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NETWORKS AND QUANTITATIVE METHODS IN ARCHAEOLOGY AND ART HISTORY: ESSAYS FROM THE VENICE SYMPOSIUM (5-6 DECEMBER 2024)

edited by
Myriam Pilutti Namer, Andrea Auconi, Giulia A.B. Bordi

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PREFACE

The ongoing development of quantitative methods in the study of cultural heritage has become an increasingly significant avenue for scholarly exploration across disciplines, particularly in the fields of archaeology and art history. One of the most notable advancements in this domain has been the convergence of these traditional humanities disciplines with tools and methodologies derived from the sciences, such as data analysis, statistical modeling, and machine learning. This cross-disciplinary dialogue is at the heart of contemporary research, as it fosters innovative approaches to understanding and interpreting the past, while also addressing the complex nature of historical and archaeological evidence.

In this context, the international symposium titled *Exploring the Legacy of the Past in Venice: Networks and Quantitative Methods in Archaeology and Art History* – held at the Ca' Foscari University of Venice on December 5th and 6th, 2024 – served as an essential milestone for scholars working at the intersection of these fields. The symposium was part of the activities of the PNRR, Spoke 8, Unit Ca' Foscari Venice, and aimed to present some of the preliminary results of ongoing research within the framework of national and international projects that are testing the potential of quantitative methods in archaeology and art history. Venice, with its unique documentary, art-historical, and archaeological assets, is an ideal setting for such an exchange. As a city whose historical layers stretch back centuries and whose monumental heritage has made it a focal point of cultural significance worldwide, Venice serves as both a case study and a laboratory for experimentation with innovative research methodologies. Its architectural splendor, vibrant artistic tradition, and layered history have attracted scholars from all over the world for centuries, yet the sheer complexity of its heritage – comprising countless objects, monuments, archival records, and artworks – poses significant challenges for traditional research methods. The integration of quantitative tools has thus emerged as a promising way to unlock new insights and facilitate a deeper understanding of this multifaceted city. Indeed, by leveraging methods such as network analysis, spatial modeling, digital mapping, and machine learning, we are able to analyze vast datasets, reconstruct historical connections, and generate visualizations that would have been previously unthinkable.

The symposium, which brought together specialists from archaeology, art history, and physics, exemplified the potential for collaboration across disciplines. Not only did the event provide a platform for presenting cutting-edge research, but it also encouraged a wider reflection on the broader impact of these methodologies on the way we understand the past. In this sense, the

symposium represented more than just a gathering of experts – it was an opportunity to rethink and reframe the very nature of heritage scholarship, by asking how the combination of quantitative approaches and traditional humanities can enrich our interpretations of historical data.

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INTRODUCTION

Venice's extraordinary wealth of documentary archives, architectural monuments, and artistic legacy provides a fertile ground for exploring historical networks and cultural dynamics. At the same time, the city's layered complexity presents challenges for traditional methods of historical and archaeological inquiry. This thematic section of the journal brings together contributions from scholars across disciplines to investigate how the application of quantitative methods and network analysis can transform our interpretations of cultural heritage and historical data.

At the heart of this section is the belief that quantitative methodologies – ranging from network analysis and spatial modeling to digital mapping and machine learning – offer crucial innovations for the study of cultural heritage. These tools enable scholars to manage and interpret vast datasets, visualize complex historical connections, and address questions that would otherwise remain inaccessible. Venice, with its dense archival records and enduring artistic tradition, offers an ideal testing ground for such methodologies. By engaging with these new tools, the studies collected here demonstrate how the integration of quantitative approaches and traditional humanities scholarship can generate fresh insights into the cultural heritage of the past.

The structure of this section reflects both the diversity of methodologies employed and the richness of the case studies investigated. The opening chapter, *The New Science of Long Data* by Guido Caldarelli and Alessandro Codello, introduces the concept of 'Long Data' – a framework that emphasizes the deep historical context embedded in meticulously preserved archival records. Using artificial intelligence and data modeling techniques, the authors explore how this approach can revolutionize the study of Venice's State Archive (ASVe), one of the world's most extensive and historically significant collections. By harnessing new technologies in harmony with traditional archival methods, Long Data enables the analysis, transcription, and modeling of historical information on an unprecedented scale, paving the way for innovative insights into social and cultural evolution.

The subsequent chapters delve into specific applications of quantitative methods in archaeology and art history. Paolo Carafa, Niccolò Cecconi, and Francesco Di Stefano's contribution on the CHANGES Project emphasizes the importance of integrated advanced technologies in promoting sustainable heritage management. Their work illustrates how geolocated data and interdisciplinary collaboration can transform fragmented historical information into cohesive systems of knowledge. The case studies from ancient *Latium*, Amendolara, and Syracuse demonstrate how data-driven

approaches foster a more systematic inventory, classification, and dissemination of cultural assets.

The volume also includes studies focused on digital modeling and the reconstruction of lost heritage. Indeed, George Bruseker, Kathleen Christian, and Denitsa Nenova discuss recent innovations in the *Census of Antique Works of Art and Architecture Known in the Renaissance*, a long-running research project established in 1946 that traces the knowledge and reception of antiquities during the Renaissance by linking them with early modern visual and textual records. Over its history, it has evolved from an analog system to one of the earliest digital art history projects and now to an online database. Recent innovations (2021-2023) have transformed the database into semantic data using the CIDOC-CRM ontology, aligning it with FAIR principles and encouraging broader engagement with its rigorously-researched dataset. By using the X3ML language and the 3M tool for mapping and verification, the database ensures consistency and compatibility with other datasets, such as those in the CORDH network. This semantic transformation opens new avenues for research, enabling advanced queries through SPARQL and extending the database's utility beyond its original scope in art history and archaeology.

In addition, the 'Sacra Absentia' project, presented by Simone Piazza and Giulia A.B. Bordi, documents the lost furnishings of medieval Venetian churches, using archival documents, historical texts and iconographic evidence to compile a comprehensive database. The interactive map system developed for this project offers an essential tool for reconstructing the original appearance and historical context of these sacred spaces, with a particular focus on the church of Sant'Agnese. The chapter on the church of San Fantin in Venice by Carlotta Zaramella, Myriam Pilutti Namer and Giulia A.B. Bordi similarly combines digital modeling, archival research, and material analysis to reconstruct the building's architectural evolution and its reuse of ancient marbles, highlighting the significance of spolia in the city's material culture. The article by Ruggero Longo and Elisabetta Scirocco explores the integration of quantitative methods and digital approaches in art historical research, focusing on the 'Mapping Sacred Spaces' project investigating medieval sacred architecture in southern Italy. It emphasizes the need to reconcile scientific and humanistic disciplines through data-driven analysis, digital tools, and interdisciplinary collaboration for more accurate reconstructions.

Innovative digital methodologies also play a key role in the study of architectural heritage beyond Venice. Carlo Bianchini and his co-authors explore the church of San Lorenzo in Miranda in Rome demonstrates how tools like GIS, BIM, and integrated large-scale surveys can foster a more accurate understanding of ancient structures and their transformations. This approach underscores the importance of shared digital infrastructures and open-access policies in cultural heritage research, enabling the integration

of heterogeneous data and the development of interoperable systems that connect historical, architectural, and graphic sources.

Finally, the section turns to the application of advanced scientific techniques for the analysis of artworks. The study of the painting *Saints Peter and Stephen* at the Fondazione Giorgio Cini by Mauro Missori and his co-authors showcases the potential of remote reflectance spectroscopy to identify pigments and material choices while preserving the integrity of fragile artworks. This non-invasive method, inspired by astronomical techniques, offers new insights into the artist's material practices and demonstrates the feasibility of remote diagnostic tools in heritage science. As a final contribution, Myriam Pilutti Namer's review of two recent volumes on archaeological network research underscores the current state of the field and situates the discussions within broader theoretical and methodological debates.

Together, these contributions illustrate the transformative potential of quantitative methods and interdisciplinary collaboration in the study of cultural heritage. By embracing innovative approaches and fostering dialogue across disciplines, this thematic section aspires to provide valuable models for heritage research on a global scale.

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THE NEW SCIENCE OF LONG DATA: PRESENTATION OF THE VENICE LONG DATA PROJECT

1. What is Long Data?

Our shared European history is preserved in an infinite variety of documents stored in historical archives scattered across the continent. These state, municipal, institutional, industrial, and private archives form the backbone of our cultural heritage and serve as the primary source of knowledge about our past. Yet, this collective memory remains largely out of reach-difficult to access and scarcely interconnected. As Italian and European scientists and humanists, our duty is not only to document and safeguard this heritage for future generations but, more importantly, to make it accessible and explorable for all. To achieve this, we must develop a new science of Long Data – a groundbreaking approach to historical sources and archival information that enables both an unprecedented cultural heritage experience and a more integrated capacity for scientific research on this vast, largely uncharted database.

In an era overwhelmed by the rapid production of digital data, our ability to coherently organize Long Data spanning thousands of years is a unique asset. Moreover, historical archives contain highly structured and verified information that encodes the true, multifaceted history and cultural heritage of Italy, Europe, and the Mediterranean. Long Data represents the intangible record of our past, complementing the tangible reality of archaeological sites, monuments, museums, and cities. In this respect, Italy stands out as one of the most – if not the most – Long Data-rich countries in the world. The Long Data approach seeks to establish a foundation for studying history from a macroscopic perspective, complementing the traditional microscopic approach. It always begins with original sources while leveraging the most advanced techniques available for analysing and transcribing historical records.

This emerging science integrates Artificial Intelligence Network Theory and Big Data-while respecting and incorporating traditional archival and historical methodologies-to accomplish tasks once thought impossible. These include transcribing and analysing entire archival series or even interlinking and modelling all the information contained within one or more historical archives. By combining methods from Digital Humanities and quantitative sciences, such as Complex Networks and Economics, Long Data enables a deeper understanding of the historical development of societies, as well as the evolution of language and culture over centuries. There are two key distinctions between Big Data and Long Data that must be kept in mind.

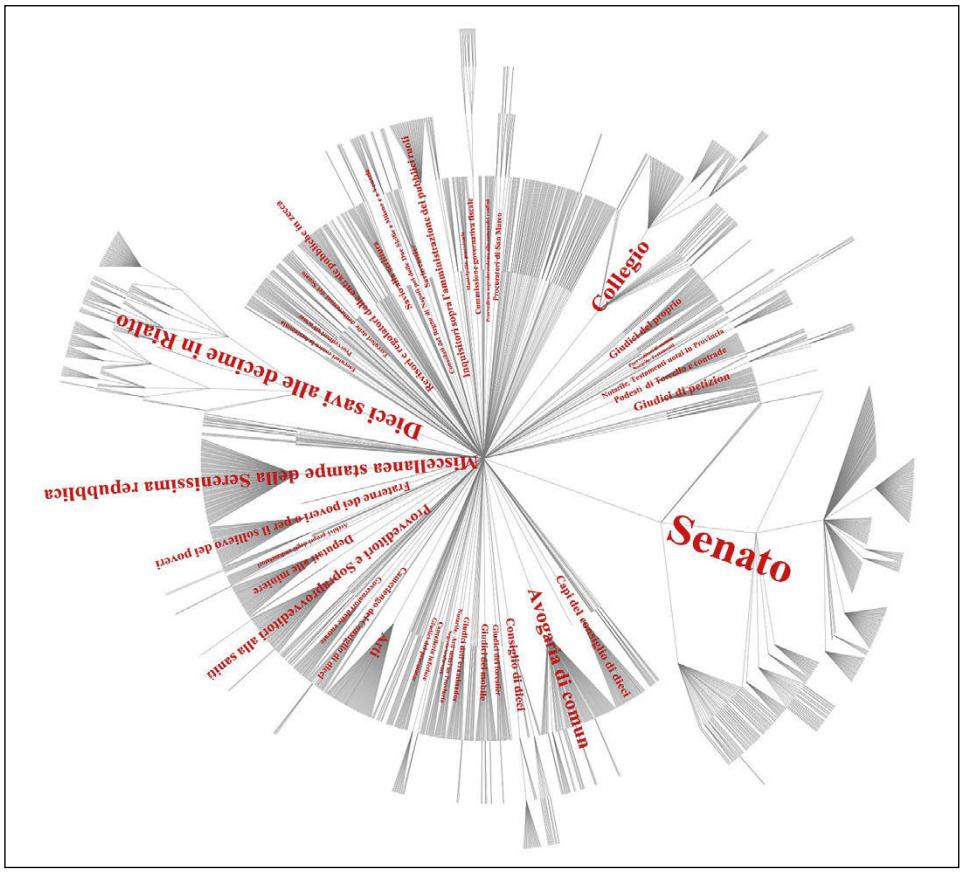


Fig. 1 – Hierarchical structure of Archives. Archives are generally structured in a hierarchical way that reflects the underlying operation and organisation of the institutions that created them (except for archives that have been, a posteriori, completely reorganised according to a different organising principle). Here we show a dendrogram map of the ASVe with over-impressed the names of the major archival fonds (the map shows only those fonds initiated under the rule of the Republic of Venice).

First, Big Data is wide-it consists of vast amounts of information generated daily-but thin, as it spans only a few decades since the advent of the Internet. In contrast, Long Data is relatively small in volume but extremely deep in the temporal dimension, containing records that stretch back over a thousand years and archival series that remain uninterrupted for centuries. Second, Long Data is far more valuable and rare than Big Data. Much of it is encoded in centuries-old manuscripts and concentrated in a limited number of archives. This rarity demands a significantly greater effort in its preservation, management, and analysis. Long Data is processed following rigorous

humanities standards for historical sources and represents a tangible form of cultural heritage in its digitised state. Due to the vast quantity of historical records in our archives, the complexity of transcription, and the constraints of traditional methods, only a small fraction of archival documents has been systematically integrated into our collective knowledge base. For example, in the case of the Senato collection at the Venice State Archive (ASVe), less than 1% of the documents have been transcribed (Fig. 1). This suggests that our understanding of the past may be far less complete than we assume, particularly regarding quantitative historical data, which remains largely unexplored.

The primary scientific goal of Long Data is to bridge this gap, providing historians and researchers across disciplines with comprehensive access to archival sources. By doing so, it enables the construction of a more complete and data-driven picture of our past.

2. What is complex networks theory?

The science of complex networks provides a powerful framework for analysing relationships and structures within vast and intricate datasets. Originally developed in fields such as physics, biology, and social sciences, network theory has proven to be an essential tool for uncovering hidden patterns and correlations in seemingly unstructured information. By representing data as a network of interconnected elements – whether individuals in a society, genes in a biological system, or historical figures in archival records – complex networks allow for a systematic and quantitative approach to studying connectivity and influence across different domains. One of the most significant contributions of complex network science is its ability to measure correlations and define a metrical space within a dataset. By quantifying the strength of connections between elements, it becomes possible to assess distances and similarities in a structured and mathematically rigorous way. In the humanities, this capability is particularly transformative, as it enables the mapping of relationships between historical entities, such as people, institutions, and events, based on archival sources (Fig. 2). This approach goes beyond traditional qualitative analysis, allowing for a quantifiable understanding of historical and cultural dynamics that were previously difficult to measure.

In the context of archival texts, network analysis can reveal latent structures and thematic clusters, providing a new way to interpret historical documents. By modelling texts as networks – where words, concepts, or entities are nodes connected by linguistic or contextual relationships – it is possible to identify patterns of influence, textual similarities, and the evolution of ideas over time. This application of complex networks in the humanities represents a paradigm shift, offering a mathematical foundation for exploring cultural heritage, much like how it has revolutionised other scientific fields.

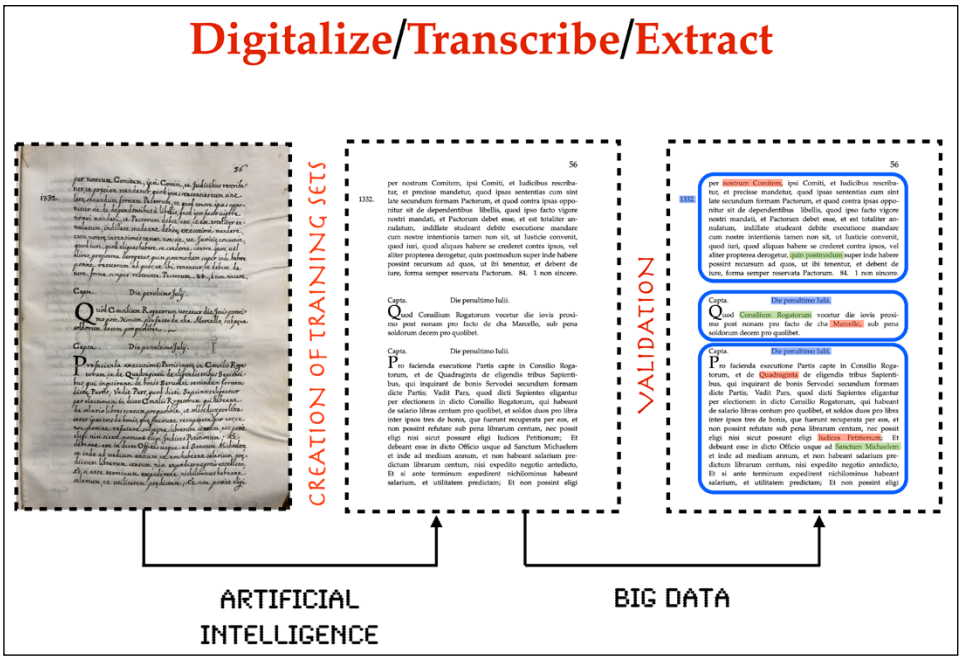


Fig. 2 – Long Data in action. After digitalisation, Artificial Intelligence is first trained on sample pages prepared by expert palaeographers and then used to automatically transcribe all compatible documents, which are successively validated by historians; feature extraction (people and locations in the example) follows document segmentation and dating (Big Data techniques); the resulting data is organised in a temporal multi-layer network that fully represents the information contained in the archival documents considered (Science of Networks approach).

3. Venice Long Data

On a broader scale, Italy is one of the most Long Data-rich countries in the world, with more than fifty state archives holding an invaluable wealth of historical records that remain largely untapped. The Long Data revolution presents a unique opportunity to transform the study of history and cultural heritage, breathing new life into archival research and elevating it to a cutting-edge, data-driven discipline for the 21st century. In particular, Venice, with its vast historical archives, libraries, museums, and private collections, along with its unique role in European and Mediterranean history, is the ideal starting point for the systematic development of the new science of Long Data. Among its many treasures, the Venice State Archive (ASVe) stands out as one of the richest Long Data repositories in the world. Spanning over 80 km of shelves and preserving more than a thousand years of uninterrupted records, ASVe offers an unparalleled depth and continuity of historical data, meticulously

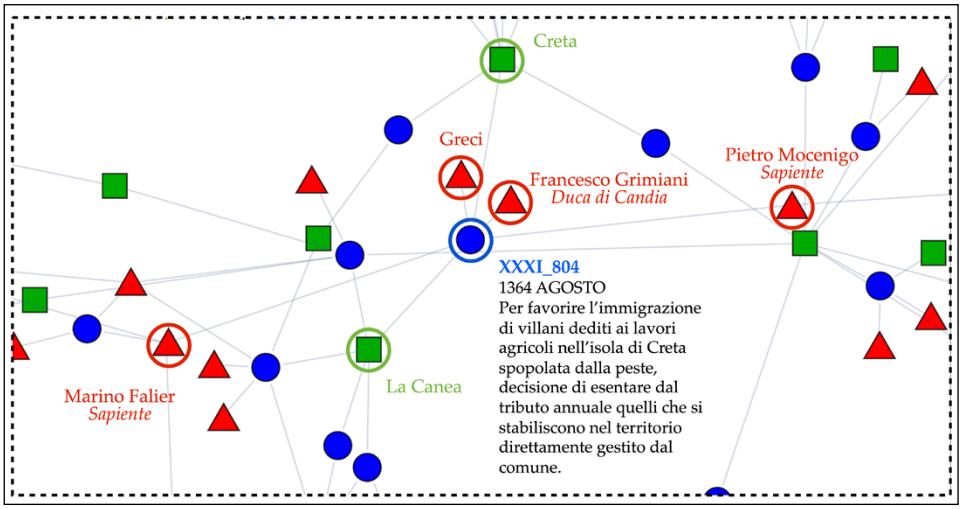


Fig. 3 – Temporal multi-layer network. The information contained in archival documents is naturally described by a temporal multi-layer network linking documents, people, locations and any other relevant quantitative or semantic data; this network structure is the basis for new integrated instruments for scientific studies and cultural experiences. In the Fig. deliberations from the Senato-Misti series (represented as blue dots) are connected to the people (red triangles) and locations (green squares) they (implicitly or explicitly) mention. The 'regesto' of deliberation n. 804 of register XXXI (August 1364) is shown as an example of additional data characterising a node.

conserved over centuries. This unprecedented richness allows us to propose an interdisciplinary research project that approaches historical inquiry from a quantitative perspective.

Rooted in the wealth of historical data provided by ASVe and other archives in the Venetian lagoon, the project integrates methodologies from Artificial Intelligence, Big Data, and Network Science. Its dual objective is to develop a historical meta-database, a fully transcribed, interconnected, and searchable digital version of the Venetian archives, and to establish the foundation for a quantitative study of the history of Venice, Europe, and the Mediterranean (Fig. 3).

4. Times are mature for Long Data

We can now realise the promises of the Long Data revolution because the time is ripe to integrate several cutting-edge technologies in the Digital Humanities, which have been evolving over the past two decades. First, digitisation has become standard practice in most archives, driven by the advancements of the Fourth Industrial Revolution. Second, automatic transcription of historical texts has significantly improved, thanks to the rapid progress in Artificial

Intelligence. Third, Natural Language Processing (NLP) and Semantic Web technologies have matured to the point where they can effectively handle the complexity of centuries-old archival sources. Beyond these advancements, we can also apply quantitative analytical methods from Network Science, which, for instance, propose the use of temporal multi-layer networks as a natural way to represent the rich, interconnected information encoded in historical archives. This approach enables a structural and dynamic understanding of archival data, revealing patterns and relationships that were previously difficult to analyse. The urgent task now is to coherently integrate these technologies to revolutionise how we study and preserve history. The time has come to adopt a quantitative, document-driven approach to our past, to systematically 'back up' our archives for better preservation, and to develop new ways of sharing and interpreting the invaluable stories they contain.

5. Multidisciplinary

Long Data has the potential to empower a new generation of humanists and scientists, fostering an interdisciplinary approach to history where network science, economics, social sciences, and historical studies converge to offer a new perspective on the past. By integrating diverse fields, Long Data provides a framework for collaboration between disciplines that traditionally operated in isolation, opening the door to innovative methodologies and a deeper, data-driven understanding of history. Several key domains contribute to the Long Data approach. Cultural Heritage Studies (Beni Culturali) play a crucial role in the management, preservation, and organisation of archives and artistic sources. Digital Humanities and Archival Sciences oversee digitisation, access, and storage while also setting the standards for digital preservation. Informatics provides the backbone for Artificial Intelligence applications in automatic transcription, as well as techniques to transform language into structured data and manage the databases encoding cultural heritage. History defines and oversees Long Data methodologies, ensuring the accuracy of transcriptions and the validation of metadata and extracted features. Network Science and Economics supply modelling tools and quantitative analysis techniques, while Linguistics enables the study of language and cultural evolution over time. Lastly, Communication Sciences and Information Design play a key role in dissemination and outreach, combining state-of-the-art infographics, compelling storytelling, and modern media to make historical insights widely accessible.

This (necessarily incomplete) list of interdisciplinary synergies demonstrates that Long Data stands as a powerful bridge between the humanities and quantitative sciences. It has the potential to revolutionise the way we approach, analyse, and share our collective cultural heritage, marking a paradigm shift in historical research and public engagement.

6. Outcomes and benefits of Long Data

In conclusion, the benefits and outcomes of an extended Long Data treatment of our historical archives are manifold and affect positively the whole system of cultural heritage as well scientific research in the humanities. The most relevant points are summarised as follows:

– Long Data techniques allow the extraction of all qualitative and quantitative information contained in our archives, including non-numeric language data and implicit information encoded in the structure and interlinking of the archives;
– Long Data offers a way to make a digital backup of our unique sources (just imagine the irreparable cultural heritage loss if fire or flooding affects an archive like the ASVe) and a way to construct online infrastructures for research that go beyond mere photographic digitalisation;
– Long Data allows the reconstruction of missing information by exploiting the inherent redundancy built into archives and ways to overcome the language barrier in the humanities (for example by automatic translation of meta-data and document summaries);
– Long Data stands as a candidate to incarnate the convergence of humanities and quantitative sciences, which will unleash a revolution in how we approach, think and disseminate our past and common cultural heritage;
– Long Data is a solution to the limitations imposed by global pandemics like Covid-19 that hamper scientific and historical research allowing complete online access to archival sources;
– Long Data fosters touristic and creative industries by making accessible to the general public the richness of our cultural heritage through innovative storytelling and engagement;
– Long Data offers lessons from the past that are relevant to our decisions on topics like climate change, pandemics and migrations.

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ABSTRACT

The article introduces the concept of 'Long Data' as an innovative approach to enhancing the cultural heritage preserved in historical archives. This concept distinguishes itself from Big Data by focusing on the deep historical context found in meticulously preserved archives, revealing valuable insights into cultural heritage. By using new Artificial Intelligence technologies in harmony with traditional archival methods, Long Data aims to analyze, transcribe, and model historical data on an unprecedented scale. This approach promises a more comprehensive understanding of history, improving studies on social and cultural evolution. A key example of Long Data's application is the Venice State Archive (ASVe), which holds documents dating back over a millennium. The initiative seeks multidisciplinary collaboration to make this vast archive accessible, thereby safeguarding cultural heritage and paving the way for a revolution in historical research.

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SHARING ASSESSED KNOWLEDGE, SHARING HERITAGE

1. Premise: Tangible Cultural Heritage as systems of contexts and processes

Within the CHANGES Project (Cultural Heritage Active Innovation for Sustainable Society), Spoke 8 focuses on integrating advanced technologies and scientific approaches to increase knowledge and enhance sustainability and resilience of Tangible Cultural Heritage (TCH). This Spoke thoroughly addresses the impact of anthropogenic, natural, and climatic factors on TCH, promoting integrated conservation strategies that consider the interconnection between cultural, social, and economic aspects. Furthermore, it focuses on the development of knowledge infrastructures and the promotion of participatory governance models that actively involve both public and private entities, as well as local communities, to ensure a sustainable and inclusive management of cultural heritage. The underlying premise of this research is that Tangible Cultural Heritage (TCH) can be conceptualized as a network of material entities – ranging from individual objects to structures and architectural complexes – distributed across space.

As physical entities identified (also) by specific spatial coordinates, elements of TCH inherently establish relationships with their surrounding environment. These relationships may be functional in nature or dictated by spatial proximity. Moreover, they are not static but subject to transformation over time. Similarly, the material entities themselves undergo modifications, as exemplified by architectural restorations or interior refurbishments that alter the fabric of a building. The interplay between these elements and their evolving relationships gives rise to contextual frameworks, which can be further aggregated into broader, more complex systems.

When applied to the past, this contextual-processual approach must contend with the fragmentary nature of the archaeological record. The original integrity of material entities and their relational networks has largely been lost, leaving only dispersed remnants. Objects often survive in an incomplete or deteriorated state, while architectural remains are typically reduced to ruins, stripped of the furnishings, decorative programs, colours and structural elements that once defined them. Moreover, the relational networks that once underpinned these contextual entities have been irrevocably disrupted.

Given this premise, the study of TCH necessitates a dual methodological approach (Fig. 1). The first objective is ontological, seeking to systematically document the fragmented remains of contexts and contextual systems. This process extends beyond the direct archaeological record to incorporate a

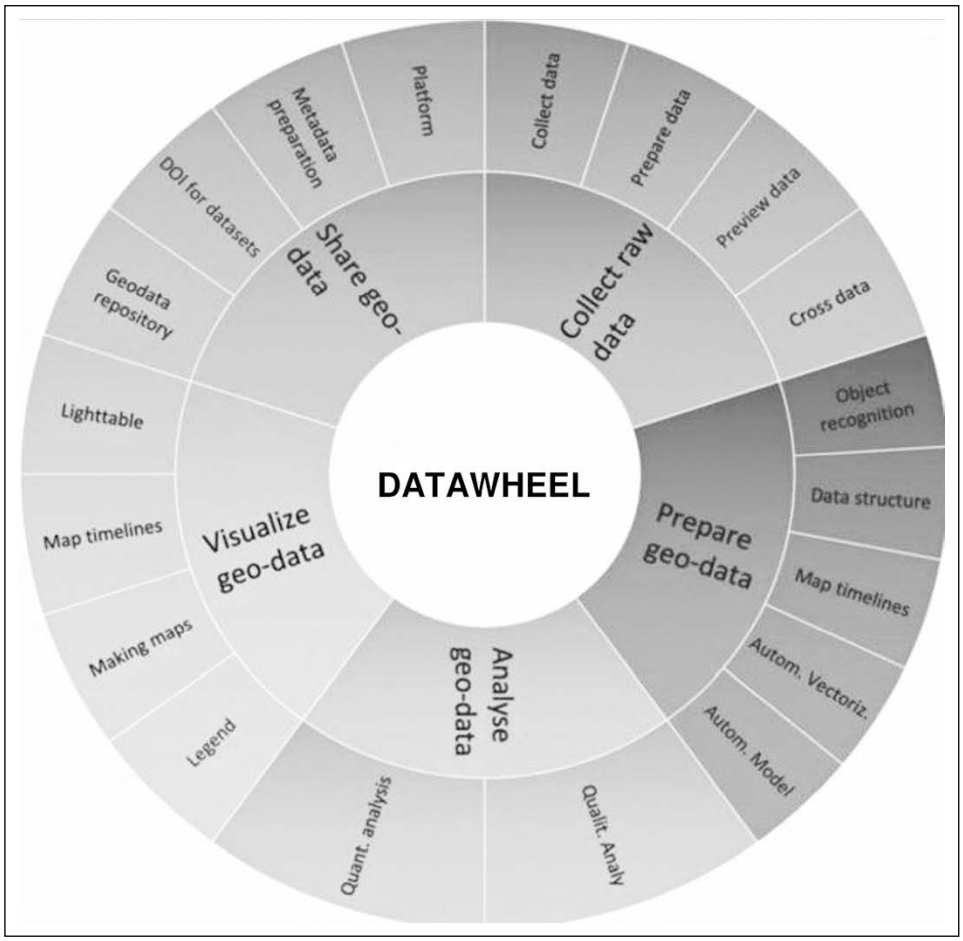


Fig. 1 – Datawheel methodology (el. Authors from Hein *et al.* 2022, fig. 31.1).

diverse range of historical sources, including literary accounts, ancient images (such as e.g. reliefs, images on coins), historical cartography, and post antique visual representations such as paintings, prints, drawings, and photographs from the Renaissance to the modern era. Any of these documents/sources of information can be located somewhere and dated – that is ordered spatiotemporally – thereby enabling the integration of many different kinds of information into topographical reconstructions.

The second objective is reconstructive, aiming to reassemble past contextual entities by examining the interrelations among fragmented

elements of TCH. Through the systematic cataloguing, classification, and spatiotemporal contextualization of these fragments, separate datasets can be transformed into systems of structured knowledge facilitating the reconstruction and dissemination of historical processes and cultural frameworks. This paper presents a selection of case studies that illustrates scientific approaches, common rules, methods, technologies and preliminary outcomes developed by the project.

2. Procedures for the creation of integrated archives and infrastructures of knowledge

2.1 *Sharing rules for assessing TCH data*

The first outcome of Spoke 8 has been to establish common methodological and operating rules which include: sharing both two-dimensional and three-dimensional information sources within a georeferenced geographic space; using the RDN 2008 coordinate system; integrating one-dimensional (textual), two-dimensional (graphic and topographic processings), and three-dimensional (3D models) data; adopting sustainable technologies already developed by other software designers; managing and assessing datasets composed of varied information sources; and developing best practices to enhance the understanding of TCH contexts while implementing strategies for their protection, enhancement, and communication of the associated historical and cultural contexts.

2.2 *From the Knowledge Map to contexts*

All the data have been collected in specific relational databases, which are part of an Information System. All archaeological, architectural, and topographical evidence, either visible or not but of certain location, can be georeferenced within an absolute coordinate system. In contrast, evidence related to epigraphic, textual, cartographic, iconographic, palaeobotanical, and paleoanthropological sources can be georeferenced either in relation to a fragment of the already mapped TCH (either visible or attested/documented) or to areas or sectors of the territory lacking archaeological, architectural, and topographical evidence. The first topographic representation of these data constitutes the Knowledge Map. Within it, where the information accumulates significantly or where it is few but sufficiently detailed, we can identify contexts that can be defined as UTs (Topographical Units; Carandini, Carafa 2017; Carafa 2021).

The UTs have a dual informational value and must be considered from two perspectives: topographical/morphological – as their position and architectural shape define the space in which they are located – and chronological, as each TU can be characterized by transformations that have

occurred over time. Topographical Units (UTs), when aggregated, can define large topographical ensembles that constitute complex realities, forming the different structures of the ancient landscape. For example, multiple UTs can constitute a complex (such as a boundary wall, altars, and temple of an extra-urban sanctuary) or a site, meaning a place considered and perceived as a unified entity in the landscape (for example: all the tombs of a necropolis, or all the buildings and infrastructures of a city), ultimately shaping the landscape.

3. Assessment and pilot cases

Such an assessment creates a series of cadastres in which all the documents have been (re-) connected to places. Thus, triggering a process of reconfiguration, reconstruction, and communication of monuments, ancient settlements, and, more generally, past (either ancient or post antique) architectural and topographical realities. These reconstruction activities push forward the assessment process, leading to different levels of analysis, from the reconstruction of frameworks to the storytelling and communication of the histories of the territories. This will be highlighted by the following case studies. They have been identified on the following criteria: readability of architectural and topographical features, along with their potential for geolocation and graphical representation; large-scale representation; extension no smaller than at least an extended urban area; multi-layered historical context; diversity and complexity of sources.

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3.1 *Ancient Latium project*

Ancient Latium project involves the mapping, classification, and reconstruction of the features that shape Lazio's landscape from prehistory to the Middle Ages (Fig. 2). This project builds upon the work carried out between 2018 and 2022 as part of an inter-institutional agreement between the Lazio Region and Sapienza University of Rome. The project aimed at the digital mapping of archaeological sites and assets dating from the 9th century BCE to the 6th century CE, located in the southern Lazio region, between the Tiber and Garigliano rivers (http://www.lazioantico.it/; Capanna, Carafa 2018; Carafa, De Paolis 2021; Carafa *et al*. 2021; Carafa 2022, 2024; Ippoliti 2023). The Ancient Latium project, in this context, served as a 'good practice' that connected the key players in scientific knowledge with the digital infrastructure that had been developed and enhanced in previous years through various innovative tools (such as the Single System for Cataloguing and Using the Cultural Heritage of the Lazio Region, the Regional Information System, the Regional Technical Map, and the open data portal).

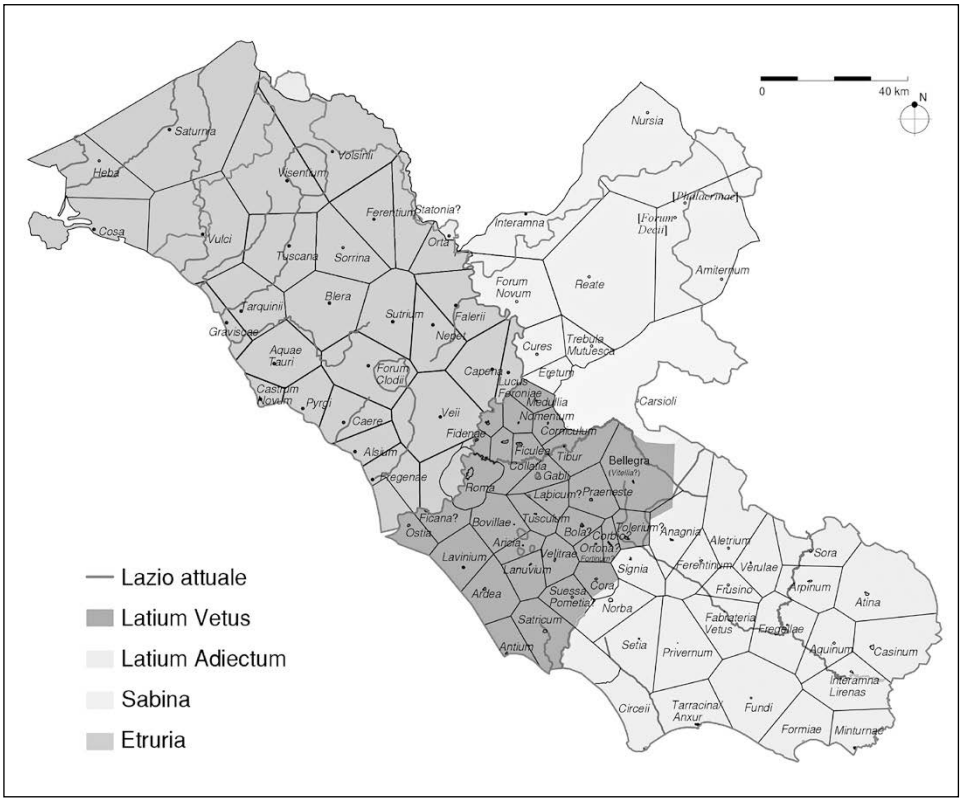


Fig. 2 – Map of ancient *Latium* with main sites and territories within the boundaries of Lazio Region.

The project promoted by Spoke 8 expands the disciplinary analysis by including epigraphical, archaeobotanical and paleoanthropological data, while also broadening its scope chronologically, covering a period from prehistory to the medieval era, and geographically, focusing on northern Lazio, which includes the provinces of Rieti and Viterbo, corresponding to the ancient territories of Southern Etruria and Sabina (including the Faliscan and Capenate areas). The research aims to present a historical narrative of the transformation of this region, analysed through the changes in its urban and rural landscapes. The vast amount of collected and standardized information will allow for a wide range of analyses aimed at defining regional and transregional processes, focusing on various topics such as the emergence, development, and eventual collapse of settlement systems. All of this aims to define different stages of cultural, social, and political complexity in the analysed territories.

The Ancient Latium project, in addition to having specific objectives, also enables the development of various thematic analyses from chronological, geographical, and topographical perspectives. In this regard, the first analysis has been focused on settlement patterns and their relationship with

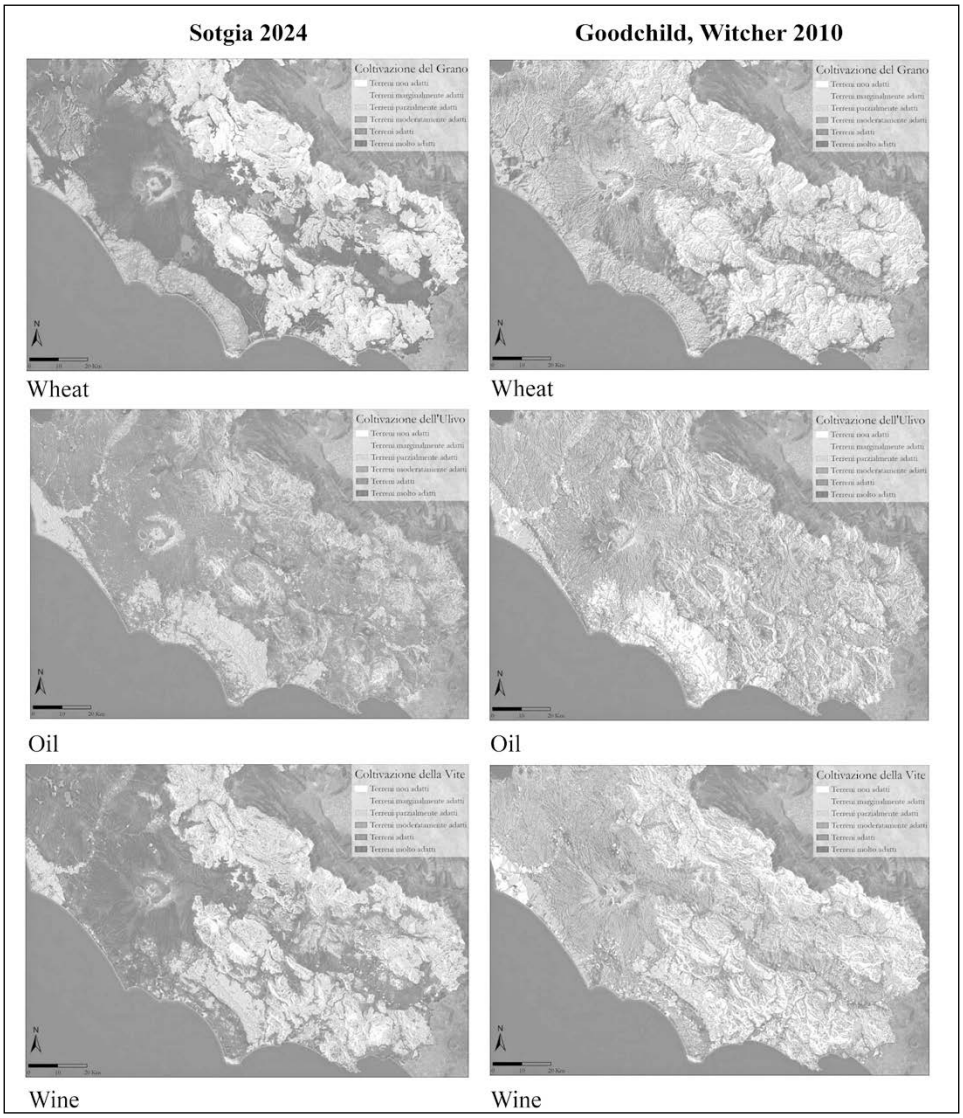


Fig. 3 – Land exploitation patterns and agricultural landscapes in Roman ancient *Latium* according to Goodchild, Witcher 2010 and Sotgia 2024 models.

environmental contexts during the prehistoric periods, examining how human settlements interacted with and adapted to their surrounding landscapes throughout time (Recchia, Marconi in press).

The second analysis investigated land use and agricultural productivity in Roman times, exploring how communities exploited and managed the land. It explores agricultural techniques, crop production, and the broader economic and social consequences of land use. The goal is to understand the connection between agriculture and the Roman economy, highlighting how natural resource exploitation played a role in the communities' growth and stability. Analyses of soil productivity have been conducted for vineyards, olive groves, and cereals, considering factors like geology, slope, exposure, elevation, humidity, soil fertility, erosion, and proximity to watercourses. These analyses are based on the *Atlante dei suoli del Lazio*, literary sources (notably works by Marcus Porcius Cato, Marcus Terentius Varro, Lucius Junius Columella, and Pliny the Elder), and GIS-based calculation methods (Goodchild, Witcher 2010; Sotgia 2024; Carafa, De Paolis 2025; Fig. 3).

