table below which is summarises the main climatic and vegetation zones of Southern Etruria which is shows how temperature, rainfall and dry periods vary across the region, and how these environmental differences create distinct types of vegetation from coastal maquis and oak woodlands to temperate beech forests in higher areas. These patterns help explain the ecological diversity that shaped land use, agriculture, and cultural practices in the Etruscan landscape.(Fig.5)

The territorial organisation of Southern Etruria developed through the interaction between these environmental elements and changing social and political systems. Etruscan communities created a kind of network of settlements on a plateaus and valleys, which all controlling agricultural farmlands, necropolises and sacred landscapes. The spatial coherence of these systems reflects a sophisticated understanding of environmental potentials and limitations. Urban centres were placed on elevated tufa platforms for defence and visibility, while necropolises were located on adjacent plateaus or along major access routes to express lineage, identity and social hierarchy. Roads carved directly into the tufa connected these components, integrating the region into a unified territorial fabric.²⁸ In Southern Etruria, communities established their settlements on both plateaus and in valleys, creating a connected network across the landscape. Each of these settlement managed the surrounding farmland, controlled nearby burial areas, and maintained sacred places that were important for community identity. This organisation shows how daily life can be close , territory and cultural practices were linked in the region.²⁹Climate factors also played a significant role in shaping the region. Southern Etruria experiences a Mediterranean climate, with hot dry summers and mild wet winters. These seasonal patterns influenced agricultural cycles, vegetation growth and erosion processes.

²⁷ Caneva, Plant Biology for Cultural Heritage.

²⁸ UNESCO, Nara Document.

²⁹ Caneva, Memoria, percezione, vegetazione.

Zone	Mean temperature (°C)	Mean Summer temperature (°C)	Mean temperature in coldest month (°C)	Rainfall (mm)	Dry Period	Vegetation	Type
Coastal	15.5	26	3.5	616–826	3–6 months	Maquis, mixed oak / holm oak / cork oak woods	Mediterranean
Hilly areas near coast	15	28.5	3	813–1000	3 months	Maquis, turkey oak / mixed oak / holm oak / cork oak woods	Mediterranean
Hilly interior	14	26	1	962–1189	2 months	Chestnut woods, turkey oak / mixed oak / holm oak woods	Transitional
Higher hilly	13	26	1	1156–1397	1 month	Beech woods, chestnut woods, turkey oak / mixed oak / holm oak woods	Temperate
Lower mountain	11	21.5	1	1159–1447	0 months	Mixed deciduous woods, beech woods, chestnut woods, mixed oak / holm oak woods, spanish broom shrublands	Temperate
Upper mountain	7.5	21.5	–3	1430–1586	0 months	Beech woods, high altitude shrublands, mixed deciduous woods	Temperate

Figure 5. Climatic and vegetation zones of Southern Etruria, showing environmental variation across the region.

Source: Blasi, C. et al. 1999; Bartolini, G. et al. 2008.

Over centuries, climatic fluctuations such as humidity peaks or prolonged droughts left measurable traces on archaeological materials, especially on tufa surfaces vulnerable to water infiltration and temperature variations. Modern conservation studies focus on that climate continues to be one of the principal threats to open air archaeological landscapes, particularly in areas where natural weathering interacts with biological growth and human activity.³⁰ By analysing these environmental factors, it becomes possible to understand how settlements like Cerveteri developed specific spatial identities rooted in the physical character of the land.³¹ Furthermore, this understanding forms a crucial basis for contemporary conservation and management strategies. The same environmental

³⁰ Italia, Codice dei Beni Culturali.

³¹ Caneva, Plant Biology for Cultural Heritage.

variables that shaped ancient territorial organisation erosion, vegetation, water dynamics and microclimatic conditions continue to affect the preservation of archaeological structures. Sustainable conservation requires an integrated approach that links archaeological documentation with environmental monitoring and territorial planning. Landscape-scale analysis helps identify zones of vulnerability, patterns of decay and potential risks, ensuring that interventions respond not only to the material conditions of individual monuments but also to the broader ecological systems in which they exist.³² Despite all these documentations, the landscape of Southern Etruria provides the essential context for interpreting the Banditaccia necropolis. The tufa plateaus allowed the creation of hypogea and monumental tumuli which will be discussed about them more in the following chapters we will see the visibility between city and necropolis reinforced social and symbolic relationships; and the environmental diversity shaped the forms of burial architecture and the continuity of ritual practices. Without understanding this territorial and environmental framework, it is impossible to fully grasp the significance, development and current challenges of the Cerveteri archaeological landscape.³³

³² Darvill, *Management of Archaeological Resources*.

³³ Stovel, *From Monuments to Living Heritage*.

2.4 Principles of Cultural Landscape and Identity Formation

The concept and the definition of the landscape is more important and has a value in the heritage studies. Specially talking about the lands which are created by the human activities and natural landscape situation during a time. Far from being a neutral background, landscape is a dynamic structure in which natural elements, cultural practices and collective memory converge.³⁴ This approach, developed progressively through contributions from geography, anthropology and conservation theory, interprets landscape as a historical document whose meaning depends not only on physical features but also on the symbolic systems that communities have constructed around them.² Brandi argued that every cultural object and by extension every cultural environment carries historical and aesthetic value simultaneously, and that separating these values compromises the integrity of the work.³⁵



Figure 6. Aerial view of the town of Cerveteri, located about 25 km northwest of Rome. The Tyrrhenian Sea is seen in the background.

Source: [Search media - Wikimedia Commons](#)

This picture perfectly shows the creation of a natural landscape by collaborating human activities and the natural vegetation and the landscape during a time. (Fig.6)

When this principle is considered at the scale of wider territorial systems, it becomes clear that the identity of a landscape develops through the continuity of its forms, uses, and meanings, which remain readable over time. This readability is crucial for conservation, because interventions must safeguard not only the physical elements but also the interpretive relationships that connect communities to their land. Recent scholarship further emphasizes that identity is not an inherent quality of a place, but a process shaped through experience, ritual practices, territorial organisation, and shared memory. Cultural landscapes thus function as repositories of collective identity, their paths, boundaries,

³⁴ Jokilehto, *A History of Architectural Conservation*.

³⁵ Brandi, *Teoria del Restauro*.

agricultural patterns, sacred spaces, and burial grounds reflect social values and the ways in which communities have perceived and used their environment. This is particularly visible in regions with strong ancient stratifications, where historical layers coexist and interact in shaping contemporary spatial perception.³⁶ International frameworks have further elaborated this understanding for example UNESCO defines cultural landscapes as the combined works of nature and humankind, focusing on their capacity to illustrate the evolution of human society under the influence of physical constraints and cultural forces.³⁷ This definition highlights three essential components, the material structure of the landscape, the cultural practices associated with it and the symbolic meanings that these practices generate. The integration of these elements forms the basis for evaluating authenticity and integrity, both of which are required for sustainable management. Identity formation also involves the way communities perceive continuity within territorial transformations. Even when landscapes undergo substantial environmental or social change, certain structural elements paths, terraces, hydrological systems, sacred sites preserve historical coherence and become anchors for collective memory.³⁸ Environmental features such as vegetation patterns, soil conditions and geomorphological characteristics play a complementary role by shaping how human interventions are organised across the land. This interplay between natural and cultural factors explains why the analysis of landscape must go beyond aesthetic appreciation and incorporate ecological, archaeological, and social dimensions. Another key principle concerns the relationship between landscape and place making. Anthropological studies underline that places acquire meaning not only through their physical form but also through narratives, rituals and daily practices that associate specific memories with the environment.³⁹ In archaeological contexts, this relationship becomes particularly relevant. burial areas, sacred routes, rural infrastructures and settlement terraces reflect the cultural logic through which ancient communities structured their world. Preserving such landscapes therefore requires an approach that protects not only material remains but also spatial relationships and cultural practices that define their identity. From a conservation perspective, recognising landscape as a cultural system obliges practitioners to adopt strategies that maintain interpretive continuity. Conservation cannot be limited to isolated monuments but it must engage with the broader territorial structures that give these monuments meaning.⁴⁰

This includes understanding traditional land uses, managing vegetation in accordance with ecological and historical conditions and preserving visual corridors that connect different components of the landscape.⁴¹ Digital tools particularly GIS and WebGIS tools which are improve this process by allowing the mapping of relationships between environmental variables, historical features and contemporary uses, supporting decisions rooted in both

³⁶ Giovanna Caneva, *Memoria, percezione, vegetazione* (2021)

³⁷ UNESCO WHC, *Operational Guidelines*

³⁸ Timothy Darvill, *The Management of Archaeological Resources* (London: Routledge, 1995).

³⁹ Stovel, *From Monuments to Living Heritage*.

⁴⁰ UNESCO, *Cerveteri and Tarquinia Nomination Dossier*, 2004.

⁴¹ Caneva, *Plant Biology for Cultural Heritage*.

scientific evidence and cultural interpretation.⁴² So the principles of cultural landscape and identity formation highlight the need for an integrated approach to heritage, where landscape is understood as a living archive of interactions between people, environment and memory. Protecting such landscapes involves safeguarding physical components, maintaining perceptual coherence and ensuring that cultural meanings remain legible across time.⁴³ These principles form an essential foundation for analysing regions such as Southern Etruria, where territorial identity is deeply embedded in landscape structures and where archaeological interpretation depends on recognising long-term relationships between natural morphology and cultural expression.⁴⁴

2.5 International and UNESCO Framework for Archaeological Protection

The protection of archaeological landscapes is deeply rooted in an international framework that has evolved over the past century, shaped by charters, conventions and global policy instruments that define how cultural heritage should be managed, conserved and transmitted to future generations. These frameworks are providing the conceptual and legal basis for understanding sites such as Cerveteri and the Banditaccia necropolis within a broader global system of heritage governance.⁴⁵ One of the foundational milestones in this evolution is the **1931 Athens Charter**, which first emphasized the importance of preserving not only individual monuments but also their surrounding environments. This early recognition laid the groundwork for a more holistic understanding of heritage protection.⁴⁶ The **1964 Venice Charter** further expanded this vision by defining conservation as a scientific and ethical practice, highlighting principles such as authenticity, minimum intervention and respect for historical layers. The Venice Charter's focus on context, material integrity and setting remains essential to the conservation of archaeological landscapes today.⁴⁷ Subsequent international documents strengthened these principles. The **1972 UNESCO World Heritage Convention** shifted global attention toward heritage as a shared resource of humanity and established the criteria for Outstanding Universal Value. This convention also introduced the concept of buffer zones and the need to safeguard not only monuments but also their territorial and environmental context an approach particularly relevant to Southern Etruria's extensive necropolises and cultural landscapes.⁴⁸ The concept of **cultural landscape**, formally recognised in the **1992 revision of the World Heritage Operational Guidelines**, marked a turning point. UNESCO defined cultural landscapes as the "combined works of nature and humankind."⁴⁹ legitimizing the idea that heritage can be both natural and cultural, tangible and intangible.

⁴² Laurenza, S., C. Putzolu, and E. Farinetti. *Re-thinking Landscape Archaeology and GIS Analyses: A Different Way of Dealing with Archaeological Landscapes within GIS*. Oxford: BAR Publishing, 2005.

⁴³ Caneva, *Memoria, percezione, vegetazione*.

⁴⁴ UNESCO, *Cerveteri and Tarquinia Nomination Dossier*, 2004.

⁴⁵ Athens Charter (1931).

⁴⁶ Venice Charter (1964).

⁴⁷ ICOMOS, *Venice Charter*.

⁴⁸ Stovel, *Venice Charter Revisited*.

⁴⁹ UNESCO, *Nara Document*.

This definition directly applies to the Etruscan territories, where geology, vegetation, ritual pathways and funerary architecture form an inseparable whole.⁵⁰ More recent frameworks—such as the **2005 Faro Convention**, which emphasizes community participation, and the **2011 UNESCO Recommendation on the Historic Urban Landscape (HUL)** promote a dynamic vision of heritage, encouraging integrated, ecological and socially inclusive approaches.⁵¹ Both documents align with contemporary conservation strategies adopted in Cerveteri, which increasingly combine archaeological science, ecological management and civic involvement.⁵² Within this international context, the Banditaccia necropolis illustrates how global heritage frameworks translate into local conservation practices. Its inscription on the **UNESCO World Heritage List in 2004** underscores its exceptional value and establishes obligations for monitoring, management, and sustainable use.⁵³ (Fig.7)

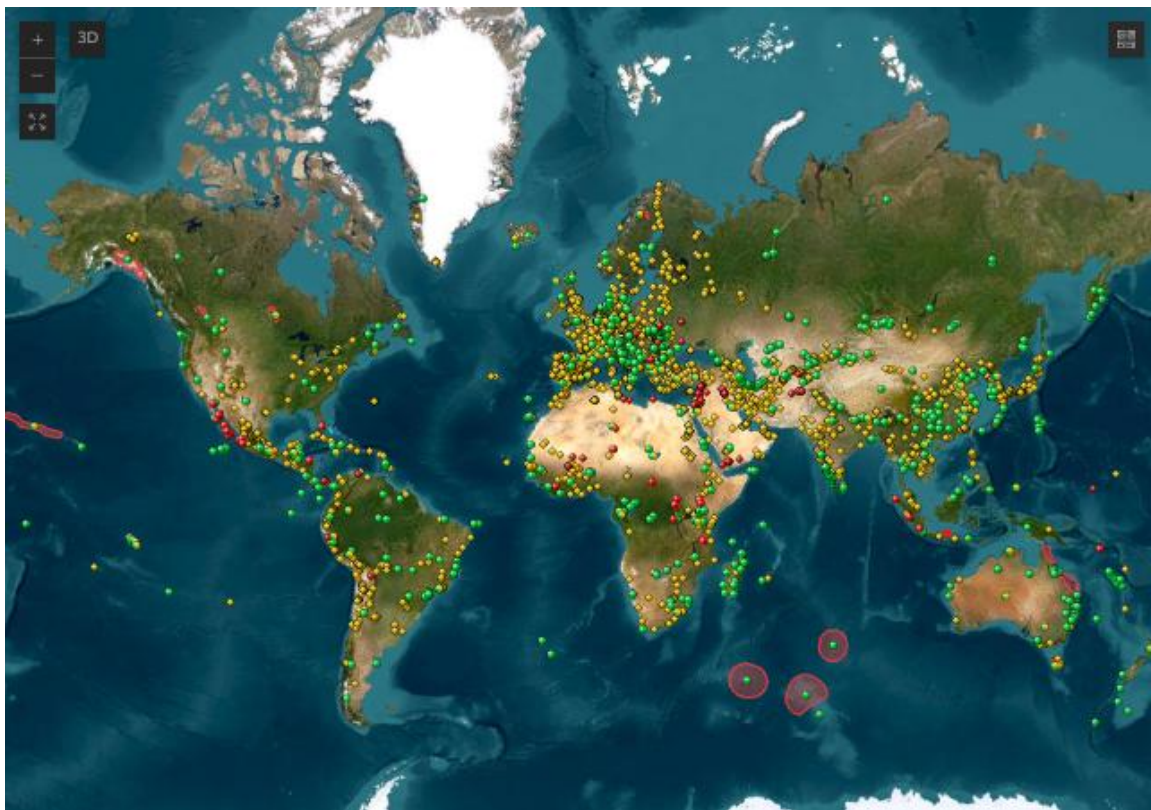


Figure 7. UNESCO World Heritage global map showing the international context of heritage protection.

Source: [Interactive Map - UNESCO World Heritage Centre](#)



⁵⁰ Caneva, Memoria, percezione, vegetazione.

⁵¹ Italia, Codice dei Beni Culturali.

⁵² Caneva, Plant Biology for Cultural Heritage.

⁵³ Darvill, Management of Archaeological Resources.

Both the Faro Convention and the HUL Recommendation align with contemporary conservation strategies adopted in Cerveteri, which increasingly combine archaeological science, ecological management and local community involvement.⁵⁴ In this international context, the Banditaccia necropolis illustrates how global heritage frameworks translate into local conservation practices. Its inscription on the **UNESCO World Heritage List in 2004** underscores its exceptional value and establishes obligations for monitoring, management, and sustainable use.⁵⁵ The coexistence of reconstructed areas and natural landscapes in Cerveteri also aligns with UNESCO's emphasis on authenticity, integrity, and landscape-based interpretation.⁵⁶ the international framework provides essential guidelines for understanding archaeological landscapes not as isolated monuments but as evolving cultural systems. For Southern Etruria, and particularly for Cerveteri, these frameworks validate conservation approaches that integrate archaeological research, landscape ecology, and community participation. They also reinforce the responsibility to ensure that future interventions respect the complex historical, environmental and social layers that define the region's identity.⁵⁷

2.6 Contemporary Issues in the Conservation of Archaeological Landscapes

Over the past two decades, the conservation of archaeological heritage has experienced deep transformation. contemporary practice has shifted from a narrow focus on individual monuments toward a broader understanding of archaeological landscapes as complex cultural, ecological, and social systems. This shift has been driven by global changes rising tourism, rapid urban development, climate instability, and new political and economic pressures that have made traditional, site based conservation approaches increasingly inadequate. Modern conservation theory now emphasises values based management, community participation, and the need to integrate both tangible and intangible dimensions of heritage into long-term planning. At the same time, technological innovation has reshaped the practical tools available to conservators. These tools allow specialists to detect hidden structures, assess structural conditions, and manage large territorial systems with a level of precision that was not possible with traditional methods. Yet the rapid expansion of available technologies has also created new challenges, particularly for decision makers who must determine which tools are appropriate for specific conservation needs, Together these theoretical and technological developments have reframed archaeological landscapes as dynamic heritage systems that require equally dynamic conservation strategies. Rather than reacting to isolated threats, contemporary conservation increasingly calls for integrated, preventive, and landscape-scale approaches that recognise the interconnected nature of environmental, social, and cultural processes.

⁵⁴ Stovel, *From Monuments to Living Heritage*.

⁵⁵ Darvill, *Management of Archaeological Resources*.

⁵⁶ Stovel, *From Monuments to Living Heritage*.

⁵⁷ Torsello, *Restauro Architettonico*.

Building on these developments, the following section examines the contemporary issues that currently affect the conservation of archaeological landscapes. (Fig.8)



Figure 8. Beirut, Lebanon. Archaeological rescue excavations have taken place in Beirut as part of the massive reconstruction after the civil war. The quality and scale of the archaeology has been extensive. Excavations by a team led by Fady Beayno are documenting this material before it is lost, but urban pressures mean that little is preserved in situ, and the display of what remains has been largely limited. Photo: Tim Williams.

Source: THE CONSERVATION AND MANAGEMENT OF ARCHAEOLOGICAL SITES, Tim Williams

Archaeological landscapes face increasing and multidimensional pressures that complicate their long-term preservation. Unlike individual monuments, landscapes are open, extensive, and continuously exposed to environmental, biological, and anthropogenic dynamics that accelerate deterioration and make management more complex. These pressures do not act in isolation but also they interact, creating cumulative risks that demand integrated and sustainable conservation strategies.⁵⁸ One of the most critical challenges is environmental degradation is climate change. Variations in temperature, humidity, and precipitation influence both the natural environment and the stability of archaeological materials. In Mediterranean regions, more intense rainfall accelerates erosion, while prolonged dry seasons contribute to cracking, soil instability, and the weakening of exposed tufa structures.⁵⁹ Archaeological landscapes that depend on delicate geomorphological balances such as the plateaus and ravines of Southern Etruria are particularly vulnerable to these processes.⁶⁰ Another important issue is the impact of vegetation growth, which plays a dual role while plant cover can provide superficial protection of soil, uncontrolled growth causes root penetration, structural displacement,

⁵⁸ Darvill, *Management of Archaeological Resources*.

⁵⁹ Caneva, *Plant Biology for Cultural Heritage*.

⁶⁰ UNESCO, *Nomination Dossier: Cerveteri and Tarquinia*, 2004.

and micro environmental variations that accelerate decay.⁶¹ Studies on vegetation dynamics show that roots infiltrate archaeological voids, destabilise walls, fracture stone blocks, and retain moisture, creating favourable conditions for biological colonisation such as mosses, fungi, and lichens.⁶² Archaeological landscapes carved into volcanic tufa are particularly vulnerable to biological and environmental deterioration, as the porous stone allows deep and rapid root intrusion. These landscapes face sustained pressure from human activity. Tourism, although economically beneficial can become harmful when infrastructure is inadequate or visitor flows are poorly managed, leading to footpath erosion, vibration, accidental damage, and the creation of uncontrolled shortcuts that expose subsurface features. Urban expansion and agricultural intensification increase the risk of the territorial coherence of archaeological areas, fragmenting the landscape through construction, mechanised farming, and new road networks. These pressures are compounded by the lack of coordinated management structures. archaeological landscapes often extend across multiple administrative boundaries, involving municipalities, heritage offices, private landowners, and local communities. Without a unified management framework, conservation actions remain fragmented and reactive, weakened by limited financial resources, insufficient professional staff and the absence of long term monitoring systems. Although Italian legislation defines those archaeological parks as complex territorial entities requiring integrated planning. the practical implementation of such frameworks remains uneven and incomplete.⁶³

These years, attention has also turned to documentation gaps. Many archaeological landscapes lack updated maps up to date documentation, condition surveys or risk evaluation. The lack of systematic data collection makes it difficult to prioritise interventions, collect resources and understand the changes over a time. As a result, conservation often becomes reactive instead of preventive, which increases costs and leads to greater loss of material. Although modern conservation emphasises the importance of continuous monitoring, traditional tools are often not sufficient for managing large and complex territorial systems.

In this case, Digital technologies, such as GIS and WebGIS platforms, provide a new way to face with these challenges. These tools allow for the integration of environmental data, archaeological documentation, administrative boundaries, and conservation records into a single spatial system that can be updated, analysed, and shared among stakeholders. By identifying patterns of vulnerability, mapping risk factors, and visualising the relationships between natural and cultural elements, GIS supports more informed decision-making. It also facilitates collaboration among institutions, enabling them to coordinate interventions and plan sustainable conservation strategies across the entire landscape rather than focusing on isolated monuments. Despite the complexities, contemporary challenges highlight that archaeological landscapes are dynamic heritage systems requiring equally dynamic approaches to their preservation. Understanding these pressures environmental, biological, administrative, and social is essential for developing strategies that protect not only isolated sites but the broader cultural and territorial networks that give them

⁶¹ Caneva, *Memoria, percezione, vegetazione*.

⁶² Caneva, *Memoria, percezione, vegetazione*.

⁶³ UNESCO, *Nomination Dossier: Cerveteri and Tarquinia*, 2004.

meaning. Integrated methods, preventive planning, and digital tools together form the foundation for addressing these challenges in a coherent and sustainable manner.

2.7 Digital Approaches and the Role of 3D Survey And WebGIS in Heritage Management

Before the implementation of GIS-based analysis, the first essential step in any archaeological or landscape oriented digital workflow is the systematic collection of spatial data through geomatics techniques. These procedures ensure that all subsequent mapping, interpretation, and conservation assessments are grounded in accurate, measurable, and georeferenced information. Data collection typically involves total station surveys, GNSS measurements, laser scanning, and the digitisation of historical cartography. Each of these methods contributes various levels of precision and detail, allowing the documentation of architectural structures, terrain morphology and environmental conditions. Accuracy of GIS and WebGIS platforms depend directly on the quality of this initial dataset, which are forms the spatial foundation upon which analysis, risk evaluation and conservation planning are developed. (Fig.9)



Figure 9. Examples of 3D digital survey and spatial data acquisition technologies used in archaeological documentation workflows, including total station, SLAM mobile mapping system and UAV survey.

Source: Google images

In recent decades, digital technologies have become fundamental and important tools for the management, interpretation and preservation of archaeological and cultural heritage sites. The transition from analogue documentation to integrated digital platforms has transformed the way archaeological landscapes are analysed, allowing archaeological, environmental and historical data to be organised within a unified spatial framework. Among these technologies, GIS and WebGIS play an important role in integrating surveys, environmental observations, historical cartography and conservation records to support spatial analysis, monitoring and conservation planning. In archaeological landscapes such as the Banditaccia necropolis, where natural processes continuously interact with funerary structures, these platforms help identify environmental risks related to different aspects such as vegetation growth, humidity, erosion and terrain instability. Also WebGIS improves accessibility and communication by allowing geospatial information to be visualised, updated and shared through interactive digital environments, supporting both heritage management and the dissemination of archaeological knowledge.

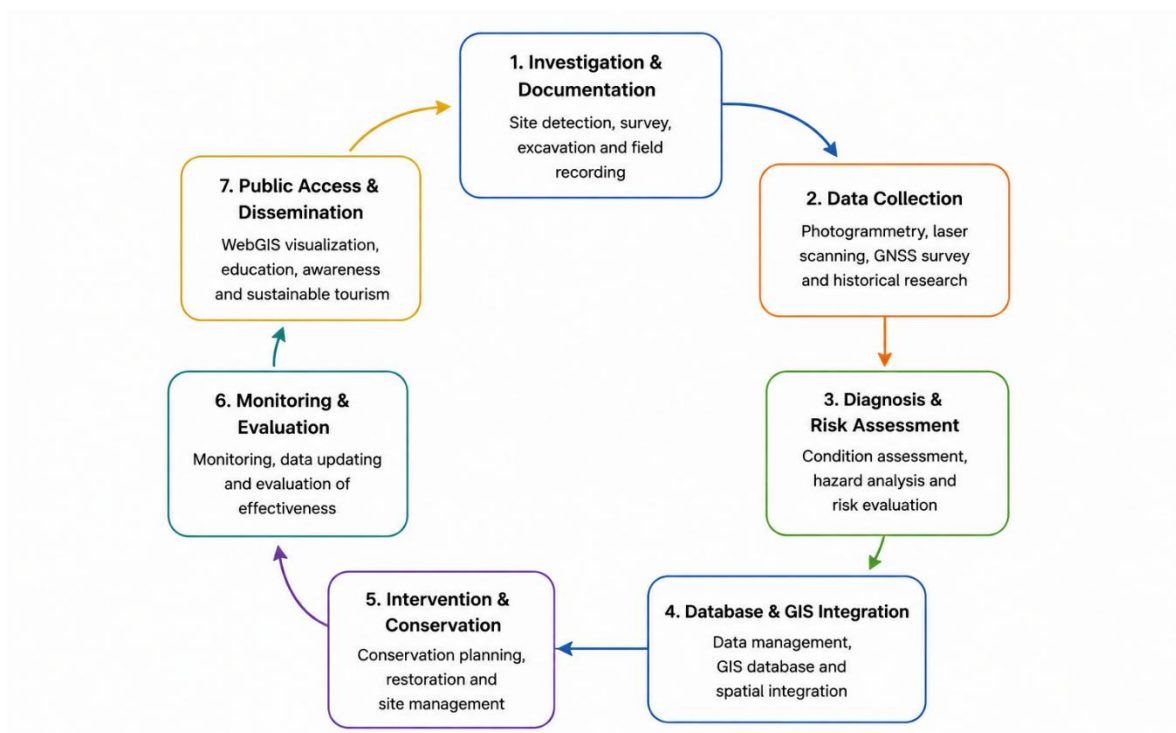


Figure 10. Simplified workflow of GIS- and WebGIS-based heritage management and conservation processes.

Source: Developed by author

The following diagram summarises the operational workflow of GIS- and WebGIS-based heritage management, illustrating the relationship between documentation, spatial analysis, conservation activities and public dissemination within an integrated digital framework.(Fig.10)



CHAPTER III

HISTORICAL BACKGROUND AND REGIONAL CONTEX

3.1 Historical Development of Southern Etruria

Southern Etruria represents one of the most historically stratified and culturally influential regions of pre-Roman Italy, forming the core of the Etruscan civilisation and shaping the social, political and territorial dynamics of central Italy for almost a millennium. Its development is inseparable from the interplay of geography, economy, belief systems and long-distance exchange. The earliest phases of occupation, traced through archaeology, literary tradition and early topographical surveys, reveal a landscape already structured by human activity as early as the Final Bronze Age, long before the rise of the classical Etruscan city-states. This long historical trajectory is more important for understanding the emergence of Caere (Cerveteri) and the great necropolises, including Banditaccia, which later became emblematic of Etruscan identity and funerary culture.⁶⁴ Beyond its historical depth, the physical landscape of Southern Etruria played an equally decisive role in shaping settlement patterns. Southern Etruria is defined geographically by its volcanic plateaus, deep tufa-cut ravines, and its proximity to the Tyrrhenian Sea. These features created a natural system of elevated defensible plateaus interspersed with fertile plains an environment perfectly suited for early settlement formation. According to early topographical documentation and nineteenth-century archaeological surveys such as those described in *The Cities and Cemeteries of Etruria*, the physical characteristics of the region directly shaped the settlement pattern, communities tended to occupy high tufa plateaus for protection while exploiting the agricultural resources of the surrounding plains.⁶⁵ (Fig.11). During the Orientalising period (late 8th–7th centuries BCE), Southern Etruria underwent major cultural change. Luxury imports, Near Eastern decorative motifs, Greek pottery, and locally adapted styles show strong connections with wider Mediterranean trade networks.

At this time, Caere (Cerveteri) became one of the richest and most outward looking Etruscan cities. Its elite invested heavily in funerary architecture, commissioning large tumuli, chamber tombs, and richly furnished graves. These monuments reflect both the wealth of the aristocracy and the importance of social status and ritual display. The Banditaccia necropolis developed into a monumental funerary landscape, expressing social hierarchy and the close relationship between the living city and the world of the dead.

⁶⁴ Bonfante, Larissa. *Etruscan Life and Afterlife*. 1996.

⁶⁵ Haynes, Sybille. *Etruscan Civilization: A Cultural History*. 2000.



Figure 11. Geographical setting of Southern Etruria.

Source: George Dennis, *The Cities and Cemeteries of Etruria*.

3.2 Origins and Evolution of Caere (Cerveteri)

Caere modern Cerveteri was one of the principal city states of Southern Etruria and played a decisive role in shaping the development of Etruscan civilisation. Its origins can be traced to the transitional phase between the Final Bronze Age and the Early Iron Age, when small, scattered communities began to consolidate on the volcanic plateaus overlooking the Tyrrhenian coast. Rather than emerging in isolation, Caere developed within a broader regional context in which geography, long-distance exchange, and ritual practices collectively contributed to the formation of early urban identity.⁶⁶ The earliest stages of settlement at Caere are closely tied to the geomorphology of the region. The city grew on a broad tufa plateau naturally protected by deep ravines and connected to the sea through the route leading to Pyrgi, its principal port sanctuary. This combination of defensible terrain, fertile agricultural land, and access to maritime routes encouraged the formation of a stable community as early as the 9th–8th centuries BCE. Early topographical descriptions and archaeological surveys consistently highlight the strategic advantages of these volcanic plateaus in the proto-urban development of Southern Etruria.⁶⁷ The geological structure of the Ceretan landscape shaped by the Sabatine volcanic system played a fundamental role in determining both urban and funerary organisation. Over millennia, streams carved deep channels into the soft tufa, creating a sequence of elevated terraces such as Banditaccia, Monte Abatone, and the Vignali plateau. These naturally defined platforms became the setting for the urban centre and its major necropolises, giving Caere a spatial configuration strongly conditioned by its environment.⁶⁸ During the Orientalising period (late 8th–7th centuries BCE), Caere underwent a profound cultural transformation. Through Pyrgi, the city became deeply integrated into Mediterranean exchange networks, receiving luxury goods, Near Eastern objects, and Greek pottery that reshaped elite identity. This cultural dynamism is most clearly visible in the funerary landscape of Banditaccia, where monumental tumuli with multiple chambers carved directly into the tufa express the power and lineage of aristocratic families. Their scale and decoration reveal sophisticated ritual practices and a high degree of interaction with external cultures, while still maintaining distinctly Etruscan forms.⁶⁹ By the 6th century BCE, Caere had consolidated into one of the most influential Etruscan cities, participating in regional alliances and maintaining diplomatic relations with Greek colonies and Rome. Literary sources describe it as a centre known for its religious traditions, skilled artisans, and political stability. Pyrgi continued to shape Caere's identity, functioning simultaneously as a commercial port and a major sacred area. The discovery of the Pyrgi

⁶⁶ Haynes 2000; Proietti, Giuseppe. *Cerveteri*. Roma: Quasar, 1986.

⁶⁷ Mauro Cristofani, *Civiltà degli Etruschi* (1985); Giuseppina Nardi Brunetti, "Cerveteri: ricognizione nell'area urbana antica," in *Archeologia della Tuscia II* (Roma, 1986); Giovanni Colonna, "La via Caere–Pyrgi," *Quaderni dell'Istituto di Topografia Antica* 1 (1964)

⁶⁸ Mauro Cristofani, *Civiltà degli Etruschi* (1985); G.C. Negretti and L. Morbidelli, *Studio geopetrografico del complesso vulcanico tolfaiano-cerite* (Roma, 1963).

⁶⁹ Bonfante 1996; Proietti 2010

Tablets with inscriptions in multiple languages attests to the city's cosmopolitan character and its role as a mediator between different cultural spheres.⁷⁰



Figure 12. Plan of the Banditaccia Necropolis showing the spatial organisation of burial zones and their historical

Source: Giuseppe Proietti's book *Cerveteri* (Rome: Edizioni Quasar , 1983)

During this period, Caere developed a complex territorial organisation that extended far beyond the urban plateau.(Fig.12) The city controlled a network of satellite villages, agricultural estates, and road systems carved into the tufa, forming a coherent landscape of production, mobility, and ritual. Roads radiated from Caere toward Pyrgi, Alsium, Veii, and the Bracciano basin, while secondary centres such as Tragliatella, Casteldannato, and Monte Abatone served strategic and administrative functions within the wider territory.⁷¹Funerary architecture provides crucial insight into Caere's social structure. The monumental tumuli of the Orientalising period reflect the authority of aristocratic lineages, whereas later hypogeal tombs arranged along orthogonal streets particularly in the later phases of Banditaccia indicate a shift toward more structured urban planning and a more regulated social order. The close spatial relationship between the city and its necropolises illustrates how memory, identity, and territorial control were deeply intertwined in Etruscan society. Banditaccia, with thousands of tombs spanning centuries, stands today as one of the most significant archaeological landscapes in the Mediterranean.⁷²In the late 6th and early 5th centuries BCE, Caere experienced major architectural and political developments. Workshops producing architectural terracottas were active not only in Caere and Pyrgi but also in neighbouring centres and even in Rome, where Ceretan artisans contributed to the decoration of important buildings. The construction of the so called Temple B at Pyrgi, dedicated by Thefarie Velianas around 510 BCE, reflects the concentration of political authority and the city's prominent role in Mediterranean power

⁷⁰ Livy (Titus Livius). *The History of Rome, Books 1–5*. Translated by B.O. Foster. Cambridge, MA: Harvard University Press, 1919.; Dionysius of Halicarnassus. *Roman Antiquities, Vol. 1*. Translated by Earnest Cary. Cambridge, MA: Harvard University Press, 1937.; Colonna, "La via Caere–Pyrgi."

⁷¹ Cristofani, *Civiltà degli Etruschi*; Thomas Ashby, *The Roman Campagna in Classical Times* (London: Society for the Promotion of Roman Studies, 1927); Raniero Mengarelli, "La città di Caere: i pagi, le vie e le ville," in *Atti del IV Congresso Nazionale di Studi Romani* (Roma, 1938)

⁷² Bonfante 1996; Proietti 1986

dynamics.⁷³ Urban excavations indicate that shortly after 490–480 BCE, Caere underwent a significant reorganisation. New sacred, civic, and industrial structures were built according to a unified orientation, corresponding to the formal definition of the city's defensive walls. This restructuring, also visible in the necropolises, suggests the emergence of a strong communal political authority capable of coordinating large-scale urban planning. During the Classical period (5th–4th centuries BCE), Caere maintained a complex relationship with Rome sometimes cooperative, sometimes resistant. Episodes such as the reception of the Roman Vestals or the return of sacred objects after the Gallic sack highlight the city's distinctive position in Roman memory. Despite increasing Roman pressure, Caere preserved its cultural identity and continued to prosper through maritime trade, although the political landscape of Etruria was gradually shifting. By the early 3rd century BCE, Caere was incorporated into the Roman state as a *civitas sine suffragio*, marking a turning point in its political and territorial history. Many public buildings were destroyed or repurposed, and Pyrgi was reorganised under Roman administration. Nevertheless, necropolises such as Banditaccia remained in use, albeit with new architectural forms and ritual practices that reflect the gradual integration of the region into the Roman world.⁷⁴

3.3 Etruscan society, culture and political structure

Etruscan society developed as one of the most complex and influential cultural systems of pre-Roman Italy, distinguished by its sophisticated social organisation, advanced craftsmanship, and strong territorial identity. The structure of Etruscan communities was shaped by a combination of different aspects such as familial lineage, aristocratic authority and religious institutions all of which contributed to the formation of a distinctive cultural model that influenced central Italy for centuries. Archaeological evidence from Southern Etruria including settlements, necropolises, road networks and sacred landscapes shows that Etruscan society was deeply interconnected with its environment, reflecting a worldview in which political power, ritual practice and territorial organisation were inseparable.⁷⁵ The core of Etruscan society was the aristocratic elite, which controlled land, trade relations and political authority. Elite families expressed their status through monumental architecture, richly furnished tombs and artistic production, as documented extensively in archaeological studies and classical sources.⁷⁶ In major cities such as Caere, Volterra, Tarquinia and Veii, elite groups played a central role in the management of long distance commerce, particularly through maritime and inland networks that connected Etruria to the eastern Mediterranean. Imported goods including Greek pottery, Phoenician metalwork and Near-Eastern luxury items not only enriched local markets but also shaped the symbolic vocabulary of Etruscan culture.⁷⁷ Religion was a fundamental and important

⁷³ Cristofani, *Civiltà degli Etruschi*; Proietti 1986

⁷⁴ Proietti 1986; Haynes 2000

⁷⁵ Bonfante, *Etruscan Life and Afterlife*.