A third level of analysis focuses on the environmental and historical-topographical study of a sub-regional area between Lazio and Umbria, falling across the northern border of ancient Sabina. This analysis examines the interaction between the natural environment and historical developments in the region, aiming to uncover the topographical features and how they influenced settlement patterns, cultural practices, and the broader historical context of the area. Specifically, the analysis focuses on the territory corresponding to the municipalities in the province of Terni, within the Valnerina region (Arrone, Ferentillo, Montefranco, Narni, Polino, Stroncone, Terni/*Interamna Nahars*). This area, which currently lacks a comprehensive assessed historical and territorial analysis, is a culturally rich and stratified context, shaped by the succession of different populations over time. It is a region where settlements and sanctuaries are found in low-density urban areas, and the relationship between archaeology and the natural and hydrogeological landscape highlights the region's territorial significance and uniqueness.

Given the complexity and multi-layered nature of this context, the analysis of this territory has been structured as an independent pilot case, named the Valnerina project, yet connected to the Ancient Latium project. Due to the largely rural nature of the area under study, it has been deemed essential to reconstruct and spatially analyse the physical landscape using a dataset that includes all the geo-environmental information required to reconstruct various geomorphological contexts. These physical landscapes, as parts of the cultural landscapes, include hills and valleys, exposed and subterranean rock, as well as deposits left by glaciers, rivers, and lakes that are perennial, seasonal, or now dried up. They are environmental contexts

subject to varying and modest degrees of change compared to anthropogenic contexts, yet they still evolve over time and influence settlement patterns and land use (McKnight, Darrel 2008).

Starting from a heterogeneous data set, it is possible to reconstruct the physical landscapes that characterized the study area from prehistory to the medieval period. To fill this dataset, various sources of information were gathered, including literary, toponymic, palaeobotanical, palynological, paleoenvironmental, and iconographic data, as well as landscape reports, regional technical maps, soil maps, geological maps, and digital elevation models (DTM, DSM, and DEM). This approach will enable the reconstruction, classification, and characterization of paleo-environmental

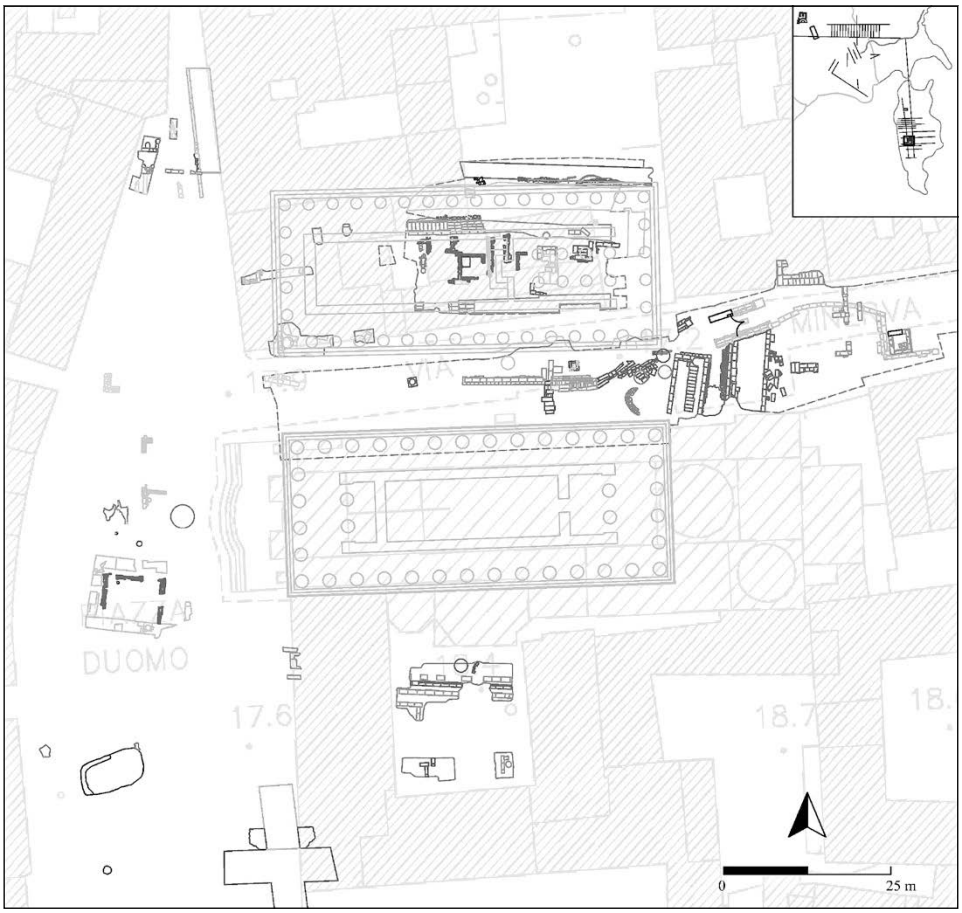


Fig. 4 – Syracuse, piazza Duomo area. Archaeological map of the evidence pertaining to the ancient city.

transformations, as well as the identification of forest resources, mining areas, and wetlands within the geographical space. Moreover, it will allow for the calculation of solar exposure and the examination of seasonal landscape changes, shedding light on how these factors influenced past human activities and settlements. The analysis of these information sources will enable the creation of digital orographic models, spatial analyses, and the definition of physiographic classes, all integrated within the historical and archaeological landscape context.

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3.2 *Syracuse - Toward an Atlas of an ancient Mediterranean metropolis*

Atlases represent a powerful instrument for cultural communication, enabling the narration of a place's history. The use of specifically designed cartography to illustrate the evolution of a landscape – whether a territory, an urban area, or a specific sector – contributes to visually reconstructing the key stages of historical, urban, and architectural transformations. We have previously employed this narrative approach to trace the changes in the urban landscapes of Rome within the Aurelian Walls, spanning from the 8th century BCE to the 5th century CE (Carandini, Carafa 2012, 2017).

As part of the CHANGES Project, we have started a new endeavour dedicated to the creation of an *Atlas of Ancient Syracuse*, following in the footsteps of the work created by Cavallari more than a century ago (Cavallari, Cavallari 1883). Since that time, the enormous amount of archaeological, architectural, and epigraphic data that has emerged in the city has never been systematized and transformed into a system of knowledge aimed at the narration of the history of the changing urban landscapes of Syracuse. Consequently, the Ancient Syracuse Atlas Project aims to pursue this goal covering a chronological span from pre/protohistoric evidence predating Greek *polis* to the de-structuring of the Roman urban framework. This work has been made possible through an Agreement between the Dipartimento di Scienze dell'Antichità of Sapienza University of Rome, the Assessorato Regionale dei Beni Culturali e dell'Identità Siciliana and the Soprintendenza per i Beni Culturali e Ambientali di Siracusa.

A significant contribution to this project derives from the integration and systematic reassessment of legacy data through specific classification procedures. These data, produced by scholars in vastly different historical and methodological contexts, require careful re-examination using contemporary archaeological and epistemological approaches. In this specific case, the access to the archive of excavation notebooks and diaries from Paolo Orsi's archaeological investigations has provided new and crucial insights into the urban and architectural organization of several sectors of Syracuse.

A preliminary outcome of the research is the assessment of a particularly significant sector of the ancient city, corresponding to present piazza Minerva and the Archbishop's Palace on the island of Ortygia. In antiquity, this area was part of the major central sanctuary of the island. Published documentation from excavations conducted in this sector by P. Orsi, G.V. Gentili, P. Pelagatti, and L. Guzzardi (Orsi 1910, 1918; Gentili 1967; Pelagatti 1973, 1982; Guzzardi 2012), has been critically re-examined alongside unpublished documents from Orsi's investigations in piazza Duomo (1922). This reanalysis has enabled the correlation, phasing, and chronological attribution of stratigraphic sequences and architectural structures. As a result, the historical development of this part of Syracuse's urban landscape has been articulated into five major chronological periods, further subdivided into ten phases, spanning from the Bronze age to the Roman era. Additionally, for each chronological phase, specific contexts and monuments have been identified and classified in UTs (see above): their construction, modification, and destruction marked the transformation process of this area (Fig. 4).

3.3 *Assessment for museums of local community. Amendolara and landscapes of ancient Sybaritides*

The historical narratives of different sites within a given territory, when examined through the lens of contexts and processes within a holistic framework, generate increasingly complex layers of assessment and provide critical insights for both museums and local communities. A compelling example of this methodological approach is the ongoing research in the territory of Amendolara, in the Upper Ionian region of Calabria. Here, a multi-scalar investigative strategy – ranging from sub-regional territorial analyses to the detailed study of individual contexts and assemblages of material culture – has been implemented through a formal collaboration agreement with Soprintendenza Archeologia, Belle Arti e Paesaggio per la provincia di Cosenza and Museo e Parco Archeologico di Sibari.

Within the broader scope of this research, encompassing the entire Upper Ionian area, a systematic study has been undertaken to gather and analyze all available data concerning past human settlement patterns, the diachronic distribution of habitation sites, and their functional classification (e.g., primary centers, villages, farmsteads, villas, necropolises, and production areas). This investigation has significantly benefited from datasets compiled during an extensive archaeological survey program conducted between 2000 and 2005, which aimed to reconstruct the ancient agrarian landscapes within the current municipal boundaries of Amendolara and Castrovillari (Carafa 2019, 2025 with previous bibliography; Capanna, Carafa 2021). The systematic surface survey – covering the entirety of the

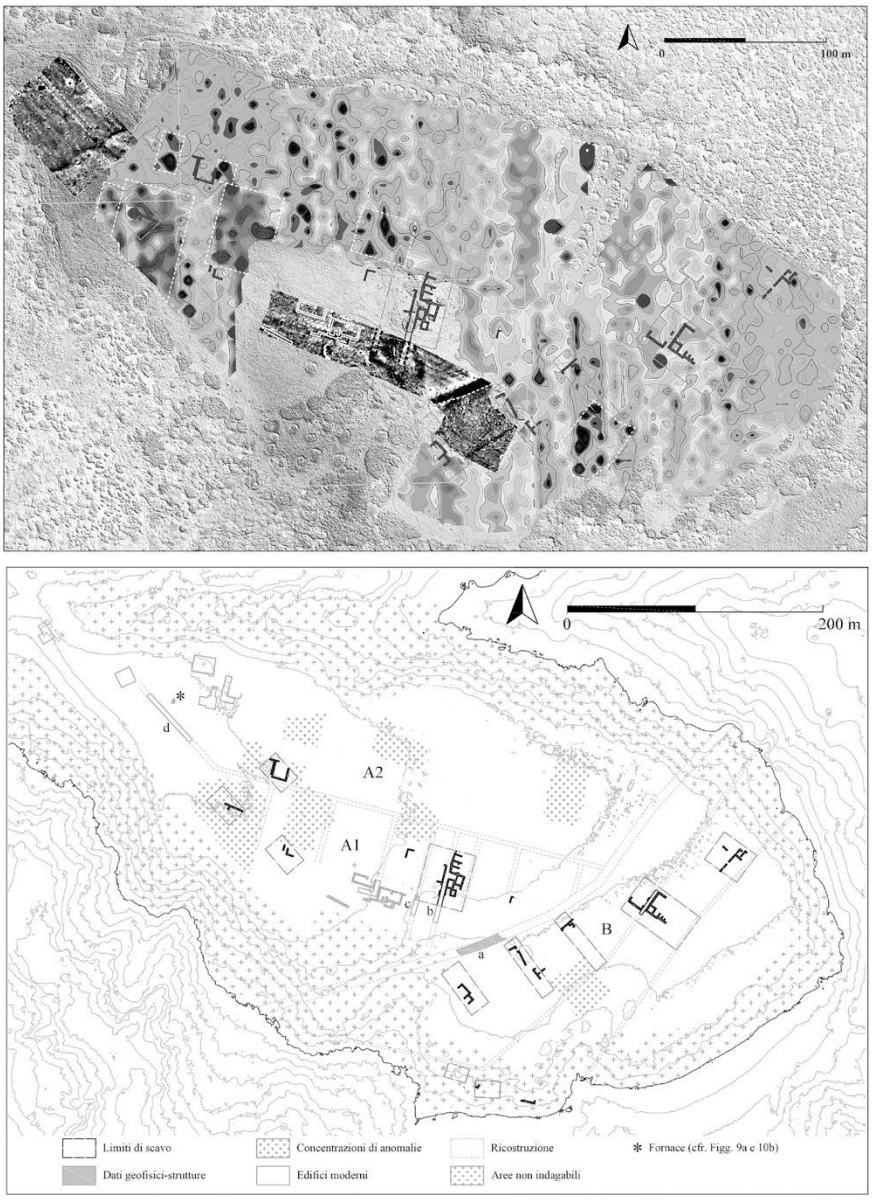


Fig. 5 – Amendolara (CS). Distribution of anomalies detected through magnetometric survey and identification of profiles and orientations detectable and compatible with buried archaeological remains. Above, in black, the archaeological remains identified during stratigraphic excavations; below, restitution of the distribution, extent, and configuration of anomalies compatible with buried archaeological remains and the main orientations detected.

Amendolara municipal territory and approximately 40% of that of Castrovillari – has yielded a substantial body of data, allowing for the reconstruction of settlement dynamics, the processes of demographic expansion and contraction, and the strategies employed for the exploitation and management of agricultural resources.

In parallel, a comprehensive cataloguing and analysis of artifacts and material culture assemblages recovered through stratigraphic excavations and field surveys has been initiated. These materials have been classified according to their respective settlements and chronological frameworks to reconstruct the networks of production and exchange that characterized this territory in antiquity.

A more targeted investigation has been dedicated to the topographical structure of a particularly significant settlement located on the plateau of San Nicola di Amendolara (CS) and to the socio-cultural identity of the community that once inhabited this site.

Archaeological research on the San Nicola plateau has been conducted through multiple field campaigns between 2021 and 2022. The methodological approach has integrated: 1) aerial mapping of the site and its surrounding landscape using drone technology and 2) geophysical prospections. The aerial survey aimed at generating a high-resolution three-dimensional digital terrain model (DTM) of the plateau, providing a detailed geomorphological framework within which to contextualize the spatial distribution of previously documented archaeological features (de La Genière 1970, 1991; de La Genière, Nickels 1975). Additionally, multispectral surface analysis was conducted to enhance the identification of potential archaeological anomalies.

Geophysical surveys, carried out over two distinct campaigns (2021 and 2022, Carafa *et al.* 2023; Carafa, De Stefano in press), initially focused on selected sample areas to test the diagnostic potential of different survey techniques, specifically magnetometry and ground-penetrating radar (GPR). The objective was to assess the comparative effectiveness of these methods in preparation for a broader-scale investigation. Both techniques detected anomalies consistent with buried archaeological remains; however, comparative analysis demonstrated that magnetometry provided a clearer and more interpretable dataset. Consequently, during the 2021 campaign, a large-scale magnetometry survey was extended across the entire San Nicola plateau, with the exception of areas rendered inaccessible due to dense vegetation or challenging topographical features.

The research conducted thus far on the San Nicola plateau has yielded significant preliminary results, contributing to a more refined understanding of the ancient settlement (Fig. 5). The integration of archaeological data with remote sensing and geophysical survey results has enabled the reconstruction

of the site's spatial organization and the identification of key structural patterns across different sectors of the promontory. These findings will serve as a foundation for the strategic planning of future excavation and research initiatives.

Alongside investigations focused on the built environment, a parallel line of inquiry has been dedicated to examining the community that inhabited the site through the analysis of associated necropolises. The funerary contexts of San Nicola di Amendolara have been the subject of only partial and systematic publication (de La Genière *et al.* 1981; de La Genière 2012), with the eastern sector of the so-called Paladino necropolis remaining unpublished. Within the framework of the ongoing research agreement, the study of this sector has now commenced. This area corresponds to a funerary zone utilized primarily between the late seventh and early sixth century BCE and the late sixth century BCE, a period that coincides with the peak expansion and political dominance of the Greek colony of Sybaris. This chronological correspondence suggests the likely integration of the San Nicola settlement within the broader territorial sphere of Sybaris. The findings from this study, soon to be published, have facilitated a preliminary reconstruction of the social composition of this community and have shed light on evolving funerary practices and cultural customs during a pivotal phase in its historical development.

The various research approaches employed – spanning multiple investigative scales – have generated new cultural content that has been directly incorporated into the curatorial design of the newly conceived exhibition at the Museo Archeologico Nazionale della Sibaritide and the development of the forthcoming Museum of Prehistory of Sibaritide in Amendolara.

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4. Concluding remarks

The Spoke 8 project is aiming at the creation of a multidisciplinary unit dedicated to enhancing the understanding, actualization, management, and dissemination of contexts, territories, and assets within TCH. The project's cultural and scientific premises are supported by a well-tested workflow, applied across several case studies. Therefore, isolated and fragmented data are turned into shared systems of knowledge. More than this, suggested procedure is basically oriented towards an innovative operating track inspired by the Datawheel methodology by Carola Hein and a group working on Maritime Heritage at Delft University of Technology (Hein *et al.* 2022). Different datasets are implemented thanks to advanced disciplinary philologies and approaches, thus validating trans-disciplinary assets available for the first time at abroad scale for the TCH management, at least in this country.

Such assets are also related to places and space transforming landscape in the main hub for the knowledge of the Heritage itself. Locating information will help in focussing our 'scientific knowledge' on specific problems and contexts in the perspective of a data driven management system.

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ABSTRACT

Within the CHANGES Project, Spoke 8 focuses on integrated advanced technologies and scientific methods to enhance the sustainability and resilience of Tangible Cultural Heritage (TCH). The project fosters the creation of a transdisciplinary unit aimed at improving the knowledge, understanding, management, and dissemination of TCH contexts and assets, supported by innovative workflows and methodologies. It emphasizes transforming fragmented data into shared systems of knowledge. By geolocating information, the project

directs scientific focus toward specific problems, promoting data-driven, interdisciplinary approaches for sustainable heritage management. The case studies, including the Ancient Latium, Amendolara (CS), and Syracuse projects, represent preliminary outcomes of this methodology, encompassing the systematic inventory and classification of diverse data, the assessment of knowledge frameworks, and the implementation of cultural narratives.

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THE SEMANTIC CENSUS: A NEW EXPRESSION OF THE CENSUS OF ANTIQUE WORKS OF ART AND ARCHITECTURE KNOWN IN THE RENAISSANCE AS OPEN DATA

1. Introduction

The Census of Antique Works of Art and Architecture Known in the Renaissance is a research project that has developed continuously since 1946. For over 75 years, it has attempted to answer a specific question: which antiquities were known in the Renaissance? Its objective has remained that of matching ancient artifacts with Renaissance visual representations and texts that depict or reference them. The Census project initially took shape as an analog system of index cards and photographs. Beginning in the early 1980s, it was digitized with the support of the Getty's Art History Information Program. It is among the first digital art history projects and possibly the oldest still in active use (Bartsch 2008). The Census database has undergone numerous technological advancements – from UNIX, to the Dyabola MS-DOS system, to CD-ROM, to an open-access database on EasyDB – and, since 2023, has been accessible on fylr, the latest iteration of EasyDB, at https://database.census.de.

Recently, between 2021 and 2023, the Census has taken further steps: its dataset was modeled according to the CIDOC-CRM ontology, creating a set of Semantic Census models that explicitly represent the knowledge and data contained within it. It was transformed into RDF following these models and made available first on Zenodo (Nenova, Bruseker 2023c) and subsequently on the eDoc server of the Humboldt-Universität (most recently, Christian 2024). With this latest shift, the Census has progressed toward the goal of FAIR data representation, delivering a corpus of rigorously researched, curated art historical data for new investigative programs beyond its original scope[1].

When it began, the Census was focused on figural antiquities and was guided by an interest in the origins of the Renaissance (1400-1527), when classical antiquity was once again 'known'. In the 1980s, the project expanded to include architecture and to encompass the whole of the sixteenth century. Now, the Census continues to evolve both methodologically and technically. At a time when born-analog research projects are being integrated into large-scale national and international research infrastructures and knowledge

[1] The semantic modeling of the Census data took place between 2021 and 2023 as a collaborative effort among the authors and was supported by generous funding from the Berlin University Alliance.

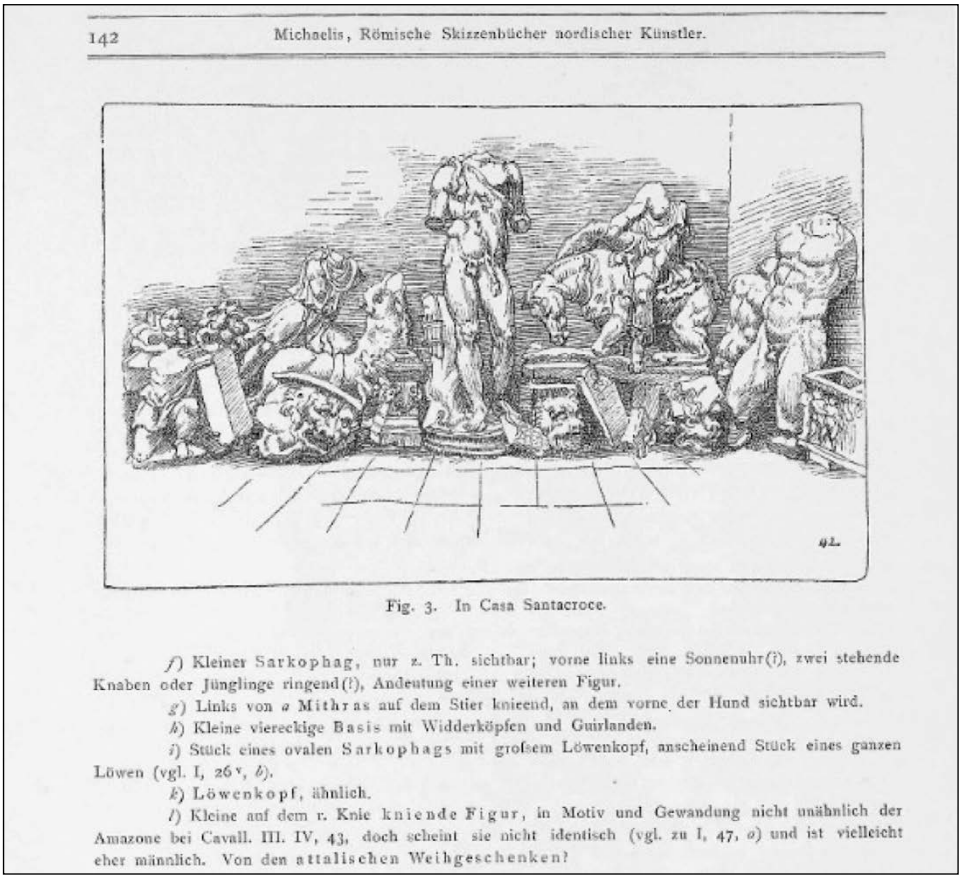
graphs, what opportunities does linked data offer for utilizing, challenging, or expanding this historic dataset? This article provides background to the Census project and its development over time, then describes the rationale and method of Semantic Census, which aims to meet the needs of the present digital landscape while laying the groundwork for future developments. It outlines how the Semantic Census builds upon the scholarly tradition of the analog Census, opening it to broader contexts, and concludes by addressing structural challenges.

2. Census history

The origins of the Census can be traced to a letter of September 1945 by the art historian Richard Krautheimer, who with his wife, Trude Krautheimer-Hess, was writing a monograph on Lorenzo Ghiberti (1378-1455). In correspondence with Fritz Saxl, director of the Warburg Institute, Krautheimer complained about a lack of basic research on the antique objects that might have inspired Ghiberti. He asked if they should organize «a corpus of antiquities known to the 15th century». Saxl responded enthusiastically, agreeing that «it is time that somebody, either at New York University or with us, tackled the subject» (Trapp 1999; *75 Years*). In the spring of 1946, Krautheimer and Saxl formulated their plans for a project that would correct a vague and inexact sense of the classical influences absorbed in the Renaissance, replacing it with hard facts about which antiquities were known, when, and where.

From its inception, the Census was not concerned with Renaissance adaptations of the antique, but with a corpus of antique artifacts that could be matched with Renaissance artistic or textual representations. Krautheimer and Saxl, with the support of Karl Lehmann at NYU, appointed the American archaeologist Phyllis Bober to develop the Census, which would occupy her from the 1940s to the 1980s. In devising a methodology, Krautheimer and Saxl followed a project developed in the 1930s by another exiled German art historian, Ludwig Burchard, who had compiled index cards at the Warburg Institute about the antiquities known to 17th-century artists (Lu 2023). The approach taken by the Census was, moreover, fundamentally shaped by a type of archaeological cataloging of Renaissance drawings first pioneered by Otto Jahn and developed by Adolf Michaelis and Christian Hülsen.

Whereas studies like Michaelis's catalog of the drawings of Maarten van Heemskerck (Michaelis 1891; Fig. 1) began with Renaissance works of art and compiled lists of the antiquities they depicted, the Census would reverse this approach by starting with specific antiquities and listing the Renaissance visual and textual descriptions that documented 'knowledge' of them. The



142 Michaelis, Römische Skizzenbücher nordischer Künstler.

Fig. 3. In Casa Santacroce.

f) Kleiner Sarkophag, nur z. Th. sichtbar; vorne links eine Sonnenuhr(?), zwei stehende Knaben oder Jünglinge ringend(?), Andeutung einer weiteren Figur.

g) Links von *a* Mithras auf dem Stier kniend, an dem vorne der Hund sichtbar wird.

h) Kleine viereckige Basis mit Widderköpfen und Guirlanden.

i) Stück eines ovalen Sarkophags mit grofsem Löwenkopf, anscheinend Stück eines ganzen Löwen (vgl. I, 26 v, *b*).

k) Löwenkopf, ähnlich.

l) Kleine auf dem r. Knie kniende Figur, in Motiv und Gewandung nicht unähnlich der Amazone bei Cavall. III. IV, 43, doch scheint sie nicht identisch (vgl. zu I, 47, *a*) und ist vielleicht eher männlich. Von den attalischen Weihgeschenken?

Fig. 1 – Page from Michaelis 1891, 142.

Census method was to create index cards, each labeled at the top with the name of an antique monument. Information about the object's excavation, restoration, and Renaissance documentation (such as drawings, statuettes, prints, or texts) followed, along with relevant bibliography. The index cards were matched in the Warburg Institute's Photographic Collection with images (Fig. 2) and, through transatlantic cooperation, two analog Censuses of index cards and photographs grew in parallel: one in NYU and one at the Warburg Institute (Trapp 1999; *75 Years*). Those familiar with the handbook *Renaissance Artists and Antique Sculpture* by Bober and Ruth Rubinstein (Bober, Rubinstein 1986) will recognize the origins of this reference guide in the working methods of the analog Census.

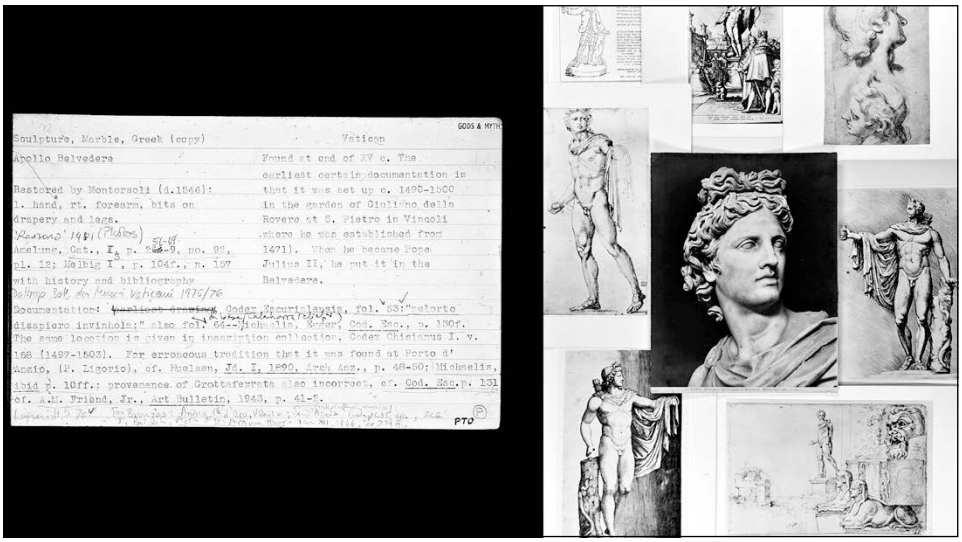


Fig. 2 – Warburg Institute, Photographic Collection, the Analog Census: Census card and photographs related to the Apollo Belvedere.

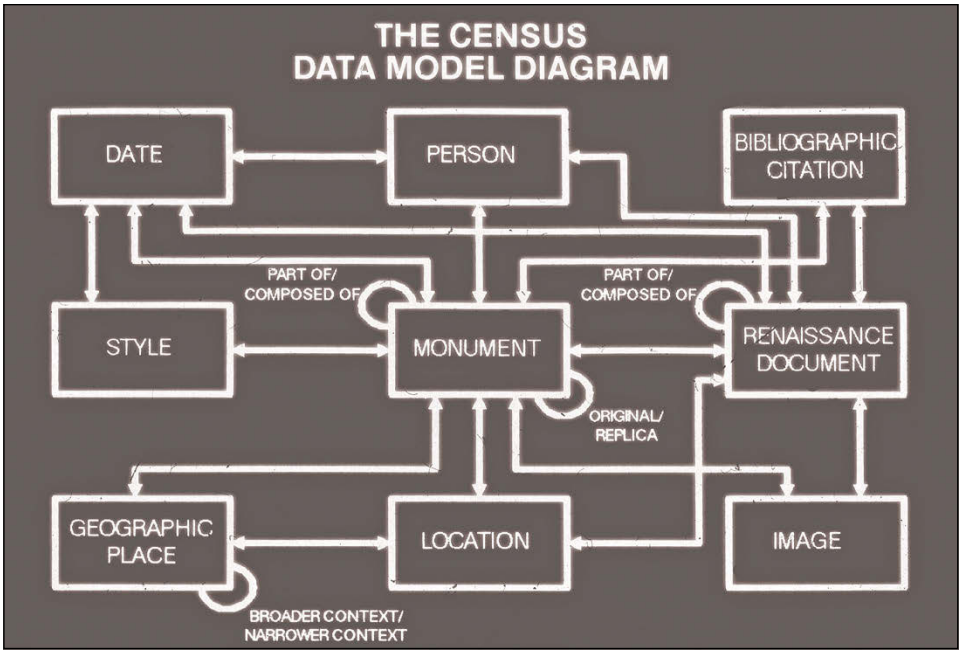


Fig. 3 – Original Census data model.

In the early 1980s, the Bibliotheca Hertziana joined the Census as a supporting partner, and the project was expanded to encompass architecture and the entirety of the sixteenth century. Starting in 1982, the Getty's Art History Information Program sponsored the development of a database system to access and search materials both in the Census and in the Witt photo archive of the Courtauld Institute. Arnold Nesselrath and the computer scientist Rick Holt developed a data model for the Census that linked two primary files: monuments (antiquities) and documents (the Renaissance texts and images that demonstrate knowledge of these antiquities). An additional set of 'authority files' (places, persons, bibliography, dates, and styles) was linked to these primary files (Nesselrath 1993; Bartsch 2009) (Fig. 3).

The digital representation of the Census put it on the cutting edge and gave it a more prominent profile at a time when art-historical interest in the reception of the antique was broadening (e.g. Settis 1984-1986). Its ordered data model provided the project with a systematic organization, which was preserved and adapted to new formats. The project moved to Berlin in the 1990s with Nesselrath's appointment as a Professor at the Humboldt-Universität, and further expansion of the content of the database was achieved through the addition of the Corpus Winckelmann and through collaboration with focused projects (*Linked Projects - Census,* https://www.census.de/en/linked-projects/).

As the Census database grew in content and became increasingly accessible, it served as a roadmap of antiquities and their Early Modern representations, filling a significant gap in research caused by the fact that antiquities in the Early Modern period were traditionally not a core concern of either archaeology or art history. At the same time, the early adoption of a fixed data model and a hierarchical, relational database format locked in a structure that could not be easily changed. Reservations about dryness and rigidity had followed the Census project since its origins (Bober 1989; Trapp 1999) and in 1982, at the earliest stages of digitization, Bober expressed hope that a computerized Census could retain a sense of flexibility and openness suited to individual use. The Census should be programmed in Pascal, she proposed, or another language likely to be taught in free evening courses, so that researchers could «make up their own program to use the data base in new searches we might not have anticipated» (*75 Years*, room 3).

The Census data model developed during an era of significant technical restrictions, when the digitization of images (originally stored on laserdisc) was highly resource-intensive. The structural and technical limitations of the systems available in the 1980s guided the database's rules of admission as well as its strict focus on its principal aim, which was to connect genuine

antique monuments with Renaissance images or texts that documented them. Defining one-to-one links between antique monuments and Renaissance documents has remained over decades the core work of the Census database, yet by today's standards, such a data model seems rigid and restrictive, prohibiting the type of flexibility that Bober hoped to achieve. Over the years, proposals have been made to expand its functionality, specifically to transform the Census into a graph database to allow it to function as a complex network (Schich 2009).

The use of databases in the humanities generally has, in numerous ways, been called into question, and much research has been invested in more nuanced, more adaptable alternatives (Oldman 2021). Although a new representation of the Census data in an entirely different format has so far remained out of reach, since 2020 the first steps have been taken to make the dataset more dynamic and more open. For example, with the relaunch of the Census in fylr (in April 2023) the categories 'Monument' and 'Document' were renamed 'Antique Monument' and 'Postclassical Work'. This change acknowledges the integrity of drawings, sculptures, and texts as creative works in their own right, while complicating their status as straightforward 'documents' proving Renaissance knowledge of antiquities (Sawatzki 2023). 'Antique Monument' is now also redefined as a more ambiguous category, which «may also include deliberate falsifications of antiquities, or objects which were judged incorrectly in the Early Modern period to be antique» (*Census Data Model Documentation*: https://census-antiquity-renaissance.github.io/census_csdm/; Mantilla 2023; Miller 2024). Another key focus, as is detailed below, has been the transformation of Census data into semantic data in order to expand the project's reach, enable its data to be utilized beyond its original framework, and open it up to broader scholarly engagement.

3. From digital resource to Linked Data

As a long-lived and successful project, the Census has spanned multiple technological shifts during the course of its existence. Moving through several analog stages and embracing the digital shift early on, it has had to evolve in dialogue with the advancement of information management technologies. Doing so, as has been detailed above, has meant both reaping the benefits and experiencing the limitations of those technologies as they arose. One approach to information management that has emerged over the later period of the Census's history is the proposal of the semantic web and Linked Open Data (Berners-Lee *et al.* 2001; Bizer *et al.* 2023). This method offers an opportunity to create an additional representation of the Census data that would not only preserve its original value but would also simultaneously free

it from the particular research perspective of its origin, to act as raw data for new research questions and methods, in art history, in archaeology, and also potentially outside of these disciplines entirely.

The idea of the semantic web proposes that data be encoded in a way that is not only human-readable but also machine-processable (Antoniou, Van Harmelen 2004). By adopting agreed common data structuring methods – formal ontologies – it proposes expressing data through a lingua franca for data encoding that is both recognizable and usable for members of a common domain, such as art history, while also being logically processable by algorithms and queries (Guarino 1997). The notion of Linked Open Data builds on this by ensuring that data is assigned unique resource identifiers, making unique items in the common data web referenceable and potentially discoverable. Linking the data by semantically meaningful predicates aims to make it fully accessible without the barrier of an idiosyncratic data structure. Together, these proposals form a key part of the concept of FAIR data (Carballo-Garcia, Boté-Vericad 2022), which has become a primary objective of the collaborative research community and, increasingly, a requirement for publicly funded research. FAIR data ensures that publicly funded data is accessible and reusable, while enabling research results to be integrated across projects over time.

Curated over several generations of scholarship, the Census dataset offers a rich seam of research data for representation in the semantic web. Moreover, its evolution as a project and dataset parallels many of the core aims of such a diachronic research effort. While the Census, as outlined above, began with targeted scholarly goals, shifts in methodology and changing interactions of scholars stretched its capacities, expanding the scope of the original data structure and of the data collected. The demands of the research, moreover, made interinstitutional data gathering and sharing a necessity. Its early digitization program, supported by the Getty, provided the Census with its first data model and engaged it in the question of how to explicitly document and share data over time. Thus, while the Census could be caricatured as a so-called data silo, its evolution shows how, in pursuing its aims, it has naturally transitioned from rigid curation criteria – dictated in no small part by the recording methods then available (index cards, early database systems) – to an international effort advancing scholarship on the reception of antiquity and on Early Modern visual culture more broadly. Thus the creation of a Semantic Census – an expression of the Census data that provides an open and reusable version of the dataset for scholars – continues the project's broadening over time and constitutes an important adaptation to the changing digital scholarly landscape. The Linked Open Data approach offers an alternate representation that removes the limitation of the record boundary, aiming to create an open network of knowledge.

4. Analysis and semantic data modeling

The first step in creating a Semantic Census was to initiate an analysis of the Census database in the first place. The case of the Census data model was particularly interesting for this process. While many data structures grow organically from the needs of research projects or are imposed top-down from the adoption of softwares which dictate an extant data structure with little or no ability to alter it, the Census data model was deliberately devised with the scholarly intent of the data recording in mind. The Census data model, devised already in the 1980s by Nesselrath and Holt, had features anticipating a semantic database already, without the formalized semantic encoding. At the heart of the data structure lay the division between Monument and Document and the relation between them. The primary focus of cataloging in the information system was monuments in antiquity. Criteria for inclusion as instances of this class were their being (a) genuinely antique and (b) referenced in a Renaissance document. The other most important class of the original data structure was the document. A document was defined as a Renaissance work, such as a drawing, print, text, or sculpture, which provided a response to the antique monument. The key relationship mapped in the Census is one of witnessing or giving evidence of an awareness, knowledge, or perception of antique monuments in the Renaissance era. Supporting these were a series of models recording persons, images, bibliography, dates, and locations.

The initial work of understanding the model for its semantic representation involved reviewing the extant documentation in sessions between Census staff and the semantic modeling team. These sessions aimed to clarify both the original intent of the models and their actual use over time. To generate a semantic dataset, a formal ontology – a high-level semantic language suitable for the dataset – must be chosen, and the original data must be translated from regular tabular format into a semantically encoded and meaningful information structure. To approach the modeling of this data, the CIDOC CRM (Bekiari *et al.* 2021) was selected as the base formal ontology for semantic representation. This decision was grounded in considerations of both adequacy and practicality. In terms of adequacy, the scope and range of the CRM ontology – which models cultural heritage and historical facts over time – aligned with that of the Census data. In terms of practicality, the CRM is a widely adopted standard in cultural heritage data projects, facilitating broader uptake and reuse.

Beyond adopting the CIDOC CRM as the semantic framework, the project aimed to create semantic translations of the original data according to commonly used patterns to ensure maximum compatibility with potential overlapping datasets. It anticipated future collaborations with like-minded

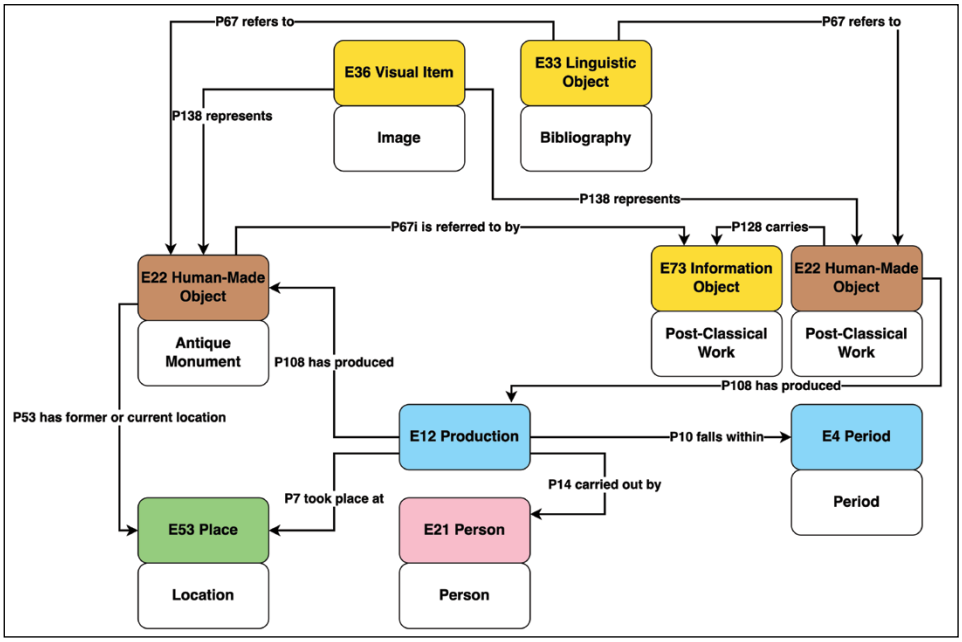


Fig. 4 – Overview of the Census ontology.

research initiatives such as those represented in the CORDH network (https://www.cordh.net/) of which the Census is a member. The Swiss Art Research Infrastructure's Semantic Reference Data Models (SARI Documentation, https://docs.swissartresearch.net/), offered within this network, serve as guidelines for basic modeling decisions in art and architectural semantic modeling using CIDOC CRM, which made them an ideal starting point. These models offer common semantic modeling patterns for basic entities in the cultural heritage sector, as well as common patterns for translating atomic elements of information, such as names or identifiers. Adopting such patterns streamlined the modeling process by providing ready-made solutions to potential problems, so that modeling efforts could concentrate on difficult areas of documentation where the ontology or the patterns did not have a predefined solution.

This process resulted in the development of eight Semantic Census models. These models provide an expression of the data captured by the original Census data structure, now aligned with the CIDOC CRM ontology. Fig. 4 provides an overview of the top-level modeling and the main connections between the models. The semantic modeling process was not unidirectional, but resulted in a reconsideration of the original models themselves. Thus with

the relaunch of the Census database in fylr in April 2023, 'Monument' and 'Document' were renamed 'Antique Monument' and 'Postclassical Work', respectively, to better describe the contents of the Census. These categories are represented neutrally as instances of E22 Human-Made Object in the CIDOC CRM ontology. Additionally, to reflect research taking place in the field of classical reception, the category of 'Antique Monument' was expanded to include not only works dated by archaeology to antiquity, but also works that were perceived as being antique during the postclassical era. Individual time spans previously documented in the 'date' model were reassigned to the relevant items and events which they temporally delineate. Periods and styles were recognized as reference data in their own right, requiring their own documentation, and were matched to the class E4 Period.