⁷⁶ Haynes 2000

⁷⁷ Torelli, Mario. *Storia degli Etruschi*. 1981.

pillar of social and political life. The Etruscans developed a highly codified religious system governed by ritual specialists (haruspices) who interpreted natural signs, celestial phenomena and sacrificial remains to guide political decisions. This religious structure was recorded in later Roman sources and is reflected archaeologically in the topographic organisation of sanctuaries, sacred groves and ritual boundaries. The integration of religion into political life reinforced the authority of ruling families and established a model of governance in which divine order and civic order were perceived as interdependent. The political structure of Etruscan cities was based on an early form of city-state (civitas), each governed by a magistrate (zilath) and supported by councils of aristocratic families.⁷⁸ Although autonomous, these cities participated in a larger federal system known as the Etruscan League, traditionally described as comprising twelve major cities. Meetings of the league took place at the Fanum Voltumnae, a central federal sanctuary whose exact location remains debated but is believed to have been situated somewhere in Southern Etruria. (Fig.13)



Figure 13. Monumental Etruscan tombs at the Necropolis of Cerveteri, Cerveteri.

Source: [The Cerveteri Necropolis, Etruscan City of the Dead | Ancient Origins](#)

⁷⁸ Smith, Christopher. *The Etruscans and Early Rome*. 2000.

This political religious league served to coordinate inter-city alliances, military obligations and ritual obligations, reinforcing shared identity while respecting local autonomy. Etruscan society placed particular emphasis on family lineage. Tombs were organised according to kinship groups, with multi-chambered funerary structures representing genealogical continuity across generations.⁷⁹ Funerary inscriptions and decorative programs reveal that personal identity was defined through ancestry, social role and civic responsibility. The monumental tumuli of Cerveteri demonstrate how burial architecture functioned as a political statement, the visibility and scale of these tombs are reflected the prestige and territorial influence of elite families.⁸⁰ (Fig.14) (Fig.15)



Figure 14. © Soprintendenza per i Beni Archeologici dell'Etruria meridionale

Source: [The Etruscan Tumuli: Underground Cities for the Dead – SOCKS](#)



Figure 15. © Soprintendenza per i Beni Archeologici dell'Etruria meridionale

Source: [The Etruscan Tumuli: Underground Cities for the Dead – SOCKS](#)

⁷⁹ Bonfante, *Etruscan Life and Afterlife*.

⁸⁰ Torelli, 1981.

Daily life in Etruscan cities was characterised by skilled craftsmanship, including bronze work, pottery production, terracotta sculpture and textile manufacturing. Workshops were often concentrated in specific districts near urban centres or along circulation routes, enabling exchange between artisans and merchants.⁸¹ The high level of technical skill evident in Etruscan artefacts indicates strong regional specialisation supported by trade and cultural exchange. Social stratification is visible in the spatial organisation of settlements and necropolises. Archaeological data show clear divisions between elite quarters, common residential areas and industrial districts.⁸² Similarly, burial practices varied according to status, the elite were interred in monumental hypogea or tumuli, while lower social classes used simpler chamber tombs or fossa graves. This differentiation reveals a social hierarchy structured around land ownership, lineage and economic power. Although they were developed, Etruscan political institutions were not static. The increasing influence of Rome from the 6th to 4th centuries BCE gradually altered regional dynamics. Some cities entered alliances with Rome; others resisted until their eventual conquest. Yet even after political absorption into Rome, many elements of Etruscan culture religion, engineering, urban planning, and iconography continued to shape Roman civilisation and demonstrating the enduring legacy of Etruscan social and political structures.(Fig.16)

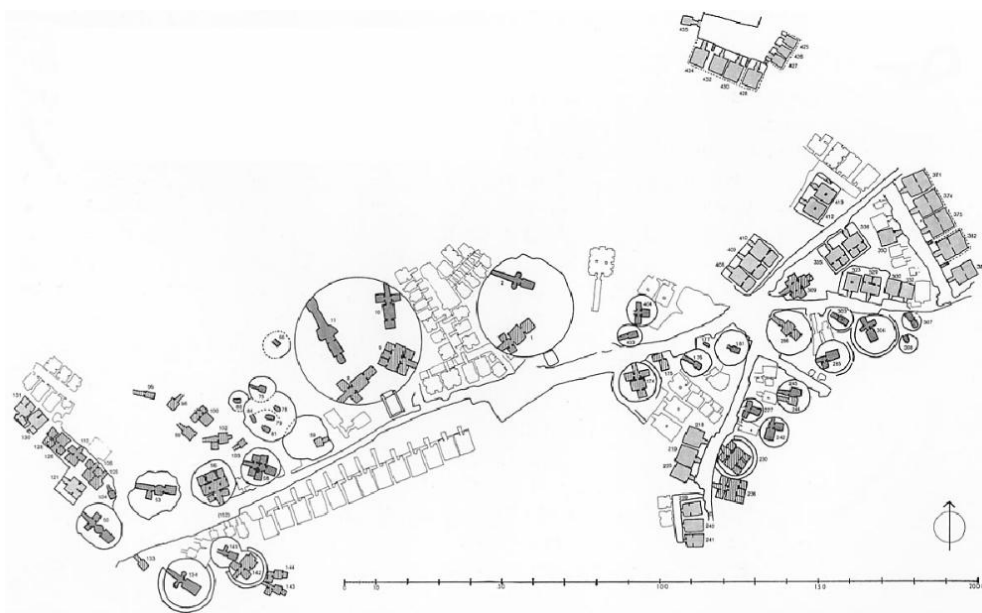


Figure 16.Part of Necropoli of the Banditaccia (plan) and structure

Source: [The Etruscan Tumuli: Underground Cities for the Dead – SOCKS](#)

⁸¹ Proietti 1986

⁸² Torelli,1981.

3.4 Funerary Practices and the Evolution of the Necropolis

The funerary world of the Etruscans constitutes one of the most distinctive cultural domains of pre-Roman Italy, offering a unique perspective into the social structures, beliefs, and identity-forming mechanisms of Southern Etruria. Unlike many ancient societies where funerary evidence is fragmentary, the Etruscans developed extensive necropolis whose architectural complexity and spatial organisation reflect the evolution of urban life, family structures, ritual practices, and political systems. From the early Villanovan phases to the monumental tumuli of the Orientalising and Archaic periods, the necropolises of Southern Etruria especially those of Caere (Cerveteri) functioned as parallel “cities of the dead” structured according to the same social hierarchies and territorial logics that shaped the settlements of the living. According to all the archaeological documents, funerary architecture was not merely a mortuary expression, but an ideological tool through which elites expressed authority, ancestry, and cosmological order. The earliest phase of Etruscan funerary tradition appears in the Villanovan period (10th–8th centuries BCE), characterised by cremation burials placed in biconical urns accompanied by simple grave goods. These burials often occurred in small clusters, suggesting a kin-based organisation of early communities.⁸³ (Fig.17)

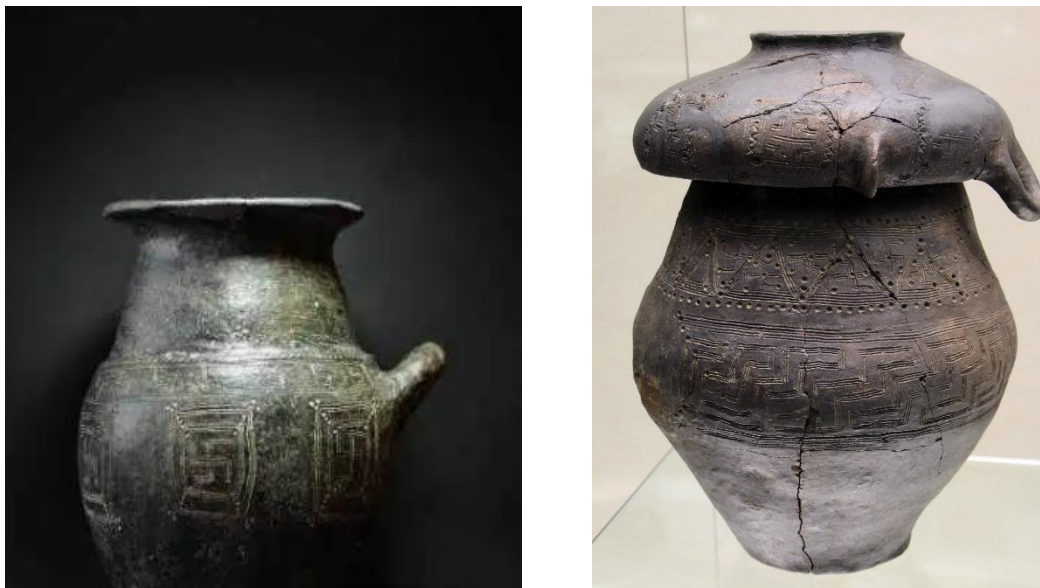


Figure 17. Biconical urns and simple grave goods from Villanovan cremation burials (8th centuries BCE)

Source: [Villanovan Biconical Funerary Urn - World History Encyclopedia](#)

As social complexity increased and wealth concentrated in emerging aristocratic families, the scale and visibility of funerary architecture also expanded. By the late 8th and early 7th centuries BCE the Orientalising period Southern Etruria underwent significant cultural

⁸³ Camporeale, *Gli Etruschi*

transformation influenced by Mediterranean exchange networks. Imported prestige goods, metalwork, Near Eastern motifs, and Greek pottery stimulated the emergence of a highly stratified elite whose identity was expressed through monumental funerary construction. It is in this context that the great tumuli of Caere were created circular mounds reaching more than 20–40 meters in diameter, containing multi-chambered hypogea carved into the tufa bedrock. These tumuli, such as those documented in the Banditaccia necropolis, represent some of the earliest examples of architectural planning in Etruria, integrating interior chamber systems with corridors, benches, carved architectural details, and symbolic spatial organisation.⁸⁴ Inside the hypogea, the carved stone architecture often models the structural features of domestic spaces ceilings shaped like wooden beams, carved doorframes, pilasters, and benches. This imitation reinforces the symbolic concept of the tomb as a “house of the dead” reflecting beliefs concerning continuity between life and afterlife. (Fig.18)



Figure 18. Tomba dei Rilievi (Banditaccia) and Banditaccia tumulus exterior

Source: [Ertruscan Necropolis of Cerveteri | Inexhibit , roma.corriere.it/foto-gallery/cultura_e_spettacoli/15_giugno_20/sulle-tracce-etruschi-820adcc8-1766-11e5-86ef-d7e3d30aa75b.shtml](https://www.inexhibit.it/foto-gallery/cultura_e_spettacoli/15_giugno_20/sulle-tracce-etruschi-820adcc8-1766-11e5-86ef-d7e3d30aa75b.shtml)

During the Archaic period (6th century BCE), changes in funerary architecture reflect broader urban transformations. The emergence of orthogonal street planning in the necropoleis such as the Via degli Inferi in Cerveteri marks a deliberate spatial ordering of the realm of the dead, mirroring the rational planning of the living city. Chamber tombs arranged along grid-like streets indicate a shift from aristocratic monumental display to a more distributed funerary landscape, where multiple social groups participated in more standardised burial traditions. This period witnesses the spread of cube tombs (*tombe a dado*), carved as rectangular blocks with interior chambers accessed through a single doorway, expressing a more regulated and collective funerary identity. The spatial coherence of these necropoleis transforms them into structured “cities,” with clear axial routes, neighbourhoods, and recognisable family compounds. Funerary iconography also

⁸⁴ Bonfante, 1996.

gained increasing complexity. Wall paintings, reliefs, and decorated sarcophagi illustrate themes related to banquets, athletic games, mythological episodes, and familial gatherings. These images do not merely depict everyday life; they encode symbolic narratives about status, lineage, and the desired memory of the deceased.⁸⁵ (Fig.19)

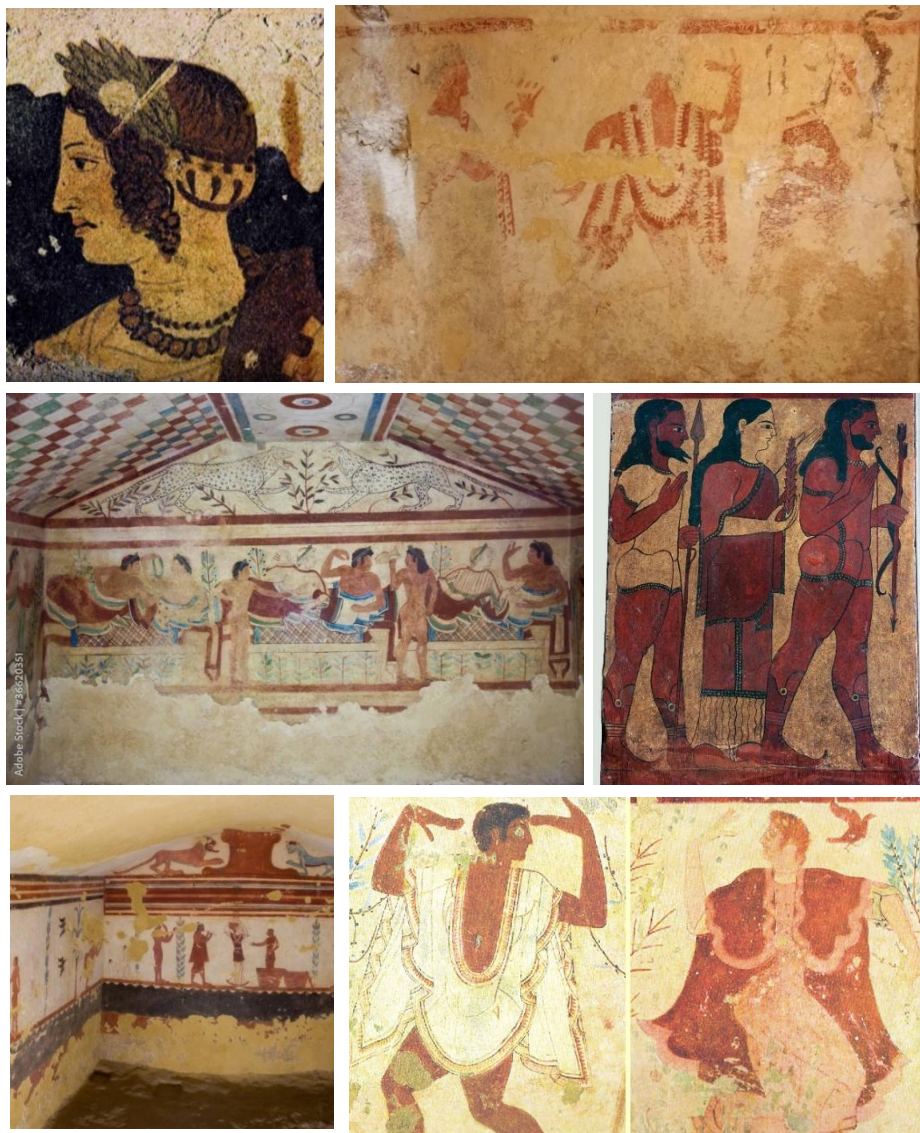


Figure 19. Etruscan wall and tomb paintings

Source: Etruscan Tomb Art Reconstruction Of An Etruscan Tomb With Etruscan

⁸⁵ Steingräber, Stephan. *Etruscan Painting*. 2006.

The funerary banquet (*convivium*) appears as a recurrent motif, expressing both elite identity and communal continuity. figures in funerary banquets can be observed holding an **egg**, often seen as a symbol of birth, renewal, and the cycle of life. It represents the potential for new beginnings and the idea of regeneration. (Fig.20)



Figure 20. Egg as a symbol of renewal in Etruscan funerary banquet imagery.

Source: [History of Etruscan Sarcophagus of the Spouses: Unveiling Etruscan Funerary Art | Romecabs](#)

The famous terracotta “Sarcophagus of the Spouses” from Caere exemplifies this symbolic tradition, portraying a reclining couple in an intimate pose that reflects both marital unity and the social prestige of the household.⁸⁶ From the 5th century BCE onward, the political decline of the Etruscan cities and increasing Roman pressure influenced funerary practices, leading to a simplification of tomb architecture and a reduction in large-scale tumulus construction but the necropoleis continued to evolve. In the Hellenistic period, some tombs developed more elaborate decorative schemes which are including painted friezes, higher quality stone carving, and monumental entrances intended to preserve the memory of increasingly complex family units. While forms changed, the fundamental principle of the necropolis as a territorial expression of social identity remained intact. The evolution of funerary practices is closely tied to the broader territorial organisation of Etruscan society. Necropoleis were never marginal spaces; they were placed deliberately on plateau edges, road intersections, and urban thresholds to assert social visibility and maintain symbolic relationships between the living community and its ancestors. In Caere, the Banditaccia necropolis occupies an elevated plateau facing the city and maintaining a visual dialogue between tombs and settlement. The placement of tumuli along approach routes created a monumental landscape intended to communicate power to visitors entering the territory. As agricultural, political, and religious systems evolved, so too did the structures of the necropoleis, whose spatial logic reveals long-term shifts in family organisation, political institutions, and cultural affiliations. Funerary practices are also essential and important for understanding Etruscan cosmology. Many tomb plans follow axial or directional principles, possibly aligned with ritual orientations. The frequent use of carved architectural features replicating domestic space reflects beliefs concerning the afterlife as a continuation rather than a rupture.⁸⁷ Grave goods including bronze vessels, weapons, jewellery, imported pottery, and personal objects function as both symbols of status and

⁸⁶ Bonfante, 1996.

⁸⁷ Steingraber, *Etruscan Painting* (2006)

markers of identity within the community. These assemblages provide insight into gender roles, social hierarchies, artisanal production, and international contacts. The necropoleis of Southern Etruria also reveal the dynamic interplay between local traditions and external influences. Imported materials and artistic motifs from Greece and the Near East were not simply adopted but reinterpreted within an Etruscan framework, producing hybrid forms of funerary art and architecture that reinforced both cosmopolitan connections and local identity. The coexistence of monumental tumuli, cube tombs, and richly decorated hypogea illustrates how burial landscapes became arenas of cultural negotiation, where elites displayed their openness to Mediterranean exchange while simultaneously affirming ancestral continuity. This duality between innovation and tradition underscores the role of funerary practices as a mirror of broader societal transformations, situating Caere and its Banditaccia necropolis at the crossroads of local identity and international networks.⁸⁸

3.5 Urbanisation Processes and Territorial Organisation

The earliest phases, traced archaeologically through settlement clusters on elevated tufa plateaus and associated cemeteries, reveal a landscape shaped by the strategic selection of defensible high grounds, fertile plains and access to water routes factors that directly contributed to the emergence of nucleated urban centres.⁸⁹ The volcanic morphology of Southern Etruria, with its system of plateaus separated by deep ravines, provided natural boundaries that helped structure territorial division and gave rise to clearly defined civic territories. By the late Villanovan and early Orientalising periods (9th–7th centuries BCE), a decisive transformation took place. Multiple small settlements gradually coalesced into larger political communities, leading to the emergence of the major southern Etruscan cities such as Veii, Tarquinia, Vulci and above all Caere.⁹⁰ (Fig.21)

Archaeological studies show that these settlements expanded according to an organised spatial logic: plateaus hosted residential and political centres, while surrounding slopes, valleys and adjacent tufa shelves were dedicated to necropolises, sacred areas and productive landscapes.⁹¹ This organisation reflects a sophisticated understanding of the environmental and territorial resources of the region, as well as the increasing political power of aristocratic families who controlled land, trade and ritual institutions. Territorial organisation was inseparable from social hierarchy. Etruscan cities relied on complex networks of kinship groups, clan-based elites and priestly authorities whose power was

⁸⁸ UNESCO, *Nomination Dossier*.

⁸⁹ Barker, Graeme & Rasmussen, Tom. *The Etruscans*. 1998

⁹⁰ Haynes 2000

⁹¹ Haynes 2000

materialised in the landscape through monumental architecture, tumuli, road systems and rural infrastructures.

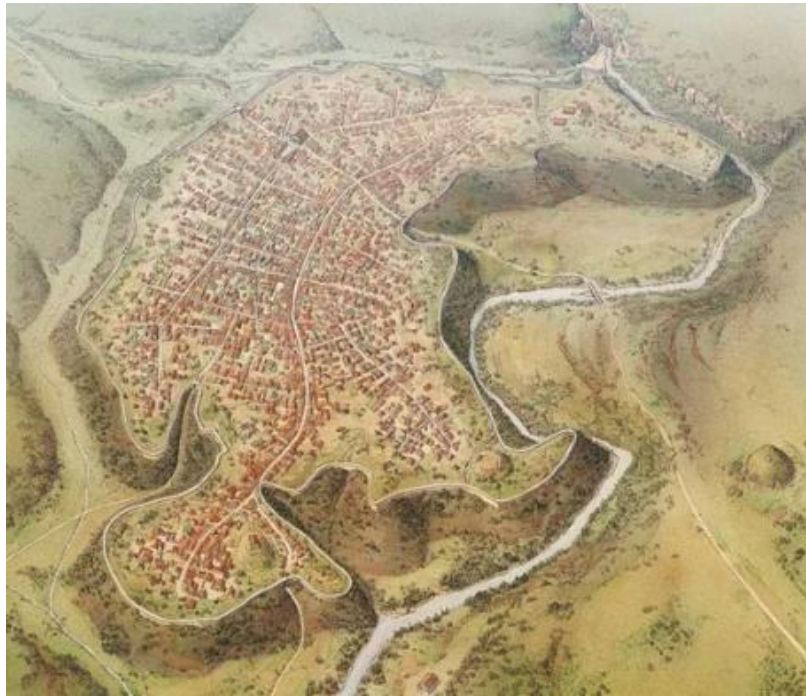


Figure 21. The ancient Etruscan city of Vulci around the 4th century BC, Italy

Source: [The ancient Etruscan city of Vulci around the 4th century BC, Italy : r/papertowns](https://www.reddit.com/r/papertowns/)

Caere developed an extensive and highly structured territory that extended from its inland plateaus to the Tyrrhenian coast at Pyrgi, its principal port sanctuary. This territorial articulation urban core, necropolis, agricultural hinterland and maritime outlet mirrored the political organisation of the city and allowed it to maintain both economic strength and religious authority.⁹² The creation of monumental tumuli in Banditaccia, aligned along principal access routes, more illustrates a deliberate urban strategy in which funerary landscapes played a central role in defining civic identity and territorial control. The development of road networks was one of the key component in the urbanisation of Southern Etruria. Routes carved directly into the tufa connected residential quarters, necropolises, rural zones and external territories, establishing a coherent mobility system across the region. Many of these roads followed natural corridors shaped by the volcanic topography, creating long-lasting territorial axes that structured both economic exchange and ritual movement. In Caere, the Via degli Inferi and other funerary avenues linked the city to its necropolises, reinforcing the integration of the living and the ancestral community within the same spatial framework. Over time, the expansion of agricultural fields, drainage systems and storage structures contributed to the consolidation of a managed landscape, demonstrating a deliberate effort to control and rationalise land use. Urbanism in Southern Etruria was strongly affected by Mediterranean connectivity. The intensification of contacts with Phoenician traders, Greek colonists and other maritime cultures in the 8th–6th centuries BCE transformed both economic structures and urban

⁹² Torelli, 1981.

forms. Imported objects, artistic motifs and technological innovations stimulated the development of specialised craft districts and monumental public spaces that signalled the political strength of elite groups. Caere became one of the principal intermediaries in Mediterranean maritime trade, and its territory evolved into a complex system balancing inland production with coastal religious and commercial functions. This integration of land and sea was unusual in central Italy and contributed significantly to the city's rise as an international power. Territorial organisation also had a sacred dimension. Etruscan cities were structured according to cosmological principles that governed the orientation of spaces, the placement of sanctuaries and the distribution of ritual zones. Sacred areas were often located at territorial boundaries, road intersections or liminal natural features such as springs and promontories. as illustrated in the spatial configuration of Caere and its necropolis. (Fig. 22)

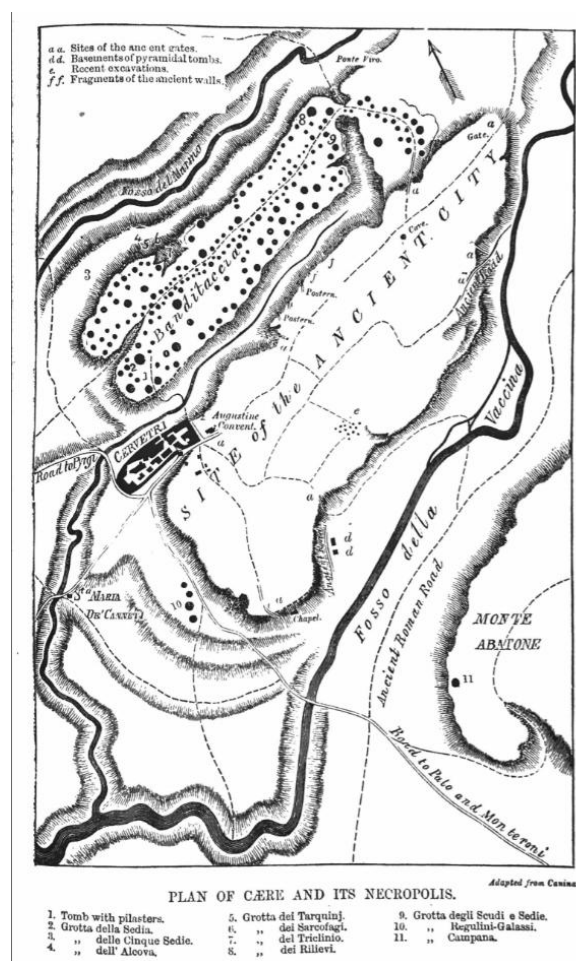


Figure 22. Plan of Caere and Its Necropolis (adapted from Canina)

Source: Adapted from Canina, in *Dennis, Cities and Cemeteries of Etruria*, 1883

This endowed the landscape with symbolic coherence and reinforced the authority of civic institutions. Caere exemplifies this pattern through its network of sanctuaries extending from the urban centre to Pyrgi, forming a spiritual geography that paralleled its political and territorial structure. The Roman conquest of the region in the 4th–3rd centuries BCE

did not erase these structures immediately; rather, Roman administration adapted existing Etruscan territorial divisions, road networks and urban layouts while gradually integrating them into the expanding Roman state. The persistence of Etruscan spatial patterns well into the Roman period demonstrates the resilience of their urban and territorial systems. Over time, however, changes in political organisation, economic strategies and demographic distribution altered the urban landscape, leading to the partial abandonment of plateaus and the reorganisation of agricultural estates under Roman rule. Recent archaeological and landscape studies emphasise that the urbanisation of Southern Etruria cannot be understood solely through its architectural remains. It is a phenomenon rooted in long-term interactions between environment, social structures, belief systems and interregional exchange. The resulting territorial organisation was neither random nor purely functional, it expressed the cultural logic of Etruscan urban life and remains legible today through the spatial relationships between cities, necropolises, sanctuaries and rural landscapes and in this case Understanding these dynamics is crucial for reconstructing the historical development of Caere and interpreting the structural context in which the Banditaccia necropolis evolved. The urbanisation processes of Southern Etruria produced a landscape in which political authority, ritual identity and territorial control were inseparably intertwined.⁹³ This integrated system supported the growth of one of the most sophisticated civilizations of pre Roman Italy and laid the foundations for the monumental funerary architecture, urban planning and territorial coherence that make Cerveteri a central case study in the archaeology of the ancient Mediterranean.

3.6 Interaction with Mediterranean Networks (Trade and Cultural Exchange)

Southern Etruria didn't develop in isolation it was part of a dense network of Mediterranean exchange. Its position between the Tyrrhenian coast, the Tiber corridor, and the inland volcanic plateaus allowed Etruscan centres especially Caere to take an active role in long-distance trade and cultural interaction.⁹⁴ From the 8th century BCE, the Orientalising period marked the first major phase of connectivity, as elite tombs and imported luxury goods show sustained contact with Phoenician, Cypriot, and Greek merchants.⁹⁵ These exchanges were not just about trade but they changed how elites saw themselves, how people practiced rituals, and how art was created in Southern Etruria. The port sanctuary of Pyrgi played an important role in these interactions such as archaeological finds, including the Pyrgi Tablets, show its political and religious significance and its direct links with the Phoenician world, and through it Caere maintained ties with Carthage and traded luxury goods like ivory, precious metals, and fine textiles The sanctuary's design, which mixes Etruscan and eastern Mediterranean styles, shows this cultural blending clearly.⁹⁶ (Fig.23)

⁹³ Torelli, 1981.

⁹⁴ Haynes 2000.

⁹⁵ Cristofani 1985

⁹⁶ Torelli 1981.



Figure 23. One of the Pyrgi Tablets, a gold inscription dedicated to the Phoenician goddess Astarte, documenting the political and religious ties between Caere and the Phoenician world. *Source: Soprintendenza Archeologia del Lazio e dell'Etruria Meridionale.*

Source: [*Adapted from Canina, in Dennis, Cities and Cemeteries of Etruria, 1883.*](#)

Greek influence became increasingly prominent from the 7th century BCE, especially through contacts with Pithekoussai, Cumae, and later the colonies of southern Italy. Imported black figure and red figure pottery, Attic kylikes, and amphorae found in Caeretan tombs demonstrate the intensity of these connections.⁹⁷ However, the relationship was not one sided. Etruscan artisans adapted Greek styles to local tastes, creating hybrid objects that show active cultural exchange rather than simple imitation, and the same is true in architecture, where Greek ideas influenced tomb design but the results remained clearly Etruscan.⁹⁸ Mediterranean exchange also encouraged technological innovation. Metallurgy, shipbuilding, and terracotta production benefited from shared technical knowledge and the mobility of craftsmen Etruscan, Greek, and Phoenician who contributed to the region's artistic and industrial growth. Caere became a major centre for bronze objects, engraved mirrors, and terracotta sculpture, industries that relied on both imported raw materials and specialised expertise. Political relations also shaped these networks, alliances with Carthage, rivalry with Greek powers, and changing diplomatic conditions affected trade and cultural exchange, while Caere's early relationship with Rome described as *hospitium publicum* which shows its importance and adaptability, later helping it integrate into the Roman world while keeping some local traditions. Religious life was also a key point of connection, as sanctuaries brought together merchants, pilgrims, and officials, and finds like Greek ceramics, eastern metalwork, and local offerings show this cultural mix, while rituals themselves adopted outside influences but still remained distinctly Etruscan. These networks enriched Southern Etruria, they also increased social inequality by strengthening elite reliance on imported luxury goods, and while maritime trade exposed communities to conflict and instability and contributed to the decline of some coastal centres, the region still showed a strong ability to adapt and reshape outside influences into a resilient cultural identity. From a broader perspective, the long history of

⁹⁷ Barker & Rasmussen.

⁹⁸ Steingräber, Etruscan Painting.

interaction between Southern Etruria and the Mediterranean reveals a region defined by movement, exchange, and adaptation. Caere emerges as one of the most cosmopolitan centres of the ancient Mediterranean open to external influences yet firmly rooted in its own traditions. These networks not only helped create large necropolises like Banditaccia but also prepared the region for its later transformation under Roman rule.

3.7 Transition to Roman Rule and Later Transformations

The transition from Etruscan autonomy to Roman domination shows one of the most significant turning points in the historical development of Southern Etruria. Caere once one of the most powerful Etruscan city states experienced profound cultural, political, and territorial transformations between the late 4th and 1st centuries BCE. These changes were neither sudden nor uniform; more, they unfolded through progressive military conflicts, shifting alliances, administrative reorganisation, and deep processes of cultural assimilation.⁹⁹ By the early 4th century BCE, Rome's expansion into central Italy placed increasing pressure on Etruscan territories. Sources indicate that Caere attempted to maintain diplomatic relations with Rome, at times acting as an intermediary power within the Tyrrhenian world.¹⁰⁰ Despite these efforts, Rome gradually absorbed Caere's political autonomy. Around 273 BCE, the city was granted *civitas sine suffragio* a status that removed political rights while incorporating the population into the Roman administrative system. This marked a decisive break from Etruscan self-governance and initiated a period of deep restructuring of civic, territorial, and social life. Archaeological evidence reveals major changes in settlement organisation during this transition. The monumental necropolises, once central to Etruscan social display, declined significantly. Elite tomb construction diminished, and funerary architecture shifted from complex chamber tombs and tumuli to simpler forms, reflecting both Roman influence and the weakening of traditional Etruscan aristocracies (Fig.24). The Banditaccia necropolis, which had reached its peak between the 7th and 5th centuries BCE, entered a phase of reduced activity, although parts of it continued to be used into the Hellenistic period. At the urban level, Caere was progressively reshaped according to Roman administrative and infrastructural models. Public buildings, road systems, and agricultural land divisions reflect the adoption of Roman planning principles.¹⁰¹ The introduction of *centuriatio* in parts of Southern Etruria reorganised the rural landscape, integrating it into broader patterns of Roman land management. This restructuring also facilitated the movement of goods, military forces, and populations, aligning the region with Rome's expanding economic networks.¹⁰² Cultural transformation accompanied these territorial changes. The Etruscan language still widely used in inscriptions until the 3rd century BCE gradually disappeared as Latin became

⁹⁹ Giovanni Camporeale, *Gli Etruschi: Storia e civiltà* (Milano: Mondadori, 2011).

¹⁰⁰ Colonna, 1964; Smith 2000.

¹⁰¹ Ward-Perkins, J.B. *From Classical to Medieval Architecture*. 1987.

¹⁰² Smith, 2000.

dominant.¹⁰³ Religious practices also shifted, with many Etruscan cults being assimilated, replaced, or reinterpreted within Roman frameworks.

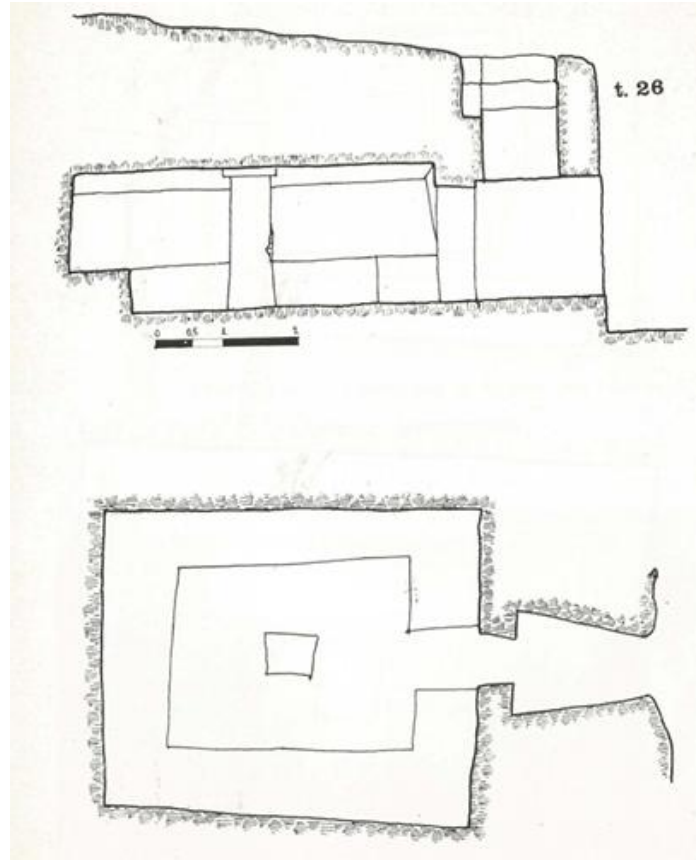


Figure 24. Tumba 26, an example of a Hellenistic hypogeum with central pillar and simplified architectural layout, illustrating the shift toward less monumental funerary forms during the Romanisation of Caere.