Each of the models is based on the data contained in Census records. But these models also allow the data to transcend the confines of the Census data model, aligning it with the CIDOC CRM framework. Integrating the data into an open semantic web enables reanalysis and reuse according to questions and concerns that extend beyond the original cataloging function. It allows the thoroughly-researched data of the Census to serve as authoritative reference data for other projects, facilitating both appropriation and critique.

5. Semantic data model documentation

The adoption of the semantic reference data model technique (Bruseker *et al.* 2025) offered a significant advantage to the Semantic Census project. It provided not only for a semantic translation of the data, but also for a standardized documentation of that model accessible to scholars, who may not be well-versed in semantic data, thereby supporting the potential reuse of Semantic Census data. The uptake in digital skills which Bober imagined in 1982 is still not realized in the fields of archaeology and art history in 2025. Bridging this technological gap requires the development of accessible pathways that enable individuals to understand and manipulate data. This goal motivated the adoption of an intensive work plan to document the Semantic Census data models in a way that is understandable to both scholars and engineers.

The semantic reference data model methodology suggests documenting semantic data projects in units of models, collections, and fields. Each unit corresponds to familiar data patterns, such as forms and tables, with which scholars are acquainted. They are defined using terminology oriented to the scholar but linked to explicit formal representations in the target ontology. The outcome of adopting this methodology was the elaboration of a rich documentation detailing the meaning of the semantic models for their long term reuse (Nenova, Bruseker 2023a), which can be accessed here:

Model Name	CRM Class	Documentation Link
Antique Monument	E22 Human-Made Object	https://tinyurl.com/46hpxs3e
Post Classical Work	E22 Human-Made Object	https://tinyurl.com/bdhud3nh
Person	E21 Person	https://tinyurl.com/9xp4ckm7
Location	E53 Place	https://tinyurl.com/3kwbu8d7
Image	E36/D9 Visual Image	https://tinyurl.com/3n4sp9ke
Period / Style	E4 Period	https://tinyurl.com/d5cmh5yp
Bibliography	E33 Linguistic Object	https://tinyurl.com/ahfe64wk

Moreover, by adopting the Semantic Reference Data Model methodology, we were able to reuse many patterns from the SARI SRDM while explicitly documenting the new fields, collections, and models proposed by the Semantic Census. In total, the Semantic Census added 95 fields and three collections, and it built eight new models. This documentation provides a guide to understanding the Semantic Census data, creating data from scratch that would integrate with it, and transforming existing data into a compatible form.

6. Mapping and transformation

After developing an ideal set of documented SRDMs, the target model for a semantic data transformation was set. In keeping with the goal of making the Semantic Census data FAIR, an explicit and reusable process to transform the extant data to a semantic format was created. For this process we used the X3ML mapping language and the 3M (Mapping Memory Manager) tool (Marketakis *et al.* 2017). This technology was chosen because X3ML is a declarative mapping language that enables explicit mapping instructions to transform data from a source to a target semantic

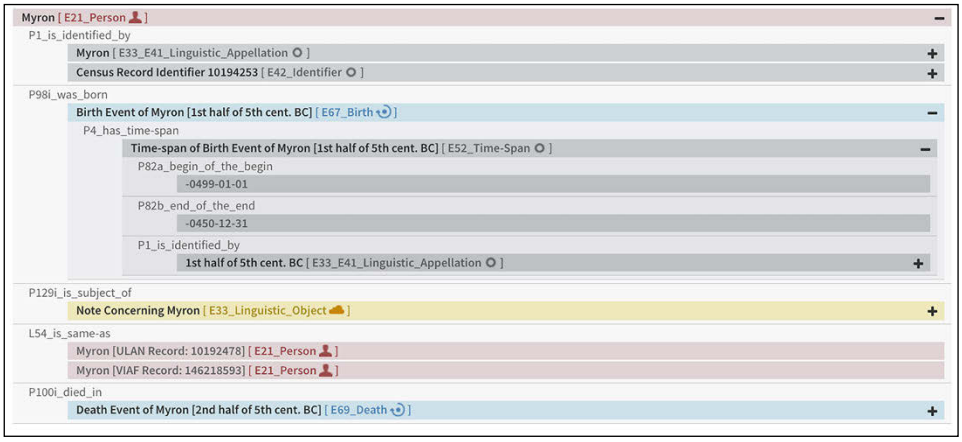


Fig. 5 – Semantic mapping.

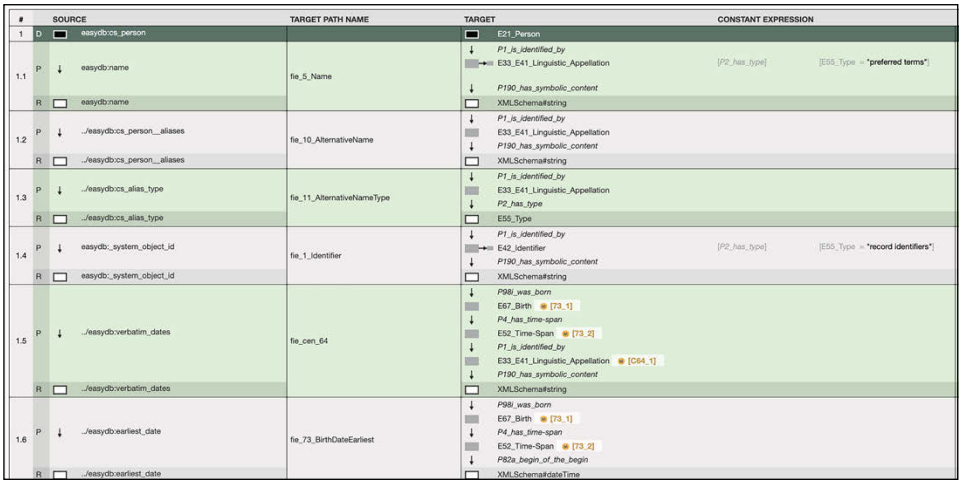


Fig. 6 – RDF visualizer.

data model. In this way, we were able to generate a mapping for each model from the original source data, expressed in relation to the semantic reference data patterns, which directly shows how each source field is translated into its corresponding target field (Fig. 5). An additional advantage of the 3M mapping tool was its integration of an RDF Visualizer (https://www.ics.forth.gr/isl/rdf-visualiser?lang=en) (Fig. 6).

This particular software provides a compact representation of RDF data structures. In terms of creating mapping instructions, as well as testing and explaining the outcomes between the data engineer and the researcher, this tool was highly important for verifying that the data transformation successfully expressed the primary data in the new semantic format. The mapping files created to generate this transformation were published as a paradigm for further transformations of data which could align to the Semantic Census data (Nenova, Bruseker 2023d).

7. Querying and research questions

While the aim of the semantic representation of the Census data was to open it to a wider audience, a key challenge of using semantic data in humanities research is that, while it has been adapted in numerous projects, basic familiarity with its creation, maintenance, or querying is far from a core skill taught to students. It was therefore considered a priority to establish an access point for researchers to begin to understand how to query the data and to envision the kind of responses it could provide. The modeling and

documentation structure of the semantic data models offered a foundation for systematically describing the types of queries that could be formulated using the semantic models. These queries were documented both as SPARQL query code and as English language questions corresponding to the types of inquiries researchers might pose of the data. Equivalences were made such as: 'Show me the monuments with creator information'.

The complete set of queries for the models was documented and published (Nenova, Bruseker 2023b). Using the field system of the SRDM approach, these queries not only represent a way to access data for a particular topic in the Semantic Census dataset, but also serve as primary material for constructing richer, more complex questions that are the result of multiple cross-model queries to the knowledge base.

8. Conclusion

The Semantic Census project aimed to build upon the scholarly tradition of the Census project by providing it with a new data expression, opening it to the Linked Open Data world and new lines of inquiry. Achieving this goal required the creation of a fully documented set of semantic reference data models for the Census, a set of explicit mapping files that can be used in a pipeline to transform and update the semantic representation of the Census on a regular basis (Nenova, Bruseker 2023e), and a systematic set of SPARQL queries to explore this data in relation to real world questions that researchers might pose. The Semantic Census is a resource that expands the project's scope, enabling its reuse across broader disciplinary contexts while adhering to the principles of FAIR content. This transformation is especially significant since the Census occupies a unique position as a bridge to the early history of art history and the early history of digital humanities. The Census is a distinctive case, moreover, given its long-standing position at the intersection of art history and archaeology, where it has been shaped by the diverse methodologies of these fields.

The Semantic Census project lays the groundwork for future research, while highlighting institutional and infrastructural challenges as well as fundamental research and pedagogical concerns. Regarding the former, a key issue is building infrastructure and identifying stable institutional homes for semantic data. Enabling partnerships and long-term collaborations – both at the software level and the institutional level – is essential to realizing FAIR principles and unlocking the potential of research across semantic datasets. In the case of the Census, while semantic data is generated regularly and stored for researcher access, it is not hosted as a live dataset, and the need for supporting software that enables interactive relationships with semantic data must be addressed. A broader issue of training is also relevant: while

the promise of Linked Open Data is to provide explicit and openly available scholarly datasets for analysis and reuse, the dissemination of fundamental skills necessary to work with this data within the humanities remains limited. Much remains to be done, since historic databases such as the Census stand to gain considerably by connecting their resources in a way that empowers not only institutions, but also individual researchers and early career scholars, to leverage open research.

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ABSTRACT

The Census of Antique Works of Art and Architecture Known in the Renaissance, established in 1946, is a research project that traces the knowledge and reception of antiquities known during the Renaissance by linking them with Early Modern visual and textual records. It has over its long history evolved from an analog system, to one of the earliest digital art history projects, to an online database (https://database.census.de). Recent innovations (2021–2023) have transformed the database into semantic data using the CIDOC-CRM ontology, aligning it with FAIR principles and encouraging broader engagement with the Census's rigorously-researched dataset. The modeling process involved creating eight Semantic Census models, supported by extensive documentation. The semantic transformation of Census data

used the X3ML language and 3M tool for mapping and verification, ensuring consistency and compatibility with other datasets, such as those in the CORDH network. Queries can now be performed using SPARQL, with documented query examples to guide researchers unfamiliar with semantic data. The Semantic Census models have the ability to facilitate new research purposes for Census data, not only in the fields of art history and archaeology, but also beyond the project's original scope.

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THE 'SACRA ABSENTIA' DATABASE ON THE LOST FURNISHINGS OF MEDIEVAL CHURCHES IN VENICE: FROM THE OVERALL FRAMEWORK TO THE CASE STUDY OF SANT'AGNESE

1. A glimpse into the Venetian context and the origin of the project

During his second pilgrimage to the Holy Land, in the years 1483-1484, the Swiss Dominican Felix Fabri of Ulm stopped in Venice (Bravi 2015). In his travel diary, he extols the Serenissima as «più bella e più pregevole di ogni altra città da me veduta», listing thirteen characteristics that made it famous, ranked by importance (Fabri da Ulma 1881, 21). Midway through this ranking, he highlights the marvellous appearance of the liturgical furnishings in sacred buildings: «Seventhly – he writes – Venice is renowned for something associated with holy relics, namely, the preciousness of its treasures. How much gold, silver, and gemstones there are in all the churches and monasteries, in the cabinets, sarcophagi, monstrances, reliquaries, crosses, images, and so on, can be partially seen by those who, astonished, observe the processions. As for the chalices and sacred furnishings, one sees them every day» (Fabri da Ulma 1881, 82). More than five centuries after this Northern European traveller's time, the interiors of Venetian churches – except for a handful of cases – have been radically transformed due to Renaissance or Baroque reconstructions (Dorigo 1983, 2003; Zorzi 1972). The furnishings used in religious functions up to that point – many likely of medieval origin – have been almost entirely lost.

The 'Sacra Absentia' project aims to trace any type of evidence related to the lost furnishings of medieval churches in Venice. The idea stems from a previous study dedicated to the memory of the city's lost wall mosaics, which led to identify around fifteen cases based on data from local scholarly texts, ancient chronicles, and archival documents (Piazza 2020). These sources occasionally shed light on other decorative elements, including architectural components such as floors, columns, ciboria, and altars, as well as movable artworks like liturgical furnishings and icons.

Jacopo de' Barbari's famous map, created around the year 1500 (Schulz 1978; Huffman 2024), serves as a valuable tool for understanding the original appearance of the numerous religious buildings – approximately two hundred (Dorigo 1995, 814) – scattered across the various districts of Venice. At that time, their structures had not yet been altered by modern renovations and thus largely retained their basilical layout, featuring three naves, a portico, and a bell tower, which had been adopted during the Romanesque period

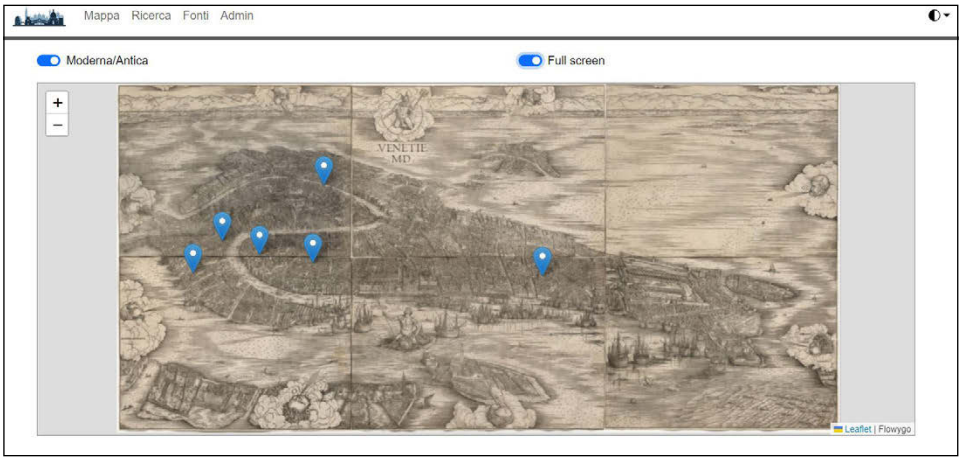


Fig. 1 – Screenshot of the 'Sacra Absentia' database with location some of the catalogued churches on the Jacopo de' Barbari map (1500).

or even earlier (Fig. 1). De' Barbari's perspective view captures the medieval configuration of many buildings, some of which would soon undergo radical transformations, such as San Salvador near Rialto and the cathedral of San Pietro di Castello (Piazza 2020, 69, 72-74). The same view also documents churches that were later demolished, such as Sant'Angelo in the San Marco district and Santa Chiara in Santa Croce (Zorzi 1972, 309-311, 323-324; Franzoi, Di Stefano 1975, 87-88, 344-346).

But what do we know about the interiors of medieval churches? In his *De situ urbis Venetae*, a late 15th century description of Venice, Marco Antonio Sabellico states that all the churches in the city were paved with marble slabs or *opus tessellatum*, had columns of 'foreign stone' (*peregrini lapidis*), both at the entrance and in the choir, and many (*pleraeque*) featured vaults adorned with golden *tesserae* (Sabellico 1722, 20). As for the *vasa sacra*, icons, and reliquaries that were once kept within them, apart from a few exceptions – such as the Treasury of San Marco, which has survived in a significant proportion, and a small number of objects that have remained in their original locations or have been moved to museums – our only knowledge comes from sources, primarily written texts, and, to a lesser extent, iconographic testimonies. The former include pastoral visits, inventories, wills, account books, local chronicles, and pilgrim diaries, some of which have been published while others are preserved in archives. The latter category consists of depictions of church interiors, which may be more or less accurate, and copies of individual objects.

Among the illustrations of monumental interiors is, for example, a canvas from the early 16th century, now in the Gallerie dell'Accademia, depicting

The Apparition of the Crucifixes of Ararat, an evocation of the vision experienced by the prior of the convent of Sant'Antonio at Castello, Francesco Ottobon, in 1511 (Zorzi 1972, 313-314; Fortini Brown 1988, 186-189, pls. XVIII-XIX). The work, executed by Vittore Carpaccio and dated to 1515, portrays the event in the actual location where it allegedly occurred, namely, the church of Sant'Antonio (Fig. 2). The painter thus sets the scene within

CHIESA			
LOCALIZZAZIONE	Indirizzo		
	Dati di geolocalizzazione		
INTRODUZIONE AL CONTESTO MONUMENTALE	Fasi storiche		
	Stato di conservazione		
BIBLIOGRAFIA			
FONTI			
TESTIMONIANZE RELATIVE ALL'ARREDO PERDUTO			
1. Decorazioni parietali			
2. Pavimenti			
3. Coperture			
4. Sculture architettoniche	4.1. Colonne (fusti, basi, capitelli)		
	4.2. Portali (architravi, stipiti, soglie)		
	4.3. Finestre		
	4.4. Rilievi in parete		
5. Arredo liturgico	5.1. Altari		
	5.2. Cibori		
	5.3. Recinzioni presbiteriali (plutei, pilastrini, transenne)		
	5.4. Coro		
	5.5. Fonti battesimali		
	5.6. Pulpiti		
	5.7. Lettorini		
	5.8. Tabernacoli		
	5.9. Campane		
6. Suppellettile liturgica	6.1. Oreficeria sacra	6.1.1. "Vasa sacra"	6.1.1.1. pissidi/bussoli
			6.1.1.2. calici e/o patene
			6.1.1.3. capselle/cofanetti
			6.1.1.3. vasetti
			6.1.1.4. bacili/lavelli
			6.1.1.5. acquamanili
			6.1.1.7. navicelle
			6.1.1.8. custodie per ostie
		6.1.2. Reliquiari	
		6.1.3. Cofanetti	
		6.1.4. Tabernacoli	
		6.1.5. Pastorali	
		6.1.6. Coperte di libri liturgici	
		6.1.7. Turiboli	
		6.1.8. Candelabri / Lampade	
		6.1.9. Croci	
		6.1.10. Corone	
		6.1.11. Paci	
		6.1.12. Ex voto	
	6.2. Avori	6.2.1. Cofanetti	
		6.2.2. Pissidi	
		6.2.3. Coperte di libri liturgici	
		6.2.4. Pettini	
		6.2.5. Pastorali	
	6.3. Libri liturgici	6.3.1. Messali	
		6.3.2. Sacramentari	
		6.3.3. Salteri	
		6.3.4. Antifonari	
		6.3.5. Evangeliari	
		6.3.6. Graduali	
		6.3.7. Breviari	
	6.4. Icone / Pale d'altare		
	6.5. Paramenti sacri	6.5.1. Tessuti d'altare	6.5.1.1. Tovaglie
			6.5.1.2. Panni d'altare (*aeres*)
			6.5.1.3. Fazzoletti per calice
			6.5.1.4. Cuscini d'altare
		6.5.2. Tendaggi	
		6.5.3. Vesti liturgiche	6.5.2.1. Pianete
			6.5.2.2. Piviali
			6.5.2.3. Camici
			6.5.2.4. Corporali
			6.5.2.5. Dalmatiche
			6.5.2.6. Ombrelli
			6.5.2.7. Mantelle
		6.5.4. Tessuti per custodia di reliquie	
		6.5.5. Tessuti per statue	
	6.6. Statue		
7. Reliquie			
8. Sepolture			

Fig. 2 – 'Sacra Absentia' database card structure example.



Fig. 3 – Venice, Gallerie dell'Accademia, Vittore Carpaccio, *Apparition of the Crucifixes of Mount Ararat in the Church of Sant'Antonio di Castello*, 1515 (after Russo 1991).

the 14th century structure, making his testimony invaluable since the entire building was demolished during the Napoleonic era. Moreover, his work meticulously captures several late medieval furnishings (Sandrelli 1996): two gilded wooden altarpieces featuring saintly effigies and a tall rood screen separating the nave from the choir.

To visually document the memory of liturgical artifacts from medieval Venice, there is also the large canvas depicting the *Procession in Piazza San Marco*, by Gentile Bellini, dated to 1496 (Fortini Brown 1988, 60-66, pl. XII; Rodini 1998). In the foreground, protected by a baldachin, is the sacred focal point of the city's parade, the reliquary of the 'True Cross' from the church of San Giovanni Evangelista (Zorzi 1972, 19). In the painting, the shape of the *staurotheca* is barely discernible, as the artist depicts it in profile, yet it is still identifiable with the example made of gold and rock crystal, which has survived to this day and is still preserved in its original location (Freeman 2011, 161-162, fig. 25; Mezzacasa 2019, 122-124). However, the golden case carried on the shoulders beneath it, with its Gothic style, parallelepiped shape, and the four golden angel candlestick holders, has been lost. Its



Fig. 4 – Venice, Correr Museum Library, Jan Grevembroch, *Reliquary with the head of Saint Mary Cleophas* (Gradenigo Dolfin ms. 65.3, 12, 1764; after Mezzacasa 2023).

appearance suggests it may have been an actual object, perhaps symbolically evoking the Ark of the Covenant (Piazza 2021, 666).

We also have the watercolour copies by Jan Grevembroch, a Dutch-born painter who lived in Venice, who in the second half of the 18th century reproduced a series of liturgical objects from Venetian churches (pissidi, chalices, crosses, and reliquaries), many of which have since been lost (Zorzi 1972, 352-353, figs. 284-290). Among these illustrations, found in the manuscript titled *Varie venete curiosità sacre e profane* (1755-1764) (BMC, Gradenigo Dolfin ms. 65.3, 12), is the particularly interesting case of the chalice from Santa Maria dei Servi in Cannaregio (Mezzacasa 2023, 214-215, fig. 95) (Fig. 4). The object has been lost, and the church itself, of 14th century origin, was demolished at the beginning of the 19th century (Tramarin 2023). In Grevembroch's work, the object, made of gold and silver with translucent enamels, is depicted in minute detail with great precision, to the point that it can confidently be attributed, due to its resemblance to a series of similar examples, to 15th century Venetian production.

However, the significance of the 18th century copy lies in the fact that the designer has depicted the upper part of a crowned skull inside the chalice, which the caption beneath the illustration explains is «the Head of Saint Mary Cleophas» none other than the head of the woman whom the Evangelist Matthew mentions as 'the other Mary' (Mt. 27:61; 28:1). The first record of the presence of this legendary relic in Santa Maria dei Servi dates back to the late 15th century: in the aforementioned description of Venice, Sabellico (1722, 11) notes the «Virginis templum cum numeroso servorum cœtu […] ad aram maximam Mariae Cleophae caput». It is possible that when the scholar saw the saint's head on the high altar of the cited church, it was already inside the chalice copied by Grevembroch. This is suggested by a similar version reproduced by Fra Giovanni da Verona at the end of the 15th century in the choir of the Neapolitan abbey of Santa Maria di Monte Oliveto (Mezzacasa 2017, 168, figs. 7-8; 2023, 214). The choice to display a skull inside a chalice may seem rather macabre, but upon closer reflection, it aligns with a phenomenon of theatricalization of the relics of saints, particularly widespread in the late medieval period and especially in Venice, a city that represented the first stop for European pilgrims awaiting departure to the holy sites of Palestine (Bacci 2020).

It is no coincidence that Felix Fabri from Ulm, cited at the beginning of this paper, ranks the display of relics sixth among the wonders of the lagoon city, even before the 'sacred vessels': «The sixth reason for the fame of Venice is the quantity of holy relics. Indeed, since the power of the Venetians expanded over the sea and the land, all the holy bodies that they obtained were brought to Venice» (Fabri da Ulma 1881, 79). This statement is followed by an extensive list of sacred remains scattered across numerous Venetian churches, linked by suggestive visitation routes that foreigners followed, motivated by both faith and superstition. A century earlier, the Florentine Simone Sigoli attested to this in his travel account from Venice to Sinai (1384-1385): «Next, we shall mention all the holy relics we saw in the city of Venice. We saw the body of Saint Lucy, and it is a beautiful relic […]. And we also saw […] the knee of Saint Christopher […] a finger of Constantine the Emperor […] a molar of the giant Goliath […] killed by King David» (Sigoli 1862, 266; Bacci 2020, 114). These were exceptional relics, artfully displayed to impress visitors, sometimes of superhuman size, as in the cases of Saint Christopher and Goliath, and other times of infant proportions, such as the collection of presumed bodies of the Massacre of the Innocents: «In Murano, – continues the naïve Simone – in the church of San Donato, […] we saw in an altar one hundred and ninety-eight innocent little children all small in swaddling clothes; and they are all intact, and they all have knife wounds, some in the throat, some in the chest, some in one place and some in another, and some with their throats slit […] their

wounds are bloody and fresh, almost as if they had died very recently» (Sigoli 1862, 265).

Whether from figurative contexts or written texts, evidence such as the ones just analysed allow us to develop theories and reasonings that help formulate hypotheses about the physical appearance of lost works and contexts. But the memory of the medieval furnishings in the churches of Venice can also be recovered through the lists of pastoral visits, which from the 15th century onwards provided brief descriptions of the inspected places of worship, with systematic lists of altars, ambones, relics, icons, and all types of liturgical furnishings. The archival material in this regard is considerable, and to enhance the large amount of information, the 'Sacra Absentia' project has created a database capable of acquiring any type of information found in published and unpublished documents[1]. To proceed systematically and in an organized manner, a board template has been developed that includes a brief description of each monument, the indication of sources, and the various types of objects, without overlooking possible information regarding the monumental contexts (floors, columns, paintings, mosaics) (Fig. 2).

The input of data into the system will allow searches by object categories, monuments, or saints' names associated with various places of worship, altars, statues, altarpieces, reliquaries, and relics. For the most effective use of the collected materials, an interactive mapping system has been created based on the de' Barbari perspective map, geolocating the churches to identify their locations in current cartographic systems (Fig. 1). The decision to use the famous Venetian view is due to the fact that it is a representation rich in architectural details that have now disappeared, many of which still have a medieval layout.

S.P.

2. Implementation of the database and the case study of Sant'Agnese

Our work on cataloguing the lost furnishings of Venetian churches has so far counted nearly ninety contexts. However, our investigation is clearly still in progress, and the database will continue to grow. To provide an example of how the records in the database are being developed, we will use the church of Sant'Agnese, in the Dorsoduro district, as a case study (for bibliography, see the most recent studies: Zorzi 1972, 487; Franzoi, Di Stefano 1976, 213-214; Dorigo 1983, 392, 480, 603 n. 1, 611, 616-617, 619, 623; 2003, 956).

[1] The technical and informatics setup of the database and the interface with both ancient and contemporary maps, required for georeferencing, were carried out by Dr. Alessandro Fiori (PhD, researcher and professor of Data Science and Database Technology at the Polytechnic University of Turin).

The first section of each database entry is dedicated to briefly reviewing the architectural phases and the historical-artistic events of each church under analysis (Fig. 2). For Sant'Agnese, the parish is first documented in 1081 (Corner 1749, 153, 155); scholars have therefore hypothesized that the church was founded between the late 10th and early 11th centuries (Dorigo 1983, 611; 2003, 956). The building that has come down to us is the result of various interventions that took place over the centuries on a structure that probably corresponded to the one that had to be rebuilt following an extensive fire spread in 1106 (Martinioni 1663, 24; Dorigo 1983, 480). Scholars attribute the phase of rebuilding certain architectural elements traceable to the medieval period still observable, such as the series of paired arches on brick columns along the external perimeter, the pillar supports that divide the three naves internally, and the semicircular apse (Figs. 5b-6). However, the portico on the façade of the church no longer exists, while only the lower part remains of the ancient bell tower, possibly dating back to the 13th century, having undergone significant alteration between 1837 and 1838 (Cicogna 1834, 624; Dorigo 1983, 392, 623; 2003, 255, 258, 260, 956). The building currently retains almost nothing of the ancient decorative features (Fig. 6).

During the 14th century, work was undertaken in the church, and a reconsecration ceremony was held in 1321 (Dorigo 2003, 255), mentioned in an inscription preserved in the church (Zorzi 1972, 487, note 2; Di Leonardo 2014, 34, note 4). Recently, Matteo Ceriana has emphasized the chronological and figurative proximity of some fragments of frescoes that still survive inside the church with the altarpiece depicting the *Coronation of the Virgin*, commissioned from Michele Giambono in 1447 for Sant'Agnese, a subject to be discussed further later (Ceriana 2016a, 46).



a b

Fig. 5 – a) Jacopo de' Barbari, *Perspective view of Venice*, 1500, part., church of Sant'Agnese; b) Venice, Dorsoduro, church of Sant'Agnese, current exterior, southern side (photo G.A.B. Bordi).



Fig. 6 – Venice, Dorsoduro, church of Sant'Agnese, current interior.

It seems that the most significant transformations to the sacred space occurred during the 17th century, starting from the early years of the century, when the church boasted eleven remarkable altars. Stringa confirms that at that time: «questa chiesa anch'ella viene abbellita, et ornata all'uso moderno» (Stringa 1604, 181*r*). Around 1670, the construction benefited from interventions promoted by the benefactor Lodovico Bruzzoni; later, in 1733, the atrium was also restored at the expense of the priest Salvatore Bertella (Cicogna 1824, 197, 200-201, 202-203, 205-206). The following century marked a period of severe decline for the parish, as it was suppressed on 18th September 1810 (Cicogna 1824, 197; Zorzi 1972, 487). Around the mid-19th century, the church was reopened for worship but following a complete renovation that preserved nothing of the original decor. Further restorations, which scholars believe contributed to altering the original character of the building, also took place in 1939 (Franzoi, Di Stefano 1976, 213). Nevertheless, it is possible to get an idea of the original appearance of the ecclesiastical building, including its attached portico and bell tower, thanks to its representation in the aforementioned bird's-eye view of the city by Jacopo de' Barbari (1500) (Fig. 5a). As regards its ancient internal appearance, however, it is possible to take advantage of manuscript traditions and descriptions by erudites (see, for example, Cicogna 1824, 197-209).

As already mentioned, in 1447, Michele Giambono was commissioned to create an altarpiece depicting the *Coronation of the Virgin* for the main altar of the church of Sant'Agnese (Ceriana 2016a, 40, 79-80; 2016b, 186-188). The central panel of this altarpiece, which has not survived intact, has been identified as a painted panel in the Gallerie dell'Accademia in Venice (Ceriana 2016a, 39-70; 2016b, 186-188). Neither this work, nor others, is unfortunately mentioned by Marcantonio Sabellico in his description of the lagoon city, compiled towards the end of the 15th century. Sabellico describes the church as «vetusta ædes» that «modice assurgit». The altar of the saint must have appeared quite old, as the scholar states that the «divæ ara» was «vetustissima» (Sabellico 1722, I, 5). A «pala del Paradiso di assai eccellente mano» is, however, mentioned at the beginning of the 17th century by Giovanni Stringa (1604, 181*r*; Ceriana 2016a, 41).

The consultation of some unpublished documents has allowed for the enrichment of the information currently available regarding the liturgical arrangement of the church and its decorative apparatus. An indication by Wladimiro Dorigo (2003, 566, n. 4, 570; 2004, 59, 63 note 74), later taken up by Devis Valenti (2019, 51) and Simone Piazza (2020, 77 note 148), highlighted the probable existence of a mosaic work within the basilica. In his will from May 1291 – which has been revisited by the author –, Matteo Bondumier, the procurator of San Marco, stated: «[…] volo que fiat opus mosaicum in Ecclesia Sanctæ Agnesis […]», commissioning the work to the mosaic artist Pietro Zaparino (ASVe, registry of Matteo Bondumier, unnumbered pages). However, based on current research, it is not possible to determine whether this testamentary provision was actually carried out.

Considering that the most significant interior renovation interventions took place during the 17th century, the reports by the prelates tasked with verifying the state of the parish towards the end of the 16th century become even more significant. Particularly rich in data are the Apostolic Visitation of 1581, carried out by the nuncio Lorenzo Campeggi and the Bishop of Verona Agostino Valier (ASPV, *Visitationes apostolicae*. Very useful is Tramontin 1967), and the Pastoral Visit of Patriarch Lorenzo Priuli, between 1591 and 1593, who inspected the Church of Sant'Agnese on 10th January 1593 (ASPV, *Visitationes ecclesiarum*, 371*r*-375*v*).

In this contribution, we will not review all the categories of furnishings listed in the aforementioned testimonies – these are instead systematically and organized in the database – but we will focus on some information that seems particularly interesting in light of the current state of the building's interior. Regarding the support system, it is worth noting that, unlike the current structure of the church, where the aisles are separated by pillars, the Apostolic Visitation mentions the presence of wooden columns (ASPV, *Visitationes apostolicae*, 258*v*). There is also a wealth of valuable information

from the surveys of all the altars that were once in the church and which no longer exist today due to the 17th and 18th century renovations and the various changes the building underwent, especially in the 19th and 20th centuries.

We will not review all the altars inspected during the two Visits, as they are also included in the database's records, but we aim to highlight some information that has seemed most noteworthy. In the case of Sant'Agnese, it is noted that there were two altars dedicated to the Blessed Virgin Mary: one was located on the Epistle side (ASPV, *Visitationes ecclesiarum*, 372*v*), also referred to as 'left' (ASPV, *Visitationes apostolicae*, 256*r*), while the other is described as being entirely made of wood and situated on the Gospel side (ASPV, *Visitationes ecclesiarum*, 372*v*). The main altar was not dedicated to Saint Agnes, the church's eponym, but to All Saints, and had what is described as a «buco nell'antipetto» (ASPV, *Visitationes apostolicae*, 257*v*; ivi, *Visitationes ecclesiarum*, 371*v*, 374*r*), a term which would suggest the presence of an opening, similar to a small window, on the front of the altar. The altar of Saint Agnes, on the other hand, was located behind the choir, where there was also the altar of Saint Mathias (ASPV, *Visitationes ecclesiarum*, 372*v*). The same choir and the *Pergolo dell'Evangelio* however, were considered too large for the liturgical needs at the time of the pastoral visit of 1593. It was therefore ordered that the pulpit be completely removed «et all'hora si facciano dui pergoleti, proportionati, uno per parti nelli pilastri d'essa capella maggiore» and that «il choro si riduca nella cappella grande serrandola con colonnelle» (ASPV, *Visitationes ecclesiarum*, 372*v*, 374*v*). The church was also equipped with a baptismal font, which «ritrovò essere un belissimo vaso […] se bene non è totalmente ridutto à perfettione» located near the Gospel pulpit, which was placed on one of the choir's pillars (ASPV, *Visitationes apostolicae*, 256*v*; ivi, *Visitationes ecclesiarum*, 371*r*, 374*r*). From the survey of the icons on the sacred altars it is possible that the «palla d'ogni santi» recorded above the main altar corresponds to the work commissioned to Michele Giambono in 1447 (ASPV, *Visitationes ecclesiarum*, 371*v*).

Among the numerous types of liturgical books and sacred goldsmithing catalogued by the visitors there is one annotation of particular interest concerning a 'peace' (i.e., a tablet with a sacred image shown for the kiss of peace before Communion during the liturgical celebration, in use from the 13th to the 18th century: Meehan 1911), as a visual record of it was found in a graphic evidence: a watercolor by Jan Grevembroch, found in the Gradenigo Dolfin manuscript 65.3 dated 1764, where the caption notes its custodianship at the parish of Sant'Agnese (BMC, Gradenigo Dolfin ms. 65.3, 4) (Fig. 7). This 'peace' depicted the central figure of a blessing Christ, surrounded by a frame of vegetal scrolls recorded in Patriarch Priuli's pastoral visit as «a pace d'argento con il Cristo di Avolio» (ASPV, *Supplemento*, 6*r*).

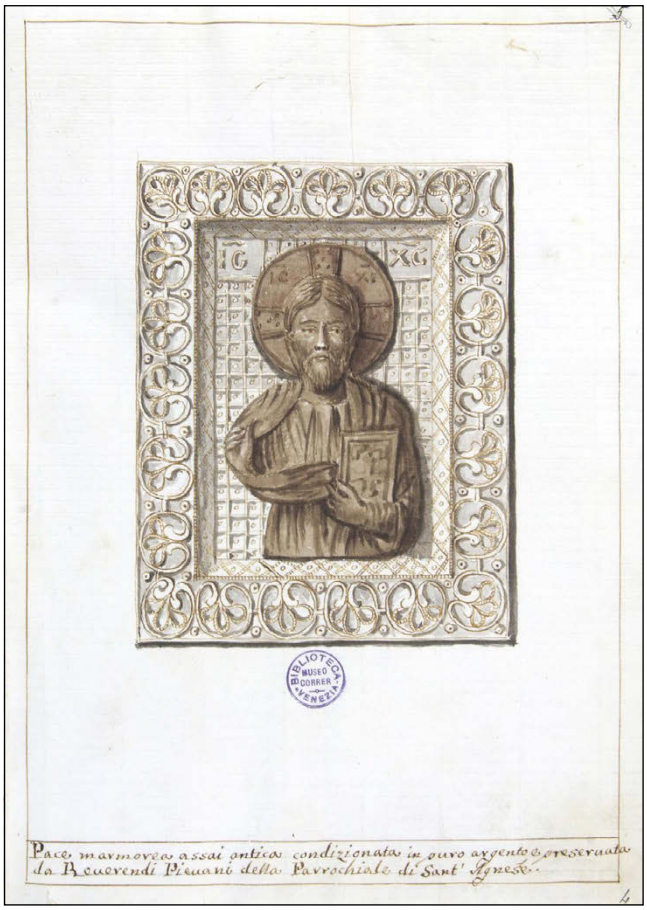


Fig. 7 – Venice, Correr Museum Library, Jan Grevembroch, *Ivory and silver 'pace' with Christ*, watercolor drawing (Gradenigo Dolfin ms. 65.3, 4, 1764; courtesy of the Correr Museum Library).

Of great importance, for the purposes of this project, are the information gathered from the sources regarding the relics held by the churches surveyed. In our case, it is noted that the altar of Saint Jerome housed sacred relics of saints referred to as 'old' (ASPV, *Visitationes ecclesiarum*, 372*r*, 374*v*), possibly from a very ancient time, while the 1581 Apostolic Visitation records the presence of relics of Saint Agnes and Saint Mary Magdalen «in vasculis inauratis, sine aliquo documento sed ex vetera traditione» (ASPV, *Visitationes apostolicae*, 257*v*).

G.A.B.B.

3. Final remarks

In conclusion, some brief methodological reflections are offered on our work. For each piece of data recorded in the database, it is possible – as is logical and correct – to trace it back to its source. In this way, when the application's implementation is completed, it will be possible to identify the most informative sources to be further used for in-depth research. Moreover, general comments and reflections on the types and purposes of the sources, and the categories of information they provide could also be developed. Furthermore, the linguistic aspect related to the systematisation of the data within the platform must be considered: for the different categories of recorded works, Italian terms have naturally been chosen (for example: 'altare', 'pala', 'icona', etc.), but it is of our interest to also keep track of the various expressions used in Latin or vernacular languages which sources refer to the elements of our study. For this reason, most of the time, we have opted to directly report the words from the documentary occurrences in quotation marks.

Another aspect where general, quantitative, and taxonomic considerations can be developed concerns the material nature of the decorative elements: by the end of this work, statistical evaluations can be made on the recurrence of specific materials used in liturgical furnishings. It will also be possible to check the frequency of certain materials in relation to types of furnishings. Furthermore, we will need to reflect on the reasons for the use of specific materials in relation to the production systems of the medieval city.

The core issue that arises from the systematic review of the aforementioned sources is primarily the difficulty in identifying, among the lost furnishings, those that can certainly be ascribed to the medieval era, as most of the usable archival documents were produced from the 15th century onward, and the data they contain are often quite essential and lack detail. Significant clues for a possible assignment to the Middle Ages, although general, sometimes emerge from references to the materials of the works or from certain phrases regarding their inadequacy or old age. Very often, the documents provide information on the arrangement of altars, pulpits, and choir screens before the liturgical adjustments prompted by the Council of Trent, but just as often they reflect the 'image' of sacred spaces in which changes had already occurred in the early Renaissance period. Therefore, it will be necessary to cross-reference the data from the sources (both published and unpublished) with studies on the history and architectural phases of the buildings.

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ABSTRACT

The 'Sacra Absentia' project, led by Simone Piazza (PI) with Giulia Anna Bianca Bordi (research fellow), is part of the PNRR (2022-2025) within the CHANGES program, Spoke 8, at University Ca' Foscari Venice. This study examines medieval and early modern pilgrims' accounts of Venice's religious heritage, informing the cataloguing and spatial reconstruction of lost or recontextualized liturgical furnishings. An online database georeferences these objects using contemporary maps and Jacopo de' Barbari's 1500 Venice view. A case study on Sant'Agnese, integrating published and unpublished sources, demonstrates the methodology's effectiveness in uncovering new historical insights.

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THE CHURCH OF SAN FANTIN IN VENICE: DIGITAL MODELING, ARCHIVAL RESEARCH, AND THE REUSE OF ANCIENT MARBLES

1. Introduction

The church of San Fantin in Venice stands as a testament to the city's rich architectural and historical evolution. While its origins in the High Middle Ages remain uncertain, the current structure reflects its Renaissance transformation, shaped by successive phases of construction and renovation. Despite the lack of definitive evidence regarding its earliest form, a multidisciplinary approach combining digital modeling, material analysis, and archival research has provided new insights into its development.

This article is structured into three sections, each offering a distinct perspective on the church's architectural history. The first section, by Carlotta Zaramella, presents a reconstruction of San Fantin's architectural phases through digital modeling and the creation of a Building Information Modeling (BIM) model, enabling a clearer understanding of its structural transformations over time. The project has been led at the University of Padua under the supervision of prof. Gianmario Guidarelli as part of a broader initiative funded by the European Social Fund (FSE), focused on the historical, urban, and architectural reconstruction of the San Fantin *insula* and its digital representation. The second section, by Myriam Pilutti Namer, examines the reuse of materials in Venetian architecture, with particular attention to the types of marble incorporated into the church's fabric. The third section, by Giulia A.B. Bordi, investigates medieval material evidence and archival sources related to two water basins, shedding light on their functional and historical significance.

M.P.N.

2. Digital modeling of the church of San Fantin: objectives and methodology

The study we present aims to explore the historical and architectural evolution of the church of San Fantin by developing a descriptive digital model. This research adopts an innovative approach that integrates traditional historical investigation with modern digital modeling technologies. The digital reconstruction seeks to make historical changes and developments more comprehensible through a scientific methodology, transposing historical views and cartographic sources into a digital system. This approach facilitates the analysis of urban transformations in relation to chronological progression.

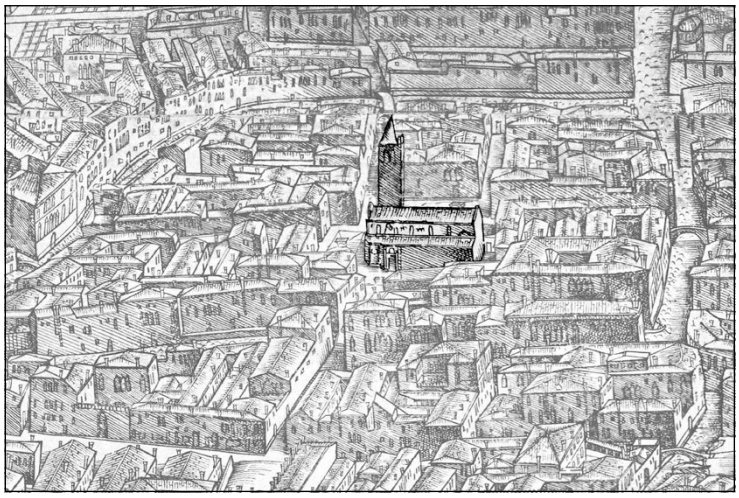


Fig. 1 – De Barbari's *Veduta* (1500) indicating the location of the church of San Fantin (reworked by C. Zaramella).

2.1 *Cartographic sources*

This study examines the period from 1500 to the present. To digitize the current state of the site, the regional technical map was utilized; however, this source provides only building boundary data without height information. Consequently, a detailed visual analysis and on-site photogrammetry of the church were necessary to complete the model. The study begins in the year 1500 with an analysis of the first primary source depicting Venice: De' Barbari's *Veduta*, which represents the city with remarkable precision through a bird's-eye view (Fig. 1). A perspective study revealed significant distortion along the E-W axis, while a geometric analysis, based on the alignment of buildings and streets, allowed for the delineation of the church in Revit. The second cartographic source selected is the Napoleonic Cadastre, the first of three cadastral maps produced for Venice, dating back to 1808. As a primary source used for taxation purposes, it was required to be highly accurate. The subsequent cadastral maps depict an urban configuration similar to that of today. While the Napoleonic Cadastre does not provide height data, it precisely represents building boundaries with continuous lines, and the pink shading indicates their surface area.

2.2 *The church of San Fantin: the three architectural phases*

For decades, scholars have debated the configuration of the earlier churches on this site. For the first time, through an innovative approach integrating

historical research and digital modeling, it has been possible to provide concrete answers. Over time, the building has evolved into three distinct churches. The first was founded and constructed in 996, financed by the Molin family (Piva 1960, 86). Little information exists regarding this structure, but it was likely aligned along the same E-W axis as the present-day church, as was customary in Venice. However, no details about its architectural configuration have been preserved. The second church was built during the 12th century, funded by the wealthy Pisani family. Its architectural structure corresponds to the one depicted in Jacopo De' Barbari's *Veduta* of 1500. The third and final church is the one that stands today. Its construction was made possible through the generous bequest of Cardinal Zen.

2.3 *A reconstruction hypothesis based on De' Barbari's Veduta*

De' Barbari's perspectival *Veduta* depicts the second church, identifiable by the inscription 'Fantin' on its side. However, a definitive interpretation of this church remains challenging due to the way it is represented; the northern part is entirely obscured from view. Through geometric analysis, it is plausible to assume that the main façade of the 15th-century church was positioned exactly where the present façade stands. By examining the alignment of Calle de la Verona, despite perspectival distortions, it becomes evident that the façade in both *Veduta* and its current state is aligned with this street. A similar approach applied to Calle Minelli reveals that the church's enclosing wall extends slightly off-axis toward the east. This corresponds to the location where the presbytery and crypt were later added in the current structure. By observing the present position of the well located S of the vestibule and its alignment with Calle del Caffettier, it is possible to deduce that the lateral entrance was situated in the same location as today but on a wall positioned further forward toward the campo.

2.3.1 The third architectural phase

The second reconstruction of the church was financed by Cardinal Zen with a bequest of 10,000 ducats, as stipulated in his will dated 1501. Construction officially began on March 25, 1507, the 'zorno de la Madona' (Sanudo 1879-1903, 369), with the laying of the foundation stone during a ceremony attended by Doge Leonardo Loredan. The initial phase of construction was entrusted to «mistro Sebastian proto» (ASPV, San Fantin, *'Tomi' di atti diversi*, XXXVIII, 160*v*, in Vio 1977, 226), identified as Sebastiano Mariani da Lugano. He worked on the project for approximately a decade (Vio 1977), though progress was slow, as he was also engaged in the fortification of Padua during this period (Zovatto 1970, 130). On August 14, 1522, records indicate the first appearance of Scarpagnino at the construction site, referred to as «mistro Antonio proto» (ASPV, San Fantin, '*Tomi' di atti*

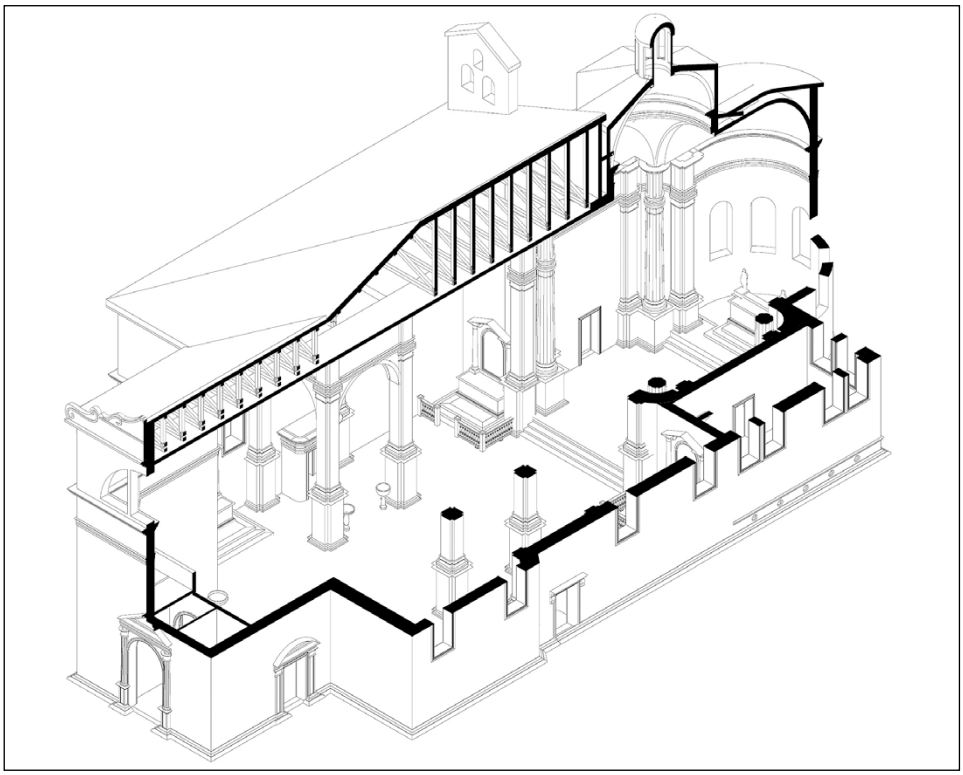


Fig. 2 – Axonometric section of the church of San Fantin (reworked by C. Zaramella).

diversi, XXXVIII, 172, in Vio 1977, 226). He worked on the project from 1522 until his death in 1549, and he is credited with erecting the church walls (Paoletti 1893, 298). In 1543, Antonio Sorella took over and completed the roofing. Scarpagnino did not live to see the final structure, leaving the project to another *proto*, possibly Jacopo Sansovino, who completed the church by constructing the presbytery. However, the authorship of this final phase remains uncertain, both historically and stylistically. The construction officially concluded in 1564, as evidenced by the presence of two marble *coretti* flanking the presbytery, dated 1562-1564 (ASPV, San Fantin, *'Tomi' di atti diversi*, XXXIII, 166, in Vio 1977, 229).

2.3.2 *The current architectural structure*

The church consists of a central nave and two side aisles, characterized by alternating barrel and groin vaults, harmoniously following the Byzantine *quincunx* model (Fig. 2). The main nave is preceded by a square vestibule that



Fig. 3 – Interior view of the church of San Fantin (photo C. Zaramella; courtesy of the Patriarcato di Venezia, Ufficio Beni culturali ed edilizia di culto).

protrudes into the 'campo' toward La Fenice Theatre. Externally, the church is defined by simple, regular lines devoid of ornamentation. The interior maintains an overall austere appearance, free from excessive decoration (Fig. 3). The spacious square presbytery is covered by a dome, which ends in a lantern that softly illuminates the space. The dome rests on four monumental, fluted Corinthian columns with recessed panels, evoking the structure of a funerary monument. At the four corners of the floor beneath the presbytery, sections of the original terracotta pavement remain visible. A distinctive feature of the church is its semi-subterranean crypt, ventilated by 17 perimeter *oculi*, some of which have been partially sealed. These openings were likely once covered with grates, which may have been anchored to the eight holes still visible around each aperture.

C.Z.

3. Reuse of ancient materials in Venice

The reuse of ancient materials in Venice was a fundamental practice that shaped the city's architectural development from its early medieval

origins through the Renaissance and beyond. This phenomenon was largely influenced by the scarcity of natural stone in the Venetian lagoon, leading to the systematic recovery, transportation, and repurposing of materials from abandoned Roman sites in the *Venetia* and other Mediterranean regions. The practice was not merely a matter of economic necessity, but also reflected cultural attitudes toward the past, a pragmatic approach to construction, and Venice's evolving role as a major maritime power (Lazzarini *et al.* 2024). The origins of material reuse in Venice date back to the early medieval period, when the settlement was expanding within the lagoon. With no local quarries available, Venetians turned to the nearby abandoned Roman city of *Altinum* and other mainland sites as sources of building materials. These materials, including marble and stone, were either repurposed directly or reworked into new architectural forms. Inscriptions and sculptural elements from earlier periods were frequently incorporated into new structures, demonstrating both a continuity with and a reinterpretation of the Classical tradition (Lazzarini *et al.* 2024, 2-25).

From the 11th century onward, as Venice's wealth and technological capabilities grew, the city expanded its sources of reclaimed materials to include regions across the Adriatic and the broader Mediterranean. The conquest of Constantinople in 1204 during the Fourth Crusade played a crucial role in intensifying these practices. Large quantities of Proconnesian marble and other valuable stones were systematically looted from Byzantine buildings and transported to Venice, where they were integrated into civic and religious structures. The Basilica of St. Mark, one of the most emblematic examples of this phenomenon, features an extraordinary array of reused materials, including columns, capitals, and friezes of varied origins, demonstrating the craftsmen's ability to synthesize diverse artistic influences (Lazzarini *et al.* 2024, 90-181). The organization of spoliation efforts in Venice suggests a high degree of coordination among merchants, patrons, and artisans. Unlike earlier, opportunistic reuse, which relied on nearby sources, the later medieval and Renaissance periods saw a more systematic approach to acquiring materials. Venetian merchants, who travelled extensively for trade, often brought back stone and architectural elements as ballast for their ships. This practice not only ensured a steady supply of building materials but also reinforced Venice's architectural grandeur by incorporating prestigious elements from across the Mediterranean world.

By the Renaissance, reuse remained a defining characteristic of Venetian architecture, though attitudes toward ancient materials evolved. The appreciation for classical antiquity led to more selective reuse, often emphasizing the aesthetic and symbolic value of spolia. The presence of ancient elements in Venetian buildings was not merely functional but became a marker of prestige and continuity with the classical past. This shift is evident in both

public monuments and private residences, where columns, reliefs, and decorative elements from earlier periods were deliberately displayed to emphasize historical depth (Lazzarini *et al.* 2024, 30-65). Even into the 19th century, the reuse of materials remained an active practice, particularly in restoration projects. More than six hundred stonemasons were documented working in Venice during this period, involved in demolition, reuse, and reconstruction efforts that continued the city's long-standing tradition of material recycling. This ongoing reliance on *spolia* highlights the resilience of Venetian architectural strategies and the craftsmen's ability to adapt its built environment to changing economic and political circumstances (Pilutti Namer 2016).

3.1 *Ancient marbles in the church of San Fantin*

Among the various types of reused marbles in Venice, three stand out for their historical and symbolic importance: verde antico, red porphyry, and proconnesian marble. These materials, originating from different regions of the ancient Mediterranean, were often repurposed in Venetian churches and palaces, serving both decorative and ideological purposes. The Church of San Fantin in Venice is an important example of this practice. One notable element is the use in tondos of verde antico, a green-colored marble highly prized in antiquity for its rarity and beauty. This marble, originally sourced from Greece, was commonly employed in Byzantine and then Venetian architecture due to its appreciation from the emperors of Constantinople (Lazzarini *et al.* 2024, 153, with further bibliography). Red porphyry, another highly significant stone in Venetian architecture that was often employed in the decoration of basilicas and palaces, is particularly notable in San Fantin for its use in the tondos placed under the tomb of Vinciguerra Dandolo. Red porphyry was among the most prestigious materials in antiquity, reserved for emperors and high-ranking officials due to its association with power and divinity. Quarried in Egypt, it was extensively used in Rome and Constantinople and since Medieval time it has been transported to Venice through trade and conquest (Lazzarini *et al.* 2024, 150-151).

Finally, it is worth mentioning the Proconnesian marble, sourced from the island of Marmara in present-day Turkey, that was the most widely used marble in Venice. Unlike the rarer verde antico and red porphyry, Proconnesian marble was easily accessible and available in large quantities, making it the primary material for architectural elements such as columns, capitals, and facades. In San Fantin, the imitation of Proconnesian marble in wood panels plays a crucial role in the church's counter-facade, contributing to the structure's overall architectural composition (Lazzarini *et al.* 2024, 67-88, 147-148).

M.P.N.

4. The baptismal font and the holy water stoup of the church of San Fantin

The church of San Fantin must have been adorned with precious marbles even in the facies preceding the reconstruction of 1507 (for which see Zaramella, *supra*; on the history of the church: Baldini *et al.* 2024, 63-78; Pilutti Namer, Bordi 2024, 79-90, with much more extensive references), since Marco Antonio Sabellico, in his *De situ urbis Venetae*, composed at the end of the 15th century, describes it as having «frons *ædis* nitida, candidoque saxo nuper instaurata» («chapel with a clear façade and recently restored with white stones») (Sabellico 1722, II, 18; also quoted by Corner 1749, 15, 319). In the second half of the 15th century, therefore, the building must have undergone renovations that must have added new marble to its decoration. In this regard, it cannot be ruled out that it was precisely during the renovation and then reconstruction of the sacred building that took place between the 15th and 16th centuries, or perhaps even with later acquisitions, that the two medieval works that are the subject of this section of the paper arrived. So far, in fact, it has not been possible to find any evidence in the sources that



Fig. 4 – Proconnesian marble baptismal font in the church of San Fantin (photo G.A.B. Bordi; courtesy of the Patriarcato di Venezia, Ufficio Beni culturali ed edilizia di culto).

could ensure their original provenance from the medieval church of San Fantin. These are, in particular, a baptismal font made of Proconnesian marble currently at mid-height of the right aisle (Fig. 4), and a holy water stoup (or possibly another baptismal font) at the foot of the left central pillar of the main nave of the church (Fig. 5).

The basin of the baptismal font (h ca. 34 cm, diam. ca. 64 cm, depth ca. 30 cm, thickness ca. 3.5 cm), made of Proconnesian marble, has smooth walls both internally and externally, with a double simple moulding with a rounded profile running just below the upper outer rim. The font is supported by a squat cylindrical shaft of the same marble. The artefact rests on a tripartite base articulated in torus, *scotia* and *torus* decorated with plain leaves at the four corners, placed on a high plinth of Istrian stone, perhaps not originally belonging to the artefact (Fig. 4) (Zaramella 2022/2023, 91-92; Amodio 2024/2025, 306, 310). On the left side of the nave of the church, at the foot of the central pillar, is a polylobate basin of a very fine-grained marble – perhaps Luni marble (h 37 cm, max. diam. 55 cm, depth 22 cm, thickness 2.5 cm) – supported by a fragment of a marble column (h 62 cm), characterised by an upward tapering that stands on an octagonal base (Fig.



Fig. 5 – Holy water stoup or baptismal font in the church of San Fantin (photo G.A.B. Bordi; courtesy of the Patriarcato di Venezia, Ufficio Beni culturali ed edilizia di culto).

5) (lastly: Tigler 2009, 144; 2013, 234 note 553; Calugi 2014, 25 note 53; Amodio 2024/2025, 305-310, with previous bibliography).

The basin has a profile articulated in eight lobes of different lengths, along which sculpted reliefs of anthropomorphic and zoomorphic figures alternate. The high level of wear of these does not allow them to be easily read. If, therefore, for the zoomorphic elements it is possible to recognise the silhouettes of pairs of leaning back felines and small birds with intertwined tails and joined beaks, placed above what appear to be small basins, the identification of anthropomorphic subjects is much more difficult. In fact, there are four almost identical figures, placed in a frontal position, with arms stretched across the chest and faces too corroded to be able to specify their gender, characterised by smooth hair with a central parting and a length that almost reaches the shoulders, ending in curls. As already mentioned, one of the problematic aspects concerning this sculptural work is the lack of data regarding its origin (Amodio 2024/2025, 306).

In the Apostolic Visitation of 1581 there is mention of a baptismal font «bene custoditus cum sua clavi» in the altar of Saint Jerome (ASPV, *Visitationes apostolicae*, 139*r*) that should have been removed for the liturgical adaptation of the altar (as ordered in ASPV, *Visitationes apostolicae*, 140*r*, where the furnishing is called «vas lapideum»). However, the order was not carried out immediately, since during the Pastoral Visit in 1593 the basin was still found at the sacred table. From the description it seems, moreover, that the font was in some way connected to the altar, since it is reported: […] «proseguendo la Visita andò nella cappelletta di san Girolamo, et nella mensa dell'altare ritrovò il Batisterio molto indecente» (ASPV, *Visitationes ecclesiarum*, 457*r*).

In the current state of research, it is not possible to establish whether the furnishings mentioned in the ecclesiastical inspections can be identified with one of the two basins in the church today. However, considering that the above-mentioned reports would seem to indicate that the baptismal font was connected to the altar of Saint Jerome, one could reflect on this notation in relation to the singularly deep recesses at the base of four of the eight lobes of the figured holy water stoup, which would lead one to hypothesise its function as a housing for interlocking supports (Fig. 5). On the other hand, we should also consider the object's dimensions, which might have been too small for it to serve as a baptismal font. To attempt a preliminary interpretation reading of the iconography of the artefact, one can observe how the articulation of the basin could perhaps be read as a reference to the octagon that, in Christian symbolism, alludes to the Resurrection of Christ, in reference to the eighth day of Holy Week (Bassan 1995, 283). Regarding the iconography, the animals represented in pairs along the shorter lobes of the basin, according to Christian exegesis, lend themselves to an ambivalent

reading. The two felines, in fact – but only hypothetically due to the heavily abraded surface – could be identified with a pair of lions or lionesses, which in the biblical text and in the interpretations of Christian writers are the expression of both mighty and courageous creatures, who bring their strength to bear against the wicked, and ferocious and cruel creatures, who unjustly persecute the weakest (Ciccarese 2007, 11-48).

So also the two birds joining in their beaks could be likened to the 'sparrows' of the biblical vocabulary. These animals, in the Holy Scriptures, sometimes symbolise defenceless creatures, easy prey to pitfalls, but also, at the same time, capable of rising up towards Heaven, thus away from the iniquities of earth, nesting in the Kingdom of God; at other times, on the other hand, the flight of the sparrow is an allegory of the lightness of an inconstant soul, of intemperance, pride and yielding to worldly flattery that lead these animals to fall into a trap. The sparrow may, however, also be the personification of the risen and ascended Christ (Ciccarese 2007, 125-145). Interesting, however, is what Maria Pia Ciccarese points out, namely that sometimes the symbolism of the sparrows is clarified by the number they are depicted. In particular, according to the scholar, the presence of the birds in the number of two would recall the passage from the Gospel of Matthew in which the example of two sparrows sold for a penny is given: «Are not two sparrows sold for a small coin? Yet not one of them falls to the ground without your Father's knowledge» (Mt, 10, 29), representing, therefore, the soul redeemed by Christ (Ciccarese 2007, 128-129). This reading would therefore seem to be in keeping with the interpretation of the depiction of pairs of birds on a holy water stoup or baptismal font, as in our case.

As for the anthropomorphic sculptures, it is not possible to determine whether they were originally conceived as monstrous beings. What is noticeable, despite the state of wear and tear, is that the four figures appear to have their wrists restrained by something overlapping them, in a manner perhaps similar to what can be seen on the holy water stoup in the parish church of Santa Maria Assunta of Rubbiano, in the province of Parma – dated at the beginning of the 12th century –, where two figures with human features are restrained by the paws of the monstrous creatures that flank them (Moretti 2019, 82, with previous bibliography). One could, therefore, perhaps hypothesise that in the San Fantin font, below the anthropomorphic figures, there were originally fantastic beings that would have been completely abraded.

Otherwise, our four figures could have been depicted in the pose of holding bifid-tailed mermaids with their hands; in that case, however, they would not have been depictions of sirens, who are almost always represented with bare chests and uncovered breasts, since it is quite clear that the figures in the San Fantin basin wear a sort of tunic with a circular cut at the base of the neck. In this regard, one might then recall – but only as a suggestion

that we intend to explore in a forthcoming study – the bifid tritons wearing a sort of cape from the baptismal font at Saint George's in Anstey, County Hertfordshire, dated between the late 12th and early 13th century (Moretti 2019, 84, fig. 16; 86-87, fig. 19). However, it does not seem to be possible to go any further with the hypothesis at present, due to the complete removal of the decoration of the lower register of the bowl. As the areas of abrasion occur in the same register as the deep recesses, it cannot be ruled out that the chiselling of any parts emerging from the body of the basin and the creation of the recesses occurred at the same time, for the same reason.

In Venice or in Northern Italy, at least to the writer's current knowledge, there do not seem to be any other holy water fonts/baptismal fonts that could serve as a fitting comparison for San Fantin's work. A small holy water stoup with eight lobes, bearing on its four sides figures of archangels holding a globe, can be found in St. Mark's Basilica, but it is a much smaller one than San Fantin's basin, which has been hypothesised to have been readapted as a lustral font by reworking a small capital. The date, placed at the 11th century (Polacco 1990), is also likely much earlier than that of the San Fantin bowl, which could perhaps be placed between the 12th and 13th centuries. An eight-lobed stoup in 'Greek marble', dated to the second half of the 13th century, is now preserved in the church of Santa Maria degli Angeli in Murano, although it has been hypothesised that it came from the monastery of San Lorenzo on the lagoon island of Ammiana, which was suppressed and incorporated into the aforementioned parish of Venice in 1438 (Fantoni 1990). However, the stoup, not much smaller in diameter than the one in San Fantin, has completely plain sides, devoid of decoration. Similarly articulated in eight lobes is the white Verona marble stoup placed along a wall of the church of San Benedetto in Gonzaga, in the province of Mantua, dated to a period after the construction of the building, i.e. after 1330. In this case, however, the lobes are uniformly decorated with vertical bullae interspersed along the upper margin with small ovoli, and there are no figured elements (Marchi 1994).

An alternation of longer and shorter lobes, according to a scansion more similar to that found in the lustral pile of San Fantin, occurs, on the other hand, in the eight-valves basin from the Albertian temple of San Sebastiano in Mantua, built from the seventh decade of the 15th century. The presence on the artefact of the Gonzaga enterprise of Olympus, also depicted in Mantegna's Camera degli Sposi (1465-1474), would constitute a further clue for the chronological placement of the work in the late 15th century and, therefore, at too low a chronological height to constitute a term of comparison for the basin of the church of San Fantin (Bazzotti 1979).

What we can note in conclusion is that perhaps in the holy water stoup now preserved in San Fantin – the origin of which we still do not know –, the possible symbolic meaning alluding to eternal life through the Resurrection,

inherent in the choice of a polylobate form articulated in eight lobes, could have been reinforced by the subjects that were sculpted in it, which perhaps, in the overall representation, staged a contrast between symbols of Good (the animals?) and symbols of Evil (the potential monstrous beings) or depicted a series of figures alluding to the necessity, for access to Salvation, of purification, ensured by the blessed water that had to be contained in the lustral pile.

G.A.B.B.

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ABSTRACT

The church of San Fantin in Venice embodies the city's architectural and historical evolution, with its origins in the High Middle Ages still uncertain. This article explores the church's transformation through a multidisciplinary approach, combining digital modeling, material analysis, and archival research. Carlotta Zaramella reconstructs San Fantin's architectural phases using a Building Information Modeling (BIM) model. Myriam Pilutti Namer analyzes the phenomenon of reused materials in Venice, with particular focus on the types of ancient marbles incorporated into the church's fabric. Giulia A.B. Bordi investigates medieval material evidence and archival records of the baptismal font and the holy water stoup.

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FRAGMENTED OBJECTS/FRAGMENTED DATA. QUANTITATIVE METHODS AND DIGITAL APPROACHES IN THE PROJECT MAPPING SACRED SPACES: FORMS, FUNCTIONS, AND AESTHETICS IN MEDIEVAL SOUTHERN ITALY

1. Introduction

The theme of the symposium *Exploring the Legacy of the Past: Networks and Quantitative Methods in Archaeology and Art History* provides an opportunity to reflect, albeit briefly, on a long-standing epistemological problem. This problem is related to the dialogue between scientific and humanistic disciplines, and thus between matter and form, or analyses of materials versus analyses of artistic forms. In other words, to paraphrase the philosopher of logic Bertrand Russell (1914), between logic and mysticism. As early as 1940, Erwin Panofsky (1938) had begun questioning the dignity of Art History in his famous essay titled *The History of Art as a Humanistic Discipline*. Art History, like all humanistic disciplines – especially those related to visual culture and thus to aesthetic processes of interpretation – should be considered, as Kant (1790, 43) declared, a field intrinsically linked to the subjectivity of the observer. One of the possible definitions of the 'qualitative' method or analysis is that of «an elemental method of research, neither statistical nor numerical, used to characterize the constituent elements of matter and describe their properties; in the social sciences, a method employed to examine subjective human experience using non-statistical methods of analysis» (Cardano, Ortalda 2020, 49). Following this definition, this approach is descriptive by nature, related to language and based on interpretation. By contrast, in the so-called 'hard sciences', methods of analysis of physical and concrete matter are primarily, if not solely, quantitative, based on numerical measurements that are objectively computable and quantifiable.

Two examples will help elucidate these concepts. In the hard sciences – meaning those that pertain to the nature and physics of matter and not to human phenomena and their related cultural production – quality matters less than quantity. In other words, quality is subordinate. For instance, knowing the elemental quality of atoms (for example, Hydrogen and Oxygen) in a molecule is not sufficient to identify the given molecule until the two atoms are understood in a numerical, quantifiable relationship. Only after ascertaining that hydrogen and oxygen are present in a 2:1 ratio, that is, having counted the atoms to find that two Hydrogen atoms exist for every one of Oxygen, can we say that it is an H2O molecule, in other words, water. Thus, quality, in the natural sciences, is always determined after an analysis of quantities.

The second example is closer to the humanities. Looking at mosaics, we can appreciate their qualitative aspects, such as shape, color, iconography, iconology, ornament, and style. Combining formal observations with other data, particularly from coeval sources, allows the work to be contextualized and dated. A pertinent example would be the mihrab of the mosque of Córdoba commissioned by the Umayyad caliph al-Hakam II in 961, traditionally attributed in literature to craftsmen from the Byzantine empire (Etthingausen *et al.* 2001, 84). Only recently has an archaeometric investigation directed by Nadine Shibille confirmed the Byzantine production of some of the glass used in the mosaic *tesserae*. To determine these Byzantine origins, conservators analyzed the glass using highly sophisticated quantitative methods. This enabled the identification of the quantity, quality, and percentage of elements contained in the glass with a resolution of 1 part per million. The techniques adopted (laser ablation coupled with mass spectroscopy) determined the percentage ratio between oxides and identified specific concentrations of Boron that correspond to those in glass produced from raw materials found only on the Anatolian Peninsula (Gómez-Morón *et al.* 2021).

From this example, we can understand well the epistemological limitations to which Panofsky alluded, namely the subjective value of purely aesthetic interpretations. At the same time, as Panofsky also noted, quantitative archaeological or taxonomic methods enable us to broaden our interpretive horizons, add more data to our research, and construct a more solid and reliable «organic situation». In other words, quantitative methods make it possible to objectify subjective analyses and perform what Panofsky (1938, 108) wittily termed «intuitive aesthetic re-creation». Accordingly, we also understand why Panofsky contrasted Archaeology with Art History, placing archaeological disciplines in the scientific realm (as the study of matter) rather than in the humanistic realm (as the study of cultural production).

With this text, we hope to strengthen the conviction, expressed throughout this volume, that Art History would benefit enormously from quantitative methods. Moreover, we believe that Art History, like Archaeology, should be considered equal to any scientific discipline, by virtue of the methods it employs. We aim to prove that the apparent dichotomy between the two disciplinary realms, scientific and humanistic, is baseless and that the scientific method is the only valid epistemological approach for any investigation. Indeed, this is true not only for the disciplines in the so-called hard sciences, aimed at the study of nature, but also for the humanities, which analyze man-made objects, whether archaeological or artistic.

When integrating qualitative, interpretive methods typical of the humanities with quantitative, computational methods typical of scientific disciplines, we must also consider the digital revolution. Digital methods

have productively encouraged the adoption of quantitative methods even in humanistic disciplines such as Art History, especially now when databases are gradually replacing more traditional *corpora*. Furthermore, Digital Humanities emerge as an effective bridge between scientific and humanistic disciplines. In the current historical moment, digital methods not only foster greater permeability between disciplinary approaches but also offer enormous potential and new challenges.

In what follows, we will pursue large-scale quantitative methods and digital approaches from two different perspectives. First, starting with the greatest amount of potential data available for our field of investigation (i.e. liturgical furnishings of medieval sacred spaces throughout Southern Italy), we will reduce the scale to concentrate on a qualitative analysis of a single object, whether whole or in fragments. Second, we will again analyze and manage a large amount of data, but this time based on a single case study in order to determine its quality.

2. Scaling and database approaches

We will begin with the first point, introducing the scope of investigation and objectives of the Project Mapping Sacred Spaces: Forms, Functions and Aesthetics in Medieval Southern Italy (https://www.biblhertz.it/en/dept-michalsky/sacred-spaces). This project investigates Christian sacred spaces and liturgical practices in medieval Southern Italy (11th-14th centuries), under the direction of the authors with Manuela Gianandrea (Sapienza University in Rome) and Tanja Michalsky (Bibliotheca Hertziana – Max Planck Institute for Art History). The Bibliotheca Hertziana and Sapienza University have collaborated on this project since 2018, and most recently were joined by the University of Siena. Since 2020, the project has offered a collaborative platform for an international group of specialized scholars, comprising art historians, architects, and digital scientists. Our colleagues are based at universities in Rome, Naples, Salerno, Venice, Heidelberg, and Cambridge.

Historical research on medieval sacred architecture requires an investigation that reconstructs an important component of its space, as many liturgical areas, their furnishings and decorations have been lost. Of course, such reconstructions by nature necessitate some speculation, though they should be carried out as reliably as possible using scientific methods. This preliminary reconstruction also enables us to investigate the perceptual dimension of the sacred in its original historical setting, comprised of spatial-sensory experiences that both included and excluded different actors through barriers, screens, and curtains. Other experiences involved the interaction of ritual and devotional practices with sensory stimulation aided by images, materials, colors, lights, sounds, and scents (Palazzo 2014; Pentcheva 2017; Bedros, Scirocco

2019). Moreover, only through this contextual analysis is it possible to reconstitute the intrinsic and extrinsic relationship between architectural spaces and their artifacts, a crucial aspect that art historical research has begun to consider only in recent decades (Piva 2006).

The remarkable role liturgical furnishings such as altars, ambos, ciboria, and enclosures had and still have in the art historical sphere should not be underestimated. Southern Italian liturgical furnishings have always enjoyed special attention as distinctive, local products since the advent of the discipline of Art History (Scirocco 2020). This is thanks to the large amount of extant documentation, despite much physical displacement, transformation, and destruction, and because of their formal and material qualities. Medieval architecture is quite difficult to see in its original state after having undergone so many transformations and restorations, and a very high percentage of Italian medieval liturgical furnishings are now lost or decontextualized. For a variety of reasons, including the Catholic Church's reforms throughout the Italian Peninsula and the functional and aesthetic demands of the Renaissance and Baroque periods, most medieval furnishings have not survived or have been dismantled and rendered fragmentary. In many cases, these decontextualized elements have been recombined in other ensembles or repurposed (Gianandrea, Scirocco 2018; Longo, Scirocco 2022).

Thus, one of the first objectives of the Mapping Sacred Spaces Project is to analyze the scattered evidence pertaining to eleventh- through fourteenth-century liturgical installations and to reconstruct the more monumental furnishings, such as enclosures, ambos, altars, and ciboria. These structures defined the sacred space of Southern Italy in terms of its form, function, and aesthetic values. This project promotes an approach based on established methodologies in Archaeology and Art History. Our approach also exploits the potential offered by the Digital Humanities and includes liturgical studies, archaeometrical approaches, and scientific investigations of materials (Longo 2011; Longo, Giarrusso 2011, 2014; Gianandrea, Longo 2020; Longo, Scirocco 2021, 2022).

Our census of monuments and sites documenting the locations and material traces of medieval liturgical furnishings held in Southern Italy currently counts 338 records. A digital map displays all this data (Fig. 1), which in its full implementation can be queried from the macroscale (territorial) down to the microscale (architectural components, fragments and decorative patterns). Already, the systematic collection and mapping of this data forms the basis for a research corpus dedicated to liturgical furnishings produced in Southern Italy between the eleventh and fourteenth centuries (a tool that may also prove useful in the future for institutions dedicated to conservation and preservation). This, however, is not the primary objective of the project and does not exhaust its potential for present and future research.

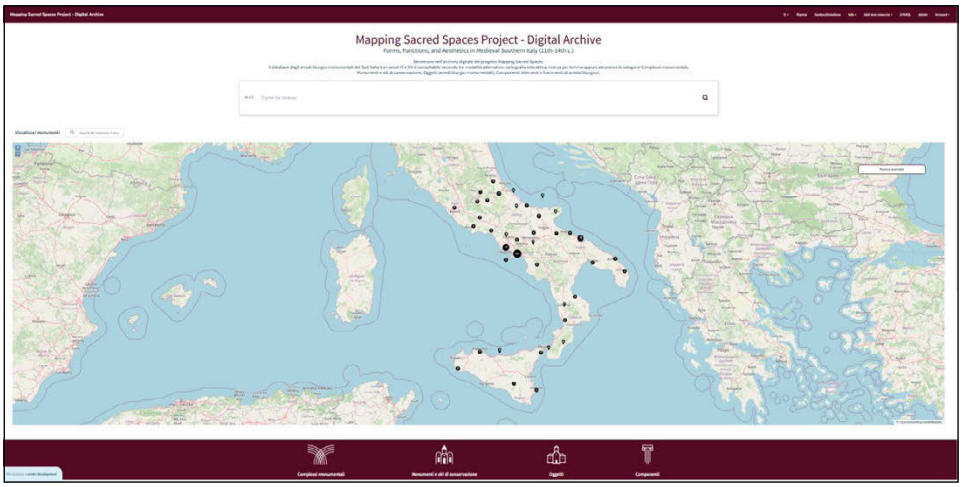


Fig. 1 – The Mapping Sacred Spaces Digital Archive. Homepage: graphic interface showing the map displaying the census of monuments and sites and documenting the locations of medieval liturgical furnishings material traces held in Southern Italy (currently 338 records).

The need to collect and compare a considerable amount of data on scattered or decontextualized objects and fragments at different spatial and temporal scales required systematic organization. We organized our data according to the project's research questions and created a digital archive connected to an interactive map. Its main functions and outputs are:

1. Organize knowledge:
   a. Collect and organize conserved and/or documented material with historical and technical data, and localize this information;
   b. Organize new data that emerges from research results;
   c. Trace or suggest relationships among objects and/or sites.
2. Answer research questions:
   a. Show and map data according to specific queries;
   b. Visualize meaningful relationships among entities.
3. Raise new research questions.

Combining interpretative complexity with quantitative methods is obviously the challenge we are dealing with. Using the monumental complex of the Cathedral of Saint Andrew the Apostle in Amalfi as an example, we briefly show how the database is organized on different scales corresponding to three hierarchical levels, ranging from monument to fragment (Fig. 2). The first level (Level A - Monuments and Collections) concerns monuments, museums, or other sites of historic preservation that contain objects and

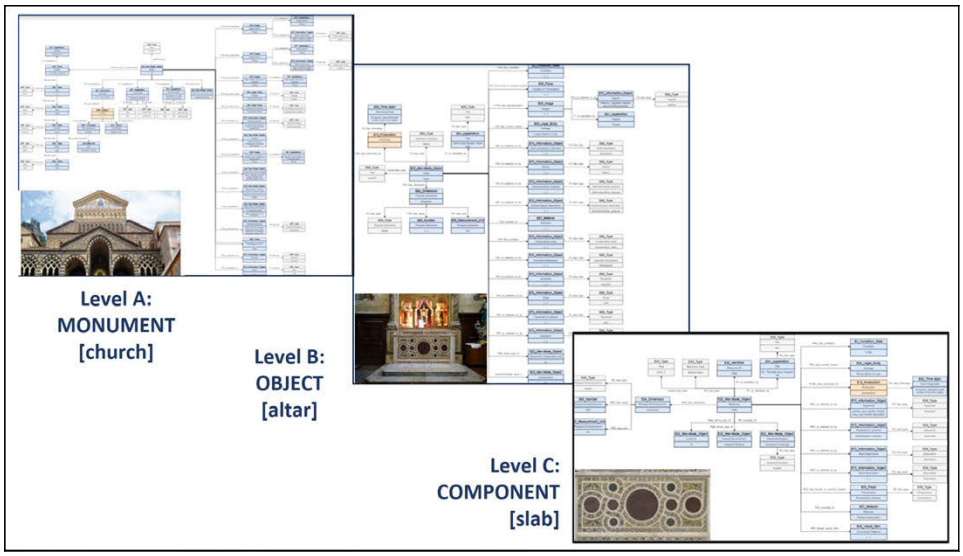


Fig. 2 – The hierarchical organization of the MSS-Digital Archive corresponding to three different ontologies and scales, ranging from monuments to components.

fragments, whose location is mapped in the building's plan. The second level (Level B - Objects) includes monumental objects, by which we mean preserved medieval liturgical installations (pulpits, ciboria, etc.), or post-medieval monumental assemblages made by reusing fragments of medieval furnishings. In the Amalfi case, this level includes two Counter Reformation pulpits, Baroque and neo-medieval altars, and contemporary liturgical furnishings. Our Level B example is an early twentieth-century neo-medieval altar made with elements from late twelfth-century furnishings. The third level (Level C - Components) catalogs the *in situ* components of these monumental objects or fragments that have scattered, placed on the same scale. In this case, we consider a marble screen reused in the altar that is likely to have come from a medieval ambo.

Together with digital scientists working on the project, we implemented different ontologies based on CIDOC-CRM for each level (A - B - C). These ontologies respond to the descriptive, historical, and relational matters at the center of our investigation. The database, created with the support of an outside firm (Advance Service, Crete) and implemented by and integrated into the data management system of the Bibliotheca Hertziana - MPI by Dr. Alessandro Adamou with the collaboration of M.A. Polina Voronova, provides a series of semantically modeled fields for specific research questions. These include the provenance of objects and fragments, the techniques used, the

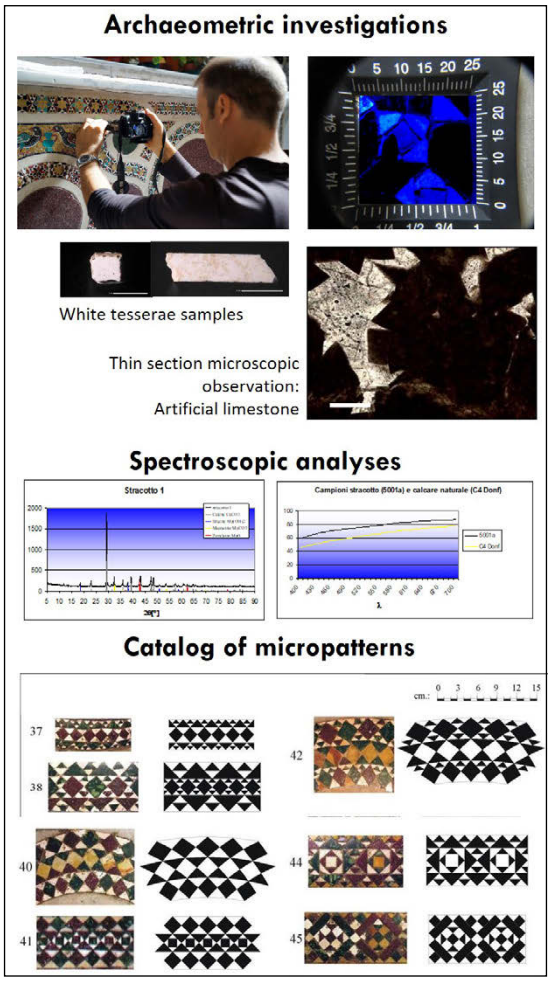


Fig. 3 – Archaeometric investigations, including UV observation, petrographic, colorimetric and multispectral analysis to identify employed materials, and cataloguing of *opus sectile* ornamental patterns.

ornamental patterns employed, documented but lost objects and fragments, and different types of relationships among objects and historical actors.

The slab fragment embedded in the neo-medieval altar underwent different types of archaeometric investigations to identify and distinguish its materials, including UV observation, petrographic analysis, and colorimetric and multispectral analysis. We also took reliefs, surveyed, and catalogued the

ornamental motifs (Fig. 3). This information enabled us to create horizontal relationships between different artworks and sites, again permitting a consideration of geography beyond individual case studies. The investigation considers, on the one hand, the chronology of the object, its original and current functions, visual forms and style, and historical context. On the other hand, it also factors in measurements, mapping, the analysis of the materials used, and processing techniques. As already noted, the integration of the qualitative analysis with the quantitative data represents one of the most ambitious challenges of the Mapping Sacred Spaces Project.

In its fullest development, the digital archive will provide large scale critical and scientific cataloging of thousands of artifacts scattered throughout Southern Italy. It already provides smaller scale tools for single case studies while also offering all available data to attempt the most reliable reconstructive hypotheses possible.

3. Case study: the reconstruction of the choir and ambo of Monreale cathedral in the late twelfth century

Turning now to a single case study involving complex data, we will focus on liturgical spaces in the cathedral church of Monreale, the center of a Benedictine complex founded by the Norman King William II in 1172 and elevated to an episcopal see in 1183 (Krönig 1965; Dittelbach 2003) (Fig. 4a). We focus here on the fragmentation and substantial disappearance of a key component of the medieval building, namely the double choir screen with its attached ambo, dismantled in 1658 at the behest of Archbishop Ludovico Alfonso de Los Cameros. Corresponding to this void is a considerable amount of data to systematize, consisting of either extant material evidence or textual and graphic sources related to the lost elements. This amount of data requires the implementation of an appropriate system for its management and interpretation, which will then facilitate the formulation of one or more reconstruction hypotheses related to the lost objects.