Source: XV Anniversario GAR (1980)

However, elements of Etruscan ritual life persisted, demonstrating that the process of Romanisation was complex and not purely one-directional.¹⁰⁴ Southern Etruria continued to play an important economic role during the Roman Republic and early Empire. Its strategic position between Rome and the Tyrrhenian coast supported agricultural production, pottery workshops, and maritime trade. At the same time, the decline of Etruscan political power led to growing social stratification, ruralisation of elites, and in some areas, depopulation. The landscape that emerged combined Roman administrative structures with enduring traces of Etruscan territorial organisation, creating a hybrid environment that modern archaeology continues to study. Despite the political subjugation of Caere, the memory of its Etruscan past remained embedded in the landscape.

¹⁰³ Bonfante, 1996.

¹⁰⁴ Francesco Roncalli

Monumental funerary zones, carved roads, and sacred areas persisted physically and symbolically into the Roman period and beyond. These layered transformations are important for understanding the later history of Cerveteri and provide a key interpretative framework for modern conservation, as the coexistence of Etruscan and Roman features forms a core aspect of the site's identity.¹⁰⁵ This long term continuity is still evident in the present-day configuration of the site, where the archaeological area and its surrounding landscape retain the imprint of these overlapping historical layers. The historical evolution of Southern Etruria and the transformation of Caere from an Etruscan centre into a Romanised territory created a landscape shaped by continuity, adaptation and long-term stratification. The funerary, urban and territorial structures that emerged across these centuries form the cultural and spatial foundations of Cerveteri as it is known today. Understanding these processes is necessary for interpreting the Banditaccia necropolis not as an isolated archaeological site, but as part of a wider system shaped by geology, settlement logic, ritual practices and political change.

This historical background provides the necessary framework for the next chapter, where the landscape of Cerveteri is analysed as a spatial system in preparation for the GIS- and WebGIS-based methodology developed later in the thesis.

¹⁰⁵ UNESCO, Nomination Dossier, 2004.



CHAPTER IV

LANDSCAPE STRUCTURE AND SPATIAL ORGANISATION OF THE ARCHAEOLOGICAL TERRITORY

4.1 Introduction to the Landscape-Based Approach

The site of Cerveteri is one of the most representative instances where the heritage is not to be analysed by monolithic monuments, architectural typologies or historical sequences. Rather, it should be conceived as a complex and dynamic system where morphology, environmental process and human intervention work together over thousands of years to create a 'unique cultural landscape'. This way of looking at cultural artefacts, heavily inspired by present-day conservation theory, draws attention away from the artifact and towards an understanding of it in its context and from the monument to the terrain, to the material matter and to those spatial relations that make heritage meaningful.¹⁰⁶ This perspective rests on theory that dates back to the twentieth century of conservation thought. We may note that Brandi stressed that the work of art, and, consequently, the cultural artefact, does not operate in isolation from the circumstances, which determine the way the work is perceived. However, this "unità potenziale dell'opera d'arte" contains not only the materiality but also the spatial (and environmental) scope that allows for the understanding of the work. On the contrary, Jokilehto elaborated to develop this concept by illustrating that conservation history gradually shifted from an aesthetic restoration perspective towards a much larger view of heritage as a cultural and historical document located in its setting. When that is the case, the landscape becomes a critical layer of interpretation, not a neutral background.¹⁰⁷ But international charters consolidate this conceptual shift. The Venice Charter also clearly identifies the role of setting, in the conservation of monuments. and the Nara Document on Authenticity applies the concept of authenticity to form, design, traditions, techniques, spirit and feeling, and that which is "interwoven with the whole of the landscape." The Operational Guidelines for the World Heritage Convention also emphasise that the quality of a site is affected by the integrity and vitality of its original physical and cultural factors such as topography, spatial ordering and environmental influences. These documents together lay the theoretical basis for a landscape perspective on archaeological heritage.¹⁰⁸ An important aspect, with this paradigm, it can be concluded that the landscape is perceived as not a physical site itself, but as an assemblage of cultures built on human decisions, symbolic meanings and long-term ecological processes. Mediterranean archaeological landscapes are an ongoing communication between vegetation growth, erosion, hydrological dynamics and microclimatic changes, human activity, and settlement patterns, agricultural practices, ritual pathways, and funerary organisation. Such interaction creates a stratified environment where the natural morphology and cultural building systems intertwine. With the same history, the landscape turns palimpsest, the visible elements of the past contribute to the present arrangement.¹⁰⁹ And Cerveteri embodies it all precisely. It is a unique geological area with a physical aspect derived from the Tolfetano Cerite volcanic complex. The tufa plateaus, deep valleys, gradual slopes and elevated ridges have in the

¹⁰⁶ UNESCO ,2019

¹⁰⁷ Brandi 1963

¹⁰⁸ ICOMOS, Venice Charter.

¹⁰⁹ Caneva, Memoria, percezione, vegetazione.

past conditioned the distribution of settlements, the location of necropolises and the organisation of circulation routes.¹¹⁰ The Etruscans had a sophisticated understanding of the landscape, choosing morphological features for funerary architecture, ritual spaces and urban planning. The relationship between the ancient city of Caere and the necropolis of Banditaccia is not coincidental but reflects an intentional territorial logic based on visibility, symbolism and accessibility. This spatial logic can only be understood through an integrated reading of the territory involving geological analysis, environmental interpretation and use of archaeological material.¹¹¹ Not only where tombs were dug but how they were oriented and accessed and thought about within a culture, were influenced by land-orientation as well. The ravines served as natural boundaries and circulation corridors; the plateaus as stable surfaces for settlement and funerary plans; the vegetation patterns as factors influencing visibility and microclimatic conditions; the hydrological system as an influence on erosion processes that still impact conservation today.¹¹² This collaborative perspective is in concert with current theories of archaeological resource use. As it is evident from the Darvill archaeological legacy, it is also an aspect of a bigger environmental context, and the natural and cultural elements that operate in this environment interact to mould the material remains/durable, permanent resources that remain. And the necessity for risk preparedness schemes that reflect environmental vulnerabilities, landscape forces and spatial dispersal of heritage assets. To provide analytical means for identifying risks, prioritizing risk and developing sustainable conservation strategies, a 'landscape-based' approach is not only interpretative it is operational.¹¹³ Cerveteri finds this perspective especially appropriate: the site's Outstanding Universal Value is intertwined with its territorial setting. The necropolis at Banditaccia is not a standalone complex, but an integral part of an overall system having the ancient urban hub, the agricultural landscape, the circulation routes from Caere to Pyrgi and other settlements along the coast, and the organic features of the landscape in that place which inform Etruscan urban use. The land scale of Cerveteri is not only highlighted in the official documents but the sense of the integrity of the site has to depend on the fact the landscape, the tufa form, the planting and the spatial relation between the site and the city.¹¹⁴ A landscape-based approach also offers a more nuanced way to analyse the environmental factors that determine site conservation. Growth in vegetation, for example, affects the ecological significance of the land itself but poses a challenge to the stability of its structures and leads to an accelerated process for loss of surface tufa. Studies of biological colonisation also highlight the fact that the activity of flora and fauna exacerbates deterioration processes, especially in porous volcanic rocks. Furthermore, erosion and hydrological instability imperil the integrity of slopes and ravines, and microclimatic fluctuations impact the preservation of painted surfaces and engraved architectural details. We can only appreciate all these processes in the context of the larger landscape system within which they take place.¹¹⁵ Following through with this holistic approach, the current chapter provides conceptual and

¹¹⁰ UNESCO, 2019

¹¹¹ Jokilehto, A History of Architectural Conservation.

¹¹² UNESCO, Nara Document on Authenticity.

¹¹³ Darvill 1995.

¹¹⁴ UNESCO, 2019

¹¹⁵ Caneva, Memoria, percezione, vegetazione.

methodological groundwork for discussing the archaeological territory of Cerveteri. It transcends monument centered interpretation, and adopts a territorial reading that links morphology, space organisation, environment and culture. This methodology is consistent with international conservation practices and will inform the method of site-specific analysis to be presented in the subsequent chapter.

4.2 Geological and Morphological Framework of the Territory

Cerveteri is defined by a geological structure shaped by the Tolfetano Cerite volcanic district, whose eruptions created the extensive tufa formations that characterise the entire landscape of northern Lazio. The terrains built around these volcanic deposits including broad plateaus, deeply incised ravines, gentle slopes and elevated ridges, the physical matrix that conditioned human habitation and territorial organisation over millennia. The tufa plateaus are one of the most distinctive morphological elements of the region. They were relatively flat and stable and provided favourable conditions for settlement, agriculture and the construction of monumental funerary structures which is the part of the important aspect of this place, particularly around the Banditaccia necropolis.¹¹⁶ The edges of these plateaus often drop abruptly into steep ravines, creating natural boundaries that historically guided circulation routes and defined territorial limits. The sharp contrast which is remain between the elevated surfaces and the deeply carved valleys cause a landscape with strong spatial hierarchies, where certain areas naturally became first points for habitation, ritual activity and visual control. The ravines are themselves products of long-term erosive processes on the soft volcanic rock. Seasonal flows of water carved narrow valleys with steep walls, generating micro environments characterised by higher humidity, denser vegetation and distinct soil conditions.(Fig.25)



Figure 25. Ravine landscape in the Cerveteri territory, showing steep volcanic cliffs, seasonal water flow and dense vegetation. This morphology illustrates the erosive and hydrological processes that shape the territory and influence conservation conditions.

Source: [Cosa fare a Cerveteri e quali sono i Luoghi da Vedere](#)

¹¹⁶ UNESCO 2004

These hydrological dynamics continue to affect the conservation of archaeological structures today because fluctuating moisture levels accelerate the deterioration of porous tufa surfaces and contribute and help to the instability of slopes.¹¹⁷Hydrology plays a fundamental role in shaping the morphology of the territory. Although the region lacks major rivers, the ravines function as natural drainage channels, collecting runoff from the plateaus and directing it toward the coastal plain. This behaviour intensifies erosion along the edges of the plateaus and affects the preservation of exposed tomb façades, particularly in areas where water infiltration increases biological growth and structural decay. Vegetation is similarly an important element in the geological morphological system. There's a Mediterranean scrub about the area that consists of evergreen shrubs and grasses and scattered tree cover, representing both the natural ecological processes and centuries of human activity. Vegetation serves to underwrite the ecology of the landscape identity, yet it also influences continuity with respect to the geological substrate of the landscape. Root systems penetrate this porous tufa, increasing fragility and the rate at which things go down; variations in shade and humidity give rise to microclimates. These microclimates influence erosion and biological colonisation as well.¹¹⁸ (Fig.26)



Figure 26. Vegetation interacting with rock-cut funerary architecture in the Cerveteri territory. The presence of moss, root systems and microclimatic shade illustrates the biological colonisation processes that affect the conservation of porous volcanic stone surfaces.

Source: [A day trip from Rome: Cerveteri, a unique beauty in Lazio • Italy's Dream Travel](#)

The interplay between geology, morphology and ecology has produced a landscape that is both structured and dynamic. The position of the Banditaccia necropolis on the edge of a plateau overlooking a network of ravines is a direct expression of this interaction between natural morphology and cultural intention. The morphology of the land conditioned the orientation of tombs, the organisation of funerary streets, the placement of tumuli and the visibility of monumental structures, demonstrating how the Etruscans used the natural

¹¹⁷ Caneva, 2014.

¹¹⁸ Caneva, 2018.

topography to reinforce symbolic meanings and spatial relationships.¹¹⁹ Understanding this geological and morphological framework is essential not only for interpreting the archaeological record but also for assessing the environmental factors that continue to influence the site today. The same processes that shaped the landscape historically erosion, water flow, vegetation growth and microclimatic variation remain active and directly affect the conservation of the necropolis.¹²⁰ For this reason, any conservation strategy must be grounded in an understanding of these processes, recognising that the necropolis is part of a living landscape rather than an isolated monument.¹²¹ This framework forms the basis for the spatial and landscape analysis developed in the following sections, explaining why certain areas of the necropolis are more vulnerable than others and how environmental dynamics shape the long-term preservation of the site.

4.3 Spatial Configuration of the Archaeological Landscape

The spatial configuration of the archaeological landscape of Cerveteri is the result of a long-term interaction between natural morphology, cultural choices and territorial organisation. While the geological structure of the Tolfetano Cerite volcanic district provides the physical foundation of plateaus, ravines and slopes, the spatial logic of the necropolis reflects deliberate planning, symbolic orientation and a sophisticated understanding of landscape structure. The Banditaccia necropolis is not an isolated funerary field but is a spatially coherent system embedded within the morphology of the land and articulated through patterns such as movement, visibility and ritual significance. At its largest territorial scale, the necropolis occupies the western edge of a large tufa plateau. This position is like both strategic and symbolic. The plateau suggested a stable and workable surface for excavation, whenever the steep ravines surrounding it created natural boundaries that defined the limits of the funerary zone. (Fig.27)



Figure 27. View of the Banditaccia necropolis along the tufa plateau edge, showing its spatial organisation within the landscape.

Source: [The Necropolis of Cerveteri – Our Bumble](#)

¹¹⁹ UNESCO 2004

¹²⁰ Caneva, 2014.

¹²¹ Darvill 1995.

The gap between elevated surfaces and deeply incised valleys made a landscape which has strong spatial hierarchies, where certain areas naturally became focal points for habitation, ritual activity and territorial control. The placement of the necropolis along the plateau edge also ensured visibility from the surrounding territory, reinforcing its symbolic presence within the wider landscape and establishing a visual dialogue with the ancient urban centre of Caere.¹²² In this area, the internal organisation of the necropolis reveals a clear and intentional spatial logic. The tumuli's that they existed before, dating to the Orientalising and Archaic periods, are concentrated and remained along the plateau edge, where their circular mounds and prominent façades were most and widespread visible from the surrounding landscape. Their placement suggests a deliberate intention to mark the threshold between the world of the living and the world of the dead, using the natural drop of the plateau as a symbolic boundary. Many of these tumuli are situated near principal access routes, which cements them as territorial markers and conduits of ritual transformation. Their massive scale and major station testify to the social and political standing of those who commissioned them spatial identity in an elite space.¹²³ Further inland, there is an increasingly regular and orthogonal spatial organization. The so called "funerary streets" are grid like, with long straight axes meeting at right angles. This layout suggests the planned extension of the necropolis in the 6th and 5th centuries BCE, with chamber tombs and cube tombs excavated in systematic rows. The orthogonal order of the plan of construction bears resemblance to urban planning, where spatiality corresponds to social order. As pathways not only of circulation, but of ritual paths as well as ritual routes, the funerary streets helped in orienting movement in the necropolis, and were, in turn, the experience of the funerary landscape. The fact that they are linear and consistent lends an element of rhythm and repetition to the spatial coherence of the necropolis.¹²⁴ This is in line with the geographic arrangement of tomb types in this spatial context; hence, the hierarchy of life forms is preserved in the necropolis. Tumuli of the monumental form appear largest along the edge of the plateau while the interiors are dominated by the cube and chamber. The distribution of each type of tomb indicates both chronological progress and social differentiation. (Fig.28)



Figure 28. Interior of a chamber tomb showing recessed burial platform and architectural articulation.

Source: [The Necropolis of Cerveteri – Our Bumble](#)

¹²² UNESCO 2004; Nardi Brunetti 1986

¹²³ Cristofani 1985; Camporeale 2011

¹²⁴ UNESCO 2004.

Bigger, more gilded tombs run along major axes, while smaller tombs line secondary streets and fringe ones. Such patterns suggest spatialisation of social hierarchy where the organisation of the necropolis mimicked that of the community it serviced. As such, the spatial distribution of tombs becomes a material reflection of social identity, lineage, and political power.¹²⁵ Orientation is also important for spatial layout of the necropolis. Many tomb façades face the main funerary streets, generating a rhythmic sequence of entrances that underscores the linearity of the routes. A point of orientation that would heighten visibility in relation to and ease of access to; and strengthen the symbolic connection between the tombs and the routes between them. In some areas it is possible to see that these tombs are oriented toward the ancient city of Caere, implying a visual and ritual conversation between the necropolis and the urban centre. These alignments reveal a logic of spatial integration, whereby the necropolis was conceived as an appendage to the city in which the routes, sightlines and territorial identity could be interconnected.¹²⁶ Motion is another fundamental factor in spatial organization of the necropolis. The funerary streets are a mass of hallways that form one network of paths organizing walking and directing visitors. Both practical and ceremonial, they were the routes on which one embarks before burial and commemoration. These tombs are arranged on the roadways in a way which results in a spatial story the sequence of entrances, façades and architectural forms are also in keeping with the community's cultural values and social structure. The necropolis movement becomes, in this sense, a spatial storytelling where even the landscape acts to convey meaning.¹²⁷ Visibility is also important in the spatial arrangement. As the necropolis is relatively high on the site, it is possible to look towards the tombs, especially the monumental tumuli, from the surrounding territory. This visibility further serves to legitimize their symbolic role and give the necropolis visual association with broader geography. In the necropolis the orientation of tomb façades and alignment of pathways form internal sightlines that organize the visitor's experience and highlight site spatial coherence. Visibility in this sense becomes a vehicle of symbolic communication but also a mechanism of spatial ordering. The spatial configuration is also affected by environmental conditions. The geometry of the plateau affected both the depth and the angle of tomb digging; and the existence of ravines controlled the limits of expansion. Differentiation of zones in the necropolis was influenced by vegetation, soil types and microclimatic changes resulting in the location and long-term preservation of tombs. This environmental dynamical relationship between natural processes and cultural planning shows us that spatial organisation should not be taken for granted in the case of the necropolis but is in fact contingent on the Eco dynamics under which it developed.¹²⁸ The Banditaccia necropolis layout also demonstrates an advanced understanding of territorial articulation. The necropolis is segmented into specific quarters of occupation with different architecture, temporal progression and spatial ordering. These sectors are connected by a path network which structure mobility in a proper spatial system.

¹²⁵ Cristofani 1985; Proietti 1983.

¹²⁶ Nardi Brunetti 1986.

¹²⁷ Camporeale 2011.

¹²⁸ UNESCO 2004.

The articulation of these zones is in consideration of not only practical factors like accessibility and terrain but also cultural features like lineage, status and ritual.¹²⁹ Collectively, the spatial organisation of the Banditaccia necropolis shows an elaborate organisation that incorporates geological form, cultural meaning and environmental forces. The necropolis is not a collection of tombs but it is a spatial system which is defined by movement, visibility, hierarchy and landscape morphology. Analysing this arrangement is important for understanding archaeological evidence and for setting conservation policies that are aligned with the spatial logic of the site. These patterns will then be employed to the zoning analysis from large scale to micro scale in the next sections in which the internal articulation of the necropolis is evaluated more fully.

¹²⁹ Cristofani 1985; Proietti 1983.

4.4 Internal Zoning and Territorial Articulation: UNESCO Core and Buffer Zones

The internal area of the Banditaccia necropolis constitutes a complicated and calculated structuration, an interaction between topography, social structure, ritual tradition and sustained territorial development. Instead of a common funerary field, the necropolis has also been divided into different sectors with different kinds of architectural typologies, chronological phases and spatial functions. This internal differentiation is the cornerstone of its territorial logic, demonstrating the Etruscans' spatial ordering of concepts of death, memory and community.¹³⁰ At its widest level, the necropolis is organised into a hierarchical series of zones that is consistent with natural morphology and cultural intention. Such monumental tumuli are placed at the plateau edge in the most traditional and the earliest region in terms of symbolism¹³¹. (Fig.29)

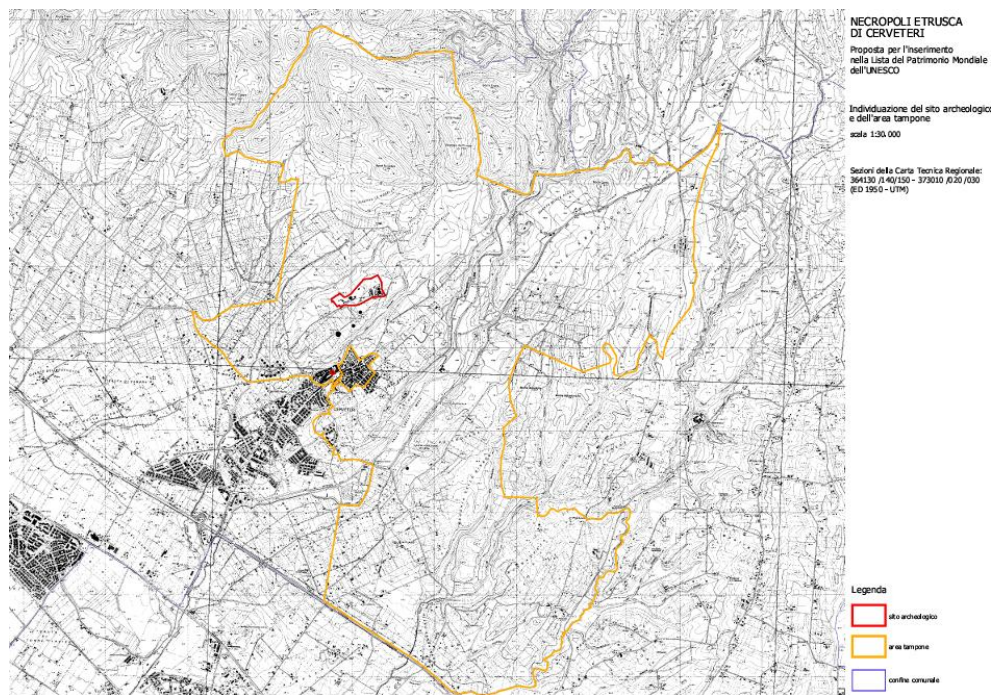


Figure 29. UNESCO zoning of the Etruscan Necropolis of Cerveteri, showing the Core Zone (sito archeologico, in red) and the Buffer Zone (area tampone, in orange), defined to protect the archaeological landscape and its territorial setting. Municipal boundaries are indicated in blue. *Scale 1:30,000.*

Source: UNESCO Nomination Dossier

¹³⁰ Steingraber 2006

¹³¹ Dennis 1883; Colonna 1964).

They stand on elevated ground, overlooking the area around and represent a very clear visual and territorial impact. This zone operates as a threshold between the inhabited and the funerary territories, mediating the border through scale, visibility and architectural emphasis. (Fig.30) (Fig.31)



Figure 30. Aerial view of the Banditaccia necropolis showing the core archaeological area (red boundary) and its elevated position in relation to the surrounding landscape.

Source: UNESCO Nomination Dossier

The tumuli express elite identity while contextualising the necropolis in the broader landscape and opening a kind of spatial dialogue with the ancient urban centre. This spatial logic grows more regular or orthogonal from the point of edge of the plateau. The central zone is characterized by a grid-like arrangement of funerary streets and the uniform layout on which cubic and chamber tombs have been systematically hollowed out and excavated. The move from the monumental demarcation of a monumental perimeter to the organization of its built-up interior follows from the symbolic territorial demarcation to a formalized state of communal interment. This orthogonally ordered scheme indicates a planned enlargement of the necropolis, in which spatial order parallels social order in a planned growth of the necropolis. These funerary streets could both carry people through circulation paths and act as paths to rituals and ceremonies and guide movement and also shape the visitor's experience of the site.¹³²

¹³² Haynes 2000.

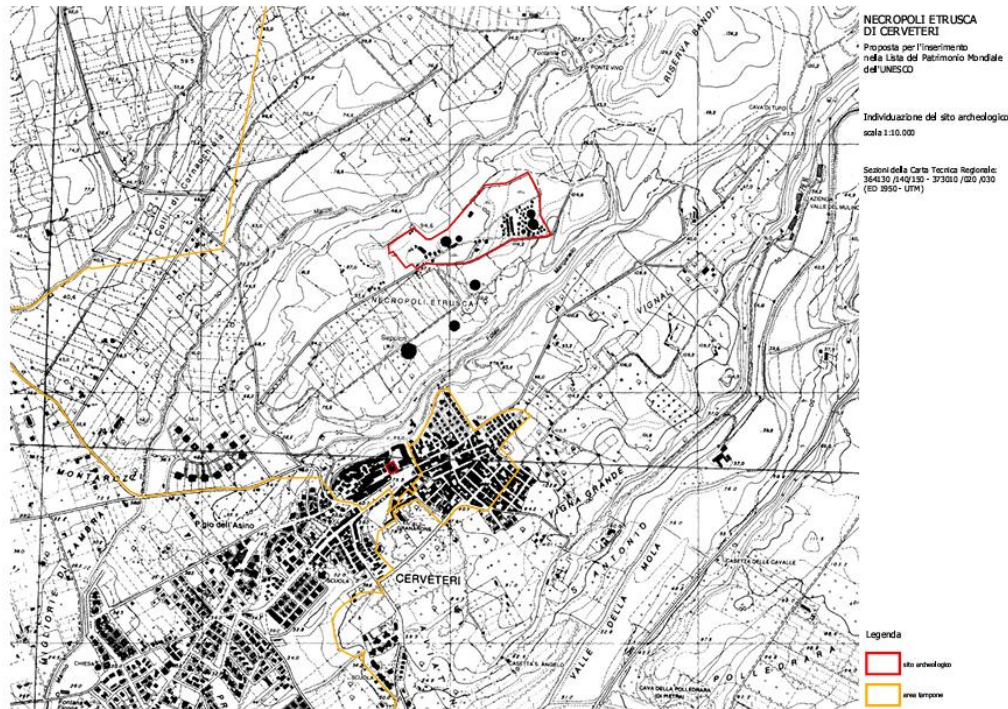


Figure 31. Detailed map of the Banditaccia necropolis illustrating the orthogonal funerary street system, the spatial organisation of tombs, and the relationship between the core area and the surrounding urban context.

Source: UNESCO Nomination Dossier

Their rhythm is achieved by their linearity and repetition creating a kind of rhythmic nature which underlines the fact the necropolis is maintained as a space that is articulated spatially, systemically. In this central zone, more internal differentiation emerges within it. Some streets feature larger, more architecturally intricate tombs, some smaller, more modest ones. This distribution corresponds to social stratification, with large families lining up the most obvious and accessible axes and the physical shape of the space acts as a material embodiment of social status, inscribing lines of descent, social class or political authority in the landscape. The necropolis serves as a spatial archive where the organisation of the living community is reflected in the organisation of the dead. A third zone appears in the more peripheral areas, smaller and less closely spaced and frequently more poorly preserved tombs.¹³³ Such fringe parts correspond both to chronological extensions and to societal developments.¹³⁴ As the necropolis develops, new areas were added into its spatial hierarchy, fitting the constraints imposed by landforms and the population's requirements. The peripheries indicate an approach to the territorial articulation in practice that is more flexible and adaptive, based on the practical situation. These differences show how such are dynamic and reactive, as the necropolis is not static but a place growing from its very starting state.¹³⁵ Orientation is important in internal zoning of the necropolis. Most of the tomb facades point to the main funerary streets. Some sectors have their tombs facing the ancient city of Caere, creating a geographic and symbolic connection between the necropolis and the city. These lines disclose a logic of

¹³³ UNESCO 2004

¹³⁴ Barker & Rasmussen 1998.

¹³⁵ UNESCO 2004.

spatial integration in which the necropolis was not considered as separate but as part of a greater city's territorial identity.¹³⁶ Time and space in circulation are also key principles of territorial articulation. The path of funerary streets serves to organize mobility in the necropolis. It was via these roads that not only was functional access taken to services, but also ritual processions that contributed to the ritualization and commemoration of burial. Movement through the necropolis is a spatial storytelling of sorts, in that the setting itself acts as a metaphor for the place in its arrangements.¹³⁷ Environmental factors greatly affect the internal zoning of the necropolis. Tomb excavation depth and angle depend on the tufa plateau morphology. Geological factors like differences in vegetation, soil composition and microclimatic conditions help define the zones. Territorial articulation is an intricate process determined largely by environmental conditions.¹³⁸ The organization of the necropolis into disparate zones also has significant conservation consequences which means Every sector has variations in susceptibility, degradation patterns and management opportunities. The monumental tumuli require structural stability and erosion protection. The orthogonal grid requires approaches to visitor passage, surface wear and biological growth. Peripheral regions may be more prone to environmental threats and should be observed by tracking and preventative conservation. The internal zoning and territorial expression of the Banditaccia necropolis reflect a complex and multiple organisations of space. The necropolis is not just a collection of tombs, but it is a dynamic territorial system associated with movement, visibility, hierarchy and the structure of the landscape. Acknowledging this system is essential for interpreting the archaeological evidence and building conservation efforts.

4.5 Integrated Reading of the Necropolis, the Urban Centre and the Environmental System

The relationship between the Banditaccia necropolis and the ancient urban centre of Caere forms one of the clearest expressions of the Etruscan territorial vision. The necropolis was not conceived as a marginal burial zone but as an integral component of the city's symbolic and political body. Its siting on elevated tufa plateaus, its orientation toward the urban core and the alignment of its funerary streets reflect a deliberate spatial dialogue in which the world of the living and the world of the dead were interdependent elements of a single cultural landscape. The tumuli positioned along the plateau edges acted as monumental markers which they are visible from the city, transforming the boundary between habitation and burial into a symbolic threshold. Funerary routes linking Caere to Banditaccia functioned as ritual corridors, structuring processions and commemorative practices that reinforced social continuity and collective memory. (Fig.32)

¹³⁶ Proietti 1983.

¹³⁷ UNESCO 2004.

¹³⁸ Caneva 2018.



Figure 32. Aerial view of the Banditaccia plateau, showing the alignment of tumuli along the edge of the tufa terraces and illustrating the spatial dialogue between the necropolis and the ancient urban centre of Caere.

Source: [Edit image, resize image, crop pictures and apply effect to your images](#)



Figure 33. Ground-level view of the funerary street within the Banditaccia necropolis, showing rock-cut tomb facades aligned along a processional path. The spatial configuration illustrates the role of funerary routes as ritual corridors structuring movement and commemorative practices.

Source: [Indonesian-recipes.com. Resize image, Download, Crop pics, Add instagram effect.](#)

This spatial relationship was shaped by environmental and ecological dynamics. The geological structure of the Tolfetano Cerite volcanic district conditioned where tombs could be excavated and how different sectors of the necropolis can be developed.(Fig.33).Variations in porosity and mechanical resistance has effect the distribution of chamber tombs and tumuli, while long-term processes such as erosion, water infiltration and differential weathering produced micro-landscapes that reveal both

ancient construction choices and ongoing natural transformations.¹³⁹ Also Vegetation patterns, root penetration, biological colonisation and microclimatic variations further contributed to the differentiation of zones within the necropolis, they has effect on the accessibility and vulnerability. Hydrological behaviour runoff, drainage and moisture accumulation determined where erosion was most active and where tombs were more susceptible to collapse, shaping the long-term spatial logic of the site.(Fig.34)



Figure 34. Vegetation growth and root penetration within the tuff rock of the Banditaccia necropolis, illustrating the impact of biological colonisation, moisture infiltration and long-term weathering processes on the structural integrity and preservation of tomb features.

Source: Author documentation, 2025

These environmental processes are not inseparable from the necropolis's cultural meaning. The elevated plateaus ensured visibility from key points of the city, reinforcing the necropolis as a landscape of memory embedded in daily life. Microclimatic contrasts between sun-exposed ridges and shaded depressions influenced not only decay patterns but also the perceptual experience of movement through the funerary streets, dromoi and monumental tumuli. In this sense, Banditaccia functioned as a second city a parallel urban structure where social hierarchy, family identity and collective memory were expressed through spatial organisation rather than domestic architecture. Understanding this

¹³⁹ Negretti & Morbidelli 1963.

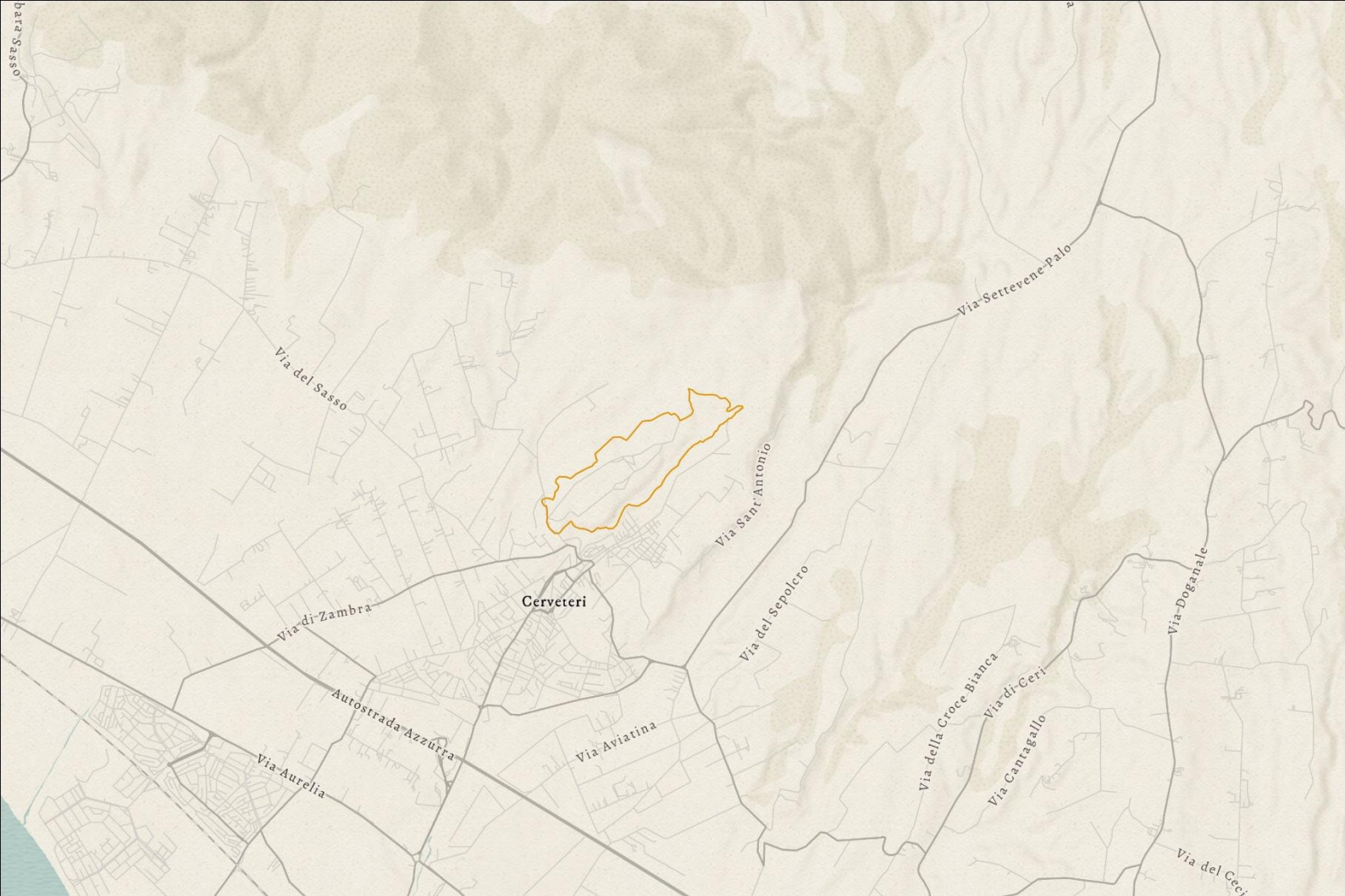
integrated system is essential and important for conservation. The necropolis cannot be known as an isolated archaeological site but its significance, vulnerability and spatial logic depend on its connection to the wider territory of Caere. So, in this case conservation strategies must therefore consider visual corridors, access routes, landscape thresholds and ecological dynamics alongside the material preservation of tombs. This approach aligns with contemporary conservation principles that they are emphasise context, authenticity and landscape continuity, recognising that heritage must be understood within its broader spatial and cultural framework.¹⁴⁰

The complexity of the necropolis also shown the need for spatial analysis. Different sectors and parts respond differently to environmental stressors and human impact. Like monumental tumuli require structural stabilisation; orthogonal street sectors demand surface monitoring and peripheral areas face greater ecological vulnerability. GIS and WebGIS they are a platform that they provide essential tools for mapping and better understanding these patterns, monitoring ecological processes and supporting evidence-based decision-making. They allow authorities to identify and see risk zones, track changes over time and coordinate interventions within a unified geospatial framework.¹⁴¹ A WebGIS-based methodology becomes the natural continuation of the landscape reading developed here, translating interpretative insights into operational strategies for long term management. Ultimately, the relationship between Banditaccia and Caere reveals a sophisticated territorial vision in which the city and its necropolis form a unified cultural organism. The necropolis is not a silent archive but an active component of the landscape, which is shaped by environmental forces and sustained by the identity of the community. Recognising this integrated system is fundamental for both interpretation and conservation, ensuring that Banditaccia is preserved not as an isolated monument but as part of the living landscape of Cerveteri.¹⁴²

¹⁴⁰ Stovel 2008.