In addition to collecting all available fragmentary evidence pertaining to medieval liturgical furnishings (Fig. 4b), we conducted several archaeological and archaeometrical observations on-site. This included the analysis of materials used in the mosaics and in the *opus sectile* floor and wall coverings. Such work made it possible to verify the authenticity of large segments still *in situ* and to identify the original floor elevations and the precise topographical areas in which the monumental twelfth-century liturgical furnishings had been located prior to their dismantling in the mid-seventeenth century (Longo, Scirocco 2020, forthcoming). Remnants of the Norman period liturgical furnishings include marble fragments from the wall coverings of the two screens and from the supports of the pulpit, a large number of red porphyry

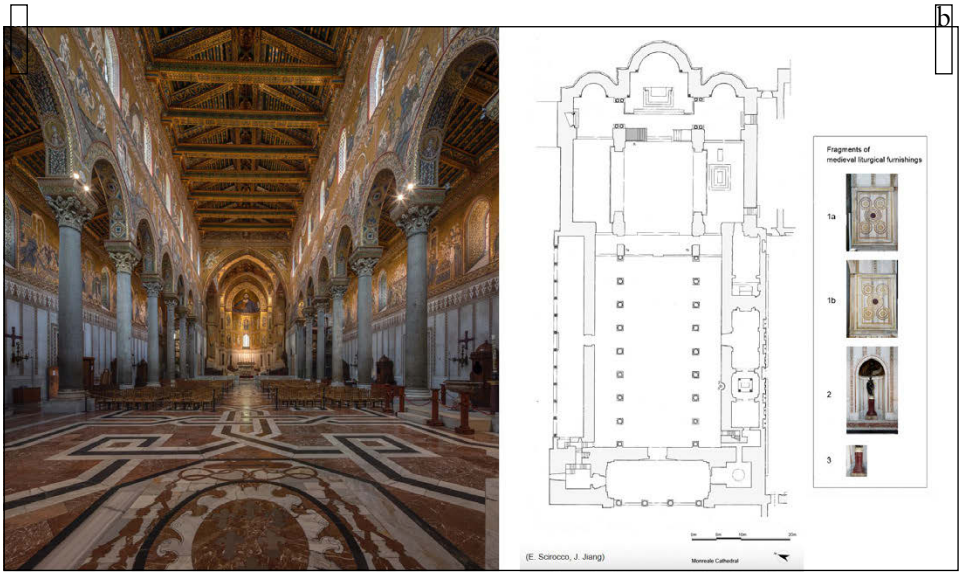


Fig. 4 – a) Monreale (Palermo), Santa Maria La Nuova cathedral, interior view looking East (Bibliotheca Hertziana – MPI, Roberto Sigismondi); b) plan of Monreale cathedral (elab. Scirocco&Jiang from Krönig 1965), with mapping and numbering of the extant remaining components and fragments of the medieval liturgical installation.

fragments, and two cipollino marble panels with a quincunx motif in the walls at the entrance to the presbytery (Fig. 4b, 1a-1b). Indeed, the cipollino panels are not far from their original location, where they once decorated the western facade of the choir's second wall. The preservation of a niche with mosaic decoration, now relocated on the wall of the southern nave, is exceptional (Fig. 4b, 2). It was once the apsis of a small chapel dedicated to Saint John the Baptist, which was situated beneath the ambo and hosted the baptismal font. This font consisted of a now-lost Roman *labrum* made in Spanish *brocatello* and supported by a sculpted porphyry column, which is still next to the aforementioned niche in the southern nave (Fig. 4b, 3). This, in sum, represents the state of the existing material data. From here, we had to begin an attempt to recover the sumptuous apparatus of liturgical furnishings of the church founded by William II of Sicily.

The research was initiated in 2009 (Scirocco 2010, 2016). Beginning 2018, it has been developed, enhanced, and perfected through the joint study of the two authors of this text (Longo, Scirocco 2020). Our research has demonstrated the unreliability of prior reconstruction proposals, which were widely accepted by subsequent studies (Figs. 5a-b). One is the graphic reconstruction (1698) developed by Gaetano Lazzara about forty years after the

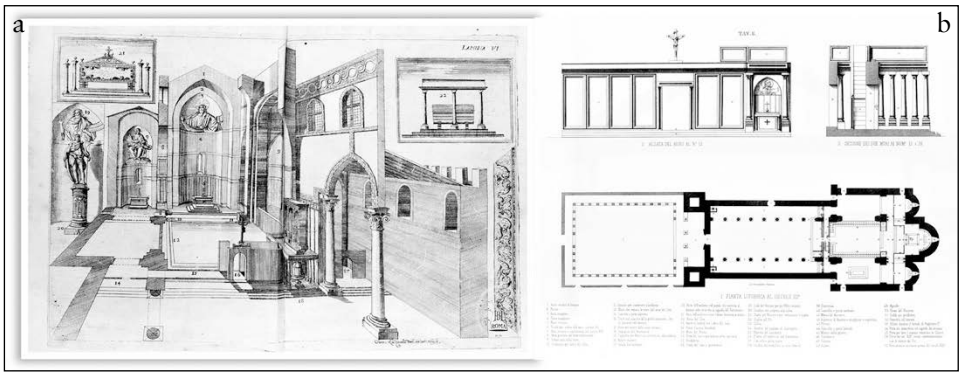


Fig. 5 – a) Gaetano Lazzara, interior view of Monreale cathedral: drawing (print on paper) with section showing the hypothetical reconstruction of the medieval furnishings (from Del Giudice 1702, tav. VI); b) hypothetical reconstruction of the medieval liturgical installation of Monreale cathedral according to Domenico Gravina. Frontal and side views of the choir screen with the attached ambo, and reconstructive plan of the church (from Gravina 1859, II, tav. 6).

destruction of the medieval furnishings (Del Giudice 1702, tav. VI). In 1859, Domenico Gravina proposed the second and very influential reconstruction (for a first critical re-evaluation, Zorić 2009) based on the detailed inventory drawn up in October 1658 during the dismantling of the ambo and the choir walls (Gravina 1859, I, 55-58, II, tav. 6).

The 1658 inventory, published by Gravina and preserved in its original form at the Monreale Cathedral Archive[1], is an extraordinary source. It provides an ordered and detailed list with the quantity, dimensions, and location of all the architectural and structural elements that comprised the furnishings, adding notes about their constituent materials and decorations. These include the enclosures between the transept and the three naves (the two «choir walls», the «right wing wall» and the «left wing wall», as they are called in the inventory), all the architecture of the ambo (from the columns to the upper part of the platform and the access stairs), and the underlying chapel of Saint John the Baptist (floor, apse, altar, and baptismal font). Thanks to the inventory, all the parts (a few hundred) that once constituted the microarchitecture of this lost twelfth-century liturgical setup could therefore be available virtually. However, their ideal reconstruction into a reliable and verifiable model generates a series of doubts and choices that require assistance and reconciliation with other data and this is where the quantitative approach comes into play. Still, potential contradictions and ambiguities might be solved by using comparative and qualitative analysis.

[1] The Authors thank Father Nicola Gaglio for facilitating its consultation.

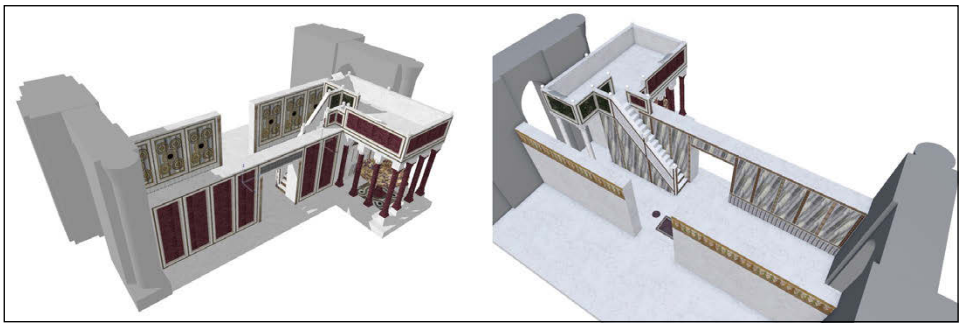


Fig. 6 – Three-dimensional views of the hypothetical virtual model of the medieval choir screen with the attached ambo in the cathedral of Monreale: left, western (exterior) side; right, eastern (interior) side. Views from the HBIM created by the Authors in collaboration with Piotr Kuroczyński and Karol Argasiński (Hochschule Mainz and the Warsaw University of Technology) (rielab. R. Longo, E. Scirocco, Bibliotheca Hertziana - Max Planck Institute for Art History).

Correlating the 1658 inventory with other older sources containing direct information about the liturgical setup of the Monreale choir when it was still in existence has been crucial. These sources include a map of the Monreale complex attached to the 1590 *relatio ad limina*, held in the Vatican Apostolic Archive (AAV, Congr. Concilio, Relat. Dioec., 574A, Schirò 2009), and early modern textual descriptions (De Caumont 1418/1858; Alberti 1567; Lello 1588,1596). All the information extracted from the interpretation of these graphic and textual sources has been cross-referenced in a synoptic table, with simple Excel worksheets. Next, we tried to visualize the results yielded from the dialogue between the data in a reconstruction (or virtual anastylosis) by using the possibilities offered by 3D digital modeling. After making several attempts beginning in 2014, which were not fully convincing due to the difficulty interpreting certain sections, we expanded the scope of the investigation by including precise surveys of the architecture and archaeological evidence *in situ* and by studying the material and technical aspects of the surviving artifacts. This work enabled the development of a new proposal, a 3D model made in collaboration with Piotr Kuroczyński and Karol Argasiński from Hochschule Mainz and the Warsaw University of Technology using HBIM methodology (Heritage Building Information Modeling), previewed for the first time here (Fig. 6). Current studies on this site and the latest knowledge about similar cases in the surrounding geographic area support the reliability of this proposal.

Let us briefly outline the main parts of the reconstructed medieval liturgical furnishings of Monreale cathedral, made around 1180, that survived with minimal modifications until 1658. The division between the central nave and the space occupied by the monks' choir in the presbytery was made with

two parallel walls. The more external one was covered with porphyry slabs surrounded by marble bands with ornamental motifs in *opus sectile*. The other, more internal wall had cipollino marble slabs and mosaic decoration in quincunx, also surrounded by bands with *opus sectile* decoration. The ambo, which rested on the more external wall and extended into the central nave towards the west, consisted of two parts: one towards the nave, dedicated to the reading of the Gospel, and the other towards the presbytery, i.e., towards the inside of the choir, dedicated to the reading of the Epistle. The first part incorporated red porphyry, and the second part featured green porphyry. The ambo housed the chapel with the baptismal font and the aforementioned apsidiole embellished with mosaics.

Thanks to the model, we were able to deduce the following dimensions: 4.2 m in height for the first wall (in relation to the nave) and 4.4 m for the second. At its peak, the ambo reached 5.5 m, and the underlying chapel measured 3.5 m on each side. Overall, the margin of error in the model's measurements is relatively low, estimated to be between five and eight cm. This margin results from an approximation inherent in the sources, such as: 1) the imprecision of the textual information itself (e.g., «1 cane and 3 scarce palms»); 2) the conversion from the Sicilian palm measurement system to the metric decimal system; 3) the mounting systems between individual architectural elements in the overall system (for example, the inventory provides the total measurements of the dismantled porphyry slabs. However, the size of those slabs, if inlaid in frames or pilasters within the wall's structure, would be two or three centimeters smaller). In the end, after holistically reconstituting the individual components listed in the inventory, thanks to the integrated analysis of sources and material data, the resultant reconstruction differs significantly from the historical proposals of Lazzara and Gravina and is perfectly consistent with the construction and aesthetic systems in Norman-era Sicilian sacred spaces.

Our goal of creating a model that would serve as a repository for research data, organized not in tabular form (as in our Excel worksheets), but in a topographical and three-dimensional form, motivated our decision in favor of a HBIM to reconstruct a completely lost ensemble even if this technology and approach are more typically used for surveying existing buildings (Attenni *et al.* 2022; Del Pozzo *et al.* 2024). Appearing as annotated links to the individual architectural elements, the sources and justifications for the reconstruction can thus be queried and verified by the scientific community, just like footnotes in a written text. However, the scientific community has not yet reached unanimity, either among the different disciplines involved or within Art History itself, qui regarding standards for 3D models. Areas under debate, among others, include shared open-access infrastructures for publishing and annotating three-dimensional reconstruction models, the

assessment of the scale of uncertainty, and standards for the publication of three-dimensional research-based models as scientific products (Apollonio 2016; Camerlenghi *et al.* 2023; Cazzaro 2023; Kuroczyński *et al.* 2023; Foschi *et al.* 2024; Papadopoulos 2024; Ioannides *et al.* 2025).

We therefore chose our first group of annotations for the HBIM model according to the needs of our case study. Currently, the model contains only a few annotations; however, the goal for the next few months is to incorporate all related metadata and paradata into the model and publish it, making it available according to FAIR principles (https://www.go-fair.org/fair-principles/). The metadata include function, dimensions, and constituent materials of the elements represented in the model (with reference to the controlled vocabularies of the Getty Research Institute's Art & Architecture Thesaurus®: https://www.getty.edu/research/tools/vocabularies/aat/). Components modeled on real extant objects specify their current location and conservation conditions. The paradata include the sources used to create the modeling, position, and texture of the individual components in the HBIM. We also indicated whether the historical existence of a given component represented in the model is hypothetical or not.

To evaluate the degree of reliability of the representation, for this specific case study, we decided to use a three-part scale of uncertainty: low, medium, and high, with a note describing the reasons for each choice made. For example, consider one of the panels with a quincunx motif mounted on the second choir wall (Fig. 7). Here, the uncertainty level is considered low because the slab with the quincunx is preserved, and its relationship to the depicted wall is definite, confirmed by all textual sources prior to 1658. The only imprecise data point is the exact position of this specific panel on the wall. In the model, we placed it in the second available slot from the left. However, there is no way to know whether this was its original position among the six possible on this wall. This missing data is ultimately negligible for the purposes of this reconstruction, since the six panels were almost identical. After we apply this criterion to all constituent parts of the model, the levels of uncertainty will be elucidated in the overall model through color coding.

In the end, we reconstructed the precise locations of the different components of the choir screens and the ambo of Monreale closely adhering to historical and archaeological data. Furthermore, the widely documented materials and decorations used in the model provide qualitative information essential to understanding the aesthetics of the furnishings. Assessing specific patterns in the ornamental *opus sectile* was not always possible, but for the 3D model we used designs resembling the original elements preserved *in situ* in the same building, i.e., the Cathedral, the Diocesan Museum, and the exhibition rooms near the Cloister Terraces.

A reconstruction model is inherently a virtual surrogate, an abstract and distilled idea of a lost original, whose real, historical qualitative features are only

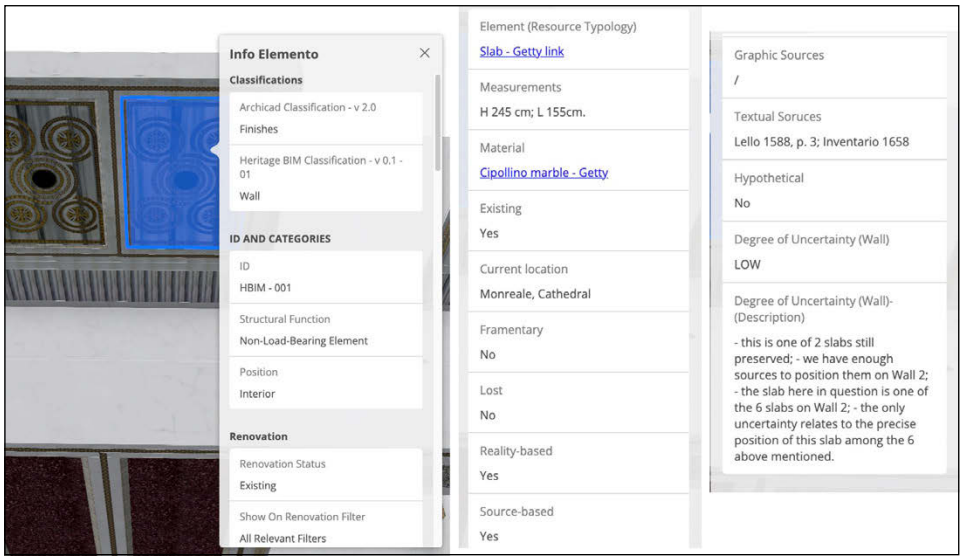


Fig. 7 – HBIM annotations with assessment of uncertainty for one of the panels with a quincunx motif mounted on the second choir wall. The annotation describes the reasons for the choice made within a three-degree scale of uncertainty (on the right).

available to us through fragmentary material evidence, and therefore destined to remain incomplete. This evidence and its degree of interpretation, however, can be integrated into the HBIM model and the metadata and paradata we applied to it (for the different aspects involved, Münster *et al.* 2024). Additionally, we would like to emphasize that the 3D modeling efforts were not undertaken solely with the intention of 'reconstructing' something lost. Trying to reassemble the whole also responds to the hermeneutic and epistemological need to cope with the large amount of available but fragmented information related to this exceptional case study. Modeling in 3D has proven to be an indispensable heuristic tool, which inevitably subjects hypotheses to verification and possible correction. Above all, it provides a dynamic tool that represents the current state of research while also being capable of modifications as new data and hypotheses emerge (Camerlenghi *et al.* 2023).

4. Conclusions: taxonomy and analytical synthesis

In conclusion, our experiences with this project as we have briefly presented them have yielded insights beyond results particular to specific research. We have deduced how Art History would benefit from quantitative and network approaches. We define 'network' not only as a web of relationships and

exchanges between different case studies, but also as one of interdisciplinary work. More broadly, we have underscored the need to question traditional distinctions between scientific and humanistic disciplines and to welcome holistic research approaches and practices. In so doing, we aim to usher in a new aspect of knowledge that balances mysticism and logic.

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ABSTRACT

According to a traditional distinction, quantitative and qualitative research approaches are the exclusive domain of the hard sciences, the former, and the humanities, the latter. Taking as its starting point E. Panofsky's reflections on the disciplinary status of Art History in relation

to its method of investigation (1940), this paper aims to demonstrate the anachronism of the hierarchy between disciplines based on the adoption of quantitative or qualitative methods, in favour of a more transversal scientific methodology. Looking at Art History in particular, it is undeniable that the digital revolution has enabled and strongly stimulated quantitative approaches and at the same time fostered transdisciplinary collaborations between different scientific areas. Based on these premises, the article presents the research methodologies and some results of the project Mapping Sacred Spaces: Forms, Functions, and Aesthetics in Medieval Southern Italy, in which the management of a large amount of fragmentary data is addressed. These are either fragmented artistic artefacts scattered over a wide geography, to be analysed at different topographical scales, or a single case study to which a large number of sources and research materials are linked, requiring a systematic and simultaneous management of data. In particular, a preview of the digital archive of the project will be offered, while the preliminary reconstructive 3D model (realised with HBIM technology) of the choir screens and ambo of the Cathedral of Monreale (c. 1180) will be presented for the first time.

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THE CHURCH OF SAN LORENZO IN MIRANDA: POPULATING AN ECOSYSTEM

1. Introduction

The concept of cultural heritage has evolved beyond being a static entity confined to museums, archives, and libraries. Instead, it is now recognised as part of a dynamic and interconnected system, a perspective that has extended far beyond the academic community. The advent of digital technologies has revolutionised our relationship with cultural heritage, transforming it into a dynamic organism where assets and communities interact, significantly influencing its preservation, accessibility, and transmission as collective memory. In essence, we are witnessing the emergence of a true ecosystem (Bianchini *et al.* 2019), where technologies, platforms, tools, researchers, and citizen scientists collaborate within a shared environment that increasingly blends the physical and digital worlds into what is now termed a phygital reality. However, for this reaction to occur and be sustained, specific catalysts are required: primarily, the data available and the information that users process and reintegrate into the system. Collecting, archiving, sharing data and transforming them into information do constitute the essential fuel for the development and evolution of the cultural heritage ecosystem.

Within this framework, the layering of data and information is crucial not only for capturing the multifaceted nature of cultural heritage, but also for enhancing its accessibility by highlighting its inherently multidimensional character. This shift suggests that the challenge for both the academic community and the wider public is no longer merely the collection and digitisation of cultural assets but rather the creation of a digital environment where different levels of knowledge can be seamlessly integrated. It is important to distinguish between data and information, a distinction often overlooked in everyday language but essential within a scientific discussion. Data refer to quantitative records obtained from an object (typically through measurement) whereas information is the result of interpreting these data. This transformation process unfolds in three fundamental stages: collection, selection, and interpretation (Bianchini 2014).

The data collection phase has benefited enormously from the transition to digital methods. In fact, traditional approaches to architectural or archaeological survey, excavation documentation, archival research do not actually generate data but rather reflect the subjective readings of the scholars conducting these tasks. This inherent subjectivity introduces a significant

methodological bias, conflicting with the scientific definition of data. Massive-acquisition tools such as 3D capturing, digital imaging, photogrammetry and diagnostic sensors have drastically reduced this subjectivity, enabling the application of rigorous scientific standards to cultural heritage studies. This paradigm shift allows multiple researchers to work on the same, reliable dataset (e.g., a point cloud) offering diverse hypotheses and interpretations based on equally consistent and verifiable data. At this stage, however, data remains 'raw' and requires further selection and interpretation before they can be transformed into meaningful information. The selection phase involves critically assessing the collected data to identify those most relevant, while interpretation consists of a comprehensive reading that aims at enhancing our understanding of the studied object and its characteristics.

A broader challenge is now emerging: how can this vast volume of data be systematically archived, searched, and retrieved? Beyond platform-related issues where efforts are underway to establish a standard, the key lies in defining a parameter that is as independent as possible from data type that, referring to cultural heritage, can encompass images, texts, 3D models, videos, sounds and much more. In this context, georeferencing is emerging as the most promising and universal method for cataloguing any cultural heritage-related data. Georeferencing is not merely about spatial localisation; it serves as the foundational infrastructure for interlinking diverse elements, including historical documentation, digital models, stratigraphic data, landscape constraints, restoration interventions and so on. This approach facilitates the construction of an integrated knowledge network where each heritage element is positioned within a unique spatial context, providing a common denominator for its different components.

The reliability of this infrastructure depends significantly on the tools employed. While open-source technologies can have margins of error up to 20 m, more precise techniques such as GNSS, laser scanning, and photogrammetry offer accuracies within just a few centimetres. The integration of these technologies enhances both localisation precision and the interoperability of data formats (e.g., GIS, BIM), promoting a more dynamic and effective management of cultural heritage. Furthermore, georeferencing enables not only the cataloguing of tangible elements, but also the diachronic documentation of their transformations, benefiting both scientific research and conservation efforts. This approach offers a viable path towards overcoming traditional divisions between archives, museums, and territorial information systems, fostering the development of a sustainable and inclusive phygital ecosystem where knowledge is continuously enriched and updated. To ensure the full effectiveness of this model, investment is needed in shared infrastructures, format standardisation, and open-access policies, as only through conscious integration can these processes be sustained.

Quite apart from these broader considerations, the digitisation of built artefacts has undergone an even more profound transformation, especially in the processes of data collection, selection, and interpretation. In this field, in fact, 3D capturing technologies have not only minimised methodological biases in data acquisition, but have also, for the first time, allowed the artefact itself to be regarded as a primary source of information for its own study. At first glance, the idea that a heritage artefact should be considered a source of information for its own analysis may seem self-evident. However, this perspective has only become truly viable due to the combined effects of two digital-age advancements. The first is the availability of scientifically reliable data, as previously discussed. The second, more procedural and design-related, concerns the comprehensiveness of acquired data relative to the physical extent of the artefact, a high-resolution model composed of billions of geometric points, maintaining consistent metric and geometric reliability.

This emergent property, combined with the prospect of widespread data sharing among scholars (as is already common practice in the hard sciences but still rare in heritage studies), means that hypotheses previously based on limited, inaccurate, and non-shared datasets can now be tested directly against the artefact itself. Producing such datasets naturally requires additional effort and cost at the acquisition stage. However, when viewed from the perspective of cultural heritage as an ecosystem, this investment becomes negligible compared to the long-term benefits in advancing knowledge, enriching data repositories, and ultimately preserving the collective memory upon which every society is built.

C.B.

2. The application of the methodology for the complex of San Lorenzo in Miranda

As part of the PNRR PE05 CHANGES-Spoke 8 project, the aforementioned challenges were tackled by testing various methodological and procedural solutions using the church of San Lorenzo in Miranda (Rome) as a case study. In this context, the traditional approach to the church's historical and architectural study was enriched with new inputs, driven by the need to build an ecosystem that ensures interoperability and interdisciplinarity in data collection and organization. With the ultimate goal of transforming data into meaningful information through a process of 'knowledge stratification', the first step involved establishing a shared coordinate system for data georeferencing, defining a standardized structure for data and metadata organization, and identifying an information system capable of storing and displaying the data.



Fig. 1 – On the left, the church of San Lorenzo in Miranda's 3D laser scanner point cloud vertical section; on the right, aerial views in the archaeological area of the Roman Forum (images acquired during the SAPR survey campaign in 2022).

Regarding data georeferencing, a two-phase 3D integrated survey was conducted in 2022 and 2024 to capture and document the monument's physical characteristics. These campaigns combined 3D laser scanning, photogrammetry, and a topographic survey to georeference the point cloud by linking it to the archaeological Park of the Colosseum's network (Fig. 1). The reference geographic system adopted was the RDN which materializes the 2000's realization of the European Terrestrial Reference System (ETRS) (Baroni *et al.* 2009). Consequently, the georeferenced 3D point cloud became a fundamental resource for analysing the church and providing precise 3D absolute coordinates for all its elements. While the georeferencing procedures were being carried out, another key aspect involved structuring the data and metadata organization. As in all fields of research concerning tangible cultural heritage (TCH), the domain of architectural documentation and analysis required identifying all potential data sources – such as cartography, existing survey drawings, historical images, point clouds, and 3D models – and classifying the relevant metadata within a standardized framework.

For the church of S. Lorenzo in Miranda, this shared database structure was adapted from the one developed within the LazioAntico project (https://lazioantico.datascape.dev/app.html), a GIS-based atlas documenting the archaeological remains of ancient Rome (Carafa 2017, 44-55). The database is

designed to associate each archaeological unit of the ancient landscape with all available data, structured according to a specific taxonomy and semantic relationships. Its hierarchical framework is based on the concept of the Topographic Unit (TU), defined as 'the smallest trace that can be identified of human settlement or activity' (Ippoliti 2023, 3). Following this 'functional' distinction, the database is structured to host several phases and periods for each TU. Phases are meant as a timeframe from the starting to the end of a meaningful constructive transformation. Although the classification methods were largely compatible, the original structure – developed for archaeological data – required further adaptation to accommodate architectural documentation. In this context, the level of detail of information retrievable from written and graphic sources can be very high, varying significantly depending on the period of construction. For instance, in the case of the church of San Lorenzo in Miranda, bibliographic and archival sources make it possible to reconstruct the worksite stages, from the initial design to completion. This extensive documentation enabled us to trace the entire evolution of this initial phase, providing valuable insights into the building's historical and structural development.

Given this, while the original database structure's first TU phase would have identified a single period spanning from the beginning of construction in 1602 to the first modifications prompted by archaeological excavations in 1810, an additional criterion was introduced to distinguish the construction phase as a separate one going from 1602 until the completion of the church in 1720. Additionally, when dealing with architecture rather than archaeological remains, information related to the material consistency, the distribution of movable objects or furniture as well as the state of conservation documentation are crucial to describe in a more complete way an architectural object. To address this need, the database structure was enriched with additional TU parameters to provide more detailed descriptions.

As a result, the dataset classification of the church aimed to reproduce the constructive features of the building through a virtual dismantling. This virtual dismantling, allowed by the semantic structure, is the base for a digital reconstruction through 3D informative systems. In this direction Building Information Modelling (BIM) solutions can play a key role in stratifying the knowledge and interacting with multidisciplinary and heterogeneous data. In this perspective, the database structure was tested also to ensure a full compatibility with BIM parameters structure for future developments.

The following paragraphs will deal with the detailed description of the data collection and cataloguing phase for the case study and with the ultimate task of transforming data into information, unveiling through a combined study of point clouds, bibliographic sources and historical graphic documentation.

M.G.

3. The case study of San Lorenzo in Miranda, from knowledge to data cataloguing by topographic units

Having regard to the directives given by the Spoke 8, the study method is divided into two main stages. The first one consists of the collection of all available sources, both in analogue and digital form. The first stage starts from the selection of websites and databases related to the architectural heritage, not only able to provide digitised and freely accessible records, but also able to identify the location of analogue sources: archival documents, graphic and bibliographic sources. The second step is the digitisation of analogue materials, inventoried on the basis of scientific criteria. This operation is preparatory for their indexing, namely for association with historical, functional, typological and material information. All new documents – such as drawings, photographic documentation, test reports – are produced in digital form. This is also a precursor to a possible georeferencing of the data: in essence, the data are suitable to be inserted in a digital environment, possibly with more spatial references: not only the location of the architectural object, but also the place of the source itself (archives, libraries or other cultural institutes). Against this background, to better explain the study method, it is appropriate to provide brief descriptive notes on the monument under study, referring to the rich bibliography for more exhaustive details.

The church of San Lorenzo in Miranda, located in the Roman Forum, was built at the beginning of the 17th century on the ruins of the temple of

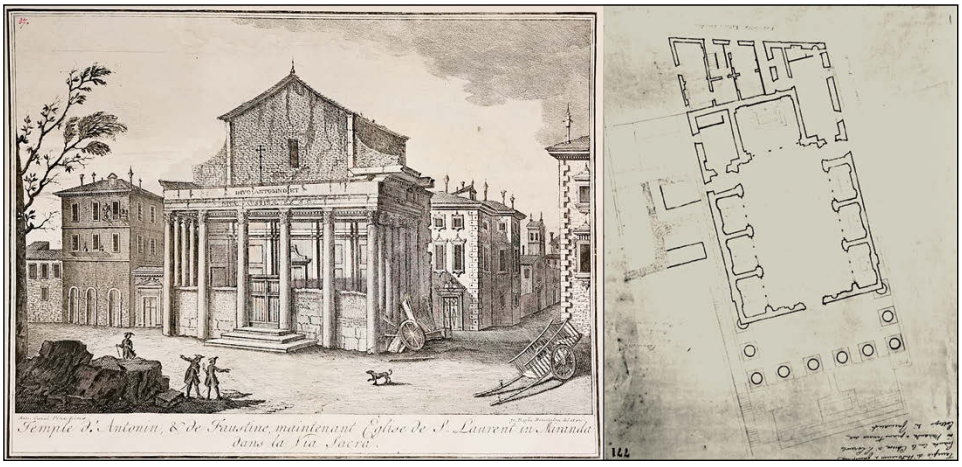


Fig. 2 – Left: J.B. Brustoloni, *Temple of Antoninus and Faustina, currently church of San Lorenzo in Miranda on the Via Sacra*, engraving, early 18th century (BIASA, Roma XI.3.VI.37); right: A. Migliorati, *Plan of the church and ground floor of the Nobile Collegio Chimico-Farmaceutico*, survey, 1903-1905 (A.S.A.RM, Archivio Disegni, Cart. Tempio di Antonino e Faustina).

Antoninus and Faustina 2nd century AD): the base, the side walls of the naos and the colonnade of the *pronaos* are closely connected to the early Baroque church, whose design is perfectly integrated with the ancient ruins. The building, therefore, is not simply rich in historical stratifications, but can be more appropriately defined as a binomial of two monuments, one within the other. Each of them retains its precise identity, but is now inseparable from the other. It is therefore a perfect subject for a study based on scientific data cataloguing criteria, as well as for the creation of an interactive product.

The ancient Roman temple – which according to reconstructions was of prostile type, preceded by a hexastyle U-shaped *pronaos*, and raised on a high base in tuff blocks preceded by a staircase (Pensabene 1996) – was transformed into a church already in 630, when pope Honorius II founded the collegiate of San Lorenzo the martyr in its ruins. This church was suppressed in 1429 by pope Martin V, who entrusted the complex to the *Universitas Aromatariorum Urbis*. Following this event, the *Speziali* (apothecaries) demolished the medieval building to make room for a small hospital and a chapel dedicated to St. Lawrence. These buildings were demolished in 1536 in the context of the redevelopment of the Roman Forum, ordered by pope Paul III on the occasion of the visit of emperor Charles V. Later, a phase of spoliation of the temple preparatory to the construction of the current church begun.

The construction of the current church, commissioned by the Nobile Collegio degli Speziali, began in 1602 under the direction of the architect Orazio Torriani (Bracciano 1578-Rome 1657, Dal Mas 2023) and ended in 1616, except for the facade, whose higher part was made only between 1721 and 1722, by the architect Matteo Sassi (Palmisano 2009). The religious building belongs to the most common type of church in the Counter-Reformation Age, consisting of a rectangular hall roofed with barrel vault, flanked by six chapels (three on each side) and concluded by a quadrangular presbytery (Fig. 2) (Benedetti 2011). The façade, in brick curtain and decorative elements in travertine, is structured with two overlapping orders of pilasters, with a curvilinear broken pediment. The sacred building was joined, on the back, by a four-storey building, designed by Torriani as a seat for the Speziali. This building was demolished in 1932, as part of the opening of Via dei Fori Imperiali. After the demolition it was necessary to redefine the rear façade of the church and rearrange the few remaining spaces as headquarter of the Order of Pharmacists, following a design provided by architect Virgilio Marchi (Dal Mas 1998).

The study of the building started from an analysis of the rich available bibliography primarily Dal Mas 1998 – which constitutes the main reference – but also subsequent articles by the same author (Dal Mas 2002, 2014, 2022, 2023) and other scholars (Pensabene 1996; Palmisano 2009), which provided a solid and reliable basis, thanks to their rich documentary

appendices. Nevertheless, further research has been conducted, unfortunately unsuccessfully, at the State Archives of Rome and the Capitoline Historical Archive. On the contrary, the collection of iconographic sources – mainly carried out at the Library of the Institute of Archaeology and Art History of Rome – was satisfactory. This research has provided a great number of images (engravings, drawings, surveys, old photographs) which show the changes of the building over time and allow to reconstruct the history of the building, integrating information from documentary sources. In total, the data collected can be grouped into three categories: 1) reliable data, documented from archival sources; 2) hypothetical data, due to the assumptions and critical reasoning of the authors who have previously studied the monumental complex, now accepted by the scientific community; 3) graphic sources, such as ancient drawings, engravings, paintings, photographs and depictions of the building.

The study of the sources has allowed reconstruction of a very rich chronology and a rather precise dating for most of the building elements. Another important step was an accurate metrological analysis on plans and elevations, obtained by a laser scanner survey. This analysis has allowed to identify the 'module' used by Orazio Torriani in the design of the 17th century church inside the ruins of the temple, highlighting also the great skill of the masons, who erected a rather regular building within an ancient pre-existence and taking into account also the many structural instabilities that have occurred over time on the wall structure, largely as a result of the 19th century's excavations.

M.P

4. The database structure

All data collected (historical information, sources and images) were stored in a GIS database, ensuring that the entire process was conducted according to established archaeological methods. Considering the history of the building, six topographic units were identified in the architectural organism. Precisely, the temple of Antoninus Pius and Faustina (unit 137), the medieval church (unit 499), the hospital of the Speziali (unit 500), the current baroque church (unit 501), the arrangement of the archaeological area (unit 502), the seat of the Speziali (unit 503). Each topographical unit has been circumscribed by accurate descriptions of architectural and artistic character. It should be noted that not all topographic units identify still existing parts of the building: in fact, the medieval church and the first hospital have been demolished and replaced by the current building, but in order to create a BIM model that would follow the complete historical evolution of the monument, it is necessary to take into account also the lost phases.

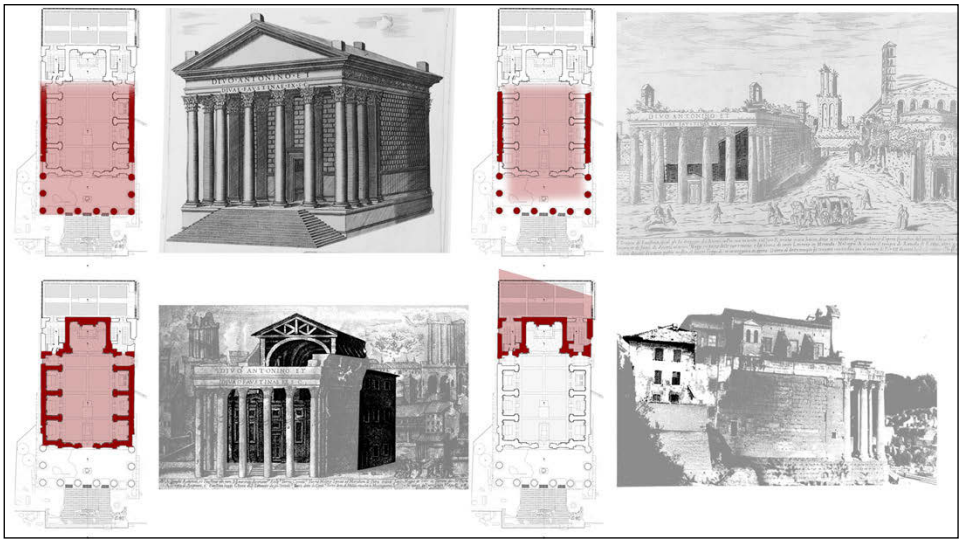


Fig. 3 – The topographic units and the corresponding graphic sources identifying them.

Moreover, the architectural history of each topographic unit has been synthesized into phases, of which chronological references and brief descriptions have been provided (Fig. 3). For topographic unit 137 (temple) a single phase has been identified: 1) stage 1 (141-present day): construction, after the death of Antoninus the temple was also dedicated to him, and the corresponding inscription was added. For topographic unit 499 (medieval church), considering the lack of information, a single phase has been identified: 1) stage 1 (630-1428): from the foundation of the church to its demolition. For topographic unit 500 (hospital of the Speziali), two phases have been identified: 1) stage 1 (1429-1535): construction and use of the hospital; 2) stage 2 (1536-1601): demolition of the hospital and partial spoliation of the temple ruins.

For topographic unit 501 (current baroque church of San Lorenzo in Miranda), five phases have been identified: 1) stage 1 (1602-1720): from the beginning of the construction of the current church, to the completion of the facade; 2) stage 2 (1721-1809): the church is regularly officiated, without significant architectural interventions; 3) stage 3 (1810-1834): first archaeological excavations in the portico of the temple, which prevented access to the church from its main door; 4) stage 4 (1835-1874): presence of a masonry bridge that connected the door of the church to the floor of the Campo Vaccino, bypassing the excavated *pronaos*; 5) stage 5 (1875-present day): demolition of the bridge and progressive continuation of excavations around the building.

For topographic unit 502 (arrangement of the archaeological area), three phases have been identified: 1) stage 1 (1810-1874): first stages of excavation. Initially only the bases of the columns and the floor of the *pronaos* were exposed, while the floor of the Roman Forum remained unaffected. The church door is accessible by a small masonry bridge built in 1835; 2) stage 2 (1875-1928): the site of the Roman Forum is progressively excavated to expose the entire base of the temple, while the bridge is demolished; 3) stage 3 (1929-present day): in 1929 the current brick staircase was built. Since that time there have been no further significant changes.

For topographic unit 503 (seat of the *Speziali*), three phases have been identified: 1) stage 1 (1613-1931): from the construction of the building up to the entire period in which the building exists; 2) stage 2 (1932-1957): from the demolition of the building and the arrangement of the rear façade of the church by Virgilio Marchi, until the period in which no major changes are recorded; 3) stage 3 (1958-present day): construction of the underground hall, behind the church choir, under the floor of the current courtyard.

The six topographic units and their phases are also referred to in the cataloguing of the graphic sources, which have been collected in a special database. Each source, in addition to parameters such as title, author, inventory number, type of representation and execution technique, has been placed in one or more historical periods of the topographic unit depicted, depending on the date of the source itself or the subject depicted. The same approach was followed for cataloguing bibliographic sources. In this way, all the materials useful for the study of the building are collected in a robust and flexible data structure, ready to support future research and analysis.

R.B.

5. Reconstructing the temple's plan: insights from survey data

The comparison between data obtained through laser scanner surveys and previously proposed reconstructions of the temple's original floor plan has revealed an important and unprecedented discovery. Current knowledge suggests a rectangular cella with a wall flush with the two external pilasters that turn onto the front, forming an L-shaped pillar (for the Roman phases of the temple: Bartoli 1914; Cassatella 1993; Pensabene 1996; Dal Mas 1998, 11-60; the modern reconstructions of the temple are based on those published in Bartoli 1914, tav. 1-2-3). For an effective graphic representation of the current state of knowledge regarding the temple's original appearance, refer to (Carandini 2012, tav. 103). However, the survey conducted during this study allowed for the precise localization of the remains of two pilaster capitals, now visible within the rooms of the current college (Fig. 4). These elements are positioned exactly in correspondence with the remains of the



Fig. 4 – Rome, temple of Antoninus and Faustina. Upper image: capital from the interior of the left wall of the cella; lower image: capital from the interior of the right wall of the cella. Today, both capitals are in the rooms of the College of Apothecaries.

external pilasters of the temple's cella wall, long known, thus creating a pillar free on three sides and anchored to the wall of the cella on the fourth side. The capital within the N-W wall logically continues into the peperino blocks corresponding to its base, which protrude from the wall line, despite erosion, indicating the presence of the pilaster itself. On the opposite side, later interventions have not preserved further traces.