¹⁴¹ Laurenza, Putzolu, and Farinetti, *Re-thinking Landscape Archaeology and GIS Analyses*, 2005.

¹⁴² UNESCO 2004.



CHAPTER V

3D SURVEY , GIS AND WEBGIS METHODOLOGY FOR LANDSCAPE ANALYSIS AND CONSERVATION

5.1 Introduction to the Methodological Framework

The methodological framework adopted in this research is designed to support the documentation, analysis and interpretation of the archaeological landscape of Cerveteri through an integrated geomatics-based approach. While the previous chapters introduced the historical, environmental and cultural context of the necropolis, the present chapter outlines the operational workflow that enables the transformation of raw spatial data into structured, interpretable and conservation-oriented information. The focus is on how different spatial datasets that are acquired, processed and organised through geomatics tools. Particular attention is given to the definition of archaeological entities, typological classification, chronological attribution and conservation-related attributes, which form the basis of the GIS database and support subsequent spatial analyses within the WebGIS environment. (Fig.35)



Figure 35. Methodological workflow adopted for the documentation, organisation and dissemination of archaeological information within the GIS and WebGIS framework.

Source: Developed by author

Archaeological landscape documentation increasingly relies on geomatic technologies capable of acquiring, processing and managing spatial information at different scales. Among the most widely adopted approaches are UAV photogrammetry and Mobile LiDAR SLAM systems, which allow the generation of accurate three-dimensional datasets for archaeological recording and analysis. These techniques provide the spatial foundation for GIS and WebGIS environments by transforming raw survey data into georeferenced digital products suitable for mapping, interpretation and conservation-oriented applications. The following sections introduce the study area and describe the survey methodologies adopted in this research.

5.1.1 3D Survey and GIS as the Basis of the Methodology

The methodological framework adopted in this thesis is grounded in the integration of digital spatial technologies and a landscape-based approach to archaeological documentation and conservation. The Banditaccia Necropolis is considered not as a collection of isolated monuments, but as a complex of cultural landscape in which morphology, vegetation, hydrology and archaeological structures interact across multiple spatial and temporal scales. Documenting and interpreting such a system require methodologies capable of integrating heterogeneous datasets within a coherent geospatial framework. In this context, geomatics provides the conceptual and technological basis for the acquisition, processing and management of georeferenced information. As an interdisciplinary field, geomatics integrates geodesy, cartography, surveying, photogrammetry, remote sensing and spatial analysis techniques into a unified methodological system for documenting and analysing complex environments. The integration of these disciplines enables the acquisition of accurate spatial information and the production of reliable digital representations of archaeological landscapes. Archaeological landscape documentation increasingly based on geomatic technologies capable of operating across different spatial scales and environmental conditions. Surveying methods provide metric and positional accuracy, photogrammetry enables the generation of high-resolution three-dimensional models and orthophotos, while remote sensing techniques support the observation and interpretation of broader territorial patterns. All These technologies contribute to the acquisition and organisation of spatial information necessary for archaeological analysis and conservation activities. In this methodological framework, Geographic Information Systems (GIS) represent the principal environment for the organisation, management and spatial analysis of the georeferenced datasets acquired during the survey activities. GIS enables the integration of heterogeneous information, including photogrammetric outputs, LiDAR point clouds, GNSS measurements, archaeological records and environmental data, within a unified geospatial framework. Through the creation of thematic layers and spatial relationships, GIS supports the interpretation of archaeological landscapes at multiple scales, facilitating the analysis of topography, monument distribution, vegetation patterns and conservation conditions. In this research, GIS was therefore employed not only as a data management platform but also as an analytical tool supporting spatial interpretation, documentation and conservation-oriented investigations within the Banditaccia Necropolis. Among the geomatic techniques most widely adopted in archaeological documentation are photogrammetry, GNSS surveying and SLAM-based mobile mapping systems. These technologies support different phases and aspects of spatial acquisition, georeferencing and three-dimensional reconstruction, contributing to the creation of integrated digital datasets for archaeological analysis and conservation oriented research. For instance, Photogrammetry has become one of the most commonly used techniques for the documentation of cultural heritage thanks to its ability to extract geometric information from overlapping photographs and generate spatially accurate three-dimensional models. The development of digital photogrammetry and UAV-based image acquisition has significantly expanded its application within archaeology, allowing large areas to be

documented efficiently through high-resolution imagery. Through Structure-from-Motion (SfM) algorithms and image triangulation, photogrammetric workflows enable the reconstruction of dense point clouds, digital surface models (DSMs) and orthophotos, providing an accurate spatial basis for mapping and landscape analysis. GNSS surveying was employed to support the georeferencing and spatial alignment of the different datasets acquired within the Via degli Inferi sector. The acquisition of reference coordinates and control points ensured the spatial consistency of the photogrammetric and mobile mapping datasets within a unified geospatial framework, facilitating their subsequent integration within GIS and WebGIS environments. On the other hand, SLAM-based mobile mapping systems have emerged as valuable tools for archaeological documentation, particularly in environments characterised by narrow pathways, dense vegetation and limited accessibility. Unlike image-based reconstruction methods, SLAM technology continuously estimates sensor position while simultaneously generating a three-dimensional representation of the surrounding environment. The integration and evolution of UAV photogrammetry and SLAM-based mobile mapping has different effects such as improves the documentation of complex archaeological landscapes by combining large-scale spatial coverage with detailed environmental and morphological information.

In this research, these geomatic techniques formed the basis of the survey activities conducted in the Via degli Inferi sector of the Banditaccia Necropolis, supporting the generation of georeferenced datasets subsequently organised, analysed and visualised within the GIS and WebGIS framework.

Also, in this chapter, we first explain these methods and provide a brief overview of the survey in which these instruments were used. Then, we directly discuss the activities carried out with TEAM DIRECT and location of the case study.

5.1.2 Geographic Information Systems (GIS): Definition and Structure

A Geographic Information System (GIS) is a kind of computer-based system which is designed for the acquisition, storage, management, analysis and visualisation of geographically referenced data. GIS enables spatial information to be organised within a unified digital environment in which geographic coordinates are associated with descriptive and analytical datasets. By meaning this, GIS supports the interpretation of spatial relationships, territorial organisation and environmental patterns across multiple scales. Unlike conventional cartographic systems, GIS does not function only used as a mapping tool, but as an analytical framework capable of integrating geographic information, database management and spatial modelling. Geographic entities can be showed through vector and raster data models, while associated attribute tables store descriptive information connected to each spatial feature. This structure allows geographic data to be queried, analysed and visualised dynamically according to different research objectives. The structure of a GIS is generally composed of several kind of interconnected components, including hardware, software, spatial data, analytical methods and users. Hardware provides the technological infrastructure required for data acquisition and processing, while GIS software enables cartographic production, geospatial analysis and database management. Spatial data stablish the core element of the system and may include topographic information, satellite imagery, aerial photographs, survey data and georeferenced archaeological documentation. One of the principal characteristics of GIS is the analytical capability. Through spatial analysis tools, GIS allows the investigation of proximity relationships, spatial distribution patterns, terrain morphology, visibility conditions and thematic correlations between different datasets. These analytical functions transform GIS into a powerful methodological instrument for spatial interpretation and decision making processes. IS also plays a fundamental role in cartographic visualisation. By organising information into thematic layers, the system enables complex spatial datasets to be represented through maps, diagrams and digital visualisations. This layered structure facilitates both the interpretation and communication of geographic information within scientific and applied research contexts. Because of the capacity to integrate, analyse and visualise spatial information, GIS has become an essential technology in numerous disciplines such as urban planning, environmental management, geology, cultural heritage documentation and archaeology.

5.1.3 History and Development of Global Navigation Satellites System (GNSS)

The development of Global Navigation Satellite Systems (GNSS) originated during the Cold War period and was initially driven by military navigation requirements. The first operational satellite navigation system was the United States NAVSTAR Global Positioning System (GPS), developed by the U.S. Department of Defence during the 1970s. The system became fully operational in the 1990s and was later made freely available for civilian applications, leading to a rapid expansion of satellite-based positioning technologies worldwide. Following the success of GPS, several countries and international organizations developed independent satellite navigation constellations. These include GLONASS which developed by Russia, Galileo developed by the European Union, and BeiDou developed by China. Together all these systems form the modern GNSS infrastructure, providing global positioning, navigation, and timing services for civilian, scientific, industrial, and military applications. The continuous development of satellite technologies, signal processing, and positioning algorithms has significantly improved GNSS accuracy, reliability, and availability. Modern GNSS receivers are capable of simultaneously using multiple satellite constellations and frequencies, enabling centimetre-level positioning accuracy through advanced techniques such as Differential GNSS (DGNS), Real-Time Kinematic (RTK), and Precise Point Positioning (PPP).¹⁴³ (Fig.36)

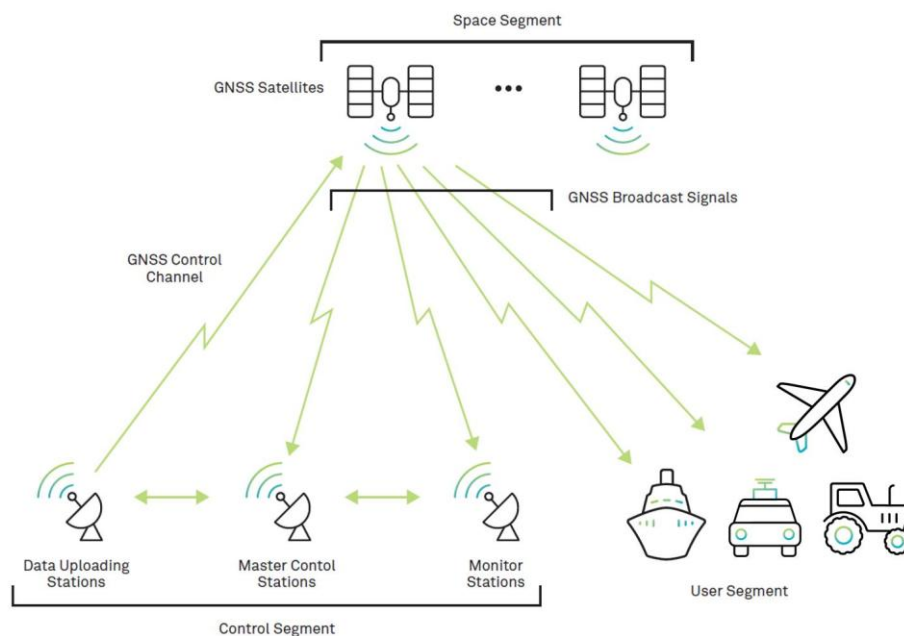


Figure 36. Main global GNSS constellations including GPS, GLONASS, Galileo, and BeiDou.

Source: Adapted by the author from NovAtel, *An Introduction to GNSS*.

¹⁴³ Bradford W. Parkinson and James J. Spilker Jr., *Global Positioning System: Theory and Applications* (Washington, DC: American Institute of Aeronautics and Astronautics, 1996).

5.1.4 Fundamentals of GNSS, Satellites

Global Navigation Satellite System (GNSS) is a satellite-based positioning technology that provides location, navigation, and timing information anywhere on Earth through a constellation of orbiting satellites. A GNSS system is generally composed of three main components: the space segment, consisting of navigation satellites transmitting positioning signals; the control segment, including ground monitoring and control stations responsible for satellite management and signal correction; and the user segment, represented by GNSS receivers that process satellite signals to determine geographic position. The positioning principle of GNSS is based on trilateration, in which the receiver calculates its position by measuring the travel time of radio signals transmitted from multiple satellites. By determining the distance between the receiver and at least four satellites, the system can accurately compute three-dimensional coordinates and receiver clock corrections.¹⁴⁴ Modern GNSS receivers are capable of simultaneously processing signals from multiple satellite constellations, improving positioning accuracy, reliability, and availability for surveying, navigation, geomatics, and photogrammetric applications.¹⁴⁵ (Fig.37)

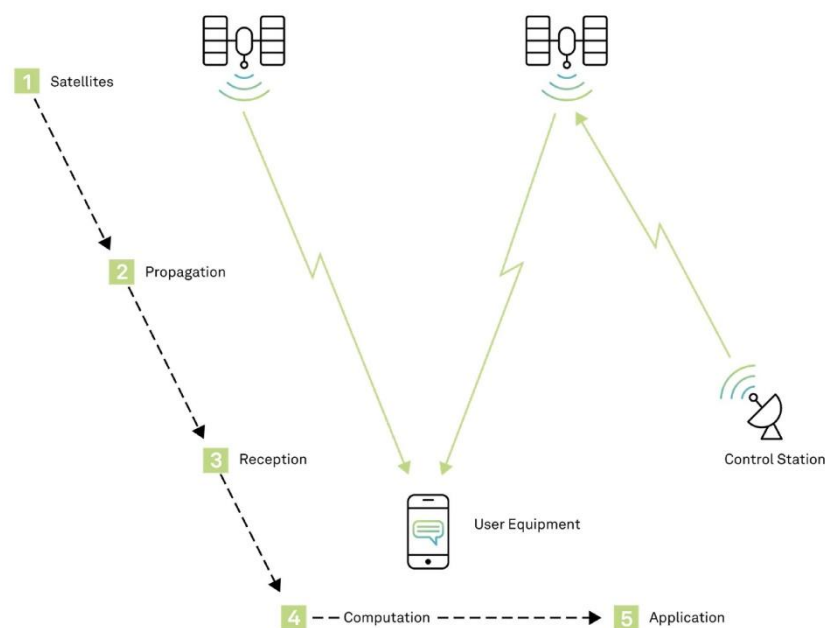


Figure 37. Main global GNSS constellations including GPS, GLONASS, Galileo, and BeiDou.

Source: Adapted by the author from NovAtel, *An Introduction to GNSS*.

¹⁴⁴ Paul D. Groves, *Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems*, 2nd ed. (Boston: Artech House, 2013)

¹⁴⁵ European Union Agency for the Space Programme (EUSPA), "What is GNSS?," accessed June 14, 2026, [EUSPA GNSS Overview](#).

5.1.5 Photogrammetry: Historical development

The origins of photogrammetry date back almost to the same period as the invention of photography itself. During the first decades of its development, photogrammetry was mainly applied to close range architectural surveying rather than large scale topographic mapping. Shortly after the emergence of photography in the 1830s and 1840s through the work of pioneers such as Fox Talbot, Niépce, and Daguerre, the French military officer Aimé Laussedat began experimenting with methods for obtaining measurements from perspective images. In 1849, he carried out studies using drawings of the façade of the Hôtel des Invalides in Paris to investigate the possibility of extracting geometric information from images. Although Laussedat is widely regarded as the first photogrammetrist, his earliest experiments were conducted using a camera lucida, since photographic equipment only became available to him in 1852.¹⁴⁶



Figure 38: Early example of photogrammetric field recording, about 1867 (Laussedat 1898).

Source: Thomas Luhmann, Stuart Robson, Stephen Kyle, Jan Boehm

Figure 38 illustrates one of the earliest examples of photogrammetric field surveying carried out by Aimé Laussedat around in 1867. His work shows an important step in the development of photogrammetry, demonstrating the use of images for measurement and mapping purposes in military and architectural applications. He used photography as an alternative to manual methods of measuring façades. For this he developed important aspect which was his own large-format, glass-plate cameras. (Fig.39)

¹⁴⁶ Luhmann, Thomas, Stuart Robson, Stephen Kyle, and Jan Boehm. *Close-Range Photogrammetry and 3D Imaging*. 3rd ed. Berlin/Boston: Walter de Gruyter, 2020.

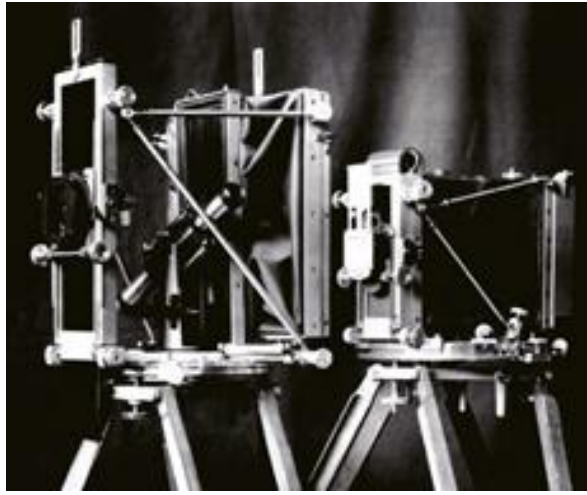


Figure 39: Metric cameras by Meydenbauer (ca. 1890); left: 30×30cm², right: 20×20cm² (Albertz 2009)

Source: Thomas Luhmann, Stuart Robson, Stephen Kyle, Jan Boehm

During the late nineteenth century, photogrammetry underwent significant development with the introduction of stereoscopic measurement techniques. The use of stereo images enabled the reconstruction of three-dimensional geometry through the intersection of corresponding image rays, considerably improving measurement accuracy and topographic mapping capabilities. At the same time, analogue photogrammetry became widely adopted through the development of stereoplotters and optical-mechanical instruments designed for image interpretation and mapping. Early stereometric camera systems and stereo plotting devices are illustrated in Figure 40.



Figure 40: Zeiss TMK 6 metric camera and Zeiss SMK 40 and SMK 120 stereometric cameras.

Source: Thomas Luhmann, Stuart Robson, Stephen Kyle, Jan Boehm

From the 1950s onward, the emergence of computers marked the transition toward analytical photogrammetry. Numerical computation gradually replaced manual and analogue plotting methods, allowing more accurate and efficient processing of photogrammetric data. During this period, mathematical approaches such as bundle adjustment became fundamental for determining camera orientation and object coordinates simultaneously. Analytical photogrammetry significantly improved the precision, flexibility, and automation of photogrammetric measurements. Examples of analytical stereoplotters and photogrammetric instruments from this period are shown in Figure 41 and since the 1980s, the rapid development of digital cameras and computer technology has led to the evolution of digital photogrammetry. Digital image processing, automated feature extraction, and image matching techniques enabled faster and more reliable three-dimensional reconstruction. In recent decades, computer vision approaches

such as Structure from Motion (SfM) and dense image matching have further transformed photogrammetry by enabling automated orientation of large image datasets and the generation of dense point clouds and textured three-dimensional models. Examples of digital photogrammetric systems and computer-based processing environments are presented in Figure 42.¹⁴⁷



Figure 41: Zeiss Terragraph stereoplotter.

Source: Thomas Luhmann, Stuart Robson, Stephen Kyle, Jan Boehm



Figure 42: Rollei MR2 multi-image restitution system (ca. 1990)

Source: Thomas Luhmann, Stuart Robson, Stephen Kyle, Jan Boehm

¹⁴⁷ Luhmann et al., *Close-Range Photogrammetry and 3D Imaging*.

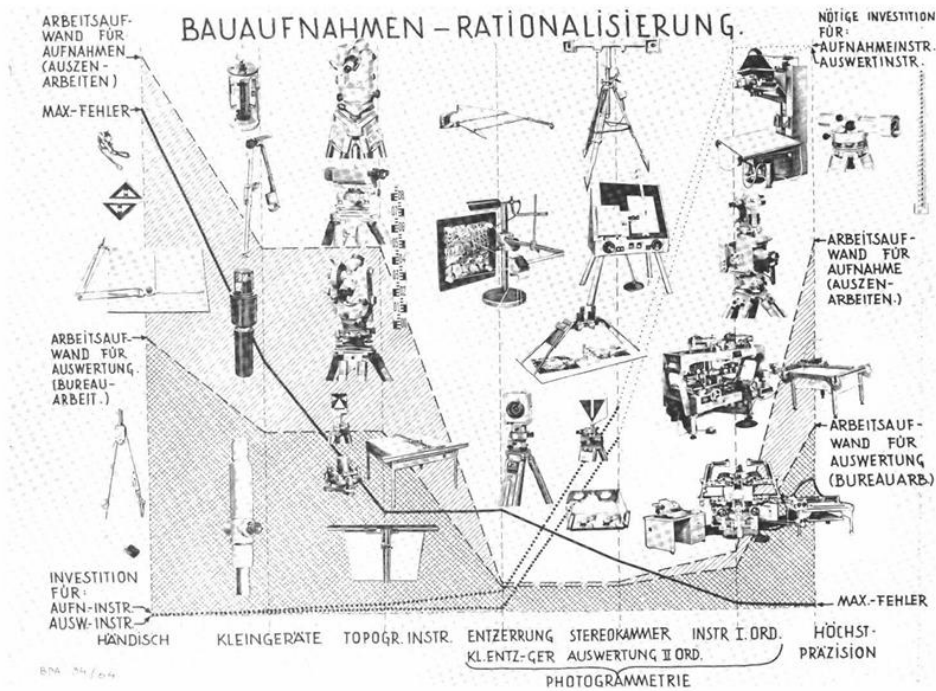


Figure 43. Comparison of architectural survey methods according to accuracy, operational effort and instrumentation requirements (after Foramitti, 1964).

Source: Adapted from Foramitti, H. (1964)

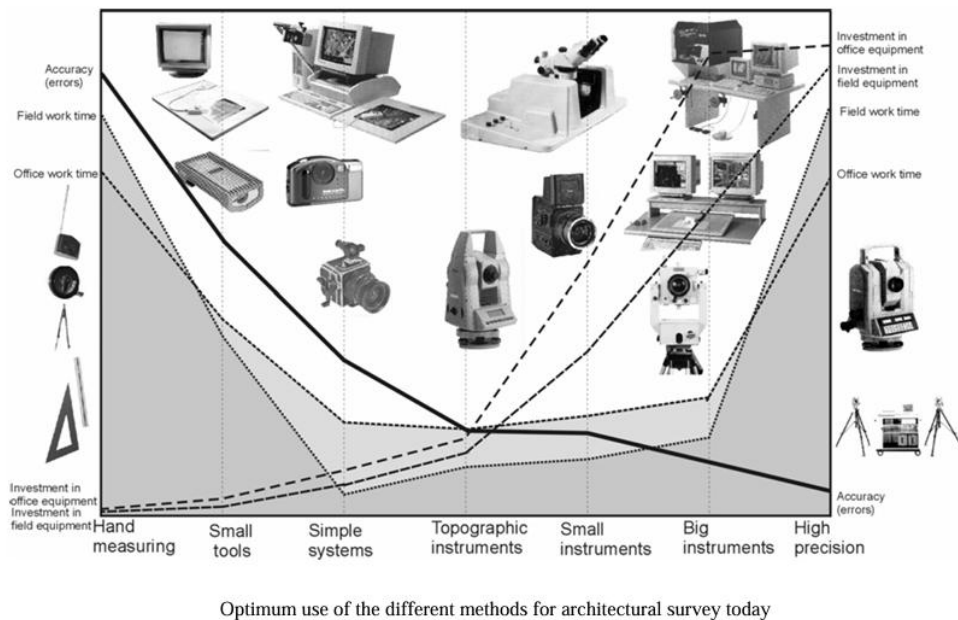


Figure 44. Evolution of architectural survey methods and their relationship with accuracy, fieldwork effort, office processing and equipment investment in contemporary digital workflows.

Source: Adapted from Foramitti, H. (1964)

Photogrammetry is a multidisciplinary measurement and documentation technique that is closely related to fields such as geomatics, surveying, computer vision, remote sensing, GIS, and digital image processing which is Depending on the size of the object and the required level of accuracy, different photogrammetric methods and technologies can be applied for spatial analysis, mapping, and three-dimensional reconstruction. Figure 45 shows clearly the relationship between measurement methods, object size, and accuracy, demonstrating how techniques such as UAV photogrammetry, aerial photogrammetry, terrestrial laser scanning, GNSS, and industrial photogrammetry are used at different spatial scales and precision levels. The theoretical basis of photogrammetry relies on the principle of central perspective projection. In this geometric model, light rays reflected from an object pass through the camera perspective center and are projected onto the image plane, establishing a relationship between object space and image space. When the same object point appears in two or more overlapping images, the intersection of the corresponding image rays enables the reconstruction of the three-dimensional coordinates of the object through triangulation. This principle forms the foundation of stereo photogrammetry, Structure from Motion (SfM), and modern digital reconstruction techniques. Figure 46 shows that the principle of photogrammetric measurement based on central projection and ray intersection, showing how multiple images acquired from different viewpoints can be used to reconstruct the geometry and spatial position of an object in three-dimensional space.

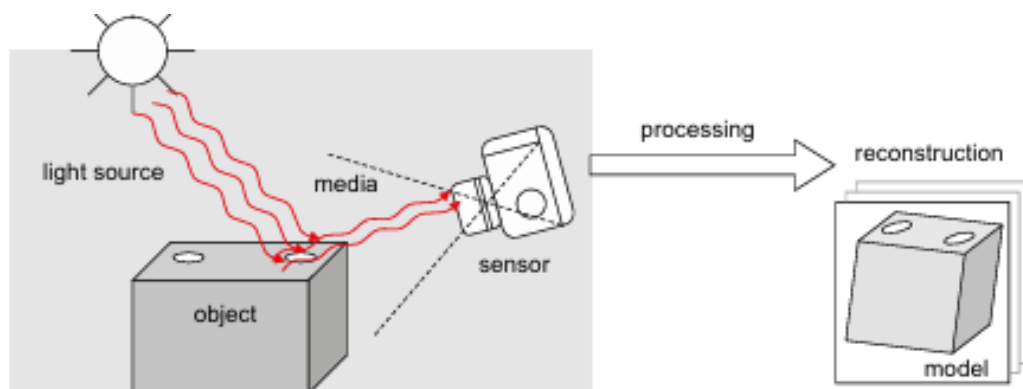


Figure 45. From object to image

Source: Thomas Luhmann, Stuart Robson, Stephen Kyle, Jan Boehm

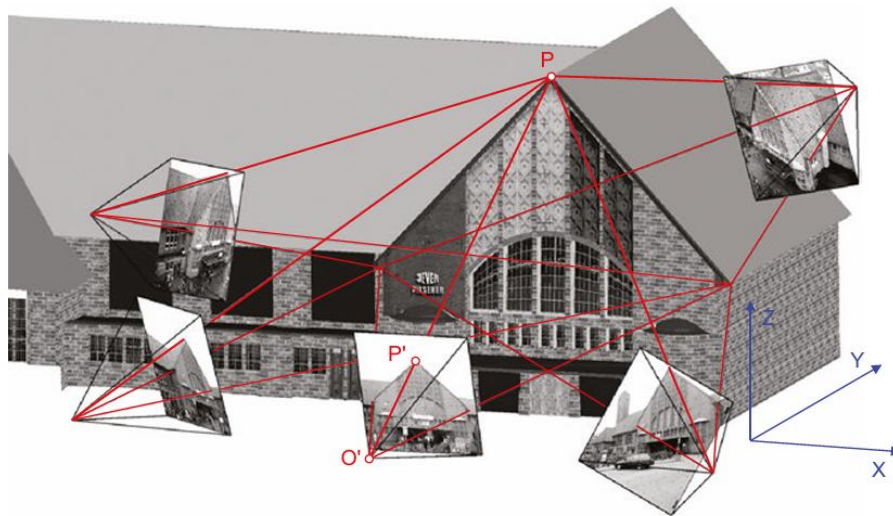


Figure 46. The photogrammetric process: from object to model

Source: Thomas Luhmann, Stuart Robson, Stephen Kyle, Jan Boehm

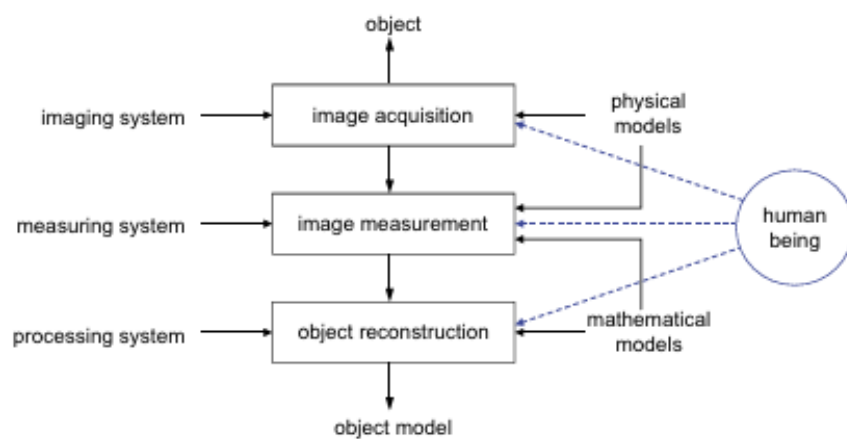


Figure 47. The photogrammetric process: from object to model.

Source: Thomas Luhmann, Stuart Robson, Stephen Kyle, Jan Boehm

Figure.47 General workflow of the photogrammetric process. The workflow includes image acquisition, image measurement, and object reconstruction through the application of mathematical and physical models. Human interpretation and processing also play an important role in ensuring the quality and reliability of the final reconstructed model.

5.1.6 Collinearity Equations

The collinearity equations define one of the fundamental mathematical models in photogrammetry. They describe the geometric relationship between an object point in three-dimensional space, the perspective center of the camera and its corresponding image point on the photograph. The basic principle states that the object point, the camera projection center and the image point lie on the same straight line (collinear). This geometric condition forms the basis for reconstructing three-dimensional coordinates from two-dimensional images and is important and necessary for different aspects such as photogrammetric measurements, camera orientation and 3D modeling. Photogrammetry relies on the central perspective projection model which all rays passing through object points intersect at the camera perspective center before being projected onto the image plane. The collinearity equations mathematically express this perspective relationship by connecting image coordinates (x, y) with object-space coordinates (X, Y, Z) . According to all these equations, it is possible to determine the position and orientation of the camera and subsequently calculate the spatial coordinates of unknown points. This concept is particularly important in archaeological documentation, where accurate reconstruction of monuments, excavation sites and cultural heritage features is required. The formulation of the collinearity equations requires knowledge of both the interior and exterior orientation parameters of the camera. Interior orientation parameters describe the geometry of the camera itself which including the calibrated focal length, principal point location, and lens distortion characteristics. Exterior orientation parameters define the camera position and attitude in object space through three translation parameters (X_0, Y_0, Z_0) and three rotation angles (ω, ϕ, κ) . Together, these parameters establish the transformation between image space and object space.¹⁴⁸

The mathematical form of the collinearity equations can be expressed as:

$$x - x_0 = -f \frac{r_{11}(X - X_s) + r_{12}(Y - Y_s) + r_{13}(Z - Z_s)}{r_{31}(X - X_s) + r_{32}(Y - Y_s) + r_{33}(Z - Z_s)}$$
$$y - y_0 = -f \frac{r_{21}(X - X_s) + r_{22}(Y - Y_s) + r_{23}(Z - Z_s)}{r_{31}(X - X_s) + r_{32}(Y - Y_s) + r_{33}(Z - Z_s)}$$

¹⁴⁸ Schenk, Thomas. *Introduction to Photogrammetry*. Columbus, OH: Department of Civil and Environmental Engineering and Geodetic Science, The Ohio State University, 2005.

where c is the calibrated focal length, (x_0, y_0) are the principal point coordinates, (X, Y, Z) are the object-space coordinates, (X_0, Y_0, Z_0) represent the camera position, and r_{ij} are elements of the rotation matrix describing camera orientation. In practical photogrammetric applications, the collinearity equations are used in several important procedures. During image orientation, they allow the estimation of camera parameters through bundle adjustment. In stereophotogrammetry, corresponding points identified in overlapping images are connected through the collinearity condition to determine their three-dimensional coordinates. According to all This process enables the generation of dense point clouds, digital elevation models (DEMs), orthophotos, and detailed three-dimensional models. The method has become a standard approach in modern digital photogrammetry and cultural heritage documentation.

In archaeological investigations, collinearity equations have an important effect which provide the mathematical framework for converting image observations into accurate spatial data. When combined with Ground Control Points (GCPs), GNSS measurements, or UAV imagery, they allow researchers to produce highly detailed and georeferenced 3D reconstructions of archaeological structures and landscapes. Their ability to integrate image geometry with real-world coordinates makes them one of the most important tools for digital heritage recording and preservation.

5.1.7 UAV Photogrammetry

The rapid development of digital photogrammetry and computer vision techniques has significantly expanded the use of Unmanned Aerial Vehicles (UAVs) in geomatics and spatial documentation. Equipped with high-resolution digital cameras and integrated positioning systems, UAV platforms enable rapid, flexible, and cost-effective image acquisition for three-dimensional reconstruction, mapping, and spatial analysis. Compared to traditional airborne photogrammetry, UAV systems provide low-altitude image acquisition with high spatial resolution and reduced operational costs, making them particularly suitable for archaeology, cultural heritage documentation, and small-scale surveying applications. A typical UAV photogrammetric workflow includes mission planning, image acquisition, camera calibration, image triangulation, and the generation of digital products such as orthophotos, Digital Surface Models (DSMs), and three-dimensional models. Figure 2 illustrates the general UAV photogrammetric processing pipeline, including flight planning parameters, image acquisition, image triangulation, and digital photogrammetric processing stages leading to orthophoto and 3D model generation. (Fig.48)

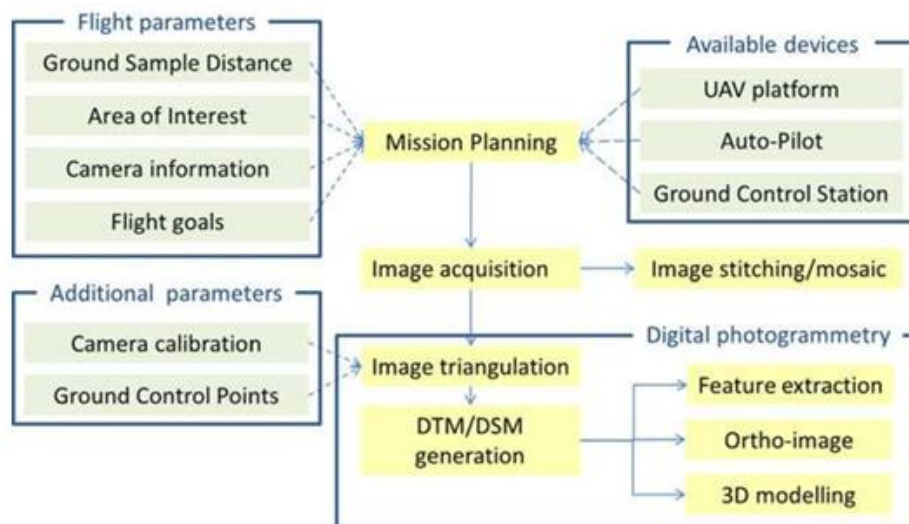


Figure 48. General workflow of UAV photogrammetry, illustrating mission planning, image acquisition, image triangulation and photogrammetric processing leading to the generation of orthophotos, Digital Surface Models (DSMs) and three-dimensional models.

Source: UAV for 3D mapping applications: Francesco Nex, Fabio Remondino

The flight planning stage is one of the most important phases of UAV photogrammetry because it directly influences image quality and reconstruction accuracy. Parameters such as flight altitude, image overlap, Ground Sample Distance (GSD), camera focal length, and flight path geometry must be carefully defined before image acquisition. High image overlaps and low-altitude flights are generally required and developed for detailed three-dimensional reconstruction and accurate photogrammetric measurements. UAV image acquisition may be performed manually, semi-automatically, or autonomously through integrated GNSS/INS navigation systems and autopilot technologies. The use of automated navigation systems improves image overlap consistency, flight stability, and overall data acquisition quality. Figure 49 demonstrates different flight acquisition modalities and illustrates how image overlap and navigation quality influence the final photogrammetric dataset.¹⁴⁹

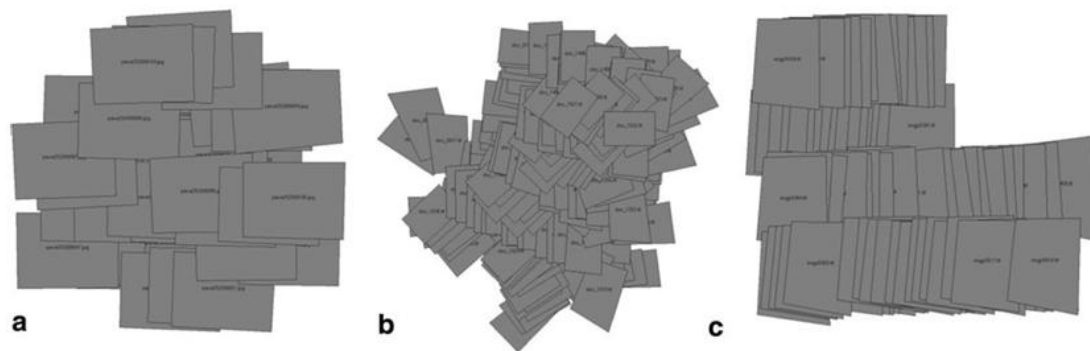


Figure 49. Different flight execution modalities illustrating variations in image overlap and acquisition geometry during UAV photogrammetric surveys. The figure compares manual image acquisition, irregular image overlap, and automated flight acquisition achieved through high-quality navigation systems.

Source: UAV for 3D mapping applications: Francesco Nex, Fabio Remondino

Following image acquisition, photogrammetric processing techniques such as image orientation, bundle adjustment, dense image matching, and surface reconstruction are applied to generate dense point clouds and three-dimensional models. These outputs can subsequently be used for orthophoto generation, archaeological documentation, terrain analysis, volume estimation, and GIS integration. Modern UAV photogrammetry has therefore become one of the most widely adopted methods for high-resolution spatial documentation and digital heritage recording.

¹⁴⁹ Francesco Nex and Fabio Remondino, "UAV for 3D Mapping Applications: A Review," *Applied Geomatics* 6, no. 1 (2014)

5.1.8 History and Development of SLAM

The other kind of important method is SLAM which is Simultaneous Localization and Mapping (SLAM) is a kind of methodology that enables a mobile sensor or platform to simultaneously determine its position while reconstructing a map of the surrounding environment. The concept of SLAM originated in the field of robotics during the 1980s as a solution for autonomous navigation in unknown environments where external positioning systems were unavailable or unreliable. Early SLAM research focused on different aspects like reducing positioning uncertainties and improving map consistency during movement through probabilistic and mathematical estimation methods.¹⁵⁰ During the 1990s and early 2000s, Important developments in computer vision, laser scanning technologies, inertial sensors and computational capabilities contributed to the rapid evolution of SLAM methodologies. The integration of cameras, LiDAR systems, and inertial measurement units enabled more reliable real-time localization and three-dimensional mapping. During a time, SLAM also evolved from a robotic navigation technique into an important methodology in geomatics, mobile mapping, autonomous navigation, and spatial documentation. The fundamental principle of SLAM is based on the simultaneous estimation of sensor trajectory and environmental reconstruction and During data acquisition, the system continuously records spatial information while identifying corresponding geometric or visual features which are between consecutive observations.

¹⁵¹(Fig.50)

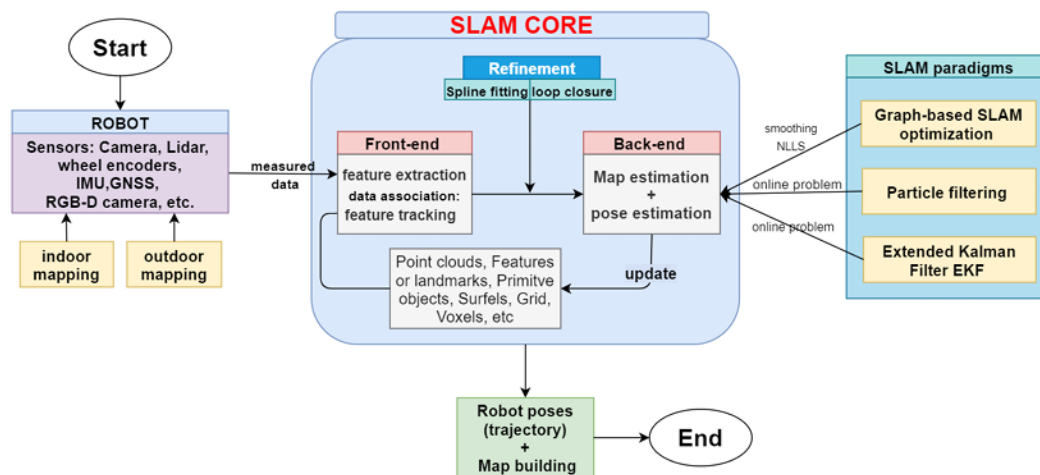


Figure 50: SLAM techniques overview.

Source: Modified after Schenk (2005).

¹⁵⁰ Hugh Durrant-Whyte and Tim Bailey, "Simultaneous Localization and Mapping: Part I," *IEEE Robotics & Automation Magazine* 13, no. 2 (2006)

¹⁵¹ Bashar Alsadik and Samer Karam, "The Simultaneous Localization and Mapping (SLAM): An Overview," *Journal of Applied Science and Technology Trends* 2, no. 2 (2021): 147–158.

These relationships are then used to estimate sensor movement and reconstruct the surrounding environment through spatial alignment and optimization procedures. Modern SLAM systems generally integrate processes such as trajectory estimation, map optimization, feature matching, and loop closure detection to improve localization accuracy and reduce cumulative positioning errors. Different SLAM methodologies can be implemented depending on the type of sensor employed during acquisition. Visual SLAM systems primarily use cameras and image-based observations, whereas LiDAR SLAM systems rely on laser scanning measurements and point cloud alignment for spatial reconstruction. Mobile LiDAR SLAM has become increasingly important in geomatics and archaeological documentation because it enables rapid acquisition of dense three-dimensional spatial information in environments characterized.¹⁵²

Today, SLAM technologies are widely applied in different aspects such as robotics, autonomous navigation, geomatics, mobile mapping, cultural heritage documentation, and archaeological surveying. In archaeological documentation, SLAM has become increasingly valuable because it enables rapid acquisition of spatial information in environments where GNSS reception is limited or absent. Compared with conventional surveying methods, SLAM-based mobile mapping systems can efficiently document large archaeological areas, complex architectural remains, vegetation-covered landscapes, and confined spaces while maintaining an acceptable level of positional accuracy. The integration of SLAM with photogrammetry, GNSS surveying, LiDAR systems, and GIS platforms has considerably expanded its role within digital documentation and spatial analysis workflows. The integration of UAV photogrammetry, GNSS surveying and Mobile LiDAR SLAM show the importance of combining different geomatic techniques for archaeological documentation and spatial analysis. Each method contributes specific advantages such as in terms of accuracy, coverage, accessibility and data acquisition efficiency. Based on these methodological principles, the following section describes and show clearly the practical survey workflow adopted in the Via degli Inferi archaeological area which is including data acquisition procedures, orthophoto generation, georeferencing activities and the integration of the collected datasets in the GIS environment.

¹⁵² [FARO – What is SLAM?](#)

5.2 3D Survey Methodology and Data Acquisition

The data acquisition phase represents the foundation of the methodological workflow, providing the geometric and radiometric information necessary for the documentation and interpretation of the Via degli Inferi sector. To ensure both high-resolution coverage and geometric reliability, a combined strategy was adopted, integrating UAV photogrammetry, Ground Control Point (GCP) collection, and mobile LiDAR SLAM acquisition. These complementary techniques allow the capture of detailed spatial information even in areas where visibility is limited by vegetation or morphological constraints, ensuring the production of a metrically accurate orthophoto that serves as the primary reference layer for subsequent GIS-based structuring and analysis. The integration of UAV imagery, GCPs and SLAM data was essential to overcome visibility limitations caused by vegetation and narrow corridors, ensuring complete spatial coverage that would not be achievable through a single survey technique. UAV photogrammetry was employed to acquire high-resolution aerial imagery of the Via degli Inferi pathway and surrounding tombs. A UAV equipped with a high-quality RGB camera was flown over the area following a predefined flight plan designed to guarantee sufficient forward and side overlap between images. This ensured stable illumination conditions, consistent coverage, and robust image alignment during the Structure-from-Motion (SfM) processing phase. (Fig.51)

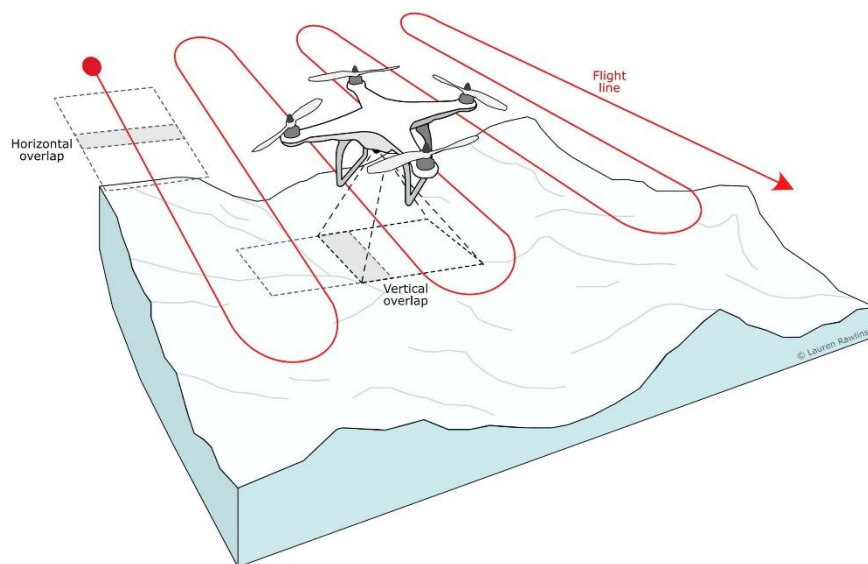


Figure 51. Schematic representation of forward and side overlap adopted in UAV photogrammetric surveys for Structure-from-Motion (SfM) processing.

Source: <https://www.antarcticglaciers.org>

The photogrammetric workflow was supported by the collection of Ground Control Points (GCPs), measured with centimetric accuracy using a GNSS receiver. These GCPs provided the absolute georeferencing framework necessary to anchor the photogrammetric model and ensure the positional accuracy of the final orthophoto. In parallel, mobile LiDAR SLAM acquisition was carried out along the pathway to document areas where aerial visibility was reduced, such as narrow corridors, shaded zones, and spaces partially covered by vegetation. The SLAM-based point cloud provided continuous three-dimensional geometry, complementing the aerial dataset and improving the overall completeness of the spatial documentation. The integration of UAV imagery, GCPs, and SLAM data ensured that the resulting orthophoto and 3D information were both geometrically consistent and suitable for detailed GIS-based analysis. (Fig.52)(Fig.53)(Fig.54)(Fig.55)(Fig.56)(Fig.57).



Figure 52. Field data acquisition activities including GNSS measurements for GCP collection (left) and mobile LiDAR SLAM surveying (right). **Source:**Team DIRECT , 2025



Figure 53. Example of Ground Control Point (GCP) placement used for UAV georeferencing within the Via degli Inferi study area.

Source: Developed by author , Team DIRECT , Summer 2025

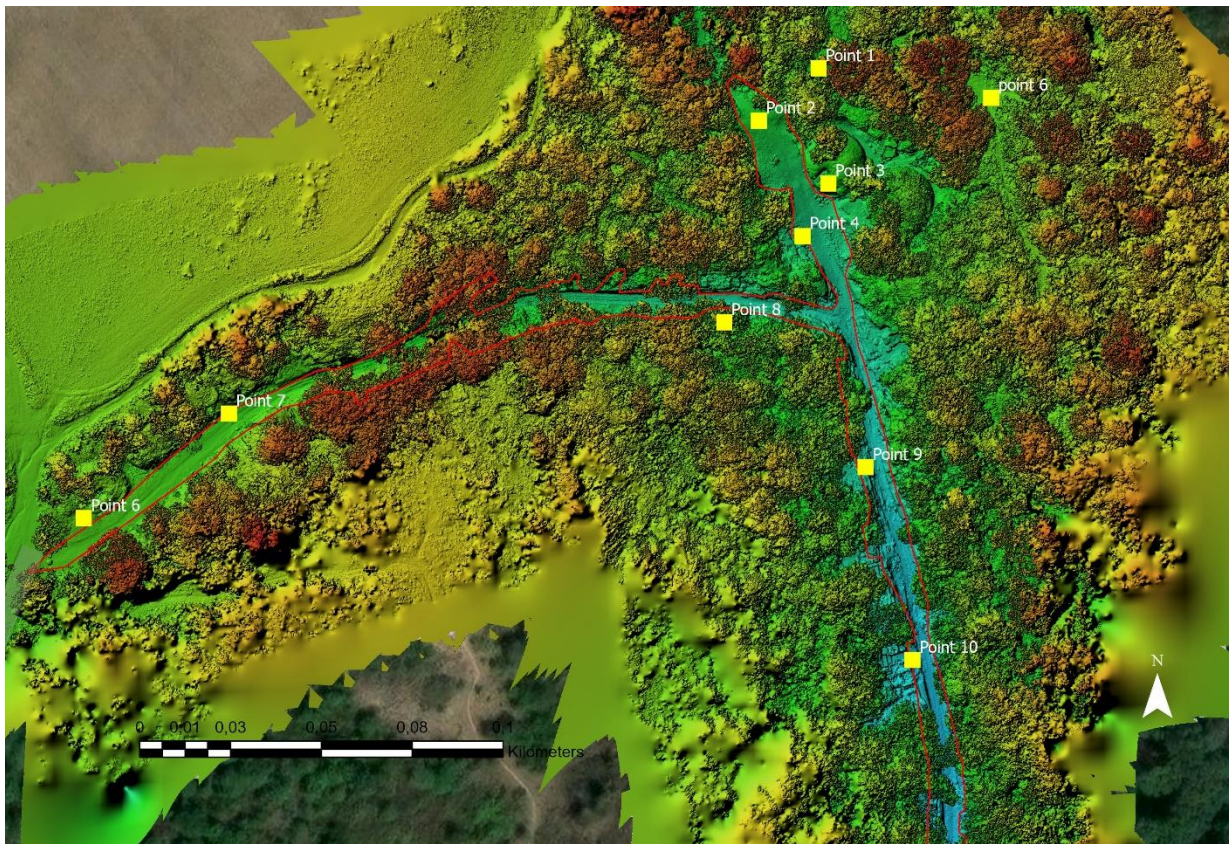


Figure 54. GCP points positioning, Developed By Author In ArcGIS pro

Source: Developed by author



Figure 55. GCP points positioning

Source: Team DIRECT , 2025



Figure 56. Sample UAV images acquired during the photogrammetric survey showing the overlap required for SfM processing.

Source: Source: Developed by author In Metashape



Figure 57. Dense point cloud generated in Metashap through Structure-from-Motion processing of UAV imagery acquired within the Via degli Inferi study area.

Source: Team DIRECT , 2025

The field survey was conducted in collaboration with **Team DIRECT** within the Via degli Inferi sector of the Banditaccia Necropolis. The field campaign integrated UAV photogrammetry, GNSS measurements for Ground Control Point (GCP) acquisition and mobile LiDAR SLAM surveying, providing the primary spatial datasets used throughout this research. The author actively participated in the planning and execution of survey activities, including UAV flights, GCP measurements and SLAM data acquisition in areas affected by vegetation and limited accessibility. The integration of these complementary datasets enabled the generation of georeferenced orthophotos, dense point clouds and three-dimensional spatial information, forming the basis for the subsequent GIS analysis and WebGIS development presented in this thesis. This survey carried out by the Politecnico di Torino and Team DIRECT at the Necropoli della Banditaccia was highlighted by local media outlets, which emphasized the innovative use of multi-sensor documentation for heritage conservation. These publications underlined the importance of integrating advanced spatial technologies such as UAV photogrammetry, LiDAR and SLAM and highlighted how these technologies can support the practical management and protection of archaeological areas and acknowledged the contribution of the academic team to the future preservation of the site. The media coverage reflects the broader cultural impact of the project and reinforces the role of geomatics as a bridge between scientific research, public awareness and institutional decision-making.(Fig.58)



Figure 58. Collection of Fieldwork activities conducted with Team DIRECT during the survey campaign at the Via degli Inferi sector, Summer 2025.

Source: <https://baraondanews.it/il-politecnico-di-torino-collabora-con-il-pact-per-rivoluzionare-la-gestione-della-conservazione-delle-nostre-aree-archeologiche/>

5.2.1 Example of GNSS and Georeferencing During The Survey

GNSS surveying was employed to support the georeferencing and spatial alignment of the different geomatic datasets acquired during the fieldwork activities. The collected GNSS coordinates were used to establish accurate reference points for the integration of UAV photogrammetry, terrestrial laser scanning, and archaeological documentation within a unified spatial reference framework. The use of GNSS techniques was more important for ensuring positional accuracy and spatial consistency between the different datasets and their subsequent integration within GIS and WebGIS environments. Field surveying activities were carried out using GNSS receivers positioned within the study area to acquire reference coordinates and support the georeferencing workflow. Figure 59 illustrates the GNSS surveying operations conducted during the field documentation campaign which did in different location.



Figure 59. Surveying activities conducted for georeferencing and spatial alignment of archaeological datasets within the study area.

Source: Author's field documentation

The acquired GNSS data were subsequently integrated with the photogrammetric and laser scanning datasets to improve the spatial reliability and geometric consistency of the final three-dimensional documentation and mapping products.

5.2.2 Mobile LiDAR SLAM Acquisition

In several parts of the site, UAV photogrammetry alone was not sufficient to capture detailed geometry. Because of this, a mobile LiDAR SLAM device was additionally used, especially in shaded areas and narrow ancient passages along the Via degli Inferi. In these sections, vegetation and terrain conditions often reduced the effectiveness of aerial documentation. The system was carried manually through the pathway during the fieldwork to collect point cloud data from ground level. At the same time, the device continuously estimated its own trajectory using real-time localization algorithms. The use of SLAM proved useful for documenting surfaces and spatial details that were difficult to record through UAV imagery only. This included tomb entrances, wall surfaces, and small topographic irregularities visible along the pathway. The additional dataset also improved the completeness of the final 3D reconstruction. (Fig.60)(Fig.61)



Figure 60. Mobile LiDAR SLAM Survey process documentation

Source: Team DIRECT Survey.



Figure 61. Processing of the SLAM point cloud in CloudCompare, showing cleaning, subsampling and trajectory estimation prior to export for GIS integration

Source: by the author

5.2.3 Photogrammetric Processing And Orthophoto Validation

The photogrammetric processing of the UAV imagery was carried out using a Structure-from-Motion (SfM) and Multi-View Stereo (MVS) workflow. This phase transforms the raw aerial images into metrically reliable spatial products, including the sparse point cloud, dense point cloud, digital surface model (DSM) and the final orthophoto. The processing was performed in Metashape, following a sequence of standardised steps to ensure geometric accuracy and internal consistency. The workflow begins with the alignment of the UAV images. (Fig.62) and then During this step, the software identifies homologous points across multiple photographs and reconstructs the relative camera positions. The result is a sparse point cloud that provides an initial geometric structure of the scene. Once the alignment is completed, the Ground Control Points (GCPs) collected during the field survey are imported and manually identified within the images. (Fig.63). These points are used to refine the camera calibration and to georeference the model, ensuring that the reconstruction is accurately positioned within the real-world coordinate system. After the optimisation of the alignment, the dense point cloud is generated. This step produces a detailed three-dimensional representation of the terrain and archaeological features, capturing variations in elevation, vegetation and structural morphology. The dense cloud is then used to create the digital surface model (DSM), which serves as the geometric basis for the orthophoto generation. The orthophoto is produced by projecting the original images onto the DSM, resulting in a geometrically corrected image with uniform scale and minimal distortion. This makes the orthophoto suitable for use as a base map in the GIS environment, where precise spatial relationships between features are essential. A validation phase follows the generation of the orthophoto. This includes the analysis of GCP residuals, which provides a quantitative indication of positional accuracy, and a visual inspection of areas prone to distortion, such as steep surfaces, vegetation edges and shaded zones. The comparison between the orthophoto and the known reference points confirms the reliability of the georeferencing and ensures that the dataset meets the accuracy requirements of the research.

The final orthophoto then exported and imported into ArcGIS Pro, where it becomes the primary reference layer for digitisation, spatial structuring and thematic mapping. Its geometric consistency ensures that all subsequent vector layers and attribute data are correctly aligned, forming a robust foundation for the GIS-based analysis presented in the following sections.

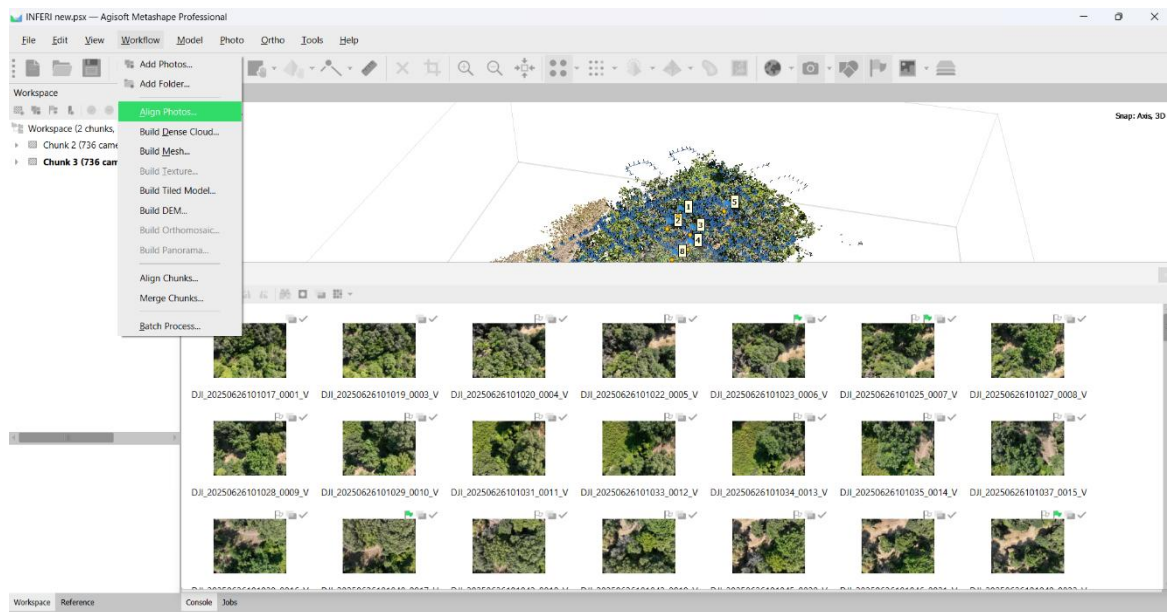


Figure 62. Initial photogrammetric processing workflow in Agisoft Metashape showing image alignment and camera orientation prior to dense point cloud generation.

Source: Author, 2026

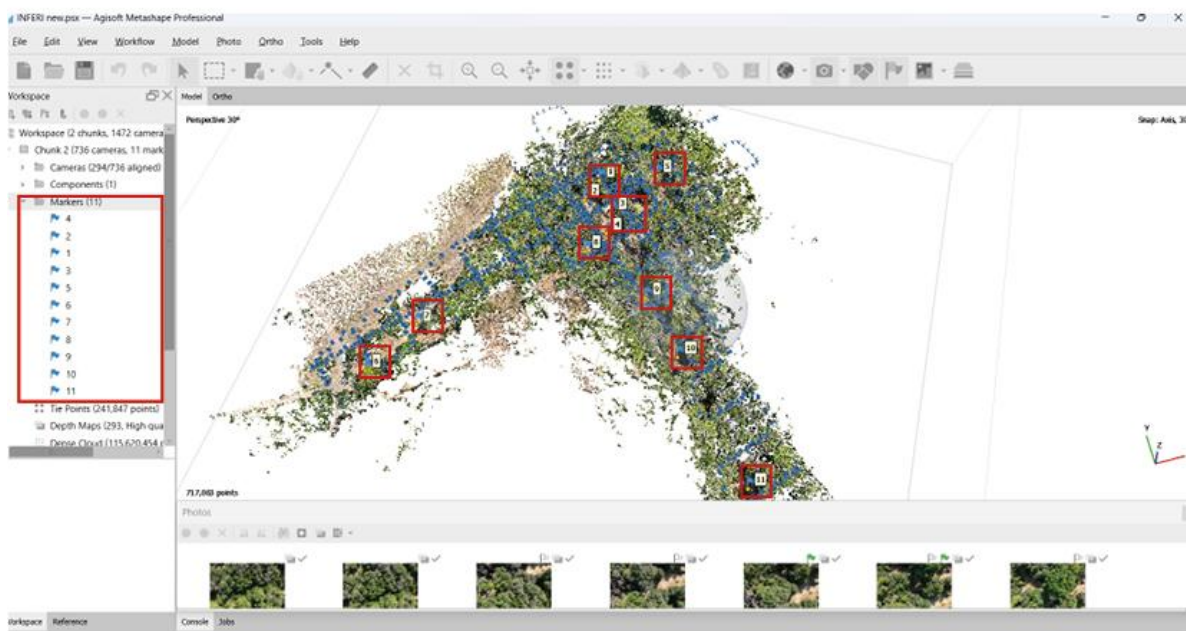


Figure 63. Ground Control Point (GCP) integration and georeferencing stage in Agisoft Metashape.

Source: Author, 2026

5.2.4 The Orientation Phase Of The UAV Images

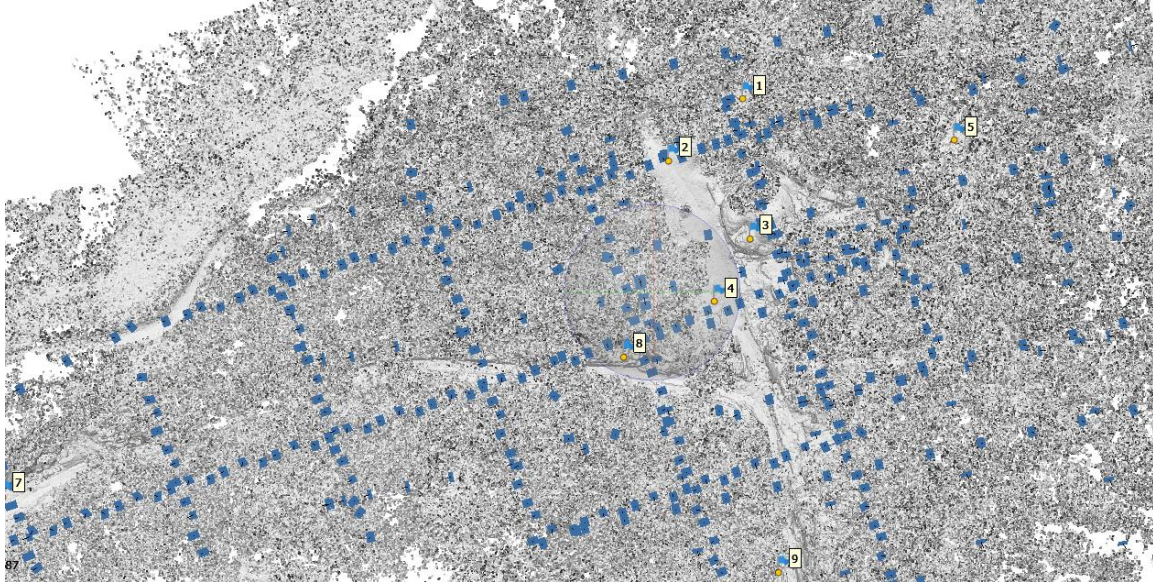


Figure 64 : Image orientation of the model in Metashape (mean residual: GCPs 1.5 cm , CPs 2 cm)

Source: Developed by author in Metashape

The image orientation phase in Agisoft Metashape begins after importing the UAV photographs collected during the field survey. During this process, the software identifies homologous points between overlapping images and reconstructs the relative position and orientation of each camera. During the alignment procedure, the software generates the initial geometric structure of the surveyed area, creating the basis for the subsequent photogrammetric reconstruction, which is more important for the next steps and the accuracy of the orientation process depends on different aspects such as the quality and overlap of the UAV images, as well as the correct distribution of Ground Control Points (GCPs) used for georeferencing and spatial validation. (Fig.64) The oriented image block constitutes the foundation for the subsequent photogrammetric workflow. Once the alignment and georeferencing processes are completed, the resulting dataset is used to generate the final products of the survey, namely the orthophoto and the Digital Surface Model (DSM). (Fig.65)(Fig.66).

Figure 67 and Figure 68 illustrate the final result of orthophoto and DEM ,DSM in the ArcGIS Pro with the correct coordinate system.

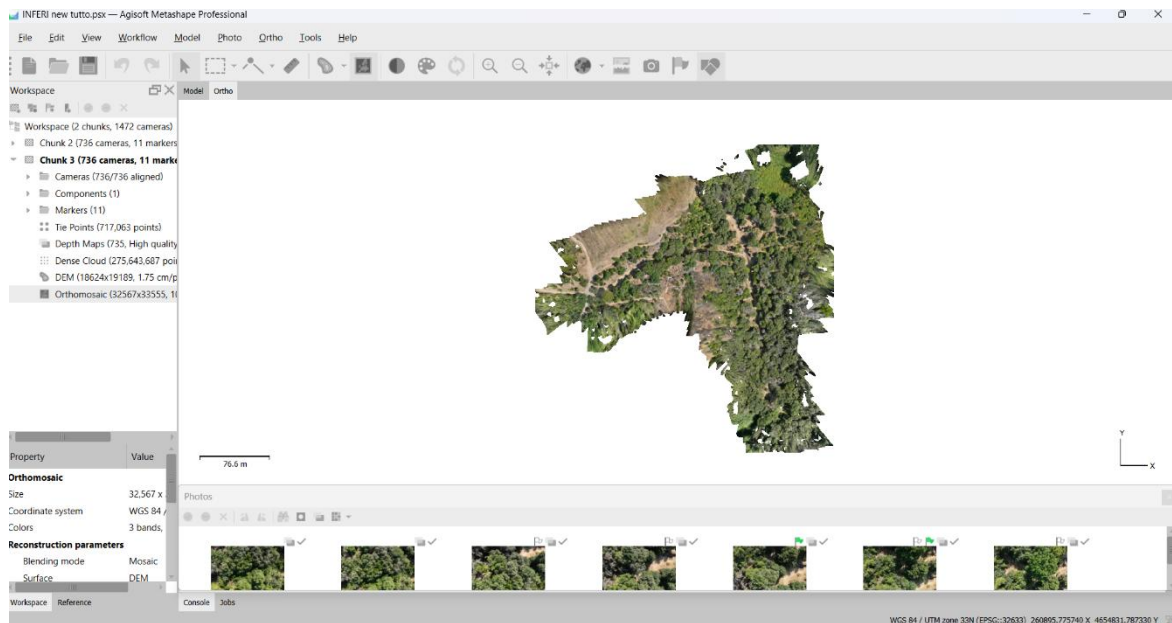


Figure 65 : Orthophoto generated from the UAV photogrammetric survey in Agisoft Metashape following image alignment, GCP integration and model optimisation.

Source: Author, 2026

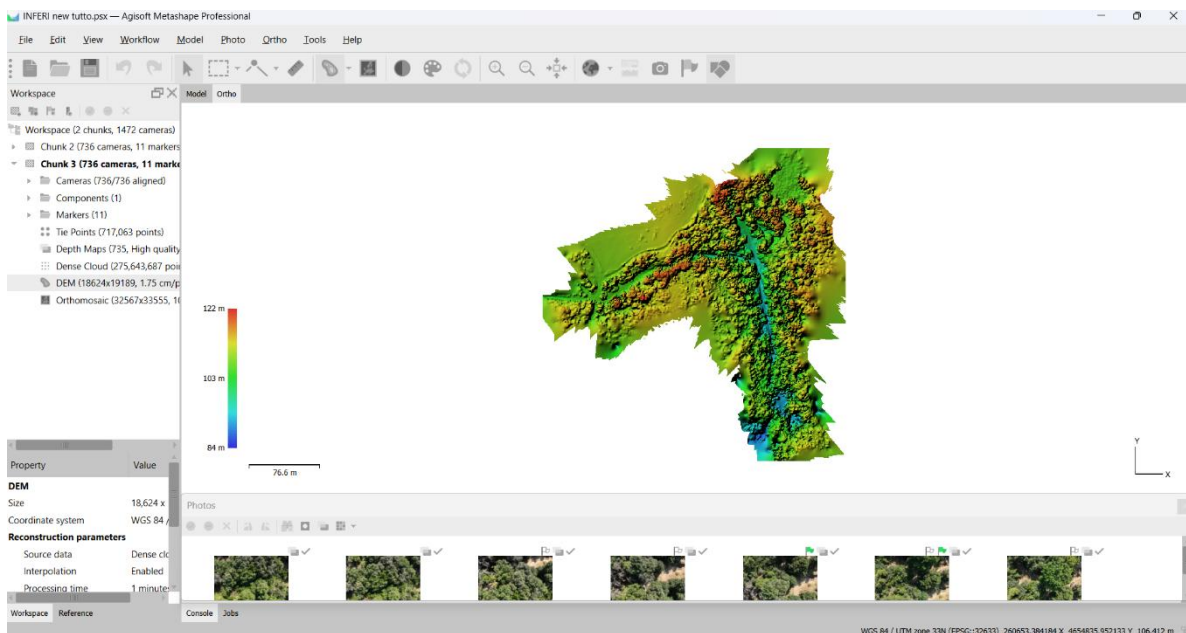


Figure 66. Digital Surface Model (DSM) generated from the dense point cloud in Agisoft Metashape, illustrating elevation variations across the surveyed area.

Source: Author, 2026

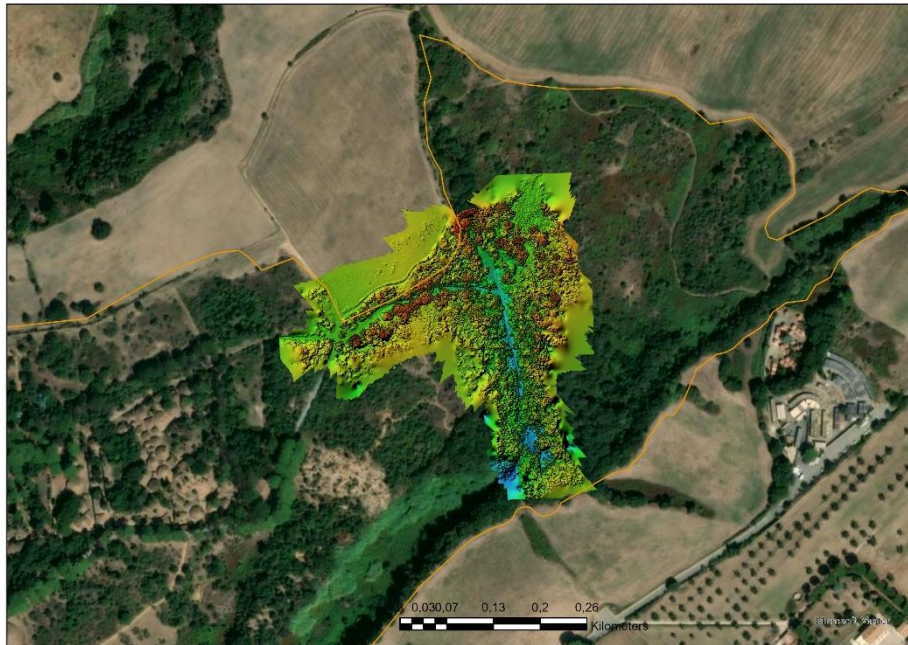


Figure 67. Final Digital Elevation Model (DSM) imported into ArcGIS Pro and overlaid on the orthophoto, confirming the correct georeferencing and spatial alignment of the photogrammetric outputs.

Source: Author, 2026 in ArcGIS PRO



Figure 68. Orthophoto of the Via degli Inferi study area imported into ArcGIS Pro and used as the primary base layer for digitisation and GIS-based spatial analysis.