These observations suggest that the temple's cella could not have had the floor plan currently attributed to it, where the naos wall is flush with the external pilaster. In this configuration, the wall would conflict with the presence of the internal pilaster. Consequently, this wall must be shifted inward by an indeterminate measure. The examination of historical representations of the temple helps to better understand this issue, which seemed to be recognized at least until the 18th century. A reconstruction of the temple's plan with the

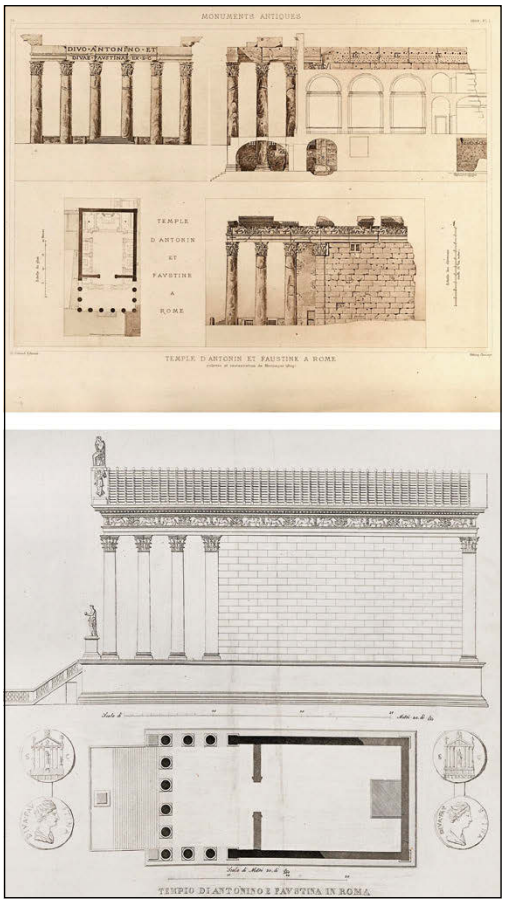


Fig. 5 – Upper image: sections and plan of the remains of the temple of Antoninus and Faustina (from D'Espouy 1905, II, 96, pl. 1); lower image: graphic reconstructions of the temple of Antoninus and Faustina (from Canina 1848, II, tav. XXIV).

cella wall flush with its front limit was already proposed by Palladio (1570, lib. IV, cap. IX, 33) and hinted at, with slight variations, in the drawings of Baldassarre Peruzzi (Bartoli 1914-1922, IV, fig. 506, tav. CCCVII) and Giovan Battista da Sangallo (Bartoli 1914-1922, IV, fig. 506, tav. CCCVII). The drawings by Giovanni Antonio Dosio (Bartoli 1914-1922, V, fig. 838, 839, tav. CDLVI) and Antonio da Sangallo the Elder (Bartoli 1914-1922, I, fig. 101, tav. LXVI), however, left the cella open, unable to identify the wall in question. Antonio da Sangallo the Younger presented an incomplete drawing

suggesting the presence of the wall without fully depicting it (Bartoli 1914-1922, III, fig. 477, tav. CCXC). Renaissance graphic documentation thus reveals that even then, there was uncertainty about the cella wall's location. Architects hypothesized its alignment with the external pilasters, without significant protrusions of the longitudinal cella walls.

In the 18th century, studies on the temple led to new reconstructions of its appearance and floor plan. Investigations promoted by the French Academy identified the capitals within the cella wall, corresponding to the external pilasters. Their presence suggested that the cella wall was set back from the longitudinal walls'ends by the width of the pilaster itself (D'Espouy 1905, II, 96, pl. 1) (Fig. 5). Luigi Canina also recognized the issue posed by the internal capitals and hypothesized the wall was recessed by an intercolumniation (Canina 1848, II, tav. XXIV) (Fig. 5). Historical reconstructions thus formulated two hypotheses, those of Canina and Mesnager, both plausible given the surviving remains. However, Canina's hypothesis appears more credible, as there is no trace of the cella wall adhering to the internal pilaster, implying a more inward placement. A third possibility exists for the arrangement of the temple of Antoninus and Faustina's cella wall, proposing the absence of a wall and the presence of a colonnade composed of four columns between the antae. This solution would explain why the wall has not been traced since the Renaissance and could find a partial parallel in the Templum Pacis in the Forum of Vespasian, where the cella wall was replaced by a colonnade. However, the extreme rarity of such an arrangement makes this hypothesis unlikely. It is more probable that the cella wall was dismantled earlier than other structures, as it did not support the roof, which rested on the lateral walls. This hypothesis also explains the complete absence of traces of the temple's rear wall, likely dismantled before the Renaissance, possibly alongside the front wall.

The structure, consisting of a pillar free on three sides at the ends of the cella's longitudinal walls, finds precedents in temples where the cella's side walls extend towards the front columns, as seen in the later phases of the *Aedes Iani* and *Aedes Iunoni Sospitae* at the current church of San Nicola in Carcere. Additional comparison comes from the temple of Juno Regina at the Portico of Octavia (Viscogliosi 1996), which features a similar floor plan, particularly regarding the cella wall and the arrangement of front columns extending along the side for three intercolumniations. The layout under examination also finds a strong parallel in the *Hadrianeum* (Presicce, Baldi 2024), whose cella presented a similar solution with pillars at the ends of the longitudinal walls. Notably, while the *Hadrianeum* was a peripteral temple, the core structure of the cella and its pronaos resemble that of the temple of Antoninus and Faustina, a significant detail considering the same patronage and their use as temples commemorating relatives of Antoninus Pius.

R.D.A.

6. Conclusion

In conclusion, the presented work highlights how the integration of digital technologies in the field of cultural heritage studies is radically transforming research, documentation, and conservation methods. The use of advanced tools such as GIS and BIM allows for a deeper and more accurate understanding of artefacts, overcoming the limitations of traditional practices. The ability to archive and share data in digital format also fosters the creation of a collaborative and shared working environment among researchers, professionals, and citizens, paving the way for a phygital ecosystem in which cultural heritage becomes a dynamic and constantly evolving resource. Digitization is not limited to mere data preservation but rather opens up new opportunities for the interpretation and enjoyment of heritage. Emerging technologies allow for overcoming the divisions between archives, museums, and territorial information systems, integrating different types of data into a single knowledge network. This multidisciplinary and interoperable approach enables a more comprehensive analysis of artefact characteristics, improving the quality and accuracy of the available information.

The case study of the Church of S. Lorenzo in Miranda demonstrates how the combination of historical analysis, digital data, and comparisons with similar examples allows for rethinking and reinterpreting the monument's structure in a more informed and scientifically grounded way. The differences in the diachronic stratification of the elements that make up the artefact and the details examined (such as the capital) highlight the need for a revision of traditional hypotheses, based on a more careful and precise reading of the available data. The aim is to build an active memory that crystallizes a diverse range of perspectives focused on the same cultural asset, defining the cross-cutting role of digitization as central to the study and conservation of Cultural Heritage.

In summary, advancements in digital technologies offer new fundamental tools for the conservation and enhancement of cultural heritage, transforming our ability to understand, manage, and preserve the material witnesses of our past civilizations. However, for these tools to be effective in the long term, continuous investment in shared infrastructures, the standardization of formats, and the adoption of open-access policies are necessary, ensuring that cultural heritage becomes an open and globally accessible resource.

F.P.

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ABSTRACT

This paper explores the impact of digital technologies on the study, conservation, and enhancement of cultural heritage, highlighting how tools such as integrated large-scale surveys, georeferencing, GIS, and BIM are transforming the research and management landscape of cultural assets, particularly in the integration of heterogeneous data. The paper emphasizes how the collection, selection, and interpretation of such data can be integrated into an interoperable system that connects various types of sources (historical, architectural, graphic) within a shared and phygital environment. The case study of the Church of San Lorenzo in Miranda (Rome) is presented to demonstrate how the collected data enable a more accurate understanding of ancient structures and their transformations. The proposed approach allows overcoming the limitations of traditional methods, offering new opportunities for documentation, research, and conservation. The paper concludes by highlighting the need to invest in shared digital infrastructures and open-access policies to ensure that cultural heritage becomes a global and sustainable resource for future generations.

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REMOTE REFLECTANCE SPECTROSCOPY ON THE PAINTING 'SAINTS PETER AND STEPHEN' CONSERVED AT THE FONDAZIONE GIORGIO CINI

1. Introduction

The preservation of Venice's cultural legacy, as emphasized by the Cini Foundation's motto, is not the worship of ashes but the stewardship of fire. This stewardship aims to pass down traditions, expertise, and the beauty of Venetian culture to future generations. The growing awareness of cultural heritage and technological advancements have driven the development of Heritage Science, a multidisciplinary field dedicated to improving «the understanding, care, sustainable use, and management of tangible and intangible heritage to enrich people's lives today and in the future» (ICCROM). Applied globally, Heritage Science highlights that effective conservation and preservation rely on understanding the material, historical, and artistic characteristics of artworks, along with their condition and degradation processes (Soldovieri *et al.* 2024). These factors are crucial for characterizing heritage items – be they objects, buildings, or sites – offering insights into historical contexts and craftsmanship while enabling precise restoration and long-term documentation.

Material characterization focuses on identifying materials, assessing their conservation state, and understanding degradation processes to guide restoration efforts. Several scientific disciplines can contribute to this goal: particularly physics (Mosca Conte *et al.* 2014) and, more specifically, the Science of Complexity, which has the appropriate scientific method to face the challenges of real complex objects such as ancient artworks (Marchant 2025). Among diagnostic techniques, non-destructive and non-invasive methods are preferred. These approaches, based on the interaction of electromagnetic radiation with matter, include imaging and portable spectroscopic systems. Techniques are classified by the specific electromagnetic spectral regions used or generated during measurement.

Multispectral and hyperspectral imaging capture objects across defined wavelength ranges beyond human vision (Vasco *et al.* 2024). Optical spectroscopy explores electromagnetic interactions with matter in the UV (200-380 nm), visible (Vis) (380-750 nm), NIR (750-1100 nm), and SWIR (1100-2500 nm) regions, typically in transmittance or reflectance modes. Photoluminescence, in turn, measures visible radiation emitted by materials under UV stimulation. These methods provide qualitative and quantitative data and are widely used in cultural heritage for pigment and dye analysis and for monitoring artwork cleaning processes (Picollo *et al.* 2019). The advent

of Fiber Optic Reflectance Spectroscopy (FORS) introduced a non-invasive technique, further refined with portable instruments capable of spanning UV to SWIR wavelengths. However, FORS is traditionally limited to cases where the probe can be placed in contact or near-contact with the artwork (Missori *et al.* 2019; Titubante *et al.* 2022). This study addresses that limitation by introducing a novel approach for remote FORS measurements.

Inspired by astronomical techniques, earlier attempts to achieve remote diagnostic reflectance measurements include the PRISMS system, which imaged wall and ceiling paintings from ground-level distances of tens of meters (Liang *et al.* 2007). More recently, advanced stand-off systems, including Raman spectroscopy, LIBS, hyperspectral imaging, and others, have expanded spectral range and resolution for remote sensing at distances of approximately 10 meters (Li *et al.* 2024). Additionally, Fourier-transform infrared spectroscopy has been adapted for remote applications, exemplified by the TWINS FT-HSI portable hyperspectral camera, which enables rapid investigation of paintings with enhanced spectral capabilities (Perri *et al.* 2019).

In this article, we present a method for remote FORS and apply it to the study of the colorants in the painting on a wooden panel, *Saints Peter and Stephen*, tentatively attributed to Antonio del Massaro da Viterbo (circa 1450-1516) and dated to the early decades of the 16th century. The painting is conserved at the Fondazione Giorgio Cini on the island of San Giorgio in Venice, Italy. To demonstrate the validity of the remote method, the analyses were conducted both in contact using a standard FORS setup and at an 8-meter distance from the painting using a specifically designed optical setup.

2. The Painting of *Saints Peter and Stephen*: attribution, historical context, and restoration interventions

The painting depicting *Saints Peter and Stephen* (Fig. 1), an artwork of debated attribution – with proposed names including the Faenza-born painter Giovanni Battista Bertucci the Elder (ca. 1465/1470-1516), Cola dell'Amatrice (ca. 1480/1489-1547/1559), and, more recently and still tentatively, the Viterbo artist Antonio del Massaro, known as Pastura (ca. 1450–before 1516) – can be linked to the figurative culture of early Renaissance Central Italy (late 15th/early 16th century), characterized by a lexicon rooted in the Perugian style. The painting, a precious tempera on panel (dimensions: 152.5×66 cm^2, with frame: 178×94×8.5 cm^2), was part of the collection of the Marquess of Lothian (Newbattle Abbey, Dalkeith, Scotland) and entered the Cini collections in 1958 as part of a group of ancient works intended to decorate the Castle of Monselice. It was housed in the Sala del Castelletto, as evidenced by documentation preserved in the Giorgio Cini Foundation (a letter from Bruno Visentin to Adolfo Cattin, custodian of the Castle of Monselice, dated May 9, 1980).



Fig. 1 – The painting depicting saints Peter and Stephen (late 15th/early 16th century) recently and tentatively attributed to Antonio del Massaro, known as Pastura (ca. 1450-before 1516). In the image, the measurement points are indicated.

The «large panel with a sculpted and gilded frame» was undoubtedly part of an altarpiece polyptych and portrays the two saints, Peter on the left and Stephen on the right, standing with their respective, prominently displayed iconographic attributes: a pair of large keys for the former, signifying his preeminence within the ecclesiastical hierarchy, along with the book he holds and his intense gaze; stones – the instruments of martyrdom – for the latter, conspicuously displayed on his halo, with his upward gaze situating him in a superior, contemplative dimension achieved through Christian sacrifice. Additional stones are scattered on the ground beneath their bare feet, resting on a stony terrain dotted with sparse tufts of grass. Behind the saints unfolds a hint of landscape against an intensely blue sky, signalling the master's adoption of

the harmonious manner of the Central Italian tradition. The artwork, currently housed in the Council Room of the Giorgio Cini Foundation, underwent restoration in 2011 due to several losses of colour on the lower part of the painted surface and a general dullness caused by dust deposits and altered past treatments, which impeded its full readability. The conservation and aesthetic intervention allowed the painting to recover clarity and legibility.

3. The Fondazione Giorgio Cini

The Fondazione Giorgio Cini, established in 1951 by Vittorio Cini in memory of his son Giorgio, is dedicated to promoting dialogue between cultures, fostering humanistic and scientific research, and advancing knowledge. Its primary goal was to restore the dilapidated San Giorgio Maggiore Island in Venice, transforming it into an international centre for cultural, research, and scholarly activities. Over the decades, the Fondazione has hosted numerous events, seminars, and conferences on contemporary challenges in technology, ethics, philosophy, and global issues, attracting top researchers and experts worldwide. It has also played a significant role as a meeting place for East and West during the Cold War and has collaborated with major organizations such as UNESCO and the G7. The Fondazione houses seven institutes and three research centres focused on theatre, music, spirituality, art, and cultural heritage preservation through digital technologies. Notably, the Vittore Branca Center provides residential scholarships for scholars from around the world.

San Giorgio Maggiore island, the Fondazione's home, boasts a rich history, evolving from a medieval monastic centre to a Renaissance landmark. Architects like Andrea Palladio and Baldassare Longhena shaped its iconic structures, while thanks to restoration efforts led by Vittorio Cini after the Second World War, the complex was returned to its ancient splendour. In addition to preserving historical architecture, the Foundation has repurposed spaces like the Manica Lunga as a modern art history library and created new landmarks such as the Teatro Verde amphitheatre and Le Stanze del Vetro for glass art exhibitions. The Foundation continues to be a hub for cultural preservation, artistic innovation, and scholarly exchange.

4. Remote set-up description

Reflectance spectra in the visible (Vis) and near-infrared (NIR) regions of the spots of interest in the painting Saints Peter and Stephen were measured in contact using a standard Fiber Optic Reflectance Spectroscopy (FORS) set-up, and at a remote distance using the innovative method described below. The contact reflectance of the colourants of the painting were measured by a standard FORS set-up from Avantes (The Netherlands), composed of an AvaLight-DH-S-BAL ultraviolet (UV), Vis and NIR radiation source, connected through an

800 µm diameter solarized optical fibre (model FC-UV800-2-SR) to a 50 mm diameter AvaSphere-50-REFL integrating sphere with sample-port of 10 mm in diameter. A gloss trap, coated with black absorbing material, was used in the sphere to avoid measuring specular reflection from the surface of the painting. The integrating sphere was connected to a 600 µm diameter optical fibre (model FC-UV600-2) that transferred the radiation to the AvaSpec-2048×14-USB2 spectrometer. This spectrometer used a diffraction grating enabling applications in the 248-1050-nm range and a fixed 100-micron slit to achieve a spectral resolution of 4.3 nm. Contact FORS measurements were calibrated using a Spectralon® (Labsphere, USA) reflectance standard (model SRS-99-010) with a nominal reflectance of 0.99 over the UV-VIS-NIR spectrum.

The remote reflectance spectra in the Vis and NIR regions were measured by a setup formed by an achromatic refractor telescope from Celestron, model AC 70/400 TravelScope AZ, with 70 mm aperture and 400 mm focal length, with a 45° diagonal erecting prism (Fig. 1). The telescope was mounted by using a suitable connector support on a photographic tripod equipped with a head that can be rotated in three directions to allow aiming towards the region of interest of the painting. The painting was about 8 m from the telescope: at such distance, the collected region is a spot about 2 cm in diameter, therefore it has double the diameter of the sample port of the integrating sphere. The collected region in the painting was illuminated by a light projector using an 18 W GE1649 incandescent lamp focalized by a convergent lens with a diameter of 8 cm and f-number 1. The lens can be moved relative to the lamp to allow the image of the filament to be focused on the painting. Inserted in the 45° diagonal erecting prism was a connector for the 800-µm-diameter optical fibre enabling the transmission of the radiation to the AvaSpec-2048×14-USB2 spectrometer used for the contact set-up. A personal computer was used for spectrometer control and data recording. Remote reflectance calibration was achieved by measuring the reflectance of a white cardboard placed at the same distance as the painting. The contact reflectance of the white cardboard was measured separately by the standard FORS set-up allowing the calibration of the remote reflectance measurements.

The telescope was positioned perpendicular to the painted surface, while the radiation from the light projector had an incidence angle of approximately 20 degrees with respect to it. In this configuration, most of the specular reflection is excluded, as in the contact measurements. Additionally, assuming that the painted surface is a Lambertian surface that reflects light uniformly in all directions, according to Lambert's law of diffuse reflection the intensity I of the radiation collected by the telescope varies as:

$$I \propto \frac{I_0 \cos \alpha}{d^2}$$

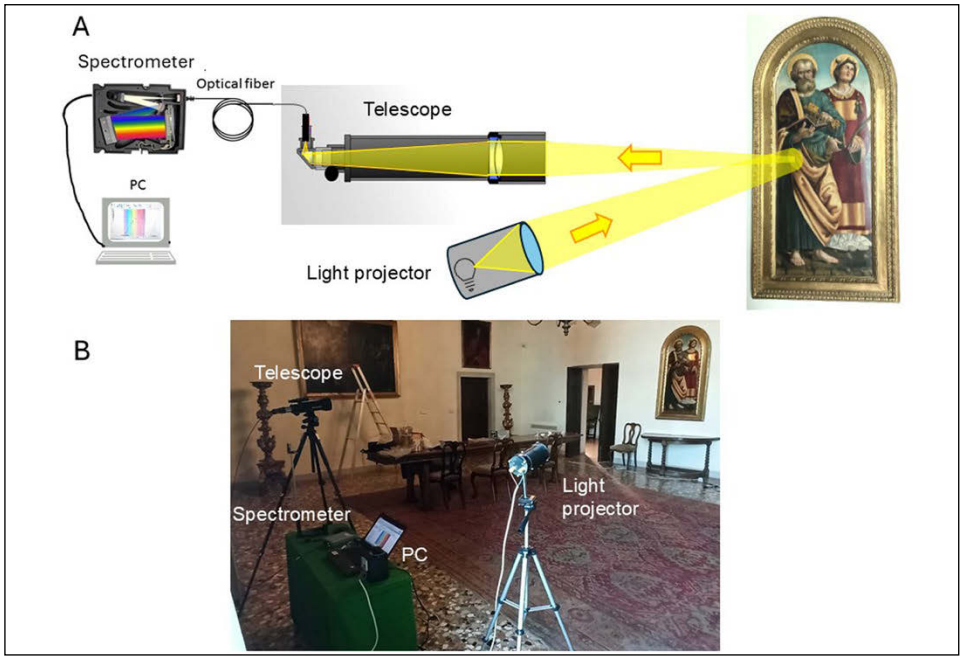


Fig. 2 – A) Schematic of remote reflectance spectroscopy; B) image of the setup during the measurement session of the painting of saints Peter and Stephen.

where I_0 is the intensity of the incident illumination within the area of the fiber projected onto the painting, α is the angle of observation relative to the normal, and d is the distance between the painting surface and the telescope (Kortum 1969). For all measured points on the painting and the calibration white cardboard, α and d were carefully maintained within a range that ensured that the intensity of the radiation collected by the telescope varied less than ±1.5%. Contact and remote measurements were carried out on 6 points shown in Fig. 2, in correspondence with specific coloured features of the painting: Saint Stephen's white robe (a), Saint Peter's yellow robe (b), Saint Stephen's red robe (c), Saint Peter's green/blue robe (d), Saint Stephen's yellow robe (e), and cyan sky (f).

5. Results and discussion

The reflectance spectra collected at contact and remote distances are shown in Figs. 3-5. The spectra for point a, acquired at the location of Saint Stephen's white robe, are shown in the left panel of Fig. 3. The spectra in the two acquisition modes show very similar trends, with higher reflectance values of about

0.5-0.6 in the NIR region and a decrease in reflectance values for wavelengths below approximately 600 nm, reaching about 0.2 at 400 nm. The reflectance spectrum acquired in the contact mode overall shows lower reflectance values, with differences ranging from 5% to 10% less than those acquired in the remote mode, depending on the wavelength. This trend can be interpreted as being due to chromatic inhomogeneities in the paint layer at point a of the painting. These chromatic inhomogeneities are visible in this point in Fig. 2 and are caused by the use of a dark pigment for depicting the drapery of Saint Stephen's white robe. Therefore, while the overall spectral behaviour of reflectance in the two modes is qualitatively similar, the lower overall values in the contact mode are likely due to slight differences in the measurement point between the two techniques in an area of the painting that exhibits inhomogeneities in the brightness of the white colour. In fact, in Renaissance paintings, white was often combined with dark pigments (e.g., umber, charcoal black) to create chiaroscuro effects and detailed drapery (Martin Kemp 1992).

Concerning the identification of the kind of colorant used for the white robe, the lack of evident spectral features makes these materials difficult to identify using reflectance spectroscopy. Pure white corresponds to almost total reflection of visible radiation, so reflectance spectra of typical white pigments, such as lead white, bone white, and gypsum, are very similar in the visible range, showing an unshaped and relatively flat spectral curve line at high reflectance values. However, the decrease in reflectance below approximately 600 nm, specifically in the violet, blue, and green spectral regions, and the relatively higher reflectance values above 600 nm, specifically in the yellow and red spectral regions, suggest that the white pigment could be white lead, which is subject to yellowing with aging (Pastorelli *et al.* 2024). The reflectance spectra for point b, acquired at the location of Saint Peter's yellow robe, are shown in the right panel of Fig. 3.

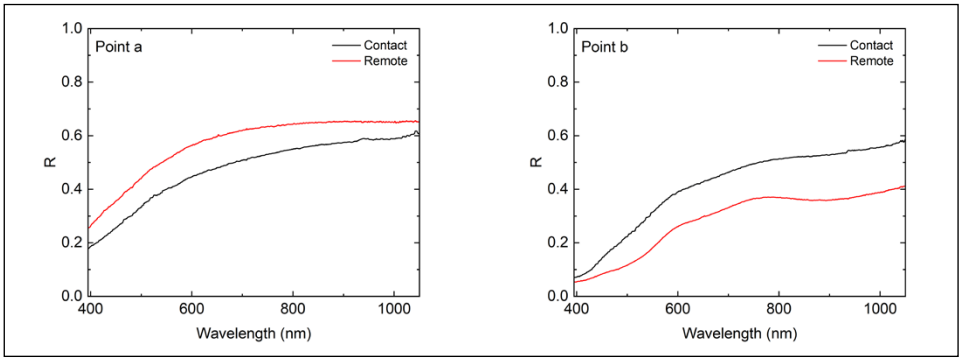


Fig. 3 – The contact and remote reflectance spectra in the Vis and NIR of points a (left) and b (right).

The spectra in the two acquisition modes show similar trends and spectral features even if the remote reflectance appears more structured. Even in this case, a general difference in the intensity of the reflectance spectra is noticeable, with the spectrum acquired in contact mode showing values up to 17% higher than those acquired in remote mode. However, the same considerations made previously for point a can also be applied to this spectrum for point b: the difference can be interpreted as being due to chromatic inhomogeneities in the paint layer at point b. These chromatic inhomogeneities are visible in this point in Fig. 2 and are caused by the use of a dark pigment for depicting the drapery of Saint Peter's yellow robe, as in Renaissance paintings, yellow was often combined with dark pigments (e.g., umber, charcoal black) to create chiaroscuro effects and detailed drapery (Martin Kemp 1992). Therefore, while the overall spectral behaviour of reflectance in the two modes is qualitatively similar, the lower overall values in the contact mode are likely due to slight differences in the measurement point between the two techniques in an area of the painting that exhibits inhomogeneities in the brightness of the yellow colour.

In the spectra, starting from the lower wavelength, are evident an increasing of the reflectance, a flex (more evident for the contact mode spectrum) at about 550 nm, two shoulders at about 600 and 770 nm with a central reflectance minimum (which correspond to absorption maxima of the material) at about 640-650 nm, and another absorption at about 900 nm. These features can be easily identified in the different yellow iron-based pigments, such as yellow ochre, goethite, natural sienna and natural umber earths (Aceto *et al.* 2014). Based on the results of the contact or remote reflectance, it is not possible to discriminate among the different yellow iron-based pigments mentioned.

The reflectance spectra for point c, acquired at the location of Saint Stephen's red robe, are shown in the left panel of Fig. 4. The spectra in the two acquisition modes are superimposed in a large part of the spectral range and show reflectance intensity differences as small as 5%, particularly above 900 nm. This very good coincidence may also be due to the homogeneity of the paint application for point c, as observed in Fig. 1. The two acquisition modes give spectra consisting of a non-zero reflectance at 400 nm, small features in the blue-green region followed by a steady increase in reflectance before 600 nm, an inflection point at about 600 nm, and a smaller increase in the NIR region. Overall, this spectrum is compatible with that of a red lake. Since many of the absorption features of red lakes vary depending on their preparation method, the identification of red organic compounds is difficult by using reflectance spectroscopy (Fonseca *et al.* 2019). However, considering the period of the painting, it can be suggested that the red lacquer used was likely derived from natural dyes, common in the Italian Renaissance, such as:

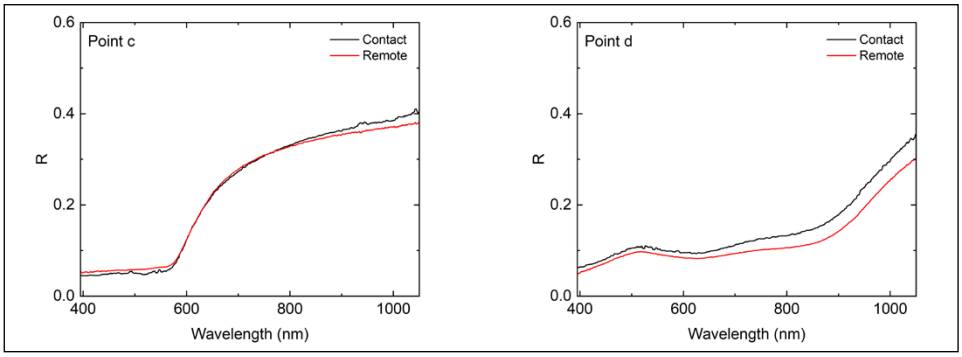


Fig. 4 – The contact and remote reflectance spectra in the Vis and NIR of points c (left) and d (right).

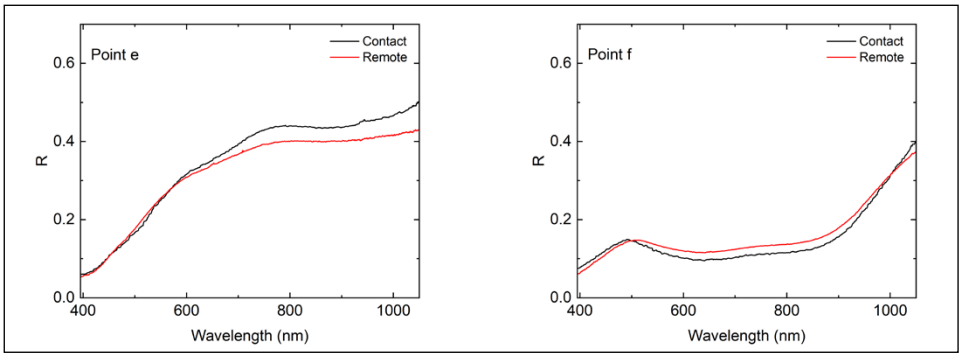


Fig. 5 – The contact and remote reflectance spectra in the Vis and NIR of points e (left) and f (right).

i) madder lacquer (Rubia tinctorum), a widely used pigment that produced various red tones, from deep red to pink, with alizarin as the main component extracted from the root; ii) carmine, derived from insects like cochineal.

The reflectance spectra for point d, acquired at the location of Saint Peter's green/blue robe, are shown in the right panel of Fig. 4. The spectra acquired in the two modes show low values of the reflectance up to about 800 nm. They show the same spectral features, namely a first reflectance peak at around 520 nm, a minimum (absorption) at approximately 630 nm, a maximum at around 760 nm, and another absorption at approximately 850 nm. At longer wavelengths, a consistent increase in reflectance is observed, reaching values above 0.5 at 1050 nm. These spectral features suggest the combination of two pigments to achieve the green/blue colour observed with the naked eye. They are consistent with the presence of malachite (a green pigment also made from copper carbonate) mixed with azurite (a

blue pigment made from copper carbonate), which exhibit absorptions at approximately 640 nm and around 800-850 nm, respectively. During the Italian Renaissance, artists sometimes mixed azurite and malachite to create green-blue shades. This combination allowed for customized tones, ranging from green to blue, ideal for depicting natural elements like skies, clothing, and vegetation, offering more realistic and harmonious nuances. The choice to mix these pigments stemmed from their chemical compatibility (both are copper carbonates) and availability as natural materials, though their use often depended on the desired colour effect, artistic technique, and the artist's financial resources, as both pigments were quite expensive.

The reflectance spectra for point e, acquired at the location of Saint Stephen's yellow robe, are shown in the left panel of Fig. 5. The spectra in the two acquisition modes show similar trends and spectral features. Up to about 600 nm, the spectra acquired in the two modes overlap and then separate at longer wavelengths, where the contact spectrum shows a higher reflectance, up to 10%. The spectra exhibit spectral features similar to those of point b (Fig. 3 right), with an inflection at about 520-530 nm, two shoulders at about 600 and 770 nm, with an absorption at about 660-670 nm at their centre, and another absorption at about 900 nm. Therefore, it can be stated that these features can again be identified in different yellow iron-based pigments, such as yellow ochre, goethite, natural sienna, and natural umber earths (Aceto *et al.* 2014). Again, it is not possible to distinguish between these materials using reflectance spectroscopy. Finally, the reflectance spectra for point f, acquired at the location of cyan sky, are shown in the right panel of Fig. 5. These two spectra are very close to each other showing a reflectance intensity difference that can reach a maximum of 0.02. The spectral features are remarkably like those of point d, with absorptions at approximately 630 nm and 840 nm. Therefore, it can also be stated that the artist used the same malachite and azurite mixture to achieve the green/blue colour of the sky filling.

6. Conclusion

We present a novel approach for remote FORS measurements using a telescope connected by optical fibres to a multichannel Vis-NIR spectrometer. This setup was employed to study the colourants in the painting Saints Peter and Stephen, conserved at the Fondazione Giorgio Cini and tentatively attributed to Antonio del Massaro da Viterbo (circa 1450-1516). To assess the accuracy of the remote FORS measurements, a comparison was made with standard FORS measurements carried out with a contact integrating sphere. The reflectance spectra collected at contact and remote distances show excellent agreement and enable the identification of the colorants used by the artist. For point a, corresponding to Saint Stephen's white robe, the spectra exhibit

similar features, suggesting the use of white lead. For point b, corresponding to Saint Peter's yellow robe, the spectral features align with yellow iron-based pigments such as yellow ochre or goethite. For these two points, the different overall reflectance intensities are attributed to chromatic inhomogeneities in the paint, likely caused by the use of dark pigments for chiaroscuro effects in the robes. At point c, the spectra for Saint Stephen's red robe are well-matched between the two modes, with minimal reflectance intensity differences, suggesting homogeneity in the paint. The spectral features are consistent with red lake pigments, such as madder lacquer or carmine. For point d, depicting Saint Peter's green/blue robe, the spectral data indicate a mixture of malachite and azurite, which were commonly combined during the Renaissance to create varied green-blue hues. For points e and f, corresponding to Saint Stephen's yellow robes and the cyan sky, the spectra are similar to those of points b and d, indicating the use of yellow iron-based pigments and the same malachite-azurite mixture, respectively. These findings provide insights into the materials and techniques used by the Renaissance artist to achieve specific colours.

We intend to further develop the remote FORS setup by improving the optical set-up to optimize the overlap between the points measured in contact mode and those measured remotely. Additional information regarding the coloured materials of Saints Peter and Stephen could be obtained through other non-destructive investigative methods, such as X-ray fluorescence spectroscopy and infrared and Raman vibrational spectroscopies.

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ABSTRACT

This study presents a novel approach for remote Fiber Optic Reflectance Spectroscopy (FORS) applied to the Renaissance painting Saints Peter and Stephen, tentatively attributed to Antonio del Massaro da Viterbo. The painting, housed at the Fondazione Giorgio Cini in Venice, was analyzed using both contact and remote FORS, with the latter performed at an 8 meter distance using a custom optical setup inspired by astronomical techniques. The reflectance spectra obtained in both configurations showed strong agreement, enabling the identification of pigments such as iron-based yellows, red lake, malachite, and azurite. The findings offer new insights into the artist's material choices and techniques, while also demonstrating the feasibility of remote FORS as a non-invasive diagnostic tool for cultural heritage. Future developments will focus on refining the optical setup to further improve measurement accuracy and expand the applicability of remote FORS in heritage science.

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A REVIEW OF TWO RECENT VOLUMES ON ARCHAEOLOGICAL NETWORK RESEARCH

The study of network science in archaeology has emerged as a promising and dynamic field, offering innovative tools and methodologies to analyze the past in its diverse components. The recent publication of *Network Science in Archaeology* (edited by Tom Brughmans and Matthew A. Peeples) and *The Oxford Handbook of Archaeological Network Research* (edited by Brughmans, Barbara J. Mills, Jessica Munson, and Peeples) marks a significant milestone in the development of this interdisciplinary area of research. These two volumes provide complementary insights, and they were likely intended to be published in the same year, 2023. Notably, the *Handbook* is listed in the bibliography of *Network Science in Archaeology* with a 2023 publication date, even though it was officially published in 2024.

Archaeological network research holds considerable promise, as it enables scholars to structure and investigate large-scale relational phenomena that have historically been difficult to analyze using traditional methods. The ability to map and explore connections – whether social, economic, or ecological – provides a new framework for addressing both longstanding and emerging questions in archaeology. By emphasizing relationships between elements, this approach allows researchers to move beyond isolated artifacts or sites and instead focus on the broader patterns and systems that shaped past human behavior. Indeed, one of the most compelling aspects of network science in archaeology can be considered as its versatility. The methodologies introduced in these volumes can be applied to a wide range of periods and regions, from prehistoric societies to more recent historical periods. The flexibility of network analysis allows archaeologists to investigate relationships and interconnections across diverse datasets, whether these involve material culture, social interactions, trade routes, or spatial arrangements. Furthermore, by examining the intricate web of connections that characterize these systems, network research offers a unique lens through which to understand how change occurred over time and how it was influenced by the flow of information, resources, and people.

Network Science in Archaeology offers a comprehensive and accessible guide to the application of network science within the field of archaeology. This work is particularly focused on helping archaeologists navigate the often complex process of turning archaeological questions into actionable network data, performing analyses, and generating meaningful results. While network science offers a set of powerful tools for exploring relational phenomena, the

editors stress the importance of aligning these tools with relevant theoretical frameworks. Network science in archaeology, as presented in the book, is not just a set of methods, but a theoretical perspective that offers new ways of thinking about relationships between entities, such as social connections, trade routes, or communication networks.

One of the key strengths of this volume is its practical focus also. The editors and contributors emphasize the hands-on application of network science tools, offering step-by-step guidance on how to collect, manage, and analyze archaeological network data. Through a variety of methods, including exploratory network analysis, network visualization, and spatial network analysis, the volume teaches how to explore and represent complex data sets, even though the mathematical and statistical content is kept to a minimum and relegated to appendices, making the volume more user-friendly for those less familiar with complex quantitative techniques. Furthermore, the Online Companion to the volume further enhances its usability. Accessible through a dedicated website (https://book.archnetworks.net/), the companion includes downloadable datasets and R code that demonstrate the application of the network science methods discussed in the book. This feature allows readers to replicate examples, explore datasets, and experiment with the methods on their own, providing a hands-on learning experience that reinforces the concepts presented in the text.

Chapters 1 through 3 lay the groundwork for the entire volume. Chapter 1 (pp. 1-25) introduces the theoretical underpinnings of network science, explaining how it fits into archaeological research. The focus here is on demonstrating how network science can be both a methodology and a theoretical framework for understanding past relational phenomena. Chapter 2 (pp. 26-63) reviews the primary applications of network science in archaeology, such as the study of social networks, transport systems, and exchanges. Chapter 3 (pp. 64-102) defines network data, providing the foundational knowledge required to handle and manipulate them in the context of archaeological research. The subsequent chapters – 4 through 7 – serve as more technical guides. They focus on practical applications and methodologies in network analysis, including exploratory analysis, uncertainty quantification, visualization techniques, and spatial networks. These chapters provide clear guidance for archaeologists looking to incorporate network methods into their research, offering both conceptual explanations and practical advice for implementation.

For example, Chapter 6 (pp. 196-236) on network visualization discusses how to graphically represent complex networks to better understand relationships between elements in archaeological contexts. Chapter 8 (pp. 263-280) returns to a critical theme introduced earlier in the volume: the relationship between method and theory. The authors argue that network

science in archaeology should not be applied in isolation from the theoretical perspectives that drive its use to ensure that the insights generated are meaningful and contribute to broader understandings of the past.

Complementary to the manual in many respects, *The Oxford Handbook of Archaeological Network Research* is the first comprehensive and authoritative reference work that explores the application of network science in archaeology. The introductory chapter, authored by Matthew A. Peeples, Jessica Munson, Barbara J. Mills, and Tom Brughmans, provides an overview of the role of network research in archaeology. It discusses the evolution of the field, the increasing adoption of network approaches, and the potential of network science to address archaeological questions (pp. 1-11). The chapter also outlines the structure of the volume, which is composed of ten thematic parts, each containing several chapters that address different aspects of archaeological network research.

The section on *Archaeological Networks in Practice* (Part I, pp. 15-83) lays the methodological and theoretical groundwork for network research in archaeology. Clara Filet and Fabrice Rossi present the diversity of the methods most frequently applied in archaeology and to introduce the basic properties of graph theory mobilized by these approaches (pp. 15-33), while Matthew A. Peeples, John M. Roberts Jr., and Yi Yin discuss challenges specific to archaeological network research, such as data limitations and interpretative uncertainties (pp. 33-49). Benjamin Bach and Mereke van Garderen explore advancements in network visualization, emphasizing the need for effective representation of archaeological networks (pp. 50-66). Per Östborn and Henrik Gerding address some challenges related to the definition and exploration of spatial single mode networks inferred from archaeological data, with the aim to introduce a mode of thinking about archaeological network analysis (pp. 67-83).

The section on *Material Culture Networks* (Part II, pp. 88-161) investigates how networks can help analyze material culture and culture change. Jennifer Birch presents concepts and cases focusing on temporal and material dimensions of culture change as investigated through social network analysis (pp. 87-102), while Elliot H. Blair discusses a selection of case studies and a series of issues, related to the process of abstraction and representation that are required to generate meaning from archaeological material culture similarity networks (pp. 101-116). Daniel Sosna examines networks within mortuary archaeology (pp. 117-131), and Mark Golitko introduces the definition of 'geochemical' network as «any archaeological approach that combines geochemical information on artifacts with methods drawn from network science/analysis to examine the structure or dynamics of ancient exchange and interaction» (pp. 132-148, p. 132). Sarah M. Griffin and Florian Klimm discuss the application of network methods to museum collections, focusing

on the Met's collection illustrating how digital and physical archives can be interlinked (pp. 149-161).

The section on *Geographical Networks* (Part III, pp. 165-263) starts with Diego Jiménez-Badillo's discussion on several models for network retrieval with specific characteristics, focusing especially on the concept of relative neighborhood (pp. 165-185), while Ray Rivers, Tim Evans, and Eleftheria Paliou discuss gravity models, debating the approach of MaxEnt (maximum entropy) that lends itself naturally to networking (pp. 186-199). Irmela Herzog examines transportation networks and least-cost path (LCP) models (pp. 200-216). Mu-Chun Wu applies space syntax and pedestrian modeling techniques to facilitate studies of social-spatial phenomena from a spatial network perspective (pp. 217-229), whereas Zoran Čucković focuses on visibility networks, defined as models of explicit visual relationships between one or more observers and their visual targets (pp. 230-247). In conclusion, Eduardo Apolinaire and Laura Bastourre analyze hydrographic networks to investigate «key phenomena in archaeological research, such as large-scale population movements, the spread of ideas and material culture, exchange systems, and control over the landscape» (pp. 248-262, p. 248).

The section on *Network Simulation* (Part IV, pp. 265-307) start with Iza Romanowska's discussion on the intersection of complexity science concepts and methods and archaeology (pp. 265-279), while Wendy H. Cegielski examines the integration of agent-based modeling (ABM) with social network research (SNA) for the advancement of archaeological research (pp. 280-293). In conclusion, Viviana Amati introduces random graph models, explaining that their use in investigating archaeological data requires further investigation (pp. 293-307).

The section entitled *Biological Networks* (Part V, pp. 311-344) provide valuable perspectives on human evolution and ecological interactions. Kent M. Johnson explores the use of network analysis techniques to investigate patterns of phenotypic variation in human skeletal remains within biological distance research (pp. 331-330), while Stefani A. Crabtree and Jennifer A. Dunne examine food webs «as a type of ecological network that represents the topic interactions, or consumption links, within a community» (pp. 331-344, p. 333). The section *Text-Based Networks* (Part VI, pp. 347-426) examines the study of textual and inscriptional data through network analysis. Claire Lemercier discusses the integration of historical and archaeological network data (pp. 347-362), while Diane Harris Cline and Jessica Munson explore epigraphic networks by considering the dual nature of epigraphic evidence as artifacts and historical sources (pp. 363-377). Valeria Vitale and Rainer Simon introduce Linked Open Data (LOD) and discuss differences, commonalities and touch points of this method for publishing structured data on the web and network analysis (pp. 378-391). Allison Mickel, Anthony

Sinclair, and Tom Brughmans examine knowledge networks and the role of bibliometrics in academia (pp. 392-412), while Vojtěch Kaše, Tomáš Glomb, and Jan Fousek investigate the potential of formal network analysis for the study of religious transformations in past societies (pp. 412-426).