Source: Author, 2026 in ArcGIS PRO

5.2.5 Archaeological And Spatial Context Of The Study Area

Cerveteri is located in the Lazio Region of central Italy, approximately 40 km north-west of Rome (Fig.69). The territory is characterised by volcanic plateaus, deeply incised valleys and a rich archaeological landscape associated with the ancient Etruscan city of Caere. Within this territory lies the Banditaccia Necropolis, one of the largest and most significant funerary complexes of the Etruscan world and a UNESCO World Heritage Site since 2004, together with the Necropolis of Tarquinia. Developed between the ninth and third centuries BCE, the Banditaccia Necropolis preserves a wide range of funerary monuments, including tumuli, semi cube (dado) tombs and underground burial structures. The spatial organisation of the necropolis reflects the social structure, funerary traditions and urban characteristics of ancient Caere, creating a complex archaeological landscape in which architecture, topography and environmental processes are closely interconnected.

In this broader archaeological context, the present research focuses on the Via degli Inferi sector, one of the principal funerary axes of the necropolis. The area contains a concentration of tomb typologies, articulated spatial relationships and diverse environmental conditions, making it particularly suitable for the application of integrated geomatics methodologies. The interaction between archaeological remains, vegetation cover and terrain morphology further increases its relevance for conservation-oriented spatial analysis. The methodological framework adopted in this research operates at two complementary spatial scales. The first scale considers the entire Banditaccia Necropolis as a cultural landscape, enabling the organisation of archaeological, environmental and administrative information within a unified GIS environment. (Fig.70) (Fig.71).

The Via degli Inferi sector was selected because it contains a representative concentration of tumulus and cube tombs, well-preserved funerary pathways and diverse environmental conditions. These characteristics make it suitable for testing the integration of geomatic surveys, GIS analysis and WebGIS applications.(Fig.72) The second scale focuses on the Via degli Inferi sector as a detailed study area, allowing more in depth documentation and analysis of architectural features, typological characteristics and conservation related conditions.(Fig.73) .This multi-scale approach supports both a general understanding of the necropolis and a detailed investigation of specific archaeological contexts.

The investigated area includes open-air pathways, funerary structures and partially vegetated zones, requiring a documentation strategy capable of integrating UAV photogrammetry, Ground Control Point (GCP) acquisition and SLAM-based mobile mapping technologies. These survey activities provided the spatial data foundation for the GIS and WebGIS analyses presented in the following sections of this chapter.



Figure 69. Location of Cerveteri within the Lazio Region, Central Italy
Source: Developed by the author in ArcGIS Pro



Figure 70. Municipal boundary of Cerveteri and its geographical context within the Metropolitan Area of Rome
Source: Developed by the author in ArcGIS Pro

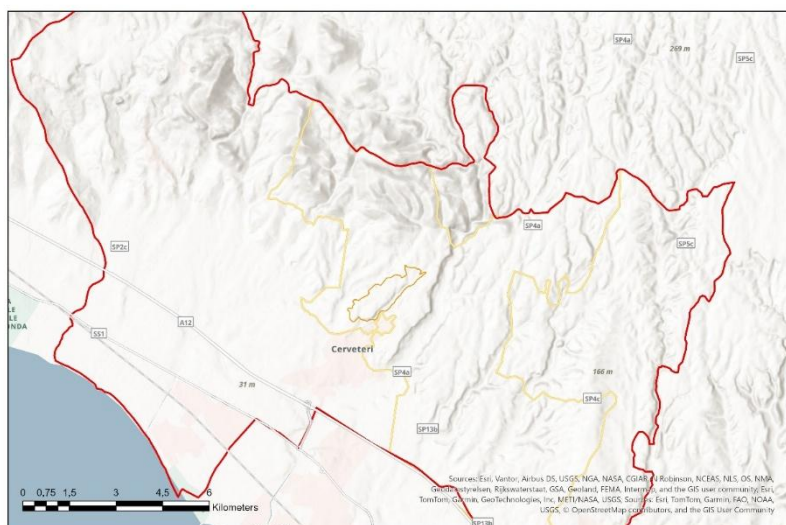
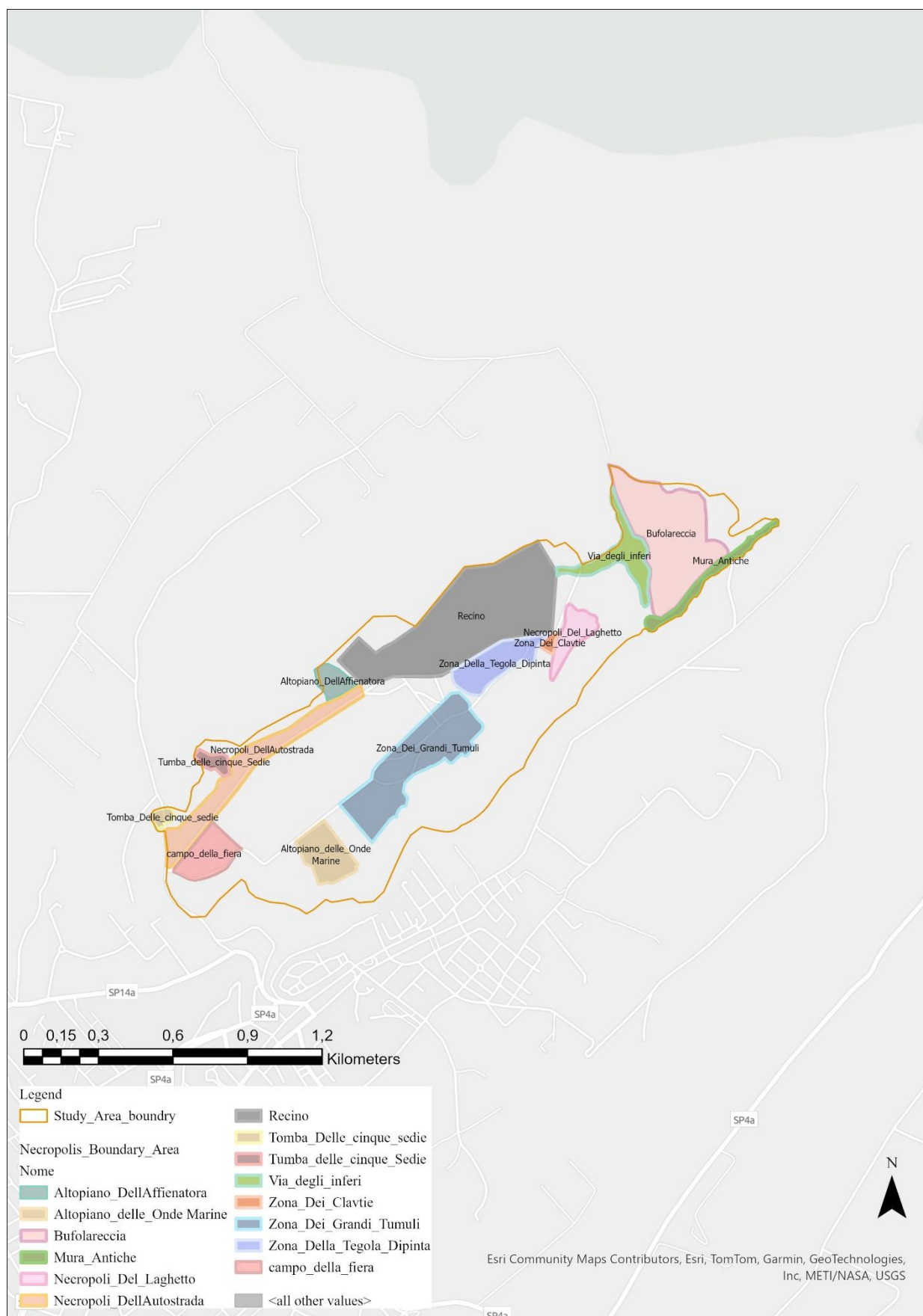


Figure 71. Via degli Inferi sector selected for detailed survey and GIS analysis, including limiti comunali and buffer zone
Source: Developed by the author in ArcGIS Pro



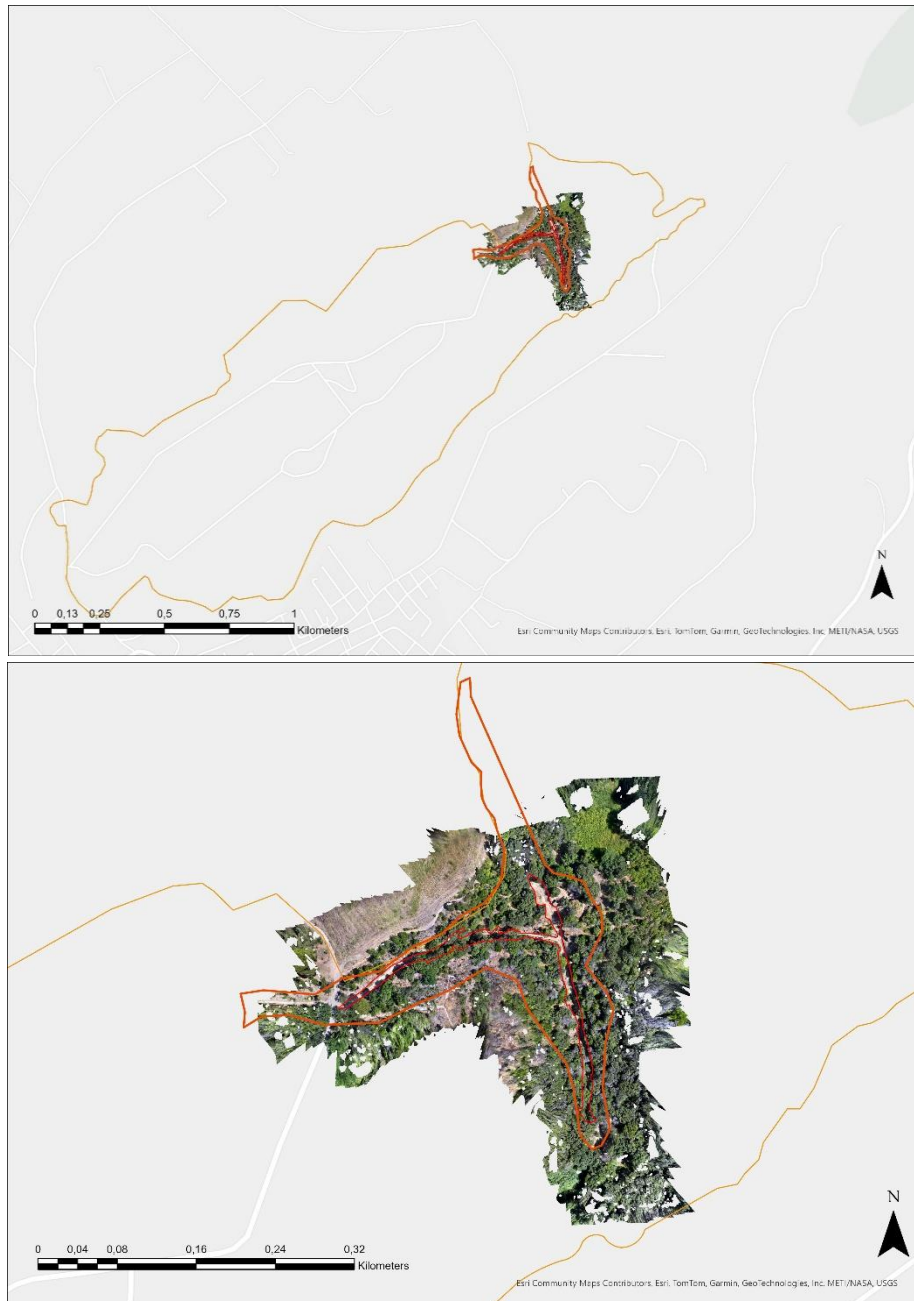
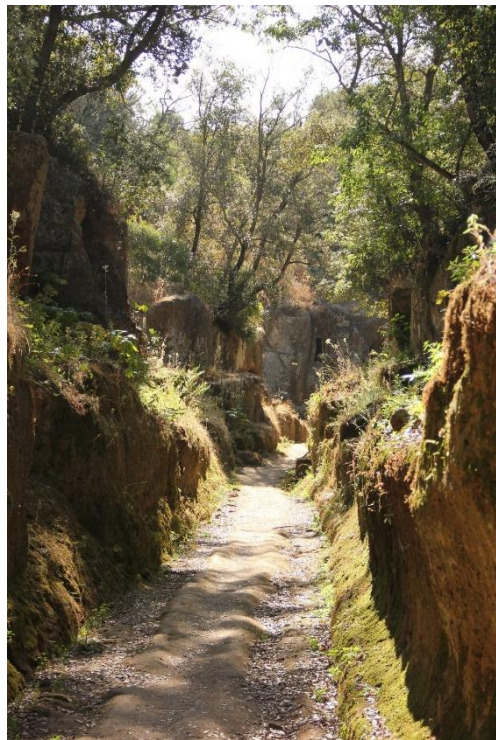


Figure 73. Via Degli Inferi , Selected Area

Source: Developed by Author in WebGIS PRO

Figure 72 illustrates the progressive definition of the study area from the broader necropolis to the specific survey sector. This multiscale approach supports the organisation of spatial information within the GIS environment and establishes the geographical framework for the detailed analyses presented in the following sections.



5.3 GIS and WebGIS Conceptual Structure

How was the GIS and WebGIS implemented in this research?

The GIS and WebGIS environment developed within this research was designed to support the organisation, visualisation and dissemination of spatial information related to the Via degli Inferi sector of the Banditaccia necropolis. The methodological workflow integrates archaeological features, orthophotos, environmental datasets and descriptive attributes within a single georeferenced database environment developed in ArcGIS Pro. The system was structured to enable the documentation and interpretation of archaeological information across multiple spatial scales, from individual funerary structures to the broader landscape context of the necropolis. The database was designed not only to record tomb locations and architectural characteristics, but also to show spatial relationships with pathways, vegetation patterns and surrounding environmental features. Through the integration of spatial and descriptive information, the platform supports thematic mapping, spatial analysis and conservation-oriented interpretation. The GIS database was organised through thematic layers containing archaeological entities, survey data, orthophotos and attribute tables associated with typology, chronology, materiality and conservation-related information. This structure allowed the management of heterogeneous datasets within a coherent geospatial framework while facilitating the correlation between archaeological and environmental variables. Following the organisation of the spatial database, the information was published within a WebGIS environment intended to improve accessibility and communication of archaeological data. The WebGIS platform enables users to explore thematic layers, attribute information, orthophotos and georeferenced documentation through an interactive browser-based interface. Pop-up windows, layer controls and thematic visualisation tools facilitate the consultation and interpretation of archaeological information within a dynamic cartographic environment. The platform was designed not only as a digital archive, but also as an interpretative and dissemination tool for supporting and archiving documentation, monitoring and conservation activities. Through the integration of survey data, thematic mapping and interactive visualisation, the GIS and WebGIS workflow developed in this research provides a flexible framework for the management and communication of archaeological knowledge.

Figure 74 illustrates the conceptual workflow adopted for the acquisition, organisation, spatial analysis and dissemination of archaeological information within the GIS and WebGIS environment developed for this research.

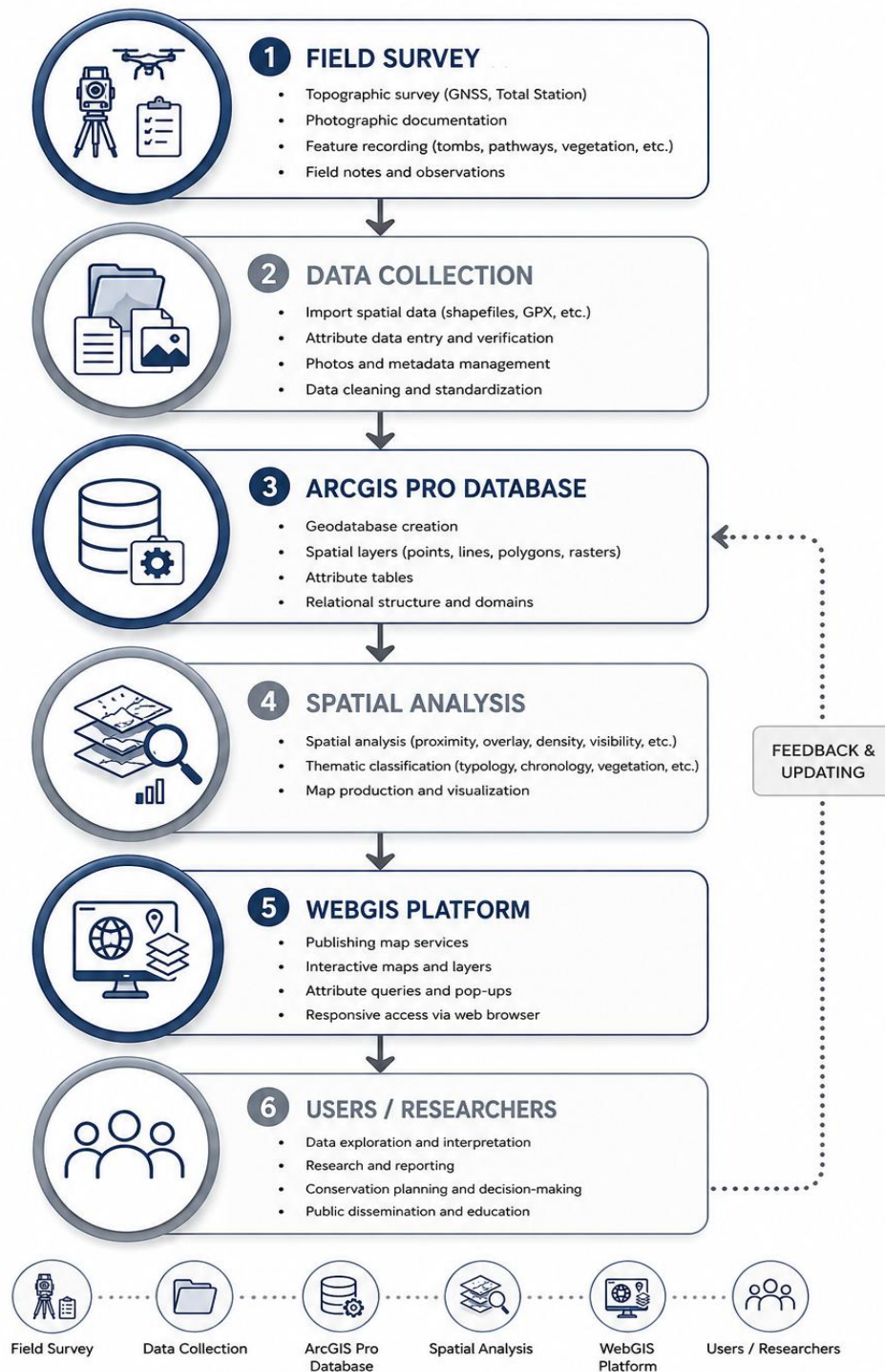


Figure 74. Conceptual workflow of the GIS and WebGIS environment developed for the documentation, analysis and dissemination of archaeological information.

Source: Developed by author

5.3.1 Architectural and Typological Framework

The GIS and WebGIS environment developed for the Via degli Inferi sector was created to organise archaeological information within a coherent and consistent analytical framework. Due to the wide variety of funerary monuments present in the Banditaccia necropolis, the database required a classification system capable of recording architectural forms, typological differences and related descriptive information in a standardised way. This framework forms the basis for the organisation, analysis and visualisation of archaeological data throughout the project. The conceptual structure of the database is based on the identification of the main funerary architectural entities documented within the study area. Following the archaeological literature on Cerveteri, the tombs were classified according to their architectural characteristics and spatial organisation. This approach made it possible to represent the morphological diversity of the necropolis while maintaining a consistent methodological structure across the dataset. The classification system was designed not only to support inventory and documentation activities but also to facilitate spatial analysis and the interpretation of relationships between monuments and the surrounding landscape. Within this framework, each tomb is treated as a spatial entity associated with a set of descriptive attributes. These attributes provide the basis for thematic mapping, conservation assessment and WebGIS visualisation. The following sections describe in detail the typological classification, construction methods, conservation parameters and attribute structure adopted for the archaeological dataset. A specific methodological issue concerned the identification of tombs that do not possess official catalogue numbers. While part of the Via degli Inferi sector preserves previously documented tomb identifiers derived from published archaeological sources, numerous structures particularly along the southern section of the road remain uncatalogued (Fig.75). Figure 76 shows the original ancient map of via degli inferi which was the base map for the digitalizing to be continued with Figure 77 and Figure 78 which show the part of via inferi which has an ID number and the other part without so in order to integrate these monuments into the GIS and WebGIS environment as traceable spatial entities, a new analytical coding system was introduced using the prefix "UT" followed by a sequential number. These identifiers were created exclusively for database organisation and spatial analysis and do not replace official archaeological inventory numbers. Tombs with existing published IDs retained their original references, whereas unnumbered structures received the new UT designation. This dual identification system made it possible to maintain methodological consistency throughout the dataset while preserving the integrity of the original archaeological documentation. (Fig.79)

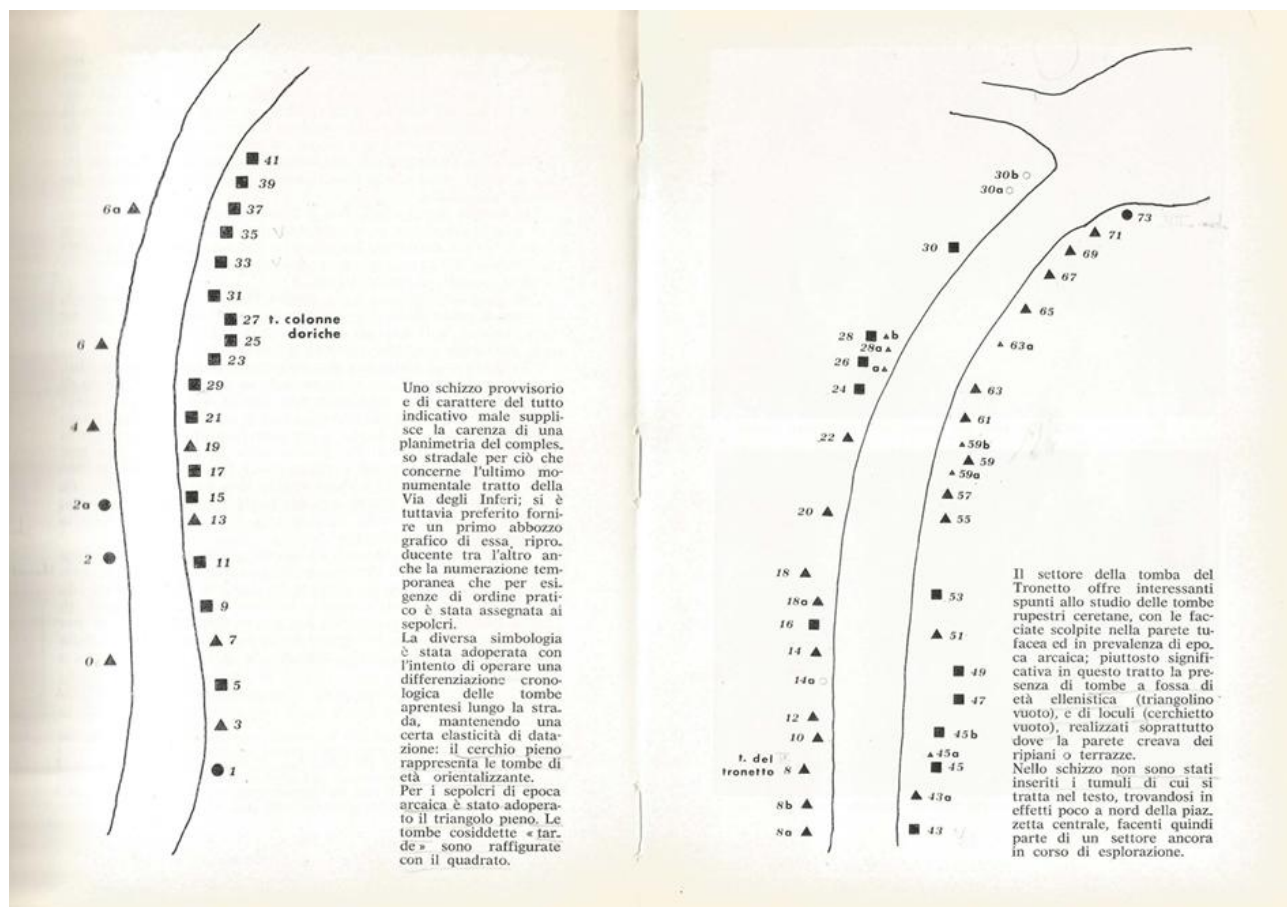


Figure 75: Historical sketch of the Via degli Inferi sector showing the temporary tomb numbering system adopted in the archaeological documentation.

Source: Adapted from Zifferero, A. (1980), *Cenni preliminari sulla Via degli Inferi (Cerveteri)*, in *XV Anniversario della fondazione del G.A.R., Gruppo Archeologico Romano*.

A more detailed sector of the Via degli Inferi preserves a partial numbering system associated with previously documented funerary structures, while several monuments remain without formal identifiers. This distinction formed the basis for the introduction of the analytical UT coding system within the GIS environment.

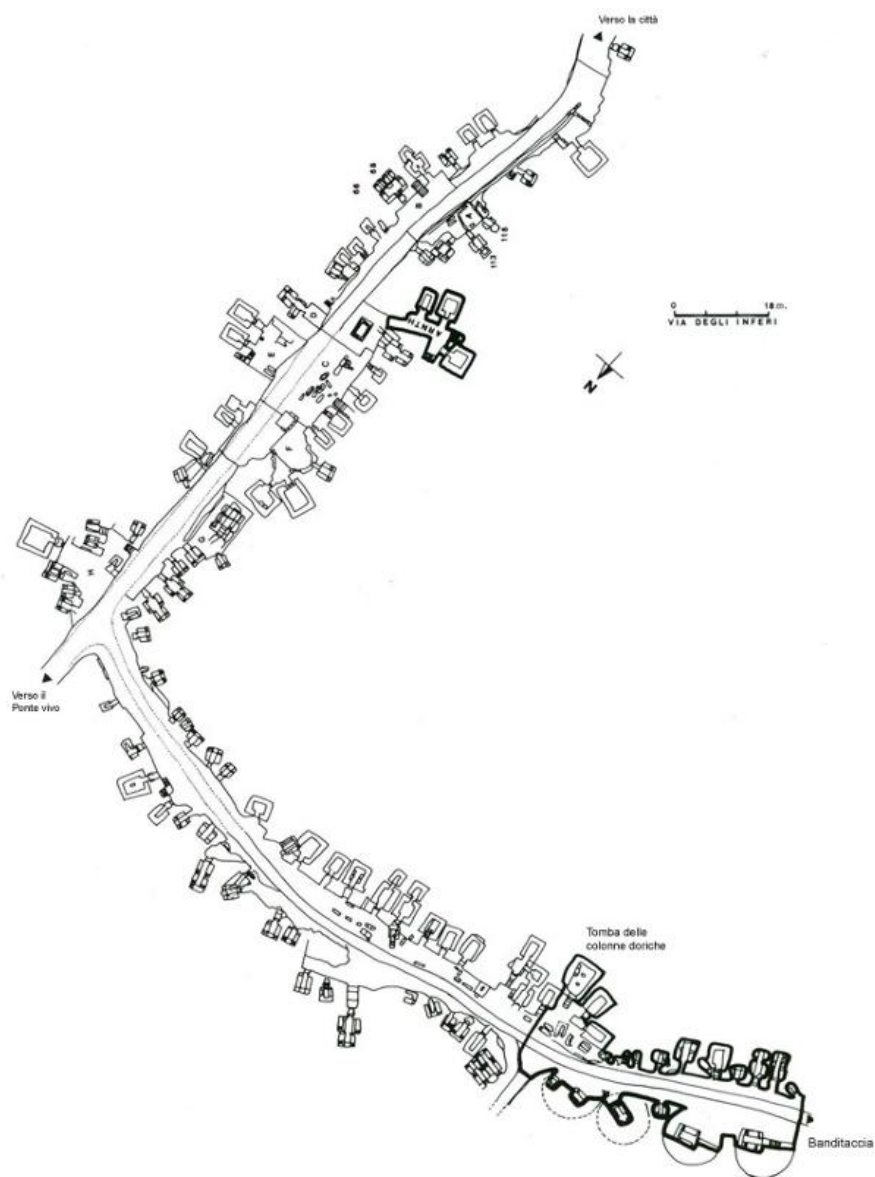


Figure 76. Detailed archaeological sketch of the Via degli Inferi sector illustrating the coexistence of numbered and previously uncatalogued tombs.

Source: Author's documentation

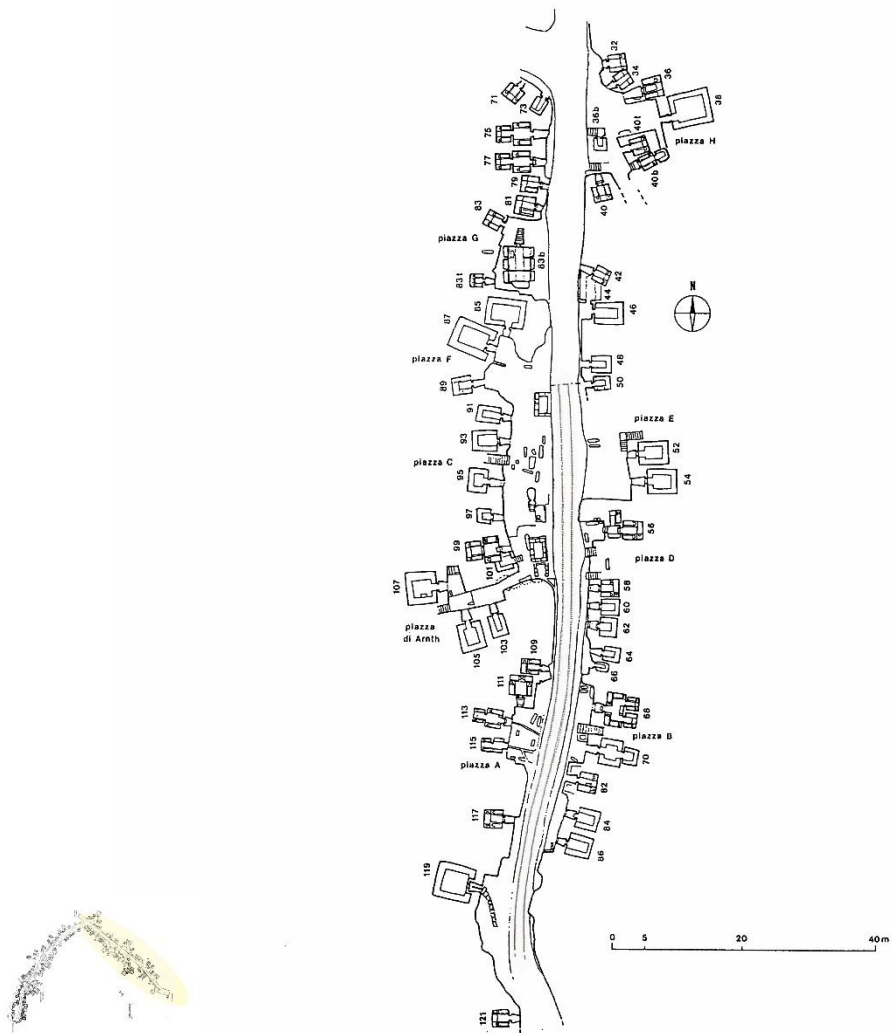


Figure 77. Detailed archaeological plan of the Via degli Inferi sector showing funerary structures associated with previously published identification numbers retained within the GIS database.

Source: Author's documentation

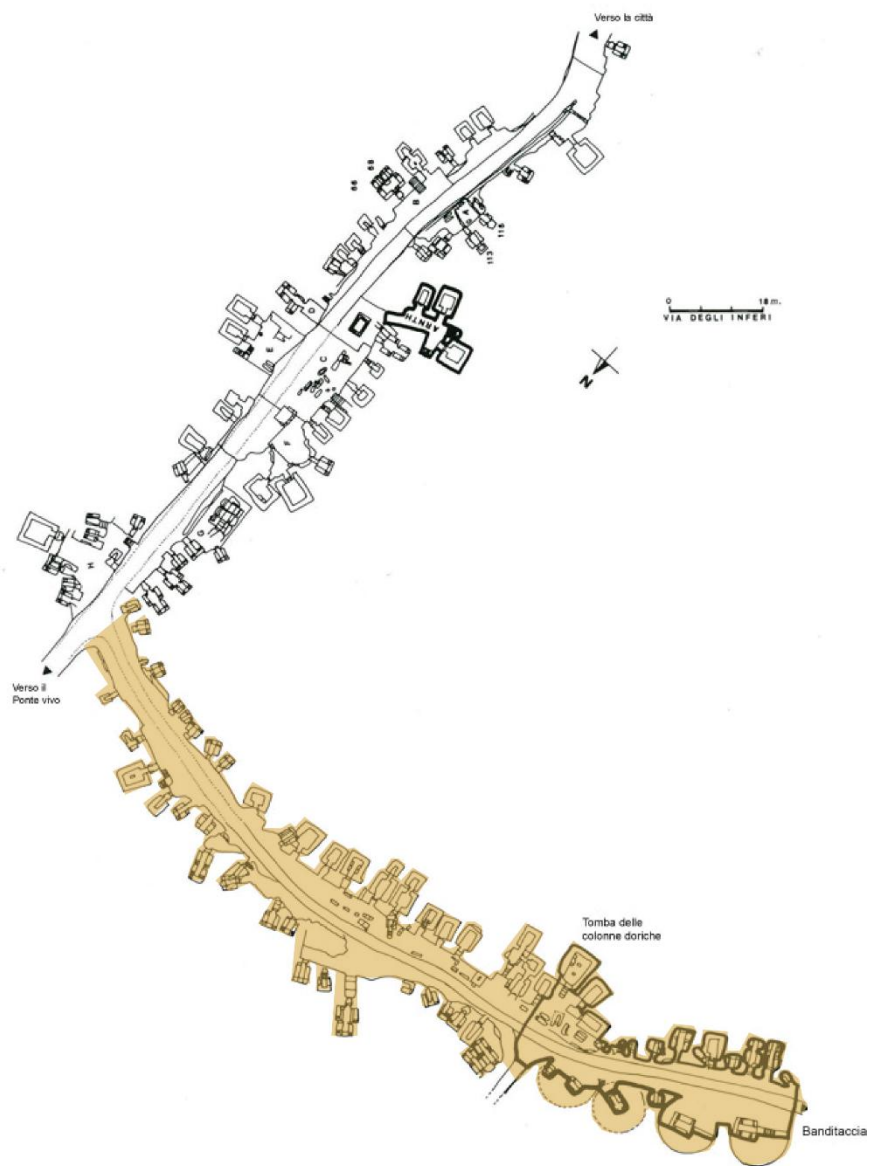


Figure 78. Southern sector of the Via degli Inferi lacking previously published tomb identifiers, highlighted as the area where new analytical UT codes were introduced during the GIS digitisation process.