The section *Cultural Transmission and Human Evolution* (Part VII, pp. 429-473) starts with Valéria Romano and Sergi Lozano's analysis of primate social networks to infer patterns of human behavioral evolution (pp. 429-442); Claudine Gravel-Miguel and Fiona Coward discuss why formal network methods are difficult to apply to the Palaeolithic and suggest combining them with other approaches, especially the agent-based models (ABM) (pp. 442-458) while, in conclusion, Briggs Buchanan and Marcus J. Hamilton examine human networks and cultural transmission in hunter-gatherer societies (pp. 459-473). The section *Movement, Exchange, and Flows through Networks* (Part VIII, pp. 477-541) starts with Justin Leidwanger's discussion of maritime space approached through network thinking and analysis applied to the material culture of interaction (pp. 477-491). Barbara J. Mills and Matthew A. Peeples focus on how the study of past migrations can be conducted through network-based approaches (pp. 492-511), while Marek Vlach explore epidemiological modelling and methods of implementing it (pp. 512-527). Shawn Graham and Damien Huffer explore how digital networks, particularly social media, have transformed the antiquities trade, shedding light on illicit activities and their implications for heritage preservation (pp. 528-541).

The section *Assessing the Structural Characteristics of Networks* (Part IX, pp. 545-621) focuses on how archaeologists study the structural characteristics of networks. Matthew Pailes discusses inequality and social network analysis (pp. 545-560), while Erik Gjesfjeld examines how networks respond to catastrophes (pp. 561-572). Jelena Grujić and Miljana Radivojević debate the concept of 'archaeological culture' and explore specific community detection methods (pp. 573-592). Scott G. Ortman applies settlement scaling analysis as a form of social network analysis (pp. 593-607), and Jacob Holland-Lulewicz investigates the methodological principles and conceptual frameworks of archaeological network analysis that can help to characterize and evaluate organizational structures connecting members of different societies (pp. 608-621)

Looking Ahead and Beyond (Part X) reflects on the future of archaeological network research. Ulrik Brandes discusses the broader implications of archaeological network science, marking the importance of a data-centric approach that should be aligned with domain-specific theories to be usefully applied in empirical research (pp. 625-633, p. 626), while John Edward Terrell explores relational thinking and contingency analysis in network thinking in archaeology (pp. 634-648). Carl Knappett and Angus Mol

discuss how archaeological network studies form a point of connection for relational theories and practices (pp. 649-663), and the concluding chapter by Jessica Munson, Barbara J. Mills, Tom Brughmans, and Matthew A. Peeples summarizes the volume's most significant insights and anticipates future developments in the field, highlighting emerging methodologies and research directions (pp. 664-674).

As demonstrated in the concise review of the two volumes, network analysis can significantly enhance quantitative approaches in archaeology, and these works can be regarded as foundational milestones for future research in the field. However, to effectively integrate network analysis into archaeological research as a practical and applied method, it is crucial to stress the importance of proper methodological application and the development of a robust theoretical framework guiding its use. Only by adopting an appropriate approach can archaeological data be properly collected, organized, and analyzed to reveal meaningful results. As an emerging and promising field, network archaeology holds significant potential to transform the discipline. However, it should be introduced only after a thorough understanding of the foundational principles of archaeological research has been established. In this regard, a professional master's program could provide an optimal framework for advanced study and training, enabling students to first develop proficiency in traditional archaeological methods before engaging with more complex and innovative approaches such as network analysis.

In Italy, one of the main challenges to integrating network archaeological research lies in the fact that applied digital methods predominantly consist of relevant tools like GIS, BIM, and 3D modeling. These tools are essential – particularly GIS and BIM – for managing data that supports the conservation and promotion of the country's cultural heritage by both public and private organizations. As a result, the time and resources allocated for testing innovative archaeological network research methodologies within Italian academia are limited. However, the extensive availability of datasets on the country's heritage represents a valuable resource for researchers worldwide seeking to apply network-based approaches to archaeological research, offering innovative perspectives on relational data. Indeed, as a rapidly evolving field, network archaeology holds significant potential for future discoveries and insights. Nevertheless, its long-term success, I argue, depends on a thoughtful and comprehensive educational framework that equips future researchers with the methodological and theoretical skills necessary to apply these approaches effectively.

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ABSTRACT

This paper discusses two recent volumes that significantly contribute to the field of archaeological network research: *Network Science in Archaeology* (2023), edited by Tom Brughmans and Matthew A. Peeples, and *The Oxford Handbook of Archaeological Network Research* (2024), edited by Tom Brughmans, Barbara J. Mills, Jessica Munson, and Matthew A. Peeples. Together, these works provide a comprehensive overview of current methodologies and applications of network science in archaeology, offering valuable theoretical frameworks and case studies.

INVESTIGATING RESILIENT ROMAN AGRICULTURAL LANDSCAPES IN SOUTHERN ITALY. AN INTEGRATED AND OPEN IT APPROACH FOR ARCHAEOLOGICAL TOPOGRAPHY OF CENTURIATION. PROCEEDINGS OF THE FINAL CONFERENCE OF THE PRIN 2022 PROJECT 'IN.RES.AGRI' (NAPLES, 20TH-21ST NOVEMBER 2025)

edited by
Rodolfo Brancato, Veronica Ferrari, Irene Rossi



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THE IN.RES.AGRI FINAL CONFERENCE. FROM PROJECT RESULTS TO FUTURE STEPS

This section brings together the papers from *An integrated and open IT approach for archaeological topography of centuriation. Final conference of the PRIN 2022 project In.Res.Agri* (Naples, 20th-21st November 2025), organised within the project 'Investigating Resilient Roman Agricultural Landscapes in Southern Italy' (In.Res.Agri). Funded by the Italian Government (PRIN 2022, project code 2022SMJCHX), the project examines the long-term persistence and discontinuities of Roman rural topography in order to understand how its components have endured over centuries within the contemporary landscapes of southern Italy. The rational organisation of space – above all through land reclamation intended to improve agricultural yields – is likely a principal reason for the survival of centuriated layouts; yet this is not the only factor, especially in areas that have retained a predominantly rural vocation, such as *Apulia*, or undergone intense urbanisation, such as the suburbs of Naples. The Archaeological Mapping Lab of the University of Naples, together with the laboratories of the Institute of Heritage Science at the National Research Council (CNR-ISPC) and of the University of Salento, advances a holistic approach that integrates topographical, archaeological, environmental and textual data. The resilience of Roman agrarian landscapes is investigated across multiple dimensions, including centuriation, route networks and settlement systems (Castagnoli 1958; Settis 1993). The project has focused – and will continue to focus – on the systematic collection of legacy (topographical, archaeological and textual) data and new field evidence in selected case-study areas of southern Italy, in the Campanian Plain, Irpinia and *Apulia* (Brancato *et al.* 2024, fig. 1).

The conference provided an opportunity to bring the project's research units into dialogue, to report on the results of the planned activities, and to share reflections on methods, documentation workflows and data management, as well as on the interpretation of the evidence integrated into our analyses. These open-access proceedings present the key outputs of the In.Res.Agri project as to November 2025. At the same time, the conference allowed to outline future steps particularly with regard to data integration, methodological innovation and future applications of the digital platform of the project (Brancato *et al.* 2024, fig. 6).

The three topographic case studies considered in the In.Res.Agri project were selected on the basis of the characteristics of the territories of southern Italy, namely Campania and Puglia: (1) evidence for centuriation emerging from previous archaeological research; (2) textual, topographical and – where

available – stratigraphic documentation; (3) environmental data from ongoing projects and investigations; (4) representativeness of different environments in southern Italy in relation to centuriation and its transformations over time. The researches accordingly range from field investigations to archival research and to the integration of archaeo-topographical data within GIS for the diachronic reconstruction of the morphostratigraphy of agrarian landscapes. Their shared objective is the historical reconstruction of these landscapes and a clearer understanding of the cultural, political and technical logics that shaped them. Ancient topography, as an archaeological discipline, is not confined to the *disiecta membra* of the past revealed by digital tools, yesterday GIS and remote sensing, today machine learning and artificial intelligence. Rather, it interrogates the technologies, the ancient technical competences and cartographic knowledge that enabled the planning and organisation of space in both urban and rural contexts (Brancato 2025). In this perspective, the archaeological map is conceived as a dynamic and complex information system, crucial not only for answering questions on 'resilient' landscapes but also for their valorisation, protection and informed planning.

Within this framework, In.Res.Agri aims to refine our understanding of the resilience of Roman agrarian landscapes in southern Italy, beginning with a renewed reading of *limitatio*. As widely discussed by historians and archaeologists, *limitatio* should not be reduced to centuriation alone but understood as a broad repertoire of practices for orienting, measuring and managing land in relation to geomorphology, infrastructures and agricultural uses over the long term. The rational management of space, particularly the reclamation of 'difficult' areas such as alluvial plains and their conversion to cultivation, is probably a principal reason why the morphology of Roman *limitatio* has survived within the contemporary landscape (cf. Quilici Gigli 2025). This holds both for deeply urbanised areas, such as the Campanian Plain, now partly encompassed within the wider metropolitan area of Naples, as well as for contexts that retain a strong rural vocation, such as Irpinia.

Methodologically, the project aims to optimise knowledge through an integrated, interdisciplinary approach combining topographical, archaeological, environmental and textual sources. In this framework, *limitatio*, articulated into centuriation, the route network and settlement systems, is adopted as a key interpretative lens for investigating long-term landscape dynamics. Since the pioneering work of Ferdinando Castagnoli (1958), interest in the forms of centuriation has grown significantly (Muzzioli 2009). In the 1980s, in Italy and France, techniques were developed for identifying regular orientations and modules referable to the Roman *actus*. It has, however, become increasingly clear that morphology alone is insufficient to distinguish ancient traces with certainty from modern or contemporary agrarian layouts. The project therefore moves beyond an exclusively topographical reading in favour of

an integrated, critical and multi-scalar analysis of landscapes. In light of this, In.Res.Agri is structured around four objectives:

1. To define an operational model for understanding Roman *limitatio* practices, through a detailed and integrated analysis of topographical, geomatic, archaeological, environmental, iconographic and textual data within a specific geographical corridor (Campania-*Hirpinia-Apulia*) and a coherent Roman-period framework.
2. To interpret diachronically the transformations of the landscape linked to agrarian rationalisation, considering how geomorphology, pre-existing road networks and reclamation works have contributed, and will continue to contribute, to making *limitatio* a highly resilient feature; archaeological maps produced in recent decades constitute a crucial evidentiary layer for relating centuriation to other structuring elements, such as the road system.
3. To experiment with hybrid methodologies integrating traditional field survey with advanced processing and dissemination workflows, including the staged deployment of machine-learning techniques for the semi-automatic detection of agrarian grids.
4. To contribute to Open Science by releasing datasets and documentation as soon as they are produced and by fostering transparency in analysis, interpretation and dissemination.

From this perspective, the project's approach can be described as an instance of 'open digital archaeogeography' (Moscati 2017), in which the integration between archaeology and geography is developed on a shared computational basis. The methodological advances also lay the groundwork for the project's future development, especially in enhancing automation, improving analytical resolution and expanding the comparative potential across wider areas of southern Italy.

For each case study the project verifies techniques adopted in previous research by consulting the photographic archives of the participating research units (Archaeological Mapping Lab, CNR-ISPC; Laboratory of Ancient Topography and Photogrammetry, University of Salento; Archaeological Mapping Digital Laboratory, DSU-University of Naples Federico II) and by acquiring additional historical and recent aerial photographs (e.g., from the Aerofototeca Nazionale, Rome). For each study area, remotely sensed imagery has been processed and georeferenced to identify axes of ancient agrarian division; each dataset has also been enriched through the systematic review of high-resolution optical satellite imagery (e.g., WorldView-3/4), orthorectified and processed for the detection of archaeological traces. Where coverage was incomplete or required further investigation, UAV (drone) survey has been undertaken, as planned, to acquire detailed imagery and produce high-resolution

digital terrain models (DTMs). As noted above, aerial and satellite imagery has also been employed in machine-learning experiments.

The increasing volume of datasets requires innovative analytical methods, such as Object-Based Image Analysis (OBIA), an AI-based framework that reduces interpretative ambiguity. In archaeological contexts, this technique operates across multiple scales – from the landscape to the individual artefact – via automatic image classification. It enables image segmentation into objects (grouping pixels with similar characteristics) and their rule-based classification, making explicit geometric, spectral, spatial and relational properties; identified objects are then assigned to categories on the basis of form, colour, texture and position. Finally, the remote-sensing outputs have been ground-truthed through surface survey and aerial reconnaissance, using sample checks in areas where detected traces appear consistent with an ancient agrarian grid.

To support the systematic collection, integration, querying and publication of the project's data, a digital platform, called Digital Groma, was developed. Its design was based on the FAIR principles, primarily aiming at interoperability with larger Italian initiatives, such as the ICCD's National Catalogue and the Geoportale Nazionale per l'Archeologia, but also at making the data freely available to reuse for the wider scientific community via an API endpoint. All research units have actively adhered to Open Science, by consciously adopting, wherever feasible, non-proprietary software and by committing to publishing the data produced during the project as open data, including a curated bibliographical dataset maintained and published via Zotero. By the end of the project, geodata and bibliography in LOD formats will be accessible from the Digital Groma platform and other websites related to the project (https://digitalgroma.cnr.it/; https://archeomaplab.it/progetti/progetto-in-res-agri-prin-2022/), also providing links to the project's open-access reports and publications.

Ultimately, advancing a diachronic understanding of how agrarian landscapes have been transformed is central to contemporary debates on territorial management. While each area retains its specific agricultural history, recurring patterns help to explain how human action has shaped the natural environment and how rural landscapes have changed, disappeared or evolved over millennia. The endurance of Roman centuriation for more than two thousand years, unlike other systems of land division, attests to a holistic and strikingly modern enterprise that anticipated today's notions of sustainable territorial design and stewardship. Building on the methodologies deployed in In.Res.Agri – from archival 'excavation' to remote sensing, OBIA/ML and on-the-ground verification – the initiative will deliver an integrated, interoperable and reusable knowledge base for a wide area of southern Italy, reducing data fragmentation across separate archives and improving research quality, while enabling wider reuse for scholarship, teaching and informed public planning.

These outcomes represent not an endpoint but the foundation for subsequent phases of research, ensuring that In.Res.Agri will continue to evolve through expanded datasets, enhanced analytical tools and deeper engagement with territorial planning.

The section starts with contributions devoted to the archaeological research carried through the integrated use of non-invasive methods application (i.e. geophysics and field survey) and digital application on remotely sensed data. The results are presented by the CNR-ISPC research unit's members: Immacolata Ditaranto and Vincenzo Giordano report on work in Eastern Irpinia, while Pasquale Merola and Francesca Di Palma examine methods of machine learning applied to the study of agrarian divisions with selected case studies from Campania. The conference proceedings bring together contributions focusing on the Campanian Plain, with particular attention to the territories of *Atella* (Brancato *et. al.*), one of the In.Res.Agri case studies, Acerra (Di Franco), and Nola (De Simone *et al.*), as well as on Southern Etruria (Fiorillo), which offers a coherent comparative framework for understanding the connections between rural landscapes and settlement systems through an integrated approach combining geoarchaeology, digital topography, and remote-sensing analysis. Within this broader context, a further comparative insight is provided by the ASH Project, whose research on the archaeology of rural landscapes across the Italian peninsula and Sicily (Pacciarelli *et al.*) investigates the relationship between volcanic soils and agricultural practices. All the papers adopt a multidisciplinary and diachronic perspective, spanning from Prehistory (Boenzi) to Late Antiquity (Tescione), with the relationship between the natural environment and human communities as a central focus (Tosolini *et al.*). The final contribution by Buono *et al.* presents the core of the IT platform, consisting of a database module able to bring to light and combine relations among diverse bodies of evidence, comprising textual and bibliographical data.

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DATA INTEGRATION FOR A HYPOTHESIS OF ANCIENT LAND DIVISION IN EASTERN IRPINIA: PRELIMINARY RESULTS

1. Introduction

The research activities presented in this paper constitute a case study in Eastern Irpinia (Fig. 1) within the framework of the PRIN Project 'Investigating Resilient Roman Agricultural Landscapes in Southern Italy' (In.Res.Agri; Brancato *et al.* 2024, 392-393), identified due to the need for a deeper analysis of the data acquired during a previous research (Ditaranto 2013, 2016, 2022, and in press). The large amount of archaeological data collected during this extensive research had already, some years ago, directed specific interest toward the question of the existence of an agrarian division in the territory of *Aeclanum* (Ditaranto 2017), with some hypotheses also concerning the areas to the S – those related to the city of *Compsa* – and the sector surrounding the Sanctuary of Mefite in the Valle d'Ansanto. During the project, a program called the 'Eastern Hirpinia Land Division' was developed. Compared with the previous research, the geographical area was expanded to the hypothesized boundaries of the ancient settlements mentioned above, and the analysis was carried out using historical cartography, aerial photographs, and high-resolution satellite images.

The interesting aspect of this research, and also the most challenging, is that we are dealing with a territory for which numerous sources (literary and epigraphic) document the occurrence of land division in the Roman era, yet no traces seem to have persisted, or they are difficult to recognize because of the geomorphological nature of the region, characterized only by limited patches of flat land. The overall examination of a dataset enriched with remote sensing documentation had multiple objectives: i) to verify the possible presence of traces and survivals throughout the studied territory in order to isolate portions of land that are actually indicative of having been subject to land division operations; ii) to identify traces related to centuriation limits through the analysis of high-resolution satellite images, the application of algorithms for automatic processing and to test the automated recognition of recurring modules in land division (see Di Palma, Merola in this volume); iii) to identify one or more modules of land division.

I.D.

2. Analysis of a complex territory. State of the art

The study area is mostly hilly, with elevations ranging approximately from m 400 to 800 a.s.l. and the landscape is strongly marked by significant

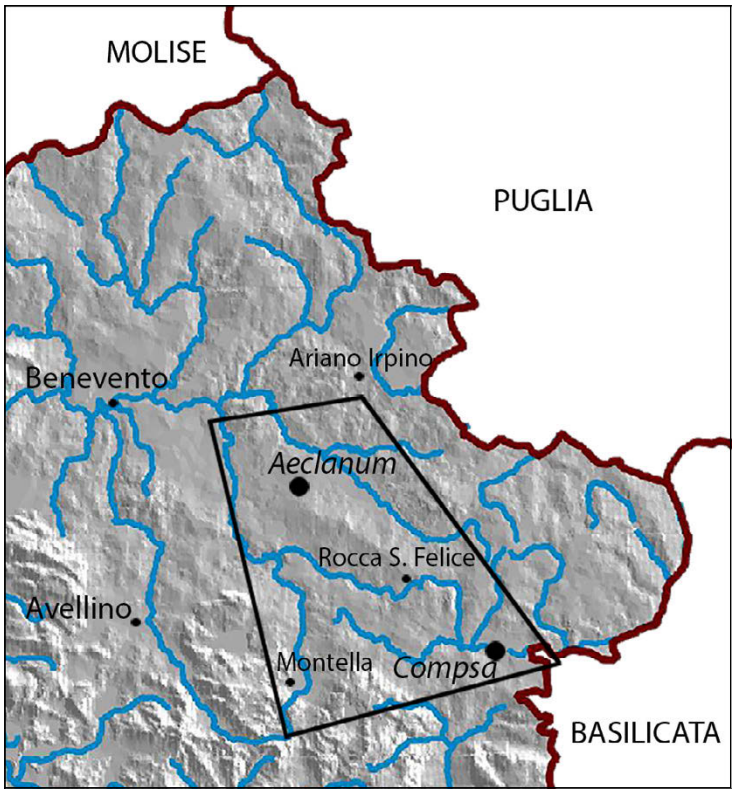


Fig. 1 – Location of the study area.

watercourses; it is very large, and understanding the historical dynamics of the involved settlements is complex (Fig. 2). The territory situated between the *agri* of *Aeclanum* and *Compsa*, and possibly relevant to a third, unknown, ancient site located near the important Mefite Sanctuary, around Frigento or Rocca San Felice, requires an analysis of the historical and topographical dynamics of this part of Irpinia in its entirety. As for the boundaries between the territories of the mentioned settlements, we refer to detailed discussion, since the debate is very broad and still ongoing (Camodeca 1996, 190; 2021; Lo Pilato 2010, 2013; Evangelisti 2014, 258, n. 2; 2017, 55-58).

2.1 Ager Aeclanensis

Aeclanum was already a partially structured pre-Roman centre between the 3rd and 2nd centuries BC. Not far from *Aeclanum*, another settlement of

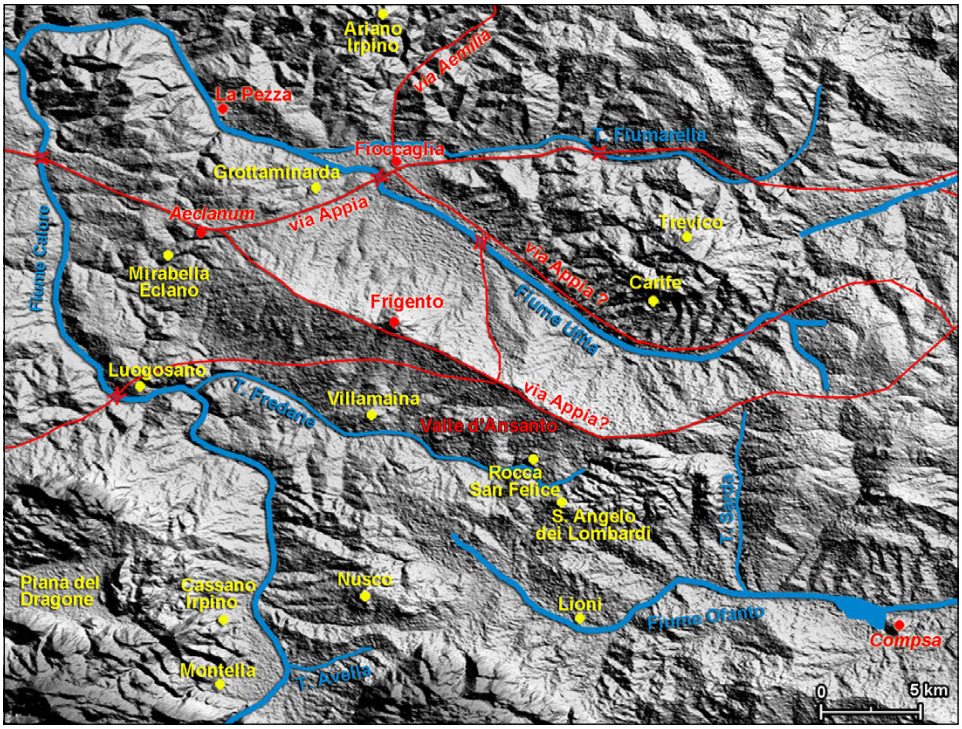


Fig. 2 – DEM of Eastern Irpinia, with the ancient settlements, the main hydrographic network, and the Roman road system.

some importance emerged during this period, immediately E of the Ufita River, at Fioccaglia place (Johannowsky 1990). In the 2nd cent. BC, *Aeclanum* was crossed by the *Via Appia*, which very likely also bordered this unnamed settlement at Fioccaglia, later called *Forum Aemilii* since it was also the head of the *Via Aemilia*, built around 126 BC. The most accepted hypothesis is that this was a *forum* serving as an administrative or directional centre, built for the community of colonists benefiting from land distribution as part of the Gracchan program of 133 BC (Camodeca 1997). However, in the surrounding territory of *Aeclanum*, no boundary stones related to land division from this period or from other significant moments in the centre's history have been discovered (founding of the *municipium*: end of 1st cent. BC; elevation to colony status: 2nd cent. AD). The only evidence of land surveying operations comes from the *Libri Coloniarum* (*Lib. Col.* I, ll. 4-6, 210; *Lib. Col.* II, ll. 5-8, 261) which tell us that the *ager* was divided using a *centuria* of 20×24 *actus* (about 710×852 m). From this, we deduce the exact

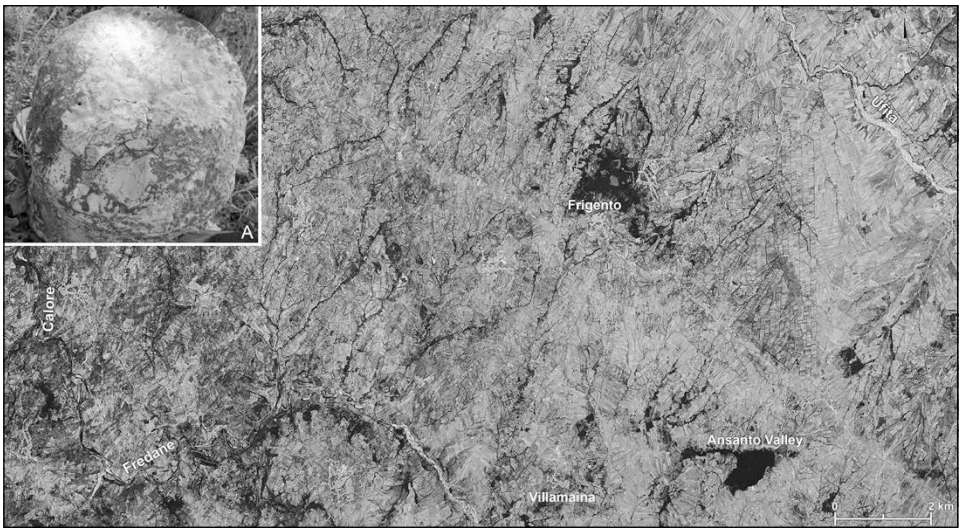


Fig. 3 – Hexagon KH-9 space photo of the central sector of the study area (ID: D3C1208-400661A012, 01-07-1974). In the square, a new boundary stone from the territory of Frigento with the *decussis* and inscription D II.

measurements of each *centuria*, its orientation (*decimanus in orientem, kardo in meridianum*), but not the specific historical moment when this operation took place. For this territory, a centuriation following the indications of the *Liber Coloniarum* has been hypothesized, with *centuriae* approximately of 710×852 m (Ditaranto 2017).

2.2 *Territory between* Compsa, Abellinum *and* Aeclanum

For this territory, a historical reconstruction has been proposed, suggesting that it transitioned from the status of *ager publicus* starting from the Second Punic War, to being governed by a *praefectura* during the Gracchan period. Later, it became a *municipium*, possibly from the Cesarian era (Camodeca 2021). Later – but not before the 2nd cent. AD – the area was assigned to *Aeclanum*, probably with the Fredane stream marking its southern boundary. The exact location of the centre remains unknown, although archaeological considerations have led in the past to a tentative placement at Frigento (Colucci Pescatori 1991, 95-98). From this area come seven boundary stones related to an ancient land division (Figs. 5-7); of these, four date back to the Gracchan period, one from the area of Villamaina, datable to 130-129 BC (Camodeca 2021, 99-100), two from the surrounding area of Rocca San Felice (*CIL* IX, 1024 -1025), precisely datable to 129 BC due

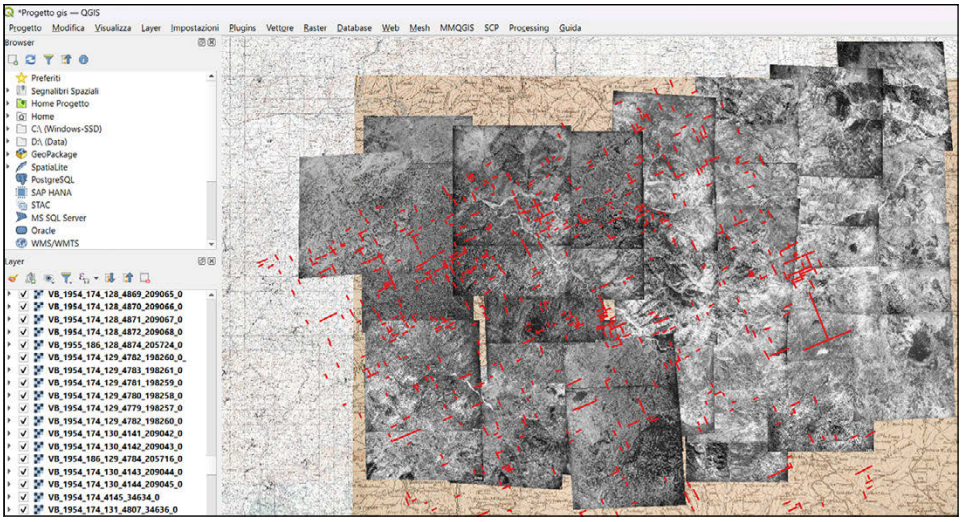


Fig. 4 – GIS platform for data management of the 'Eastern Hirpinia Land division' program.

to the presence of the third magistrate of the triumviral commission *agri iudicandis adsignatis* and one from the territory of Frigento, just unpublished (Fig. 3A). Regarding the other remaining boundary stones (*CIL* IX, 1026; Kajava, Solin 1997, 56-57) see now De Magistris 2025, who hypothesizes the pertinence of this territory to the *ager* of the colony of *Abellinum*.

2.3 Ager Compsinus

The territory that would have fallen under *Compsa* – like *Aeclanum*, a Hirpinian centre in the 3rd cent. BC – was also partly affected by the same processes as the area immediately to the N. Essentially, the entire Upper Calore Valley (the territories of Montella, Cassano Irpino, Nusco, and Lioni) became a*ger publicus* after the Second Punic War. It was assigned to a *praefectura* during the Gracchan period and, roughly during the age of Caesar, this territory was assigned to the *municipium* of *Compsa*, (Camodeca 2021). From this area come three boundary stones, found respectively in the countryside of Lioni, Nusco, and Montella, and datable to 130-129 BC (Buonopane 2010, 326-329; 2013; Colucci Pescatori 1991, 92). Confirming the implementation of the Gracchan land survey program, the *Liber Coloniarum* notes that the territory of *Compsa* was divided using Gracchan boundaries (*limitibus graccanis*: *Lib. Col.* II, ll. 1-2, 261), and that it was organized into *centuriae* of two hundred *iugera* (20×20 *actus*).

I.D.

3. Materials and methods

For the study of the investigated area, the following historical cartographic materials were acquired: a mosaic of 1:50.000 scale maps made by the Istituto Topografico Militare in 1876, particularly those relating to Sheet 63 'Salerno' and Sheet 55 'Avellino'; a composite map of IGM, Sheets 174 and 186 dating to1936, at a scale of 1:100.000; approximately 20 IGM maps of 1955 at a scale of 1:25.000, corresponding to Sheets 173, 174, 185, and 186. For the same area, around 60 vertical aerial photographs were also obtained, taken by the Istituto Geografico Militare between 1954 and 1955 and currently preserved in the archives of the Aerofototeca Nazionale in Rome. Lastly, three Hexagon KH-9 space photographs were retrieved; they offer a comprehensive view of the territory as it appeared in the 1970s (Fig. 3). To analyse this rich dataset, the creation of a geodatabase was necessary, aimed at the integration and joint management of archaeological and territorial data within a unified platform capable of virtually returning both data collected from fieldwork and those derived from subsequent processing and elaboration operations (Moscati 2017; Brancato *et al.* 2024).

For the development of this tool, the open-source software QGIS, version Bratislava 3.40.11, was employed, currently among the most widely used in archaeological and academic contexts, because of its free availability and ease

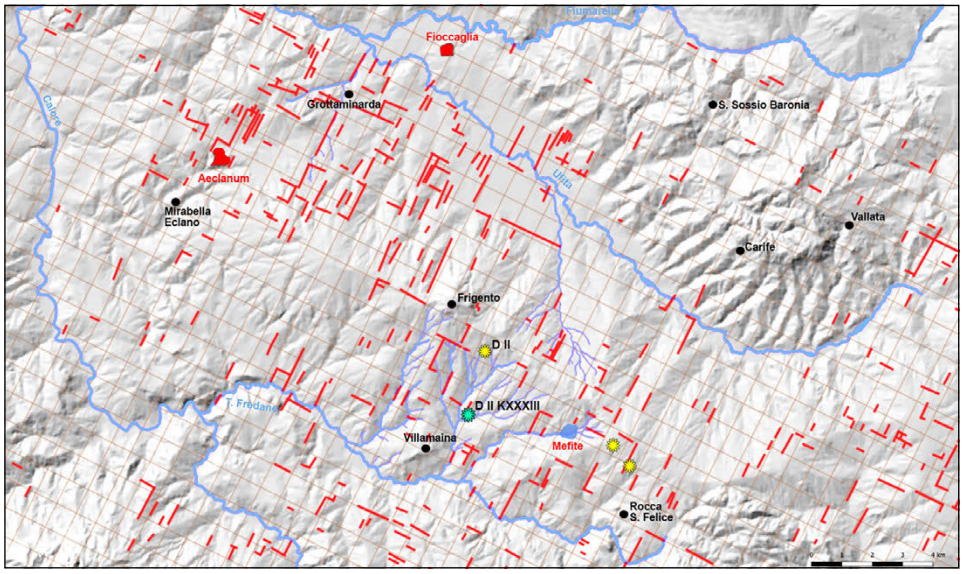


Fig. 5 – Hypothesis of agrarian division of the territory of *Aeclanum*, scheme A (20×24 *actus*; 27°E). The asterisks denote the findspots of the Gracchan boundary stones. The green asterisk is *in situ* boundary stone.

of management and implementation of heterogeneous datasets (Gazzoli 2019). A preliminary phase of the work focused on structuring the geodatabase, adopting the WGS 84/UTM 33 N (EPSG:32633) reference coordinate system. All the cartographic sources listed above were properly georeferenced and used as the base maps for the entire research work. Concurrently, these data were supplemented with a basemap representing the current territorial layout (Google Satellite), integrated via the QuickMapServices plug-in, a useful tool that allows access to a wide range of online maps through the QGIS interface. A subsequent phase in the construction of the geodatabase involved the georeferencing of historical aerial photographs (Fig. 4); these images, together with the cartographies, constitute a vast repository of information, offering a snapshot of the territory that is closer to its ancient configuration, prior to the advent of mechanised agriculture and the construction of large-scale infrastructure.

For the georeferencing of these photograms, the Polynomial 1 algorithm was used, one of the most employed methods to associate a raster image with a known geographic coordinate system. This algorithm proves particularly suitable in the presence of moderate distortions, typical of vertical aerial photographs, ensuring a good degree of precision without the need for complex and cumbersome interpolation procedures. As with the cartographic data, a dedicated and queryable layer was created for each of these photograms, accessible through the corresponding interface. The final phase of the work concerned the creation of grids using a function provided by the MMQGIS plug-in, specifically designed for the manipulation of vector layers. This tool enables a series of operations such as join, geocoding, geometric conversion, buffer generation, and central node analysis. The resulting grids, based on the preservation in maps and aerial imagery of road intersections, alignments, field divisions, ditches, and watercourses, have proven to be valuable tools for identifying further possible alignments and traces of ancient land division. Each of these elements was vectorised and accompanied by a descriptive record, compiled on the basis of information obtained from aerial images and cartographies; in addition to the dimensions and orientation, it was deemed useful to record place names when these seemed to suggest the presence of road axes and possible ancient infrastructures (e.g., Stràtola, Pilone), the agricultural vocation of the area (Vigne, Vignale, Lavinella), or the presence of potential boundaries (Limiti, Tre Croci, Crocevia, Confine).

The development of this geodatabase has thus not only enabled the gathering of data within a unified platform but also facilitated the advancement of possible interpretations regarding ancient land divisions, significantly contributing to the elaboration of diachronic reconstructive hypotheses and models of the Irpinian historical landscape.

V.G.

4. Discussion

Based on the analysis described above, three agrarian division grids have been identified. In the area between *Aeclanum*, the Ufita River to the E, and Rocca San Felice to the S (although the most substantial survivals extend as far as Frigento), a grid oriented 27° NE with a module of 20×24 *actus* has been identified (scheme A: Fig. 5). The alignments mostly consist of surviving

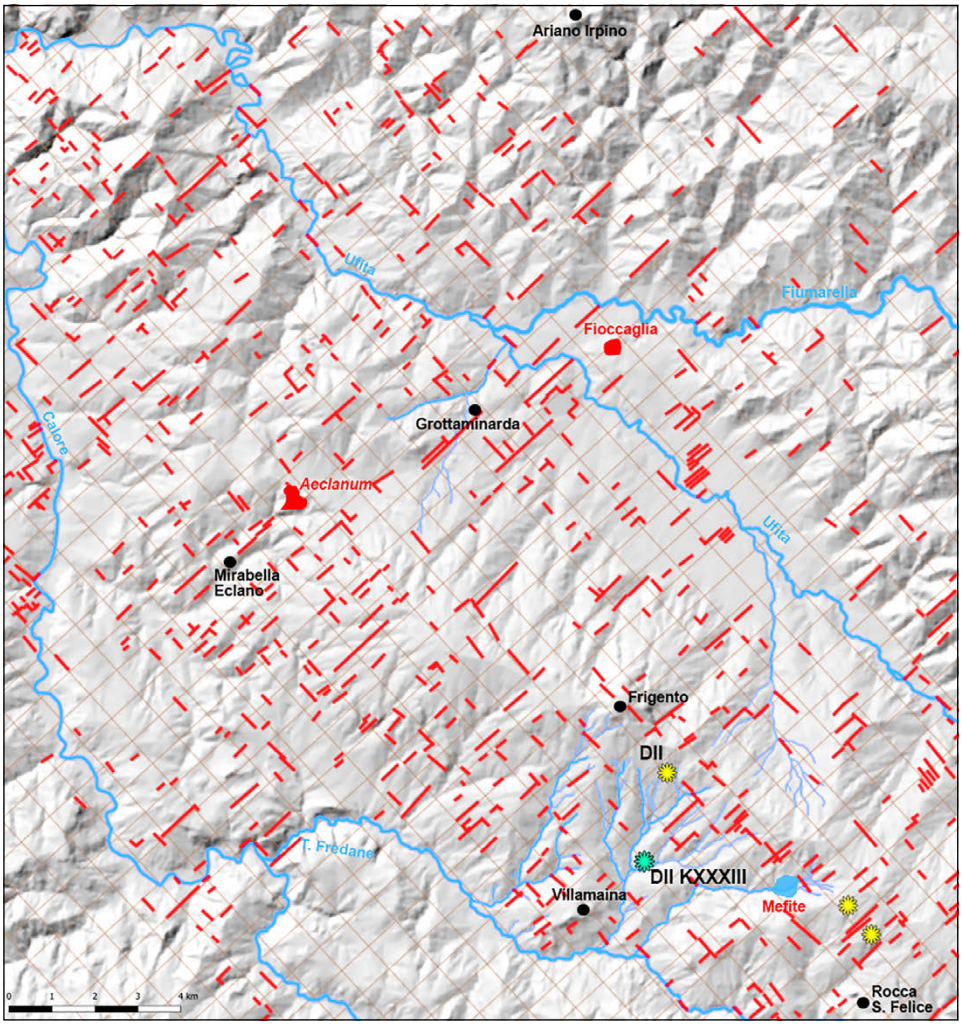


Fig. 6 – Hypothesis of agrarian division of the territory of *Aeclanum*, scheme B (20×24; 47°E *actus*).



Fig. 7 – The centuriated territory of the *ager Compsinus* close to Montella plain, in a aerial view from E.

watercourses, country paths, field boundaries, ditches, and drainage channels. If at least part of the centuriated territory corresponds to this area where such features have been identified, we may be witnessing a deliberate choice made by Roman land surveyors to divide the flattest sector of the entire area. This is the plain crossed by the *Via Appia* and by the Ufita River, predominantly extending along the river's left bank. Another substantial group of survivals identifies a grid of 20×24 *actus*, rotated 47° NE, within a territory stretching from the Calore River to the Fiumarella stream (scheme B: Fig. 6). It is difficult to establish a precise chronology for the two possible centuriation grids (for the discussion on the chronological attribution, also in relation to the data from field surveys, see Ditaranto, Giordano in press).

It cannot be ruled out that one of the two was implemented during the Gracchan period, or during the Imperial period adopting the 'non-standard' 20×24 *actus* module (Castagnoli 1958, 22). Within the intermediate territory between the *agri* of *Aeclanum* and *Compsa*, several surviving alignments appear to correspond, in the majority of cases, to the orientation defined by scheme B (Fig. 6) and they should refer to an ancient land division implemented in this sector probably starting from the 2nd century AD, when it was included in the territory of the colony of *Aeclanum*. In the territory located S of the Fredane Stream, the identification of possible traces and survivals of agrarian divisions proves more complex. The geomorphology of the area

is more rugged, and it must be considered that the numerous watercourses may have shifted or changed over the centuries. Nevertheless, a 20×20 *actus* module-oriented N-S has been hypothesized or it was possible, due to the position of the three boundary stones, that the *ager Compsinus* included two different and adjoining centuriations. It should be noted that the flattest part of this territory is located between Montella, Cassano Irpino and Nusco (Fig. 7), from where two of the known boundary stones come.

I.D.

5. Conclusions and research perspectives

Thanks to the large amount of collected data, the work on this sector of Irpinia within the framework of the PRIN In.Res.Agri project will continue to provide answers to the still open questions regarding the agrarian division of this extensive territory. Although for the area of *Aeclanum* we have data from systematic archaeological surveys that allow us to more precisely outline the centuriation program(s) (Ditaranto in press and Ditaranto, Giordano in press), for the territory of *Compsa* there is a significant gap in the diachronic understanding of settlement dynamics between the prehistoric and medieval periods, with the exception of some limited sectors (Rea 1982; Colucci Pescatori 1991; Carfora *et al.* 2014; Pugliese 2017).

I.D., V.G.

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ABSTRACT

The case study identified in Eastern Irpinia includes the territories belonging to the colony of *Aeclanum*, to the N, and ancient *Compsa*, to the S. It is a vast area bordered by the Calore River to the W, which reaches and exceeds the banks of the Ufita River to the E. It offers the opportunity to study a territory that has been little explored in relation to the topic of agrarian divisions, likely due to its decidedly complex geomorphological nature, characterized by a predominantly hilly landscape and rich hydrography, with limited plains. Furthermore, the historical interpretation of the entire territory is equally complex, for which the boundaries of each center can only be hypothesized. Following the indications of the *Liber Coloniarum*, which mentions divisions for both *Aeclanum* and *Compsa*, and considering the discovery of eight agrarian division stones, of which at least 6 dating to Gracchan period, an attempt is being made to reconstruct the agrarian divisions implemented in the territory through the analysis of historical cartography, aerial photographs and with the aid of machine-learning applications starting from high-resolution satellite images.