Source: Author's documentation

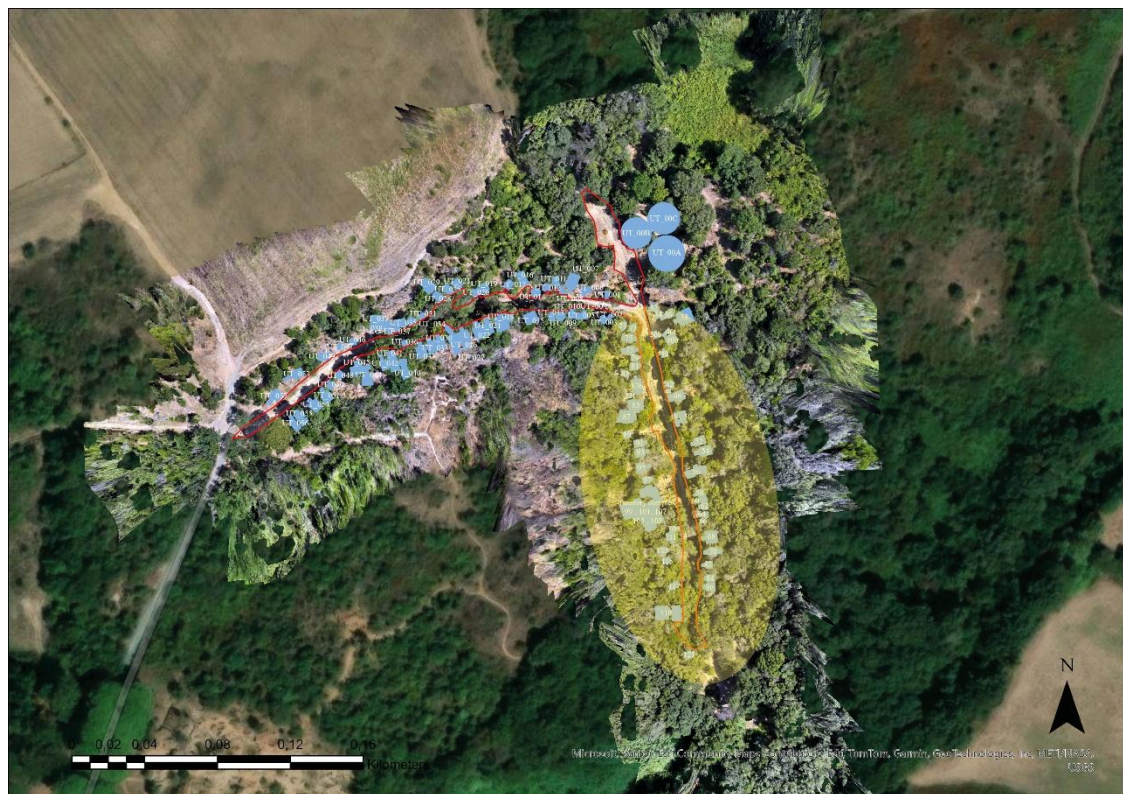
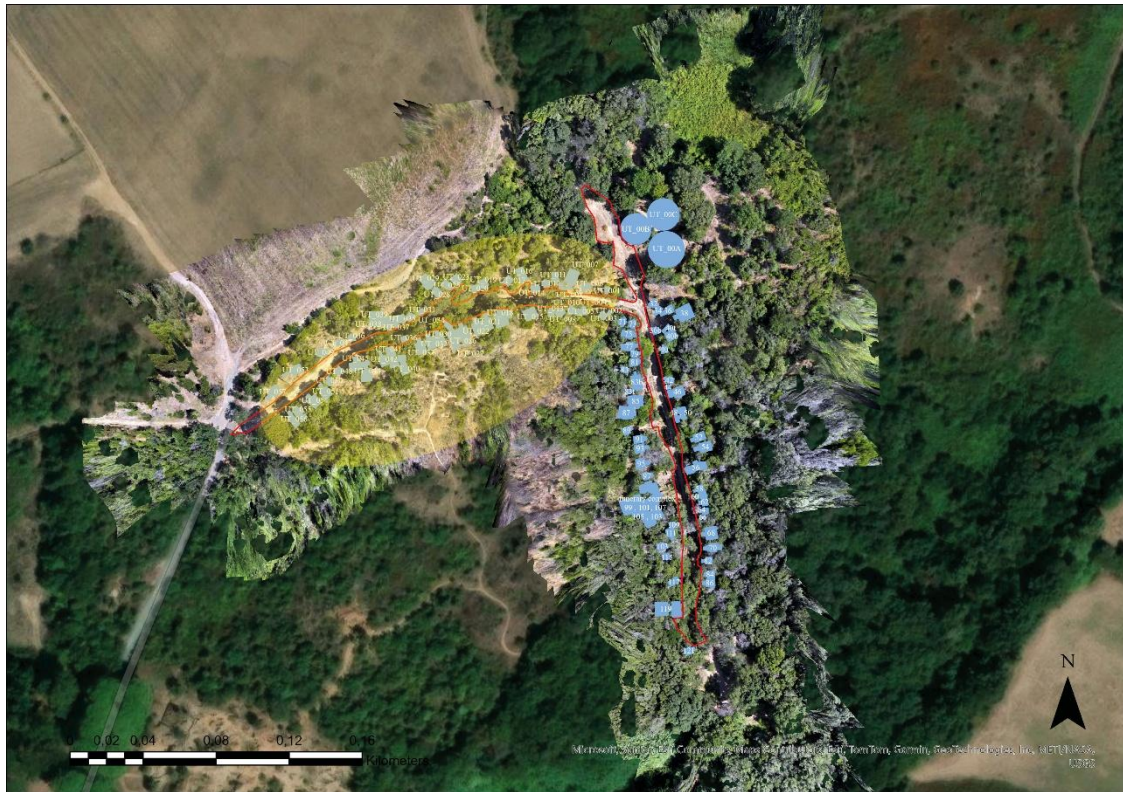


Figure 79. Digitised two sector interpretation of the historical archaeological plans of the Via degli Inferi integrated within the GIS environment, with highlighted sectors corresponding to areas analysed during the spatial classification process.

Source: Author's GIS elaboration based on historical archaeological documentation in ArcGIS Pro

5.3.2 GIS Integration of Published Tomb IDs and Analytical UT Codes

The GIS environment preserves the original archaeological numbering system where published identifiers were available, while previously uncatalogued tombs were integrated through the introduction of analytical UT codes. This approach ensured both methodological consistency and continuity with the historical archaeological documentation. (Fig.80)

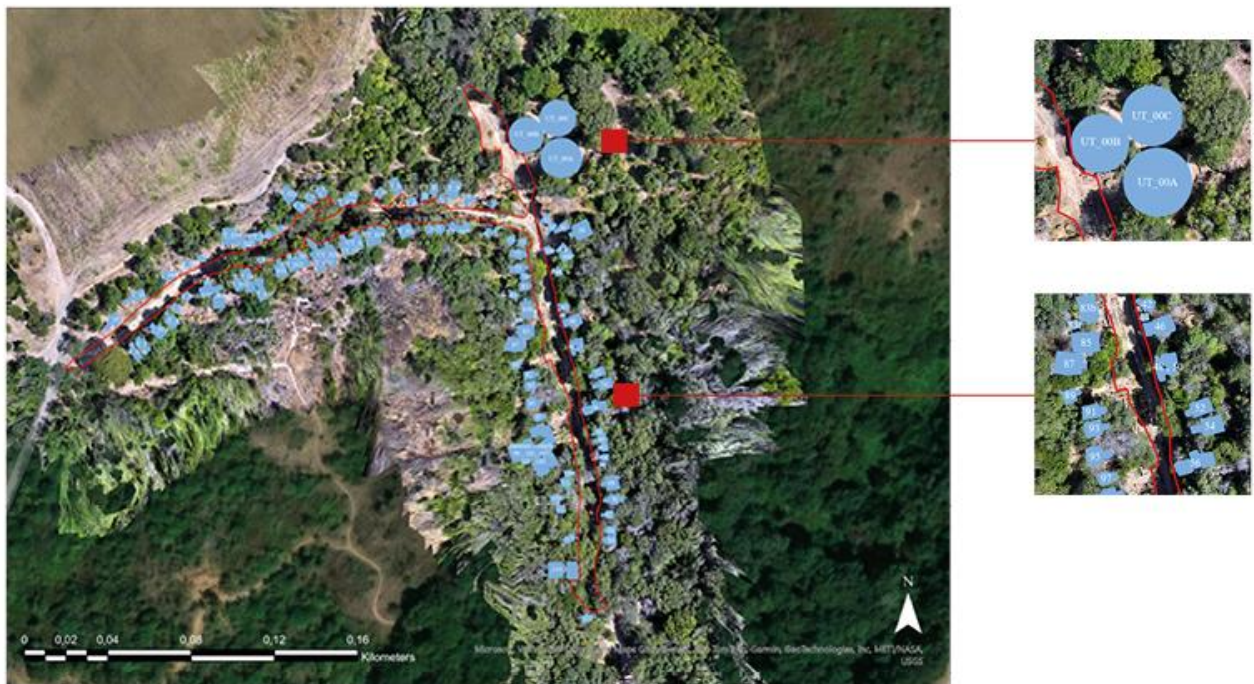


Figure 80. Detailed GIS visualisation of the Via degli Inferi sector showing the coexistence of previously published tomb identifiers and newly introduced analytical UT codes within the ArcGIS Pro environment.

Source: Author's GIS elaboration

Under this typological framework, the funerary monuments of the Via degli Inferi include different kind of typology such as tumuli, cube-shaped tombs and hypogeum tombs. The semi-dado typology represents an intermediate architectural form characterised by a partially carved lower block (dado) supporting an upper section that may be either rock-cut or constructed and most of the tombs of via degli inferi are all cube tombs. This hybrid form reflects both the way the tombs were adapted to the natural tuff escarpment and the practical needs of Etruscan funerary architecture. By incorporating these typological distinctions into the GIS environment, it became possible to show morphological variations consistently and analyse them spatially across the study area. For example, here is it possible to see different typology which they existed in Cerveteri, via degli inferi. (Fig.81)

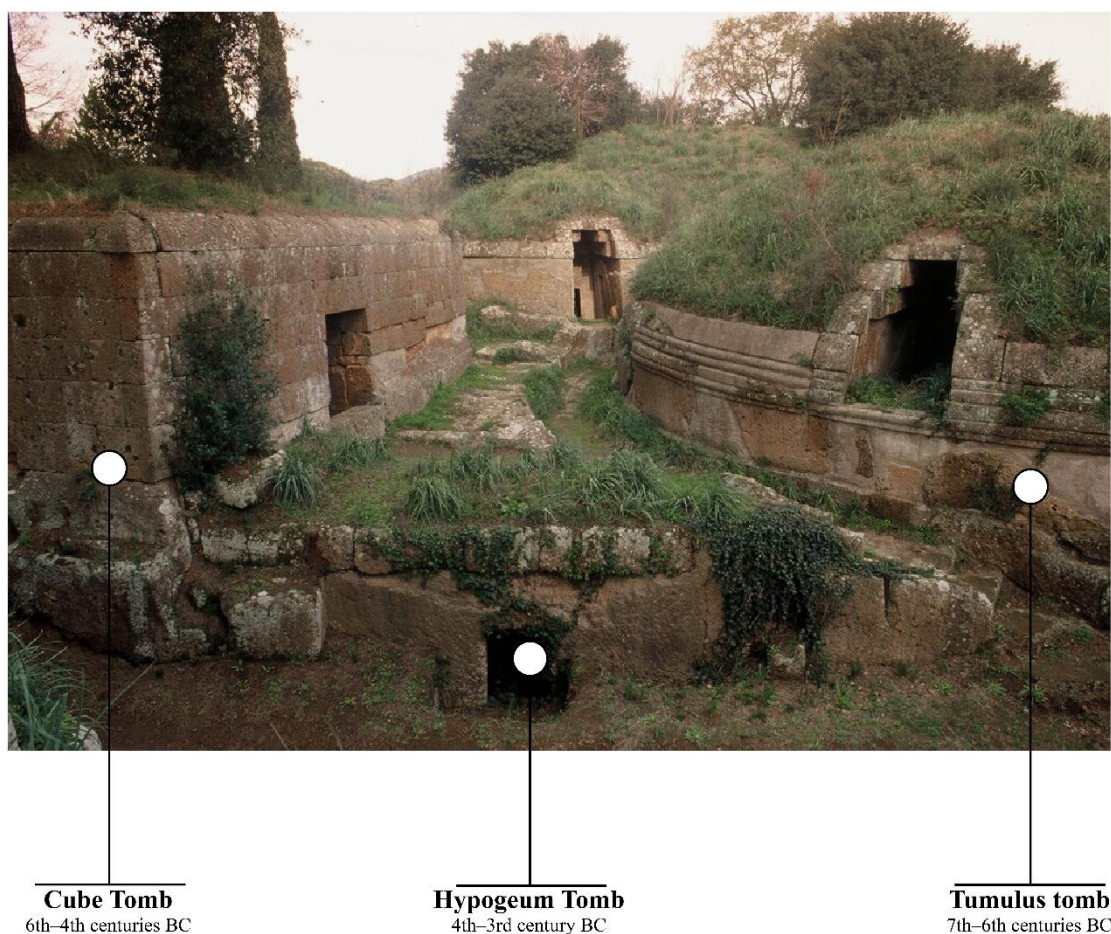


Figure 81. Comparison of the principal funerary architectural typologies documented within the Banditaccia Necropolis, including tumulus, hypogeum and cube tombs.

Source: Developed by Author

5.3.3 Conservation and Environmental Criteria

The conservation assessment was developed to document the principal deterioration processes affecting the funerary structures of the Via degli Inferi and to provide a consistent framework for comparative analysis within the GIS environment. The evaluation combined direct field observations, photographic documentation and orthophoto interpretation, considering both architectural conditions and environmental factors. Two complementary dimensions were assessed for each tomb. Structural condition refers to the physical stability of the monument and includes indicators such as fractures, collapses, material loss and evidence of instability. Surface condition, focuses on weathering processes affecting exposed tuff surfaces, including erosion, exfoliation and biological alteration. Based on the observed severity of these phenomena, each tomb was assigned to one of three conservation classes (good, medium or bad), allowing a simplified but consistent representation of conservation conditions across the study area. Vegetation was treated as an independent analytical category due to its significant influence on the preservation of rock-cut(semi dado) archaeological structures. Previous conservation studies conducted at the Banditaccia necropolis have demonstrated that vegetation can contribute to both surface deterioration and structural damage through different mechanisms.¹⁵³ To reflect these differences, vegetation was classified into three groups such as biological colonisation (mosses, lichens and algae), herbaceous vegetation, and woody vegetation represented by trees and shrubs. While biological colonisation primarily affects surface conditions through moisture retention and biochemical activity, woody vegetation may generate structural impacts through root penetration and the enlargement of existing fractures. The selected parameters provide a structured description of the funerary monuments and support thematic mapping, spatial analysis and conservation-oriented interpretation in the GIS and WebGIS environments.

¹⁵³ Ruderi e Vegetazione

5.3.4 Attribute Table Structure and Database Design

The archaeological database was designed to organise and manage the information collected during field surveys within a structured GIS environment. Each funerary monument was recorded as an individual spatial feature associated with a set of descriptive attributes, allowing archaeological, environmental and spatial information to be integrated within a single geodatabase. (Fig.82)



Figure 82. GIS database schema

Source: Developed by author

The attribute structure was developed to support both documentation and analytical purposes. In addition to the geometric representation of each tomb, a series of archaeological and environmental parameters were assigned to facilitate thematic mapping, data filtering and spatial analysis. The selected attributes reflect the main characteristics observed during the survey and were organised into different categories according to their function within the database. Archaeological attributes include the identification code of each monument,

typological classification, chronological attribution and construction method.(Fig.83).These parameters provide a basic framework for understanding the architectural diversity of the Via degli Inferi funerary landscape and allow comparisons between monuments belonging to different chronological and morphological groups.Environmental attributes were introduced to document the interaction between the monuments and their surrounding context. Particular attention was given to vegetation, following the conservation studies developed for the Banditaccia necropolis, which emphasise the role of biological colonisation, herbaceous growth and woody vegetation in the deterioration of archaeological structures. For this reason, attributes describing vegetation type, vegetation cover and vegetation-related problems were included in the database. These parameters allow the spatial distribution of environmental pressures to be visualised and compared across the study area. The resulting database structure provides a flexible framework for data management and supports the development of thematic maps, spatial queries and WebGIS visualisation. By linking archaeological documentation with environmental observations, the database contributes to a more integrated understanding of the funerary landscape and establishes the foundation for subsequent conservation-oriented analyses.

OBJECTID	Shape	Nome	Type	Description
1	Point Z	campo_della_fiera	Archaeological / Ritual Are...	Broad open area forming part of the necropolis landscape, used historically as a circulation and con...
2	Point Z	Altopiano_delle_Onde...	Plateau / Funerary Area	Elevated plateau characterized by dispersed tombs and natural tuff formations, typical of the topog...
3	Point Z	Tomba_Delle_cinque_se...	Tomb Complex / Monume...	Chamber tomb dating to the 7th century BCE, distinguished by five carved stone seats within the b...
4	Point Z	Zona_De_i_Grandi_Tumuli	Burial Mounds Area	Sector containing large earthen tumuli from the Orientalizing and Archaic periods, associated with t...
5	Point Z	Zona_Della_Tegola_Dipi...	Decorated Tomb Area/ Fu...	Mapped area of the necropolis whose name refers to decorative architectural elements: specific tom...
6	Point Z	Zona_De_i_Clavie	Funerary Sector	Sector identified in modern archaeological mapping; characterized by varied burial structures, thoug...
7	Point Z	Necropoli_De_l_Laghetto	Necropolis Sector	Area overlooking the Manganello valley, characterized by numerous burial pits and rock-cut tombs;
8	Point Z	Necropoli_De_l'Autostrada	Archaeological Burial Area	Sector documented during modern archaeological investigations linked to nearby infrastructure: cor...
9	Point Z	Mura_Antiche	Ancient Boundary Structu...	Sector where ancient wall structures are present; their precise function (boundary, terracing, or end...
10	Point Z	Via_degli_inferi	Funerary Processional Road	Deeply carved Etruscan road linking different sectors of the necropolis, characterized by high tuff wa...
11	Point Z	Bufolareccia	Peripheral Funerary Zone	Outlying area of the necropolis containing dispersed rock-cut tombs and natural tuff formations, re...
12	Point Z	Recino	Enclosed Funerary Sector	Defined area within the necropolis marked by structural boundaries, indicating spatial organization...
13	Point Z	Altopiano_De_l'Affenatora	Elevated Funerary Plateau	Plateau sector forming part of the necropolis topography; includes burial structures positioned on h...

OBJECTID	Shape	Historic_ID	Entity	Typology	Sector	Chronology	Material
2	Polygon Z	86	Semi_Dado	Semi_Dado	Piazza B	Etruscan period.6th-4t...	Tuff
3	Polygon Z	84	Semi_Dado	Semi_Dado	Piazza B	Etruscan period.6th-4t...	Tuff
4	Polygon Z	117	Semi_Dado	Semi_Dado	Piazza A	Etruscan period.6th-4t...	Tuff
5	Polygon Z	82	Semi_Dado	Semi_Dado	Piazza B	Etruscan period.6th-4t...	Tuff
6	Polygon Z	68	Semi_Dado	Semi_Dado	Piazza D	Etruscan period.6th-4t...	Tuff
7	Polygon Z	64	Semi_Dado	Semi_Dado	Piazza D	Etruscan period.6th-4t...	Tuff
8	Polygon Z	115	Semi_Dado	Semi_Dado	Piazza di Arnth	Etruscan period.6th-4t...	Tuff
9	Polygon Z	103	Semi_Dado	Semi_Dado	Piazza di Arnth	Etruscan period.6th-4t...	Tuff
10	Polygon Z	111	Semi_Dado	Semi_Dado	Piazza di Arnth	Etruscan period.6th-4t...	Tuff
11	Polygon Z	109	Semi_Dado	Semi_Dado	Piazza di Arnth	Etruscan period.6th-4t...	Tuff
12	Polygon Z	62	Semi_Dado	Semi_Dado	Piazza D	Etruscan period.6th-4t...	Tuff
13	Polygon Z	60	Semi_Dado	Semi_Dado	Piazza D	Etruscan period.6th-4t...	Tuff
14	Polygon Z	58	Semi_Dado	Semi_Dado	Piazza D	Etruscan period.6th-4t...	Tuff
15	Polygon Z	funerary complex 99 , 1...	Semi_DadoComplex	Semi-dado funerary co...	Piazza C , Piazza di Arnt...	Etruscan period.6th-4t...	Tuff
16	Polygon Z	56	Semi_Dado	Semi_Dado	Piazza F	Etruscan period.6th-4t...	Tuff

Figure 83. Structure of the archaeological attribute table used in the GIS database.

Source: Developed by author in ArcGIS pro

5.4 Thematic Mapping and Multi-Scale Visualisation

Following the organisation of archaeological and environmental information within the GIS database, a series of thematic maps were developed to support the visualisation and exploration of the Via degli Inferi sector. The purpose of these maps was not only to represent individual attributes spatially, but also to facilitate the observation of relationships between archaeological features, environmental conditions and landscape characteristics within a unified digital environment. Thematic mapping was used as a tool to transform the information stored in the attribute table into a spatially interpretable framework. Through the integration of archaeological and environmental datasets, the GIS allows different categories of information to be displayed, compared and analysed across multiple scales. This approach provides a more comprehensive understanding of the funerary landscape than would be possible through tabular data alone. Several thematic layers were created based on the classification system developed for the project. These include archaeological variables such as tomb typology, chronology and construction method, together with environmental information related to vegetation and its interaction with the funerary structures. In addition to thematic visualisation, interactive pop-up windows were configured for each funerary structure. These pop-ups provide direct access to the attribute information stored within the geodatabase, including tomb identification, typology, chronology, construction method, conservation status and vegetation-related observations. (Fig.84) By selecting individual features on the map, users can retrieve detailed archaeological and environmental information without the need to access the attribute tables directly. This functionality enhances data exploration and supports the interpretation of archaeological patterns within the WebGIS environment. (Fig.85)

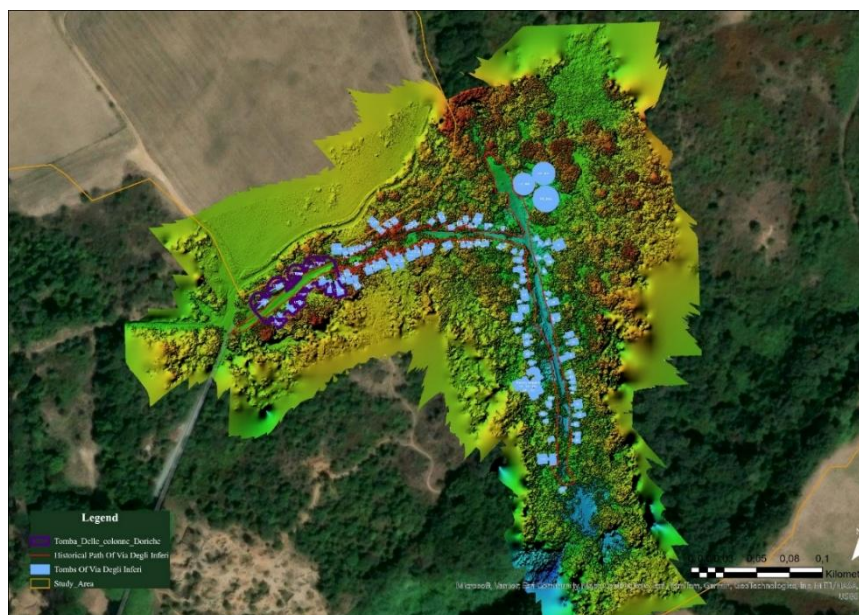


Figure 84. Overview of the GIS environment developed for the Via degli Inferi sector, showing the spatial distribution of funerary structures in relation to the historical road and the orthophotographic base map.

Source: Developed by author in ArcGIS PRO

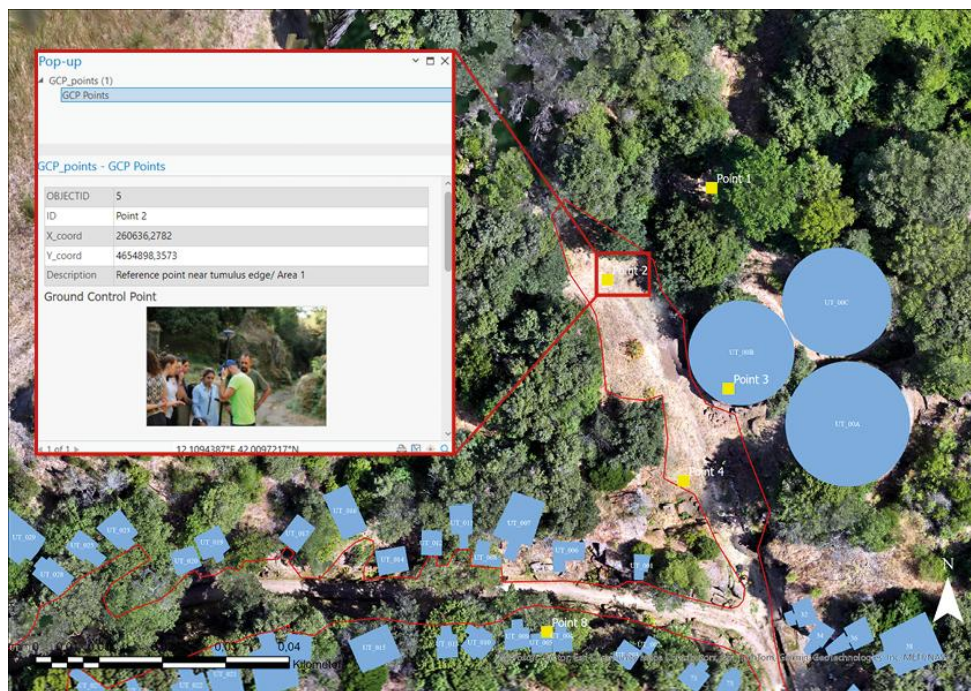
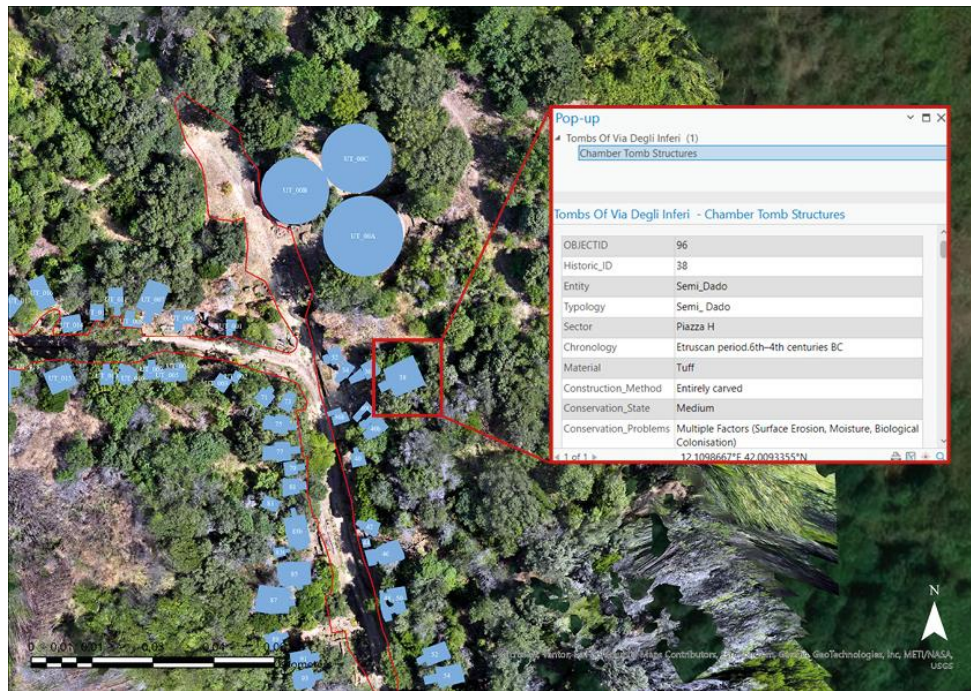


Figure 85. Examples of WebGIS pop-up functionality. The upper image shows the archaeological attributes associated with a funerary structure, while the lower image illustrates the integration of field-survey information and photographic documentation within the pop-up interface.

Source: Developed by author in ArcGIS PRO

The combination of all these datasets allowed the spatial distribution of different archaeological features to be explored while maintaining their relationship with the broader landscape context.(Fig.86) Through thematic mapping, the GIS environment provided a huge framework for visualising funerary structures, terrain morphology and the historical pathway of Via degli Inferi within a single spatial system. Rather than focusing on individual monuments in isolation, this approach allowed archaeological elements to be examined as components of a wider cultural landscape. The final maps support the interpretation of spatial patterns across the study area and highlight the value of combining archaeological documentation with environmental and topographic information. This multi-scale perspective forms the basis for the analytical and interpretative applications discussed in the following section.

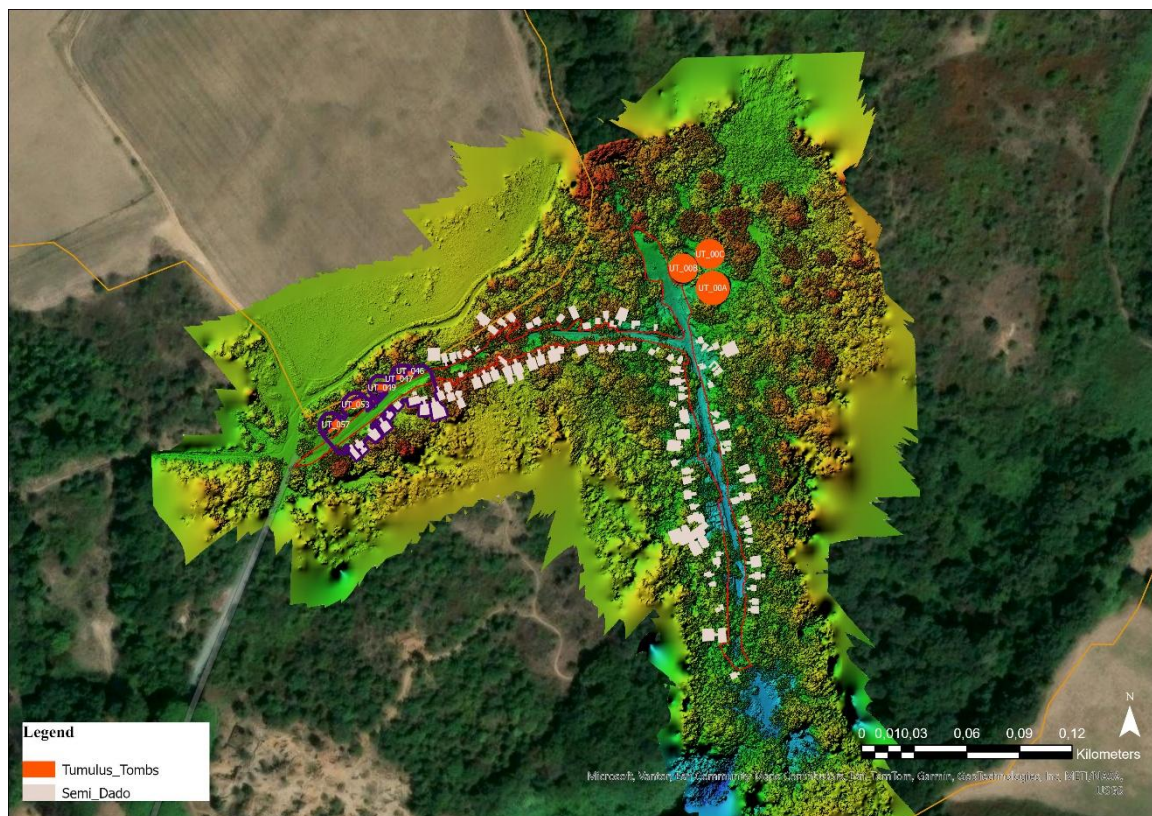


Figure 86. typological distribution of funerary structures within the Via degli Inferi study area, showing the spatial arrangement of tumuli and semi-cube tombs.

Source: Developed by author in ArcGIS PRO

5.5 GIS–WebGIS Interpretation and Application for Conservation

The GIS–WebGIS framework developed in this research was designed not just only for the organisation and visualisation of spatial information but designed for supporting the interpretation and management of archaeological and environmental data within a unified georeferenced environment. By integrating archaeological documentation, geomatic survey outputs and environmental observations like the GIS platform enabled the creation of thematic layers and spatial relationships useful for conservation-oriented analysis and landscape documentation. Through the WebGIS environment this information became accessible through interactive maps, attribute tables, pop-up windows and thematic visualisations, supporting both research activities and the dissemination of archaeological knowledge. The integration of these datasets facilitated the investigation of spatial relationships between different aspects such as funerary structures, terrain morphology and environmental conditions within the Via degli Inferi landscape. The analysis highlighted the influence of vegetation cover, topographic configuration and microclimatic conditions on the preservation of the funerary architecture. Areas characterised by dense vegetation, limited air circulation and prolonged shadow conditions frequently showed evidence of increased humidity, biological colonisation and surface weathering processes. In this framework, vegetation was interpreted not only as a potential source of deterioration but also as an active landscape component influencing the visual character and environmental dynamics of the archaeological setting also. The interaction between natural processes, funerary architecture and terrain morphology contributes to continuously evolving conservation conditions that can be effectively explored through GIS-based spatial analysis. The results obtained through the GIS environment provided the basis for a more detailed investigation at micro-scale level. For this purpose, a representative funerary sector of the Via degli Inferi was selected to further examine the relationships between archaeological structures, vegetation dynamics, terrain morphology and conservation conditions through a series of interpretative GIS-based applications. Figure 87 illustrates the overview of the Cerveteri and different funerary typologies, vegetation and conservation which are related to the landscape dynamics.



Figure 87. Representative views of the Via degli Inferi showing different funerary typologies, vegetation conditions and conservation related landscape dynamics.

Source: Author's photographs.

The interaction between vegetation and funerary structures should also be understood as part of a wide ecological process evolving over time. In unmanaged environments such as the vegetated sectors of the Via degli Inferi, natural succession progressively modifies the relationship between terrain, vegetation cover and archaeological remains, influencing both the visual perception and conservation conditions of the landscape.(Fig.88)

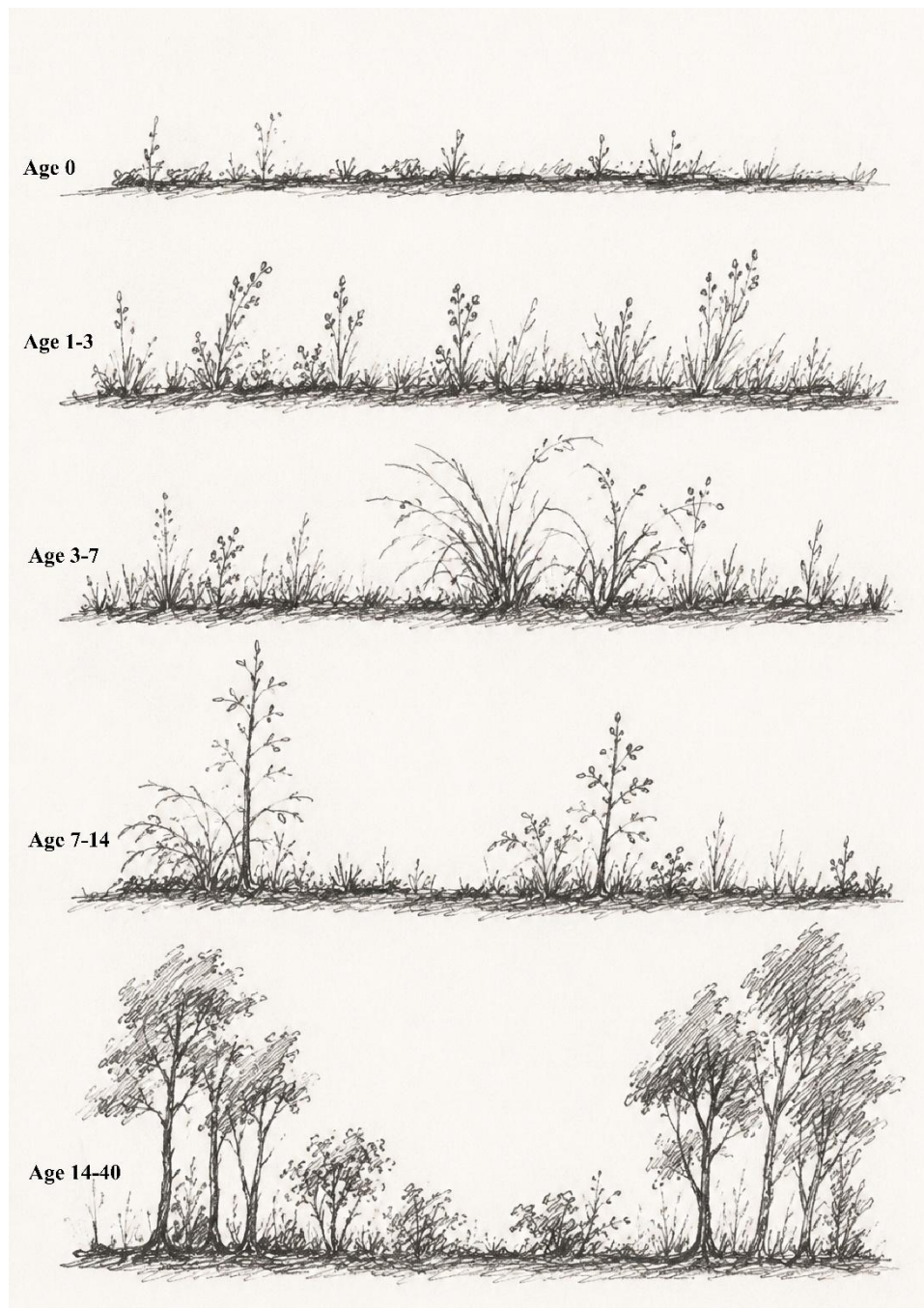


Figure 88. Simplified scheme illustrating the progressive development of vegetation and ecological succession processes in unmanaged environments (adapted from Ruder e Vegetazione).

Source: developed by author based on Ruder e Vegetazione

5.5.1 Selected Area / Tumuli and Cube Tombs Near the Via Degli Inferi

In this research decided to choose micro scale area to show more specific information which are all connecting with the GIS and Web GIS and the importance. The selected area identified in the Via degli Inferi sector matches to a small funerary cluster composed primarily of tumuli associated with nearby semi-cube tombs. The sector is characterised by funerary structures excavated into the tuff plateau and positioned along the deeply incised pathways of the necropolis. The presence of different tomb typologies within a limited spatial extent reflects the architectural and chronological stratification that characterises the broader development of the Banditaccia necropolis.

In general, this area is important because of these three tumuli that preserve significant original architectural features and were not affected by the restoration interventions carried out in other sectors of the necropolis during the twentieth century. Other option of this area is that the area is characterised by dense vegetation cover and irregular topographic conditions, creating a microenvironment strongly influenced by humidity, shadow, and limited air circulation. These environmental conditions contribute to the persistence of mosses, lichens and herbaceous vegetation along the funerary corridors and exposed stone surfaces. The excavated morphology of the Via degli Inferi pathways further supports the accumulation of moisture and the development of biological colonisation processes. In several areas, vegetation growth and root systems interact directly with the funerary structures, contributing both to the visual character of the archaeological landscape and to conservation related vulnerabilities affecting the stone surfaces and architectural elements.

The selected area focused on a suitable context for investigating the relationship between funerary architecture, terrain morphology, vegetation dynamics and conservation conditions within the broader landscape of the Via degli Inferi. The integration of GIS analysis, orthophoto interpretation and field observations enabled these spatial and environmental relationships to be examined within a unified geospatial framework.

The selected funerary sector was identified through GIS analysis and field observations. The area contains a representative concentration of tumuli and semi-dado tombs associated with dense vegetation cover and variable environmental conditions. The progressive zoom from landscape scale to site scale allows the spatial context of the analytical investigation to be established before the interpretation of conservation-related observations.(Fig.89)

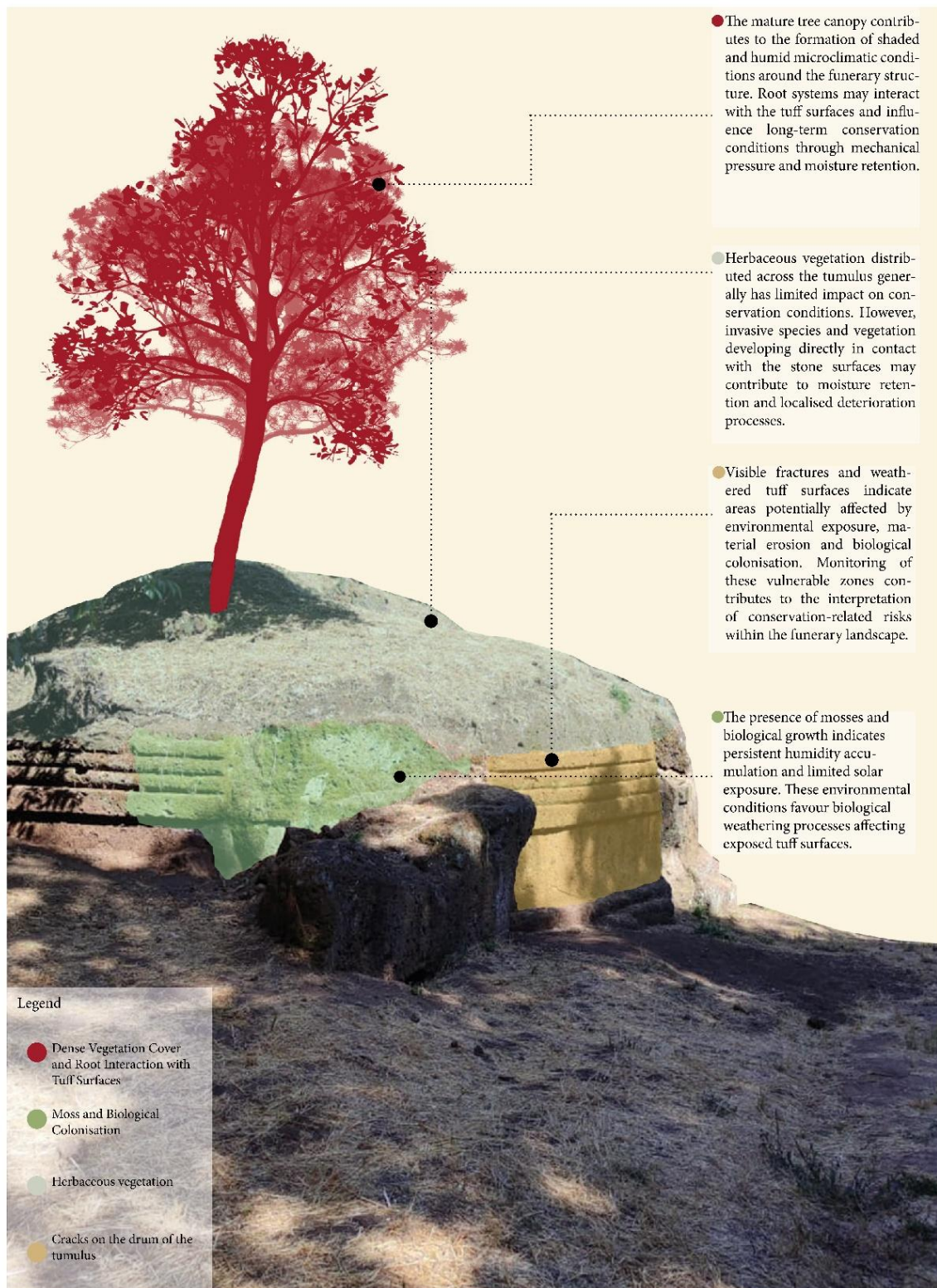


Figure 89. selected area in via degli inferi

Source: Developed by author In ArcGIS PRO

5.5.2 Analytical Visual Plates of Selected Area

The analytical plate synthesises GIS analysis, orthophoto interpretation and field observations collected within the selected area. The objective is to highlight potential relationships between vegetation dynamics, environmental conditions and conservation-related vulnerabilities affecting the funerary structures.



The observations identified through the analytical plate were further examined through field documentation collected within the selected funerary sector. The close-up photographs provide direct evidence of the interaction between vegetation growth, root systems and exposed tuff surfaces, supporting the interpretation of environmental factors influencing conservation conditions. These observations highlight how natural vegetation, root development and biological growth interact with the funerary structures and may contribute to conservation-related vulnerabilities, particularly in shaded and humid areas where moisture tends to persist over time. These observations support the conservation-oriented interpretation developed through the GIS analysis and analytical visualisation of the selected area.(Fig.90)

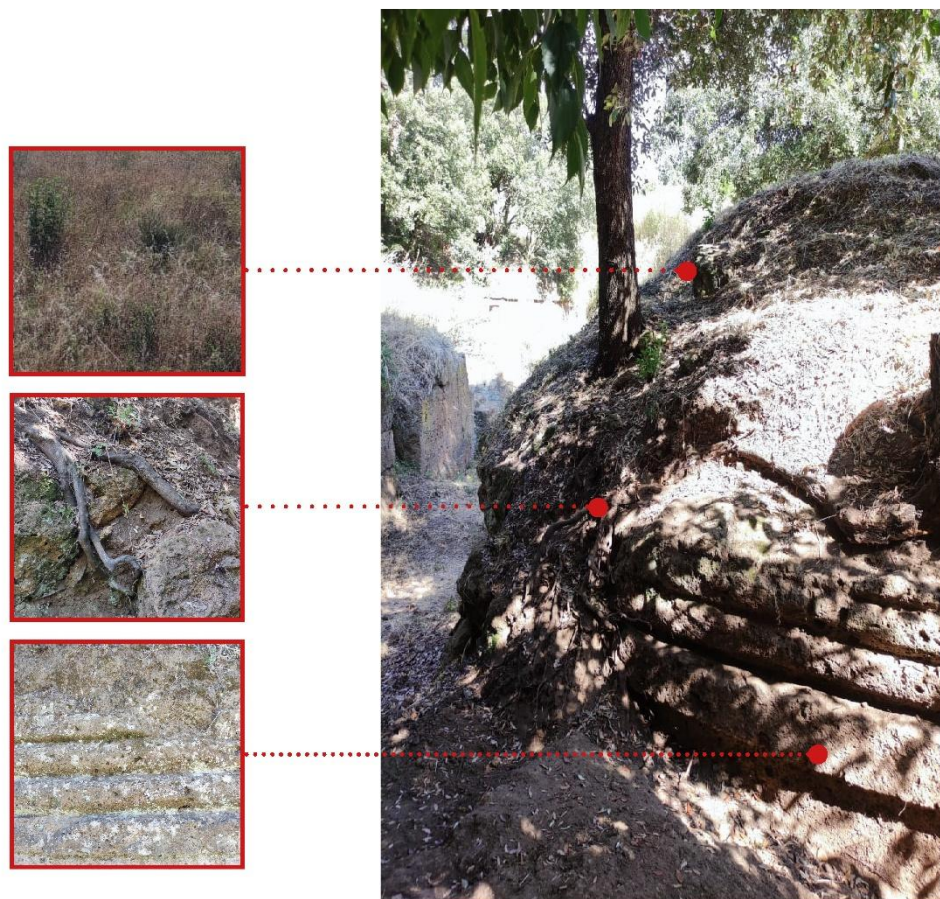


Figure 90: Field observations from the selected funerary sector showing vegetation cover, root development and exposed tuff surfaces associated with environmental conditions influencing the conservation of funerary structures.

Source : Developed by author

5.5.3 Morphological Sections and Environmental Interpretation

The morphological sections which was extracted from the point cloud dataset through PointCab were used to investigate the vertical relationship between funerary structures, terrain morphology and vegetation distribution within the selected sector of the Via degli Inferi. Unlike orthophotos and GIS-based planimetric analyses, the sections provide a vertical interpretation of the archaeological landscape, highlighting the excavated morphology of the funerary pathways, elevation differences and the spatial enclosure generated by dense vegetation cover. These sections also support and identify the interpretation of microclimatic and conservation-related conditions affecting the funerary structures. The deeply incised pathways and dense vegetation contribute to shaded and confined environmental conditions characterised by limited air circulation and humidity retention. These conditions favour biological colonisation processes and the progressive weathering of exposed tuff surfaces. Integrated in the broader GIS and WebGIS framework, the sections function not only as geometric representations but represent as interpretative tools supporting the analysis of environmental dynamics and conservation which is related vulnerabilities within the archaeological landscape.



SECTION A-A

Source : Developed by author in PointCab

The extracted section revealed a clear relationship between topography, vegetation distribution and the location of funerary structures. Areas characterised by dense vegetation corresponded to sectors with limited solar exposure and reduced air circulation, creating favourable conditions for moisture retention. In contrast, more open areas showed lower vegetation density and reduced evidence of biological colonisation. These observations support the interpretation that local environmental conditions directly influence the conservation state of the archaeological remains and should be considered in future monitoring and management activities.

Beyond the morphological interpretation, the section was integrated within the GIS environment as a supporting analytical layer. By combining the section with different aspects such as orthophotos, vegetation mapping and field observations, it was possible to relate topographic depressions, vegetation distribution and funerary structures within a common spatial framework. The section therefore provides and identifies a vertical perspective that complements the planimetric GIS analyses, supporting the identification of areas potentially affected by moisture retention, biological colonisation and conservation-related vulnerabilities. The identification of different vegetation types along the section helps to characterise the environmental conditions of the study area. Herbaceous vegetation is mainly associated with open and more exposed sectors, while dense tree cover corresponds to areas with greater shading and reduced air circulation. Shrub vegetation represents an intermediate condition between open and densely vegetated environments. The distribution of these vegetation categories shows to understanding local microclimatic variations and their potential influence on the preservation of the funerary structures. (Fig.91)

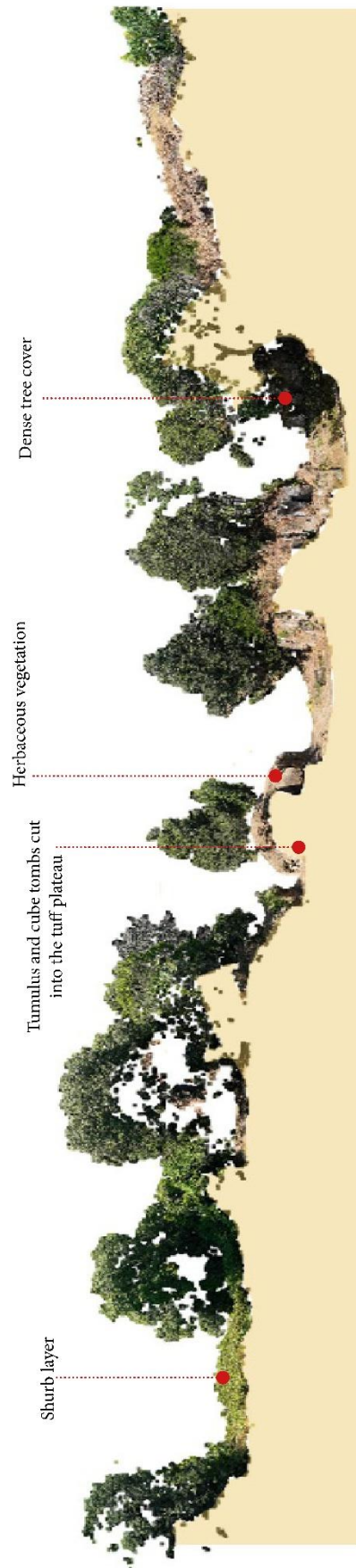
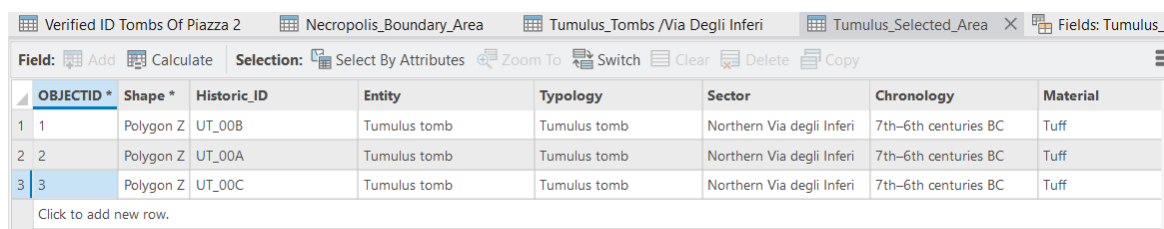


Figure 91. Morphological section A–A illustrating the relationship between terrain morphology, funerary structures and vegetation distribution within the selected area of the Via degli Inferi. The section highlights how topographic depressions and dense vegetation contribute to moisture retention and conservation-related vulnerabilities.

5.5.4 Attribute Tables and Pop-Up Configuration

As previously explained, attribute tables and interactive pop-up windows were created inside the ArcGIS Pro and WebGIS environment in order to organise and visualise the collected information related to the funerary area. So In this point of view GIS and WebGIS were used not only for mapping and visualisation, but also for organising and communicating the archaeological and environmental information collected and better understanding during the research.(Fig.92)(Fig.93)



OBJECTID *	Shape *	Historic_ID	Entity	Typology	Sector	Chronology	Material
1	Polygon Z	UT_00B	Tumulus tomb	Tumulus tomb	Northern Via degli Inferi	7th–6th centuries BC	Tuff
2	Polygon Z	UT_00A	Tumulus tomb	Tumulus tomb	Northern Via degli Inferi	7th–6th centuries BC	Tuff
3	Polygon Z	UT_00C	Tumulus tomb	Tumulus tomb	Northern Via degli Inferi	7th–6th centuries BC	Tuff

Figure 92. Attribute table integrating archaeological, environmental and conservation-related information associated with the selected funerary sector.

Source: Developed by Author in ArcGIS pro

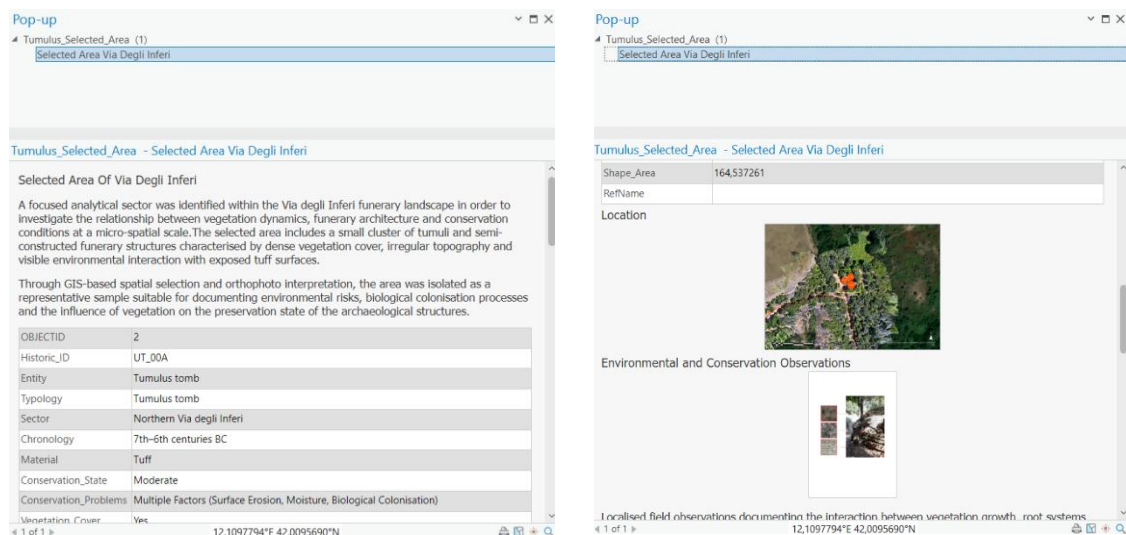


Figure 93. Interactive pop-up displaying analytical and environmental information associated with the selected funerary structures.

Source: Developed by Author in ArcGIS pro

5.5.5 WebGIS Publication and Experience Builder

At the end of all these processes and following the completion of data acquisition, photogrammetric processing, georeferencing and spatial analysis, the resulting archaeological database is more powerful and interesting because it was prepared for online publication through ArcGIS Online and integrated into ArcGIS Experience Builder. ArcGIS Experience Builder is a web application development platform provided by ESRI that enables the creation of interactive and responsive web experiences without requiring advanced programming skills. The platform allows the integration of web maps, spatial datasets, multimedia content, images, text, and analytical tools within a customizable interface, making geospatial information more accessible to a broad range of users. (Fig.94)



Figure 94. Overview of the experience builder platform

Source: Google Image

The primary objective of developing the WebGIS platform was to transform the archaeological and spatial data collected during this research into an interactive digital resource capable of supporting visualization, consultation, analysis, and dissemination activities. Traditional GIS projects generally require specialized software and technical expertise, limiting access to archaeological information. But the Experience Builder environment provides an intuitive web-based interface that can be accessed through standard desktop and mobile devices, facilitating the dissemination of cultural heritage information to researchers, heritage managers, students and the public.

The workflow began with the publication of the GIS layers to ArcGIS Online, including archaeological features which depends on the project can be like tomb locations, survey boundaries, orthophotos, Digital Surface Models (DSM), and other spatial datasets generated during the research. These layers were organized into thematic web maps and subsequently integrated into ArcGIS Experience Builder, where including interactive widgets, navigation tools, search functions, attribute tables, pop-up windows, and multimedia content were configured to enhance user interaction and information retrieval. Through this process, users can explore the archaeological landscape at multiple scales, access detailed attribute information associated with individual features, and visualize the spatial relationships between archaeological remains and their surrounding environment. One of the principal advantages of the platform is its ability to combine spatial data, descriptive records, and photogrammetric products within a single environment. The integration of interactive maps with archaeological information allows users to move from a general overview of the Cerveteri Necropolis to the detailed examination of individual tombs and archaeological features. Search tools, layer controls, and attribute queries further improve the usability of the application by enabling efficient navigation and customized visualization of the available datasets. From a heritage management perspective, the WebGIS platform represents an important tool for documentation, monitoring, and conservation activities. By providing a centralized repository of spatial information, it facilitates data sharing among researchers and institutions while supporting future archaeological investigations and preservation strategies. Furthermore, the online accessibility of the platform increases public awareness of the cultural significance of the Cerveteri Necropolis and promotes wider engagement with archaeological heritage. The result is an interactive web-based application that integrates archaeological datasets, spatial analyses, photogrammetric products and multimedia resources into a single digital environment. The platform define that how modern geospatial technologies can support archaeological research, heritage documentation, public dissemination, and long-term conservation planning while improving accessibility to archaeological information through an intuitive and user-friendly interface.

Figure 95 illustrate that the three important and main steps process which was started from the documentation in the ArcGIS PRO online and then continued to the WEBGIS online in ESRI and at the end developed in the experience builder. In this platform is possible to explore and find a wide range of information during the survey and documentation which appear in the attribute table and pop-up for each objects. This platform help users, students, expertise to find a specific information in a short time and enjoy they research.

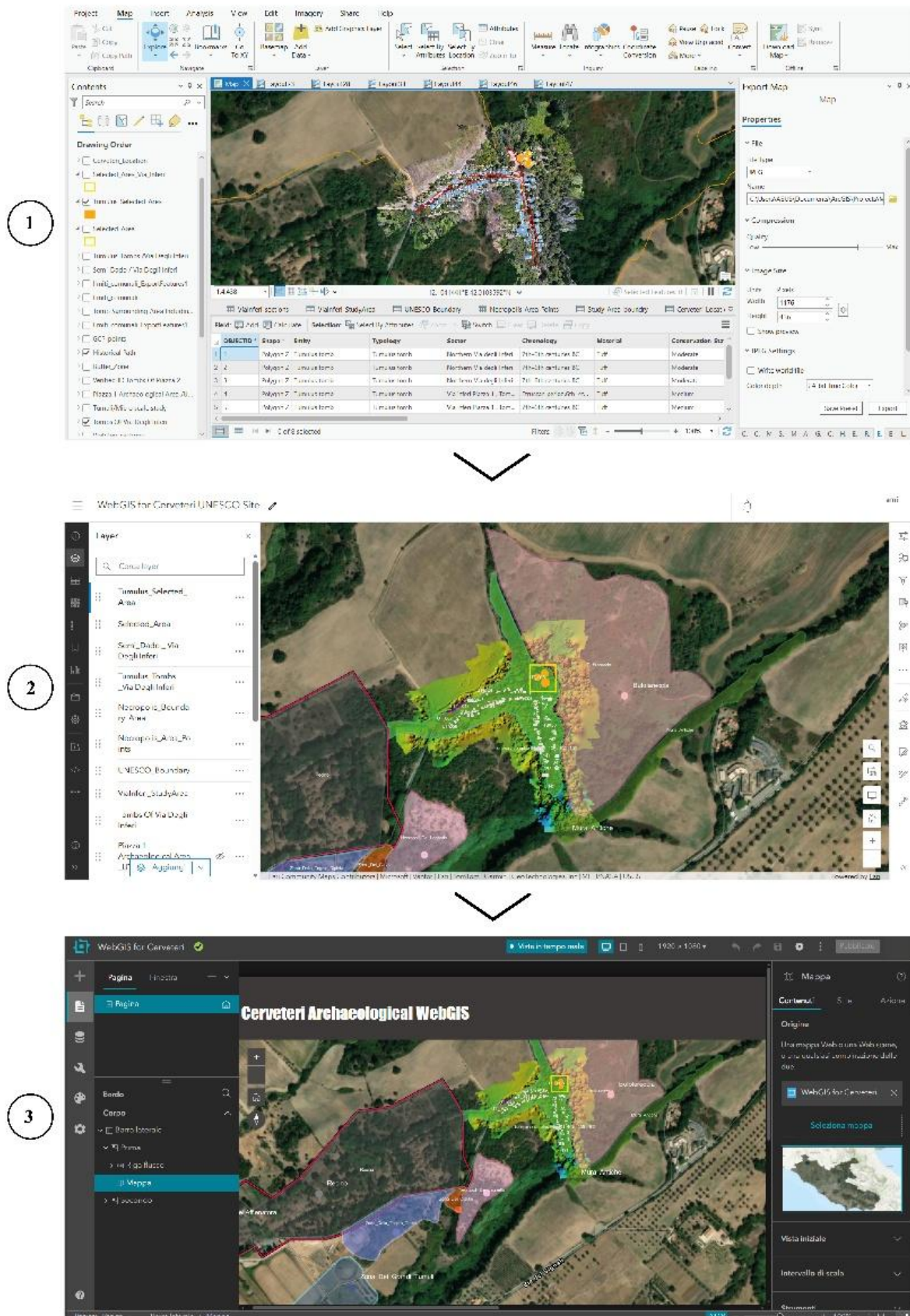


Figure 95. Workflow for publishing the GIS database and spatial analyses through ArcGIS Online and integrating them into the ArcGIS Experience Builder WebGIS application.

Source: Developed by author

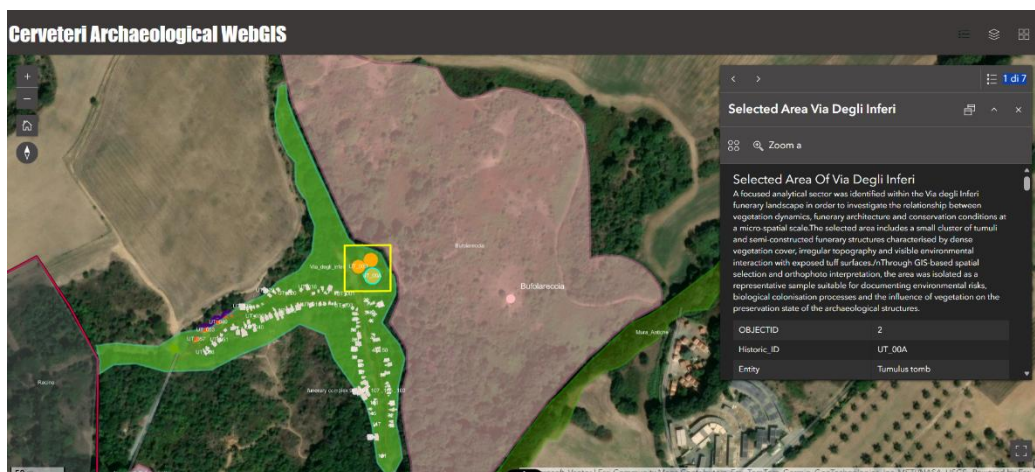
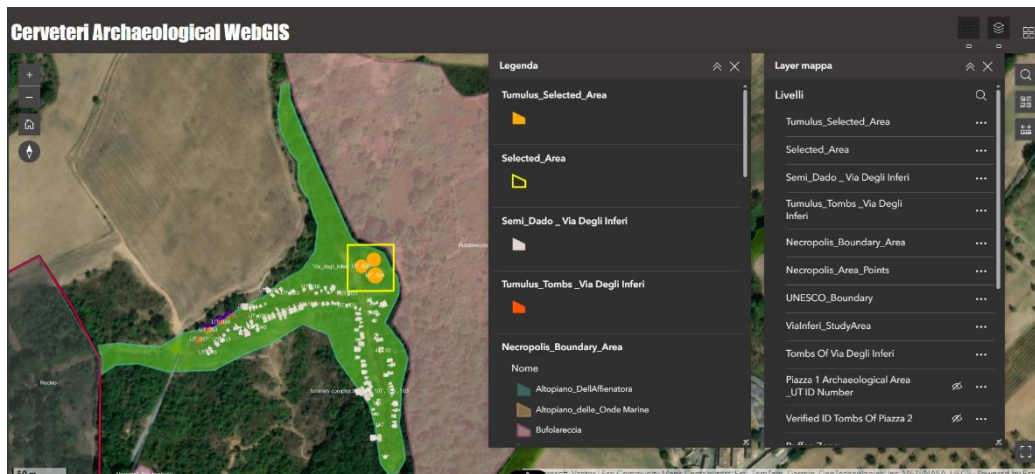


Figure 96. illustrate how exploring works in this platform which it is possible to see the pop ups, legends, layers and other important information

Source: Developed by author in experience builder

Figure 96. Example of user interaction within the Cerveteri Archaeological WebGIS developed in ArcGIS Experience Builder by author. The platform enables users to navigate the archaeological landscape, manage thematic layers, consult legends and access detailed attribute information through interactive pop-up windows associated with individual archaeological features.



Figure 97. WebGIS platform developed for the Via degli Inferi sector showing spatial datasets, tomb classification, attribute information and mobile accessibility through ArcGIS Experience Builder and final result.

Source : Developed by Author

Figure 97 show the final WebGIS platform developed within this research through ArcGIS Experience Builder. The application represents the final stage of the workflow, integrating the archaeological database, photogrammetric products, spatial analyses and descriptive information into a single interactive environment accessible through the web. The platform enables users to visualize archaeological features, explore thematic layers, access attribute information and investigate the spatial relationships between cultural heritage elements and their surrounding landscape.

The development of the WebGIS platform transformed the results of the archaeological survey from a conventional GIS database into an accessible digital resource capable of supporting research, documentation, communication and heritage management activities. Through the integration of interactive maps, attribute tables, multimedia content and photogrammetric outputs the platform provides a comprehensive framework for exploring and understanding the archaeological landscape of Cerveteri. An important advantage of this application is its responsive design, which allows access from desktop computers, tablets, and mobile devices without requiring specialized software. The mobile compatibility of the platform extends its usability beyond the office environment, enabling researchers, heritage managers, and visitors to access archaeological information directly in the field. Furthermore, the integration of a QR code facilitates immediate access to the application, promoting the dissemination of archaeological knowledge and increasing public engagement with cultural heritage resources.

The final WebGIS platform demonstrates how modern technologies can support the digital preservation, visualization, and dissemination of archaeological information. By combining spatial data, archaeological documentation and user-friendly web technologies, these applications contribute to the long-term management and conservation of cultural heritage while making archaeological information more accessible to both specialists and the wider public.



CHAPTER VI

FUTURE PERSPECTIVES AND GENERAL CONCLUSION

6.1 Results

The research resulted in the development of a complete and integrated GIS–WebGIS framework for the documentation, analysis and spatial organisation of the Via degli Inferi sector within the Banditaccia Necropolis. The combination use of UAV photogrammetry, GNSS measurements and mobile SLAM acquisition produced a coherent georeferenced dataset, including high-resolution orthophotos, Digital Surface Models (DSMs), dense point clouds and structured archaeological layers. These datasets established the geometric and spatial foundation for subsequent GIS analyses. This structured GIS database was created to integrate archaeological, architectural and environmental information in a single spatial framework. The database incorporates architectural entities, typological classifications, conservation attributes and vegetation indicators, enabling the systematic organisation of heterogeneous datasets and improving the consistency of archaeological documentation. This structure also facilitated the spatial correlation of funerary architecture with terrain morphology, vegetation distribution and conservation conditions. The integration of multiple geomatic datasets within the GIS environment enabled the systematic organisation, spatial analysis and interpretation of archaeological information in a unified digital framework. The proposed methodology demonstrated how 3D survey data, archaeological documentation and environmental information can be effectively combined to support archaeological documentation, spatial interpretation and digital heritage management beyond conventional recording approaches. The outcome of the research was the development of an interactive WebGIS platform using ArcGIS Online and Experience Builder. The platform integrates maps, thematic layers, photographs and attribute information in a single digital environment which providing a centralised system for visualisation, consultation and future updating of archaeological information. The WebGIS environment supports the exploration of spatial information at multiple scales while facilitating future monitoring and documentation activities.

Overall, the research produced a coherent digital workflow that integrates geomatic survey, GIS analysis and WebGIS dissemination within a unified spatial framework. Beyond generating digital documentation, the proposed methodology demonstrated the value of integrating geomatic datasets for archaeological landscape analysis, supporting more structured documentation and providing a reliable basis for future conservation-oriented applications.

6.2 Future Perspectives and General Conclusion

The research carried out on the Via degli Inferi sector demonstrates that archaeological landscapes cannot be fully understood through traditional descriptive documentation alone. Instead of being interpreted as collections of isolated monuments, they should be considered dynamic systems in which architectural features, environmental processes and spatial relationships continuously interact. By integrating geomatic survey techniques with GIS-based analysis and WebGIS dissemination also this research demonstrates that digital methodologies are not just technical tools for documentation, but interpretative frameworks capable of revealing spatial patterns, relationships and conservation issues that are difficult to identify using conventional approaches. One of the most significant outcomes of this research is the demonstration that geomatics can fundamentally transform the way archaeological heritage is interpreted and managed. The integration of photogrammetry, orthophoto generation and structured GIS data enabled the funerary architecture of the Via degli Inferi to be analysed as components of a broader archaeological landscape rather than as individual monuments. This shift from object based documentation towards landscape-based interpretation represents an important methodological contribution by providing a stronger basis for understanding vulnerability, defining conservation priorities and supporting long-term management strategies. Consequently, GIS should be regarded not simply as a repository of spatial information, but also as a decision-support environment capable of integrating documentation, analysis and interpretation. Another important contribution of this study lies in the methodological framework established throughout the project. The definition of architectural entities, such as typological classifications, conservation criteria and vegetation indicators provides a coherent and reproducible structure that can be adapted to other archaeological contexts. This is particularly relevant for sites characterised by fragmented documentation, the absence of standardised cataloguing systems or highly variable conservation conditions. The research therefore demonstrates that the organisation of reliable and transparent spatial data is not simply a technical requirement but a fundamental condition for producing meaningful archaeological interpretation and supporting informed conservation decisions. This study highlights the importance of continuous and multi temporal monitoring for archaeological landscape conservation. The geomatic workflow developed in this research establishes a baseline that can be progressively enriched through future surveys, allowing changes in structural stability, vegetation dynamics and environmental conditions to be systematically detected over time. Such an approach is particularly valuable for open-air archaeological sites, where deterioration processes are influenced by natural and anthropogenic factors and often evolve unevenly. Integrating periodic geomatic surveys within a GIS environment therefore provides an effective basis for preventive conservation and long-term site management. Beyond its application in the Via degli Inferi case study, WebGIS represents more than a digital interface, It demonstrates how digital platforms can facilitate continuous documentation, interdisciplinary collaboration and long-term heritage management beyond the limitations of conventional archival systems. As a shared, accessible and updateable environment, it enables archaeological information, conservation assessments and spatial analyses to be

integrated in a single framework and supporting not only visualisation but also collaborative decision-making and long-term documentation. By linking three-dimensional survey data, environmental observations and archaeological attributes within a unified geomatic framework, this approach contributes to a more sustainable, informed and adaptive model of heritage stewardship, where spatial information becomes an active component of conservation planning rather than simply a repository of documentation. Finally, the Via degli Inferi sector should be regarded not only as a case study but also as a methodological example that illustrates the wider applicability of integrated geomatic approaches. The challenges encountered throughout this research including the absence of a standardised tomb numbering system, heterogeneous architectural typologies and complex environmental conditions are common to many archaeological landscapes. The workflow proposed here demonstrates that these issues can be effectively addressed through the integration of geomatic survey, spatial analysis and digital information management. More importantly, it shows that adopting this direction can improve the quality, consistency and long-term usability of archaeological documentation while supporting evidence-based conservation strategies applicable to similar heritage contexts. This research therefore argues that the future of archaeological landscape conservation depends on methodologies capable of combining precision, interpretative depth and accessibility. The integrated GIS–WebGIS approach presented here should not be considered an endpoint but rather a methodological foundation upon which more advanced analyses, monitoring strategies and collaborative management tools can be developed. More broadly, this research supports a transition from static documentation towards knowledge-driven heritage management, where spatial information actively informs conservation planning and decision-making. Its broader significance lies in demonstrating that digital geomatics can reshape the way archaeological landscapes are documented, interpreted, protected and sustainably managed over time.

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