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REMOTE SENSING TECHNIQUES AND MACHINE LEARNING ANALYSES IN ARCHAEOLOGY: A METHODOLOGICAL APPROACH TO TERRITORY INVESTIGATIONS

1. Introduction: RS and AI methodologies

The term 'remote sensing' was coined in the 1960s by the American geographer Evelyn Lord Pruitt (Pruitt 1979). In its most general definition, it refers to the acquisition and processing of qualitative and quantitative information about an object without direct contact. The application of remote sensing in archaeology has historically been secondary, despite its initial development for Earth observation (at various scales) and monitoring in military, cartographic, and environmental contexts, among others. Following a period of research that has spanned more than half a century, the scientific community has adopted two different approaches to define this term (Campana 2017). Some archaeologists have described it as a method for obtaining information about objects by analysing data collected by sensors (cameras, scanners, radar systems, etc.) mounted on airborne or satellite platforms, without direct contact with them. In this paper the definition of remote sensing refers to the observation of buried traces without compromising the integrity of the stratigraphy (for a recent study Wang, Liu 2024).

The advent of Artificial Intelligence (AI) and Machine Learning (ML) techniques has led to a considerable augmentation in the analysis of remotely sensed data, thereby expanding and testing the potential of this methodology in archaeological research (Lambers *et al.* 2019; Orengo *et al.* 2020; Bickler 2021; Cacciari, Pocobelli 2021; Argyrou, Agapiou 2022; Karamitrou *et al.* 2022; Zhang, Zhang 2022; Agapiou, Lysandrou 2023; Kadhim, Abed 2023; Canedo *et al.* 2024; Luo *et al.* 2024; Vats, Mehta 2024). Advanced algorithms now allow the processing of large quantities of information with greater precision and speed, enabling the detection of sites and ancient anthropic structures that are sometimes difficult to identify. For instance, these tools can detect hidden patterns in multi- and hyper-spectral or radar data, improving the mapping and interpretation of archaeological landscapes in a fully non-invasive manner and guiding subsequent ground investigations (Canedo *et al.* 2024). Consequently, the integration of remote sensing with AI and ML techniques is becoming increasingly valuable for the sustainable and non-destructive management of cultural heritage.

This paper presents the results of an in-depth research project carried out by the Authors over the last year and a half, which involved the testing of two artificial intelligence software packages: ENVI (v. 4.5) and eCognition (v.

10.4 and 10.5). Both were used for the automated processing and analysis of high- and very high-resolution multispectral remotely data. A particular focus was devoted to eCognition, which was extensively tested during the research, and the main results are presented here. Specifically, imagery acquired by WorldView-2 (4 bands) and WorldView-3 (8 bands) satellites, with ground resolutions of 0.50 m and 0.30 m respectively, was processed and analysed.

The investigations covered various territorial contexts of central and southern Italy, characterized by marked orographic differences[1]. This paper presents data on the Campania region, with particular focus on two geographical and geomorphological distinct areas: the northern sub-region of Irpinia and the Campanian Plain. Methodologically, the research was structured on three levels of investigation: traditional, semi-automated, and automated.

The remotely sensed data were initially processed through the application of Spectral Indices and analysed through photointerpretation method, in order to understand the topography and orography of the area, to identify anomalies and archaeological traces. This process is essential for training ML algorithms and correcting any interpretation errors made by the software.

As several scholars have already emphasized, the integration of remote sensing analysis with modern AI technologies is transforming archaeological research and beyond, making it possible to analyse large datasets and extensive areas. At the same time, however, it is important to emphasize that AI, though powerful, requires continuous monitoring and, above all, the input of human intelligence in order to improve and evolve (Gallavotti 2024).

F.D.P., P.M.

2. State of art: from decision tree to convolutional neural network

2.1 *A comparison of the performance, commonality and differences between the ENVI and eCognition software*

In recent decades, satellite image processing has become a central role to numerous fields of research, from environmental and geological studies to urban monitoring, from land-use planning to archaeological investigations. With the advent of AI, commercial software tools for advanced remotely data analysis have rapidly proliferated (Tab. 1). Among the most widely used applications are ENVI and eCognition, which enable the extraction of complex information, simplifying otherwise laborious tasks and enabling faster and more accurate automated analyses.

[1] As with *Atella* (see Brancato *et al.* in this volume), these experiments are part of two PRIN projects: In.Res.Agri (European Union NextGenerationEU; MUR project code 2022SMJCHX) and ASH (European Union NextGenerationEU; MUR project code P2022NNE72) (see Pacciarelli *et al.* in this volume).

Software	*Analysis ability*	*Analysis accuracy*	*Learning difficulty*	*Interface friendliness*	*Algorithms quantity*	*Design oriented*
ENVI	Very powerful	Higher	Ordinary	Ordinary	Many	Yes
Geomatica	Ordinary	Ordinary	Hard	Unfriendly	Many	Yes
Qmosaic	Ordinary	Ordinary	Ordinary	Ordinary	Many	No
eCognition	Very powerful	Higher	Easy	Friendly	Great many	Yes
ERDAS	Powerful	High	Hard	Friendly	Great many	No

Tab. 1 – A comparison of five commonly used RS image analysis software packages (by Zhang 2008). Although eCognition is rated as 'easy to learn' due to its intuitive interface and graphical tools, its advanced functionalities – including object-based workflows, complex segmentation and customised algorithms – require a steeper learning curve and greater specialist expertise than pixel-based environments such as ENVI.

Since May 2024, the Authors have initiated a study aimed to understand the potential of these two software packages and their application for archaeological purposes. The objective is to develop a methodological framework tailored to specific territorial, geological, and archaeological contexts. Although ENVI's potential in the archaeological applications was already known, a systematic comparison was nevertheless undertaken between the two commercial tools (ENVI and eCognition). The comparison focused on shared features, methodological differences, and potential applications, with particular emphasis on their usability in the archaeological field.

Both software packages can process data acquired from different platforms (satellite, aerial, UAV) and support integration with GIS systems, offering advanced spatial analysis capabilities. Despite both supporting automated methods, their approaches differ: ENVI is based on pixel-based classification (PBC), which is ideal for traditional classification tasks, while eCognition adopts an object-based image analysis (OBIA) methodology, particularly effective in analysing high-resolution images and managing complex spatial features (Del Giglio *et al.* 2019), such as those typical of archaeological sites. In terms of ease of use, ENVI is generally considered more intuitive, while eCognition offers more sophisticated functionalities but requires advanced knowledge of OBIA (Tab. 2).

F.D.P., P.M.

2.2 *ENVI and Decision Tree Classification*

ENVI (Environment for Visualizing Images) is a commercial software developed by Harris Geospatial Solutions, now part of L3Harris Technologies. This program is distinguished by its ability to manage substantial image datasets and its sophisticated algorithms, facilitating the extraction of intricate information from remotely sensed data. It is one of the most comprehensive

Feature	ENVI	eCognition
Main Focus	Image processing, data analysis and visualisation of geospatial data.	Object-based image analysis (OBIA), segmentation, and classification.
Core Functionality	Image enhancement, multispectral and hyperspectral analysis, and integrate on with GIS tools.	Segmentation, classification, and spatial analysis of remotely sensed data.
Data Types Supported	Multispectral, hyperspectral, LiDAR. radar, and other geospatial data formats.	Primarily focuses on high-resolution imagery and data from various sources, including drones.
Analysis Type	Pixel-based analysis and classification.	Object-based analysis, focusing on segments of the image rather than individual pixels.
Processing Techniques	o Image processing o Spectral analysis o Classification (supervised/unsupervised) o Change detection	o OBIA classification o Multi-scale segmentation o Rule-based classification o ML Integration
Ease of Use	User-friendly with a comprehensive interface, suitable for both beginners and experts.	More complex. requiring a solid understanding of OBIA, but very powerful for high-level tasks.
Integration with the other software	Excellent integrate on with GIS platforms (ArcGIS, QGIS), Python scripting and other geospatial tools.	Integrates well with RS tools and GIS software but is more focused on spatial analysis.
ML Capabilities	Provides basic ML tools for classification, clustering, and regression.	Supports more advanced ML models, especially in OBIA classification.
Automated/Manual Process ng	Offers both manual and automated workflows (e.g. batch processing).	Highly automated with customisable rule sets for segmentation and classification, but also allows manual intervention.
Customization	Customisable through scripting (Python and IDL), plugins, and toolboxes.	Highly customisable with user-defined rulesets and scripting (eCognition Developer).
Potential Applications	o Environmental monitoring o Land use/land cover mapping o Agriculture o Disaster management	o Urban planning o Agriculture o Forestry o Environmental monitoring High-resolution imagery analysis
License Type	Commercial license with various tiers for different functionalities.	Commercial license with a focus on professional, large-scale projects.
Cost	Expensive, with a tiered pricing model based on the features	Expensive, geared towards advanced and large-scale professional users.

Tab. 2 – Summary table comparing ENVI and eCognition software for remote sensing (RS) image analysis. ENVI is primarily PBC and user-friendly, whereas eCognition adopts an object-based approach (OBIA), offering more advanced but complex functionalities (elaborated by Francesca Di Palma).

tools available for satellite image processing and geospatial analysis, combining basic functionalities (visualization and corrections) with advanced techniques for multi-/hyperspectral and multitemporal analyses. Its versatility makes it a key software both in scientific research and in professional applications (Teodoro *et al.* 2012; Wang *et al.* 2021).

ENVI supports all the latest data collection platforms (satellite, airborne, drone, terrestrial), more than 200 different data types, and modalities including

panchromatic, multispectral, hyperspectral, LiDAR, SAR, and FMV. It can process datasets of any size and provides automated tools to quickly and easily prepare imagery for further analysis (nv5geospatialsoftware.com/Products/ENVI). ENVI offers automated workflows that help users efficiently extract information from all types of geospatial data, such as:

– multitemporal analysis: monitoring territorial changes (deforestation, urbanization, climatic phenomena);
– hyperspectral analysis: identification of minerals, pollutants, or specific crops through hundreds of spectral bands.
– spectral indices: calculation of NDVI (Normalized Difference Vegetation Index), NDBI (Normalized Difference Built-up Index), NDWI (Normalized Difference Water Index).
– thematic classification: identification of different land covers (vegetation, water bodies, urban areas). Among the supervised classification techniques available in ENVI, the Decision Tree method represents a flexible and interpretable approach, particularly suitable for integrating spectral data, derived indices, and ancillary information.

A decision tree is a classification model that iteratively splits a dataset according to logical rules based on threshold values. Each node represents a condition (e.g., NDVI values), each branch a decision, and each leaf corresponds to a thematic class as vegetation, water, bare soil, urban areas, etc. (Breiman *et al.* 1984). The strength of this method lies in its simplicity and transparency: unlike more complex algorithms such as neural networks or parametric methods (e.g., Maximum Likelihood), the decision tree allows users to clearly trace and understand the rules that led to classification (Hansen *et al.* 2013).

The classification process via Decision Tree in ENVI can be summarized in several stages (Friedl, Brodley 1997):

1) data preparation: radiometric and atmospheric correction of images, calculation of spectral indices (e.g., NDVI, NDWI), generation of ancillary layers (e.g., digital elevation models);
2) definition of rules: the user establishes logical conditions based on band or index values (e.g., NDVI threshold);
3) tree construction: rules are hierarchically organized into a decision flow;
4) classification: each pixel is assigned to a class according to the logical path followed within the tree;
5) validation: results are compared with reference data (ground truth, aerial photographs, GIS datasets).

Supervised pixel-based classification (PBC) of multispectral imagery constitutes a valid tool for the production of thematic maps based on the

spatial and spectral information contained in individual pixels. This approach, which involves selecting representative sample pixels for each class, is closely integrated with supervised classification through decision trees. The analysis demonstrates the ability to distinguish classes such as 'Archaeological Traces' although classification process is often influenced by spectral similarities between classes. In fact, variations in vegetation or soil chemical-physical properties are often minimal (Merola 2011).

Despite some limitations due to modest separability between the spectral signatures of archaeological contexts and surrounding soils, the results can be considered valid both in terms of accuracy and pixel localization.

P.M.

2.3 *eCognition and the Convolutional Neural Network*

eCognition is a software developed in 2000 by Definiens, specifically designed for the automated analysis of satellite and aerial imagery. In 2014, Trimble acquired Definiens, and the software became part of Trimble's suite of products for image analysis and geospatial data management (https://www.sysdecoitalia.com/prodotti/ecognition/). In the field of remote sensing

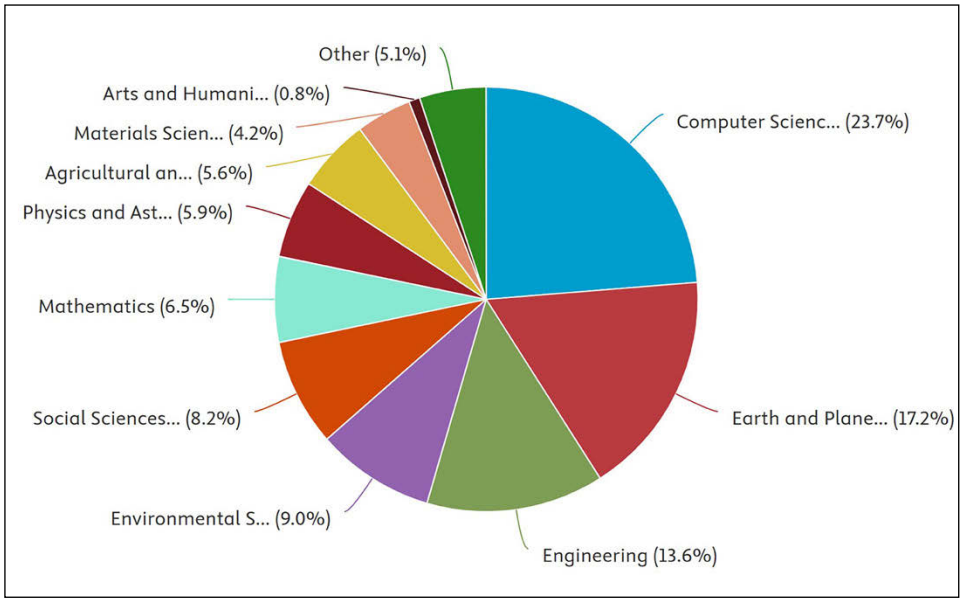


Fig. 1 – The figure presents a graph relating to all publications produced between 2000 and 2024 containing the keyword 'eCognition'. The figure delineates the percentage relating to the disciplinary sectors covered by the aforementioned publications. As is evident, the humanities sector is below 1% (source: Elsevier-Scopus).

software, eCognition is a leading solution for the processing, analysing, and interpreting geospatial data. Compared to ENVI, eCognition enables object-based analyses through segmentation and classification techniques, both semi-automated and automated (Sharma *et al.* 2024). This approach allows the combined extraction of linear and areal objects from multi-sensor image data, made possible by ML algorithms (Argyrou, Agapiou 2022). Although originally developed for environmental and territorial remote sensing data analysis, eCognition has proven extremely versatile for archaeological research (Fig. 1).

Its OBIA approach allows the identification and classification of complex landscape elements with high precision, facilitating the detection of hidden or subtle archaeological sites. Remotely sensed data (multispectral, hyperspectral, LiDAR, etc.) processed with spectral indices and analysed through segmentation and classification not only enhance the understanding of ancient topography, guiding field verification, but also allow the monitoring of site preservation over time. The integration of multispectral, geophysical, and archaeological data deepens our understanding of the historic landscape, reconstructing human-environment interactions in greater detail (Leucci *et al.* 2002; Zamuner *et al.* 2009; Merola 2011; Campana 2017; Valente *et al.* 2023; Cozzolino *et al.* 2025). Therefore, although eCognition was not originally designed for archaeology, it is now a valuable tool for the field, bridging traditional topographic research, Computational Archaeology, and the Digital Humanities.

From the outset, the Authors committed not only to studying the software but also to testing its potential – from basic remote sensing analyses to more advanced ML and Deep Learning (DL) applications. The main analytical operations in eCognition unfold in two stages: a) PBC (Pixel-Based Classification); b) OBIA (Object-Based Image Analysis).

In the first stage, the image is imported and spectral indices are calculated to highlight specific features in the remotely sensed data (in archaeological research, these can emphasize landscape anomalies). A preliminary classification based on spectral pixel values (PBC) can thus be performed. Subsequently, the OBIA approach segments the image into homogeneous objects, aggregating similar pixels into meaningful spatial entities. Statistical and geometric features are then extracted from these objects to enable more accurate, context-based classification.

Both classification types can be enhanced by applying Convolutional Neural Networks (CNNs). Neural networks are a class of algorithms that attempt to recognize underlying relationships within a dataset by mimicking the functioning of the human brain, particularly the neuronal system. CNNs are fundamental for advanced object detection, enabling the automated identification of complex patterns and hidden relationships (for applications in

archaeological detection, see Soroush *et al.* 2020). Features such as linear or regular structures can be effectively recognized by training CNNs; once validated, these networks produce stable and reliable models for analysis. The training, however, requires a preliminary learning phase using representative datasets to optimize the model's ability to generalize and accurately identify targets in satellite imagery.

The following methodological section presents in detail the processing protocols and analytical procedures developed through the use of eCognition.

F.D.P.

3. In.Res.Agri project: from the mountain to the plain. The Campania case studies: looking at different areas with different types of elevation

As part of the In.Res.Agri project (Brancato *et al.* 2024), case studies were conducted on selected areas of Campania (Irpinia and the Campanian Plain) and *Apulia* (Tavoliere). These territorial contexts were investigated by methodologically combining traditional topographical research with innovative AI-based experiments, such as ML and DL, for spatial analysis and the automated detection of archaeological traces attributable to ancient land divisions. This paper presents the preliminary results concerning the region of Campania and two distinct and complex areas of investigation, as previously mentioned: Irpinia and the Campanian Plain. Irpinia is a historical-geographical region of the Campanian hinterland, predominantly mountainous and hilly territory, largely coinciding with the current province of Avellino. In the Roman period, Irpinia underwent processes of landscape Romanization, including the construction of roads, settlements, and structured systems of agricultural exploitation such as centuriation (Johannowsky 1987).

The Campanian Plain, by contrast, refers to the flat area known in Roman times as *Campania Felix* (Strabo, *Geographica* V, 4, 3; Plin., *Naturalis Historia* III, 60-61). The region has been continuously inhabited since antiquity. It has hosted heterogeneous settlements from pre-Roman times through the Imperial period. However, the substantial post-World War II urbanization has profoundly altered the historical landscape, often obscuring or obliterating the material traces of antiquity.

The complex orography of Irpinia and the extensive transformations of the Campanian Plain today mean that archaeological research is challenging. This means that advanced investigative and territorial analysis tools are needed. For this purpose, the Authors tested the potential of eCognition (v. 10.4 and 10.5), applying it to high- and very high-resolution multispectral satellite imagery (0.50-0.30 m ground resolution) within an innovative approach for the semi-automated and automated detection of Roman centuriation.

Spectral Indices	Description	Formula	References
NDWI	Normalized Difference Water Index	(G – NIR)/(G + NIR)	McFeeters 1996
SR	Simple Ratio	NIR/R	Jordan 1969
NDVI	Normalized Difference Vegetation Index	(NIR-R)/(NIR+R)	Rouse *et al.* 1974
NDYI	Normalized Difference Yellowness Index	(G-B)/G+B)	Sulik, Long 2016
GRVI	Green Ratio Vegetation Index	N/G	Sripada *et al.* 2005
GNDVI	Green Normalized Difference Vegetation Index	(N-G)/(N+G)	Gitelson *et al.* 1996
NDSI	Normalized Difference Soil Index	(R-B)/(R+B)	Escadafal *et al.* 1994
SAVI	Soil-adjusted vegetation	((NIR - R) / (NIR + R + L))*(1+L)	Huete 1988
OSAVI	Optimized Soil-Adjusted Vegetation Index	(NIR-R)(NIR+R+0.16)	Rondeaux *et al.* 1996
NIRv	Near-Infrared Reflectance of Vegetation	((NIR-R)/(NIR+R))x NIR	Badgley *et al.* 2017
NormNIR	Normalized NIR	NIR/(NIR+G+R)	Sripada *et al.* 2005
VARI	Visible Atmospherically Resistant Index	(G-R)/(G+R-B)	Gitelson *et al.* 2002
VrNIRBI	Visible Red based built-up index	(R-NIR)/ (R+NIR)	Estoque, Murayama 2015
VgNIRBI	Visible Green based built-up index	(G-NIR)/ (G+NIR)	Estoque, Murayama 2015

Tab. 3 – Summary of the spectral indices used (elaborated by F. Di Palma, based on literature).

In detail, five multispectral satellite images were analysed: two acquired by WorldView-2 (a 4-band image of 9 April 2017, ID 103001006802B800, for Irpinia; and an 8-band image of 9 October 2020, ID 10300500A8F93B00, for the Campanian Plain), and three by WorldView-3 (a 4-band stereo image of 26 April 2018, ID 104001003C24FD00, for Irpinia; and two 8-band images of 27 December 2023, IDs 104005005BDC1C00 and 104005005BDC1B00, plus an 8-band image of 11 May 2024, ID 1040050065DCD900, for the Campanian Plain). The case studies covered areas in the territories of Sturno, Nusco, Ponteromito, Cassano Irpino, and Montella (Irpinia), and Sant'Arpino, Succivo, and Orta di Atella (Campanian Plain). The Irpinia case study was

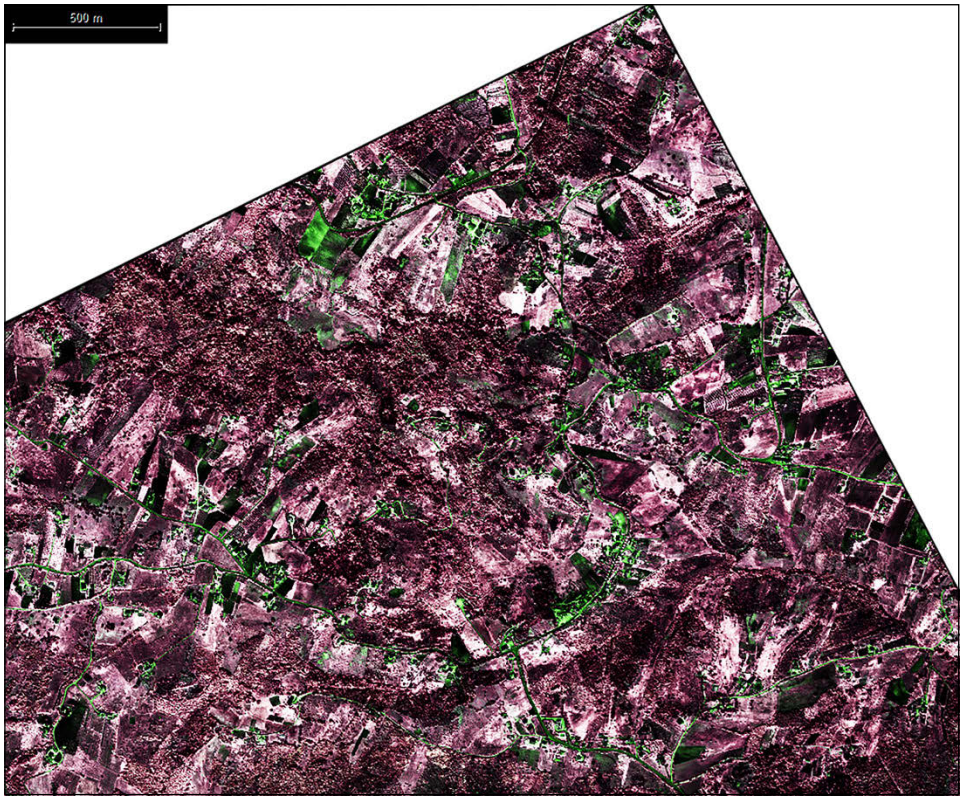


Fig. 2 – Detailed processing of the WV-3 four-band stereo satellite imagery from April 26, 2018 (ID code 104001003C24FD00). The image has been processed using a false-colour composite, with the B, G, and R channels assigned to the respective B, G, and R bands, while the Near-Infrared (NIR) band is displayed across all channels. A series of vegetation and surface indices were derived and visualized: the Normalized Difference Water Index (NDWI) in the G channel, the Simple Ratio (SR) in all channels, the Normalized Difference Vegetation Index (NDVI) in the B channel, the Green Ratio Vegetation Index (GRVI) in the R channel, the Normalized Difference Soil Index (NDSI) in the B channel, and the Normalized NIR (NormNIR) in the R channel.

conducted by the Archaeological Mapping Lab of CNR-ISPC, Lecce, while the Campanian Plain study (*Atella* archaeological site) was carried out by the University of Naples unit.

The multispectral data were processed by applying 14 spectral indices (NDWI, SR, NDVI, NDYI, GRVI, GNDVI, NDSI, SAVI, OSAVI, NIRV, NormNIR, VARI, VrNIRBI, VgNIRBI; Tab. 3). Some were pre-set in the software (NDVI, NDWI, NDSI, NDBI, NDSnI, NBR, SAVI, EVI, and GRVI), while others were calculated manually using raster calculator formulas (Fig. 2). The flexibility to experiment with multiple indices was crucial for advancing

the topographical and orographical understanding of the study areas, producing methodologically significant results. For instance, by applying arithmetic functions to bands and selected indices, it was possible to clearly emphasise elevations and microrelief traces. More specifically, combining the panchromatic band (PAN) with the Normalized Difference Water Index (NDWI) and/or Principal Component Analysis (PCA) conditioned on band variance, along with the Near Infrared (NIR) band, enabled the enhancement of relief and microrelief features (see also Cozzolino *et al.* 2025). This formula is currently being verified and systematized into a theoretical framework.

The calculation of spectral indices completed the Pixel-Based Image Analysis (PBIA) phase and provided a foundation for Object-Based Image Analysis (OBIA). This method allows for the segmentation and classification of high-resolution satellite images according to morphological, spatial, and spectral criteria, enabling the detection of regular, linear patterns compatible with ancient land divisions.

The first stage of OBIA was segmentation (eCognition 10.5 provides a wide range of segmentation algorithms, including Chessboard, Contrast Filter, Multiresolution, Multi-threshold, Quadtree-based, SAM, Spectral Difference, Superpixel, Watershed, and Vector-based segmentation). The accuracy of segmentation is directly proportional to the quality of PBIA. Optimal results were obtained by excluding the noisiest bands (Blue and Coastal Blue) and working with the remaining bands (G-R-NIR for 4-band images; G-Y-R-RE-NIR1-NIR2 for 8-band images), along with the calculated indices. This approach significantly reduced atmospheric disturbance, ensuring a more robust basis for OBIA. Segmentation is a crucial step, as the quality of extracted objects directly affects classification accuracy (Hossain, Chen 2019). The most effective algorithms tested included: Multiresolution Segmentation; Multi-threshold Segmentation; Spectral Difference Segmentation; Segment anything Segmentation.

Following segmentation, classification was performed using both Unsupervised Classification (USC) and Supervised Classification (SC) (see Alcaras *et al.* 2025 for a recent comparison). Automated classification, also known as Unsupervised Classification (USC) is a process in which statistical-computational algorithms and models autonomously categorise pixels or objects in remote sensing images, assigning each to a predefined target class (e.g., land cover, water, built-up areas). For the case studies presented, USC was performed using PCA, calculated on the variance of the bands (with Coastal Blue/Blue isolated depending on whether 4- or 8-band imagery was used, plus the 14 indices). This operation made it possible to reduce the dimensionality of the dataset and emphasise the most significant components, enabling rapid and efficient classification.

The Supervised Classification (SC) method, on the other hand, permits human intervention to define or orient the target classes, as established during

the research presented here. Conversely, automatic tools apply the rules. This approach reduced interpretation errors evident in USC (e.g., frequent misclassification of watercourses as dirt roads due to similar reflectance in the visible spectrum). Research is ongoing to refine methods that minimize these errors.

In conclusion, this methodological phase achieved a solid level of processing and analysis. Although OBIA applications have been successfully developed using shape- and object-extraction algorithms, advancing further requires moving toward Deep Learning (DL) analysis with CNNs. To improve automated classification and specifically detect regular linear features potentially corresponding to centuriation grids – hypothesized from historical cartography and partially verified in the field – the Authors are currently training a CNN model.

The eCognition workflow can be summarised in five main steps for developing a mature operational model for automated identification of linear archaeological features such as centuriation traces (Fig. 3):

1. image segmentation – using the Segment Anything Model (SAM) to identify and flexibly segment features across varied data types and landscapes;
2. creation of training samples – manually selecting representative areas of centuriation traces and other classes of interest, then generating labeled patches for training ('Generate labeled sample patches' algorithm);

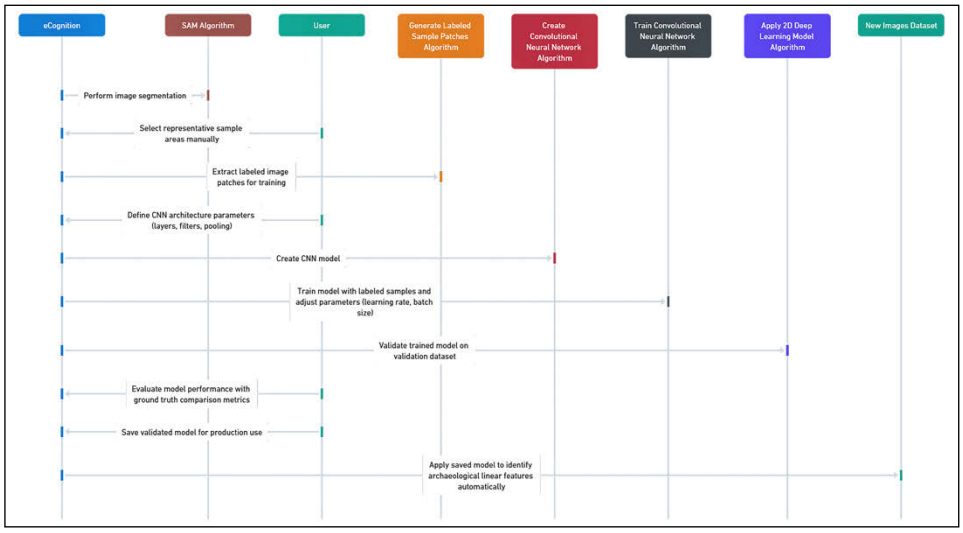


Fig. 3 – The operational workflow in eCognition for the automatic identification of archaeological linear features, from image segmentation and training sample creation to model application in production.

3. neural network training – defining the CNN architecture ('Create convolutional neural network' algorithm), increasing complexity as needed, and training ('Train convolutional neural network' algorithm) with sample data (adjusting parameters such as learning rate and batch size);
4. model validation – applying the trained model to independent validation datasets and evaluating performance against ground truth using appropriate metrics;
5. operational application – once validated, the model can be deployed to automatically detect archaeological traces in new satellite images.

At present, the research is at step 3-CNN training. The ultimate goal, closely tied to the In.Res.Agri project, is to achieve a fully operational model for the automatic identification of Roman centuriation grids.

F.D.P.

4. Results

Experiments conducted in the eCognition environment demonstrated the software's effectiveness in detecting archaeological traces plausibly related to ancient land divisions. In several cases, the analyses confirmed the existence of grid systems previously reconstructed through cartographic methods and only partially verified in the field. Furthermore, the software enabled the identification of additional anthropogenic and archaeological anomalies. The application to mountainous landscapes, such as those in Irpinia, highlighted the challenges of photo-interpretation in areas where terrain morphology and dense vegetation obscure archaeological features. Despite these difficulties, eCognition proved useful in outlining possible alignments even in complex contexts.

In Irpinia, two agrarian layouts were identified: one associated with a grid model defined by an intersection near the settlement of Fioccaglia (Fig. 4), and another oriented NE-SW (Fig. 5). These results corroborate hypotheses advanced through cartographic research and only partially confirmed on the ground (see Ditaranto, Giordano in this volume and references therein). In the Campanian Plain, analysis focused on the area surrounding the archaeological site of *Atella*. In this instance, eCognition facilitated the identification of potential archaeological evidence related to agricultural division as well as ancient structures and infrastructures. The study used eight-band multispectral data from the WV-3 satellite. Among the anomalies identified, the most promising appears to be a possible road alignment oriented NE-SW and seemingly directed towards the archaeological site (Fig. 6). Field verification is currently in progress, guiding survey activities conducted by the University of Naples Federico II.

Overall, eCognition not only confirmed previous hypotheses but also revealed new archaeological traces requiring further investigation. The

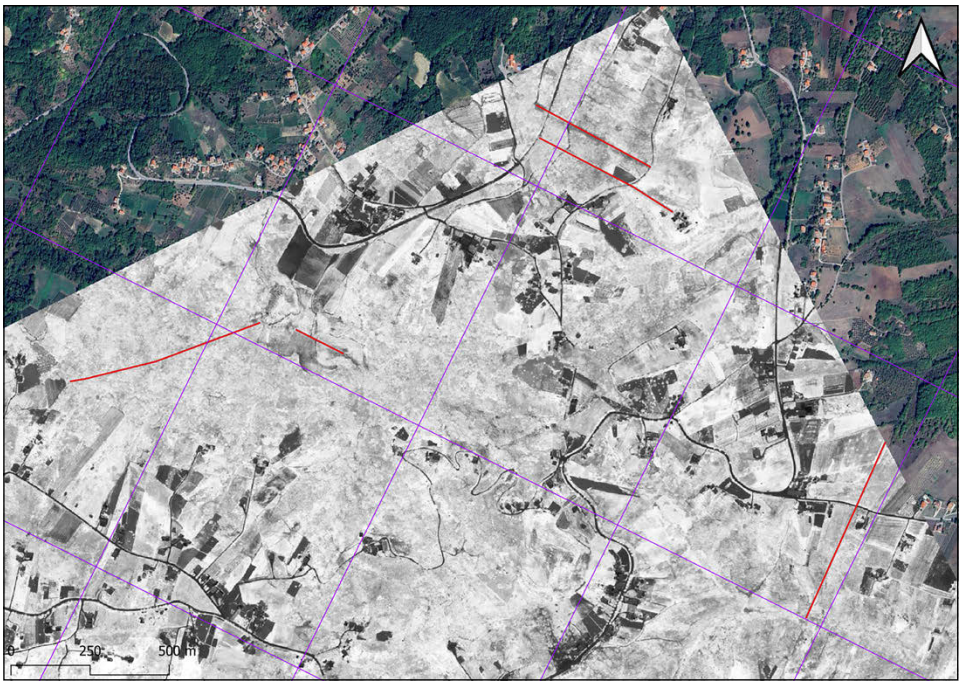


Fig. 4 – Irpinia, image WV-3 from April 26, 2018 (ID code 104001003C24FD00). Example of traces identified and associated with the grid model oriented NE-SW. The trace identification and vectorization were performed using eCognition v. 10.4 and v. 10.5, based on the SAVI index, enabling precise delineation of archaeological features in the landscape.

integration of high- and very-high-resolution multispectral data with traditional cartographic approaches proved particularly effective in complex contexts such as Irpinia and the Campanian Plain, enhancing our understanding of the archaeological landscape.

F.D.P., P.M.

5. Discussion and conclusion

The Campania region, with its two case-study areas, Irpinia and the Campanian Plain, selected within the framework of the In.Res.Agri project, served as an authentic experimental laboratory for testing the potential of artificial intelligence software in combination with more traditional approaches in ancient topography and landscape archaeology. Among the software employed, eCognition proved to be the most effective and, together with ENVI, functioned as an interface and mediation tool, simplifying access to the

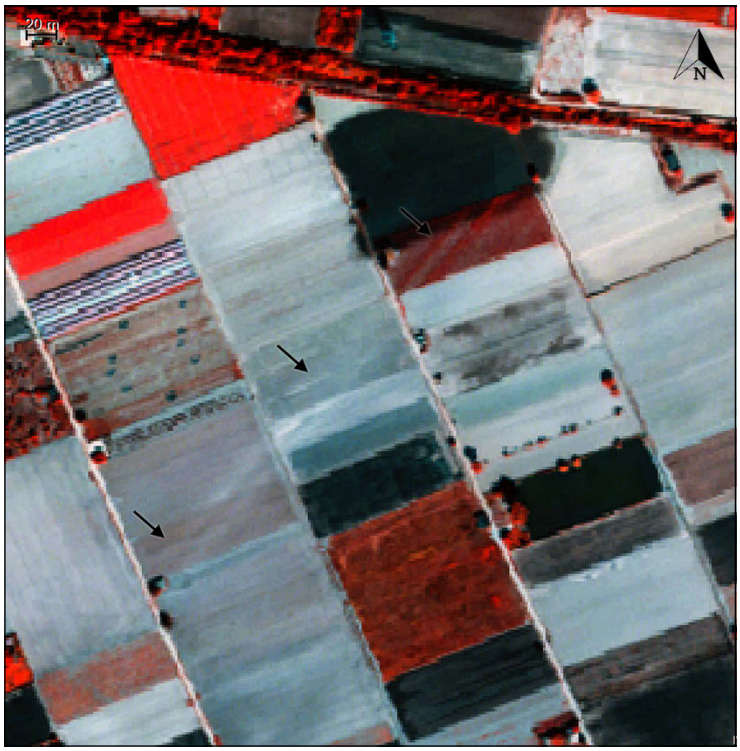


Fig. 5 – Campanian Plain, Acerra (NA), image WV-3 from December 27, 2023 (ID code: 104005005BDC1B00). A possible road trace with NE-SW orientation, seemingly aligned toward the archaeological area of ancient *Atella*. The trace identification and vectorization were performed using eCognition v. 10.4 and v. 10.5, based on the false-color composite derived from the calculated spectral indices.

complex analytical operations that characterize Computational Archaeology and the Digital Humanities.

Analysis of high- and very-high-resolution multispectral data using eCognition v. 10.5 demonstrated the effectiveness of innovative approaches in detecting archaeological traces of ancient land divisions. This made it possible to integrate information derived from cartographic investigations with new discoveries, particularly in morphologically complex contexts such as the mountainous landscapes of Irpinia and the heavily urbanized areas of the Campanian Plain.

In Irpinia, the experiments confirmed the presence of agrarian layouts that had been hypothesized in previous studies (see Ditaranto, Giordano in this volume and references therein), but were here validated through the

combined use of satellite analyses and field surveys. The identification of linear traces attributable to Roman centuriation enhanced our understanding of the Romanization of the landscape and of modes of agricultural exploitation. In the Campanian Plain, particularly in the area of the ancient settlement of *Atella*, further archaeological traces were identified, including a possible ancient road, which is currently being verified through targeted field surveys.

The results confirm the potential of the software not only to consolidate previously advanced hypotheses but also to highlight new questions through the detection of previously unknown archaeological traces. These questions may form the basis for future and promising lines of research. The adoption of these advanced techniques, however, has not been without challenges. The main issues concern the quality of the input data, the accuracy of image segmentation, and the constant need for field validation. Accurate segmentation is fundamental for the subsequent phases of classification and automatic object identification; in complex orographic contexts such as Irpinia, the spatial resolution of the imagery is also crucial to avoid distortions caused by vegetation or other natural factors. Despite these limitations, the results demonstrated that the integration of traditional methods with advanced AI tools, particularly convolutional neural networks (CNNs), can provide effective support for archaeological research, paving the way for faster and more efficient investigation strategies. The project has achieved a substantial level of data processing; however, full automation in the identification of centuriation traces will require further development and refinement of deep learning (DL) models. The ongoing process of neural networks training is expected to consolidate and enhance the model, with the ultimate goal of fully automating the identification of ancient agrarian structures.

In conclusion, the work carried out within the In.Res.Agri project confirmed the potential of modern technologies in improving the understanding of archaeological landscapes and in supporting field research. This innovative approach has two main benefits. Firstly, it increases the efficiency and accuracy of archaeological investigations, and secondly it offers a new perspective on the interpretation of ancient landscapes. The integration of sophisticated geospatial analysis techniques with the long established tradition of topographical studies has resulted in significant advances, although further field validation is required to confirm the results and to refine the predictive capacity of the algorithms employed.

F.D.P., P.M.

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ABSTRACT

This research, conducted within the framework of the In.Res.Agri project, explores the integration of advanced remote sensing and artificial intelligence techniques to investigate archaeological landscapes in the Campania region (Italy), with a focus on the regions of Irpinia and the Campanian Plain. The study utilises high- and very-high-resolution multispectral satellite imagery, processed through software such as eCognition, with the objective of identifying and analysing land divisions, including Roman centuriation, and other archaeological features. The methodology combines traditional topographical analysis with both semi-automated and fully automated deep learning approaches, notably the training of convolutional neural networks (CNNs) for the automated detection of linear features. Preliminary results demonstrate the software's capacity to validate known archaeological layouts while revealing previously unidentified structures, such as ancient road networks, in challenging terrain. The continuous enhancement of CNN models is intended to achieve fully automated detection, with the objective of accelerating landscape analysis and enabling field validation. The project under discussion demonstrates the considerable potential for the integration of geospatial analysis and AI-driven technologies to enhance our comprehension of archaeological landscapes. It is important to acknowledge, however, that such endeavours are not without their limitations, and that there is a necessity for ongoing refinement and on-site verification.

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LEGACY DATA GIS INTEGRATION AND SURFACE SURVEY FOR THE ARCHAEOLOGY OF THE ATELLAN LANDSCAPE (CAMPANIA, ITALY)

1. Introduction

This paper presents preliminary results of the research on the ancient topography of *Atella*'s extra-urban landscape, case study of the In.Res.Agri project: for this study, the legacy data integration carried out in GIS is assessed with an in deep 'archive excavation' and systematic field survey of the central area of Campanian Plain (Campania, Italy) (Fig. 1)[1].

Atella lies in the alluvial plain N of Mount Vesuvius and the Campi Flegrei caldera, within a volcaniclastic plain repeatedly affected by pyroclastic events (Fig. 2). The Atellan area was selected because its history complicates received narratives of topographic 'resilience', offering new insights into the long-term persistence and discontinuities of Roman urban and rural landscapes (Brancato *et al.* 2024). Historic-period deposits from 79 AD onwards overlie earlier Pleistocene substrates, forming stratified tuffs and lapilli layers across the plain (Di Vito *et al.* 2021). *Atella*, an Oscan city famed for the *fabulae Atellanae*, has been securely located since at least the mid-Eighteenth century (De Muro 1840; Beloch 1890; Laforgia 2007, 2014a-b; De Caro 2012; Matarese *et al.* 2023) (Fig. 4). G. Castaldi (1908) first outlined the urban perimeter; an early archaeological map records roads and walls when these were still visible (Fig. 3).

The city's origins likely date to the late fifth century BC, with urban development through the fourth (De Caro 2012, 87). Allied with Capua against Roman expansion, *Atella* received *civitas sine suffragio* after 338 BC (Fest., 50, 126) and lost autonomy in 211 BC following support for Hannibal (Laforgia 2007, 18). By the first century BC, Cicero attests *Atella* as a *municipium* with jurisdiction over an *ager vectigalis* (Cic., *Fam.* 8.7). In the early first century AD, public monuments typical of Roman centres were likely present; although

[1] The 'Unveiling Atella Project. Una carta archeologica per la città invisibile' started in 2022 by the Department of Humanities Studies of University of Naples in collaboration with the Soprintendenza Archeologia, Belle Arti e Paesaggio (SABAP) di Caserta and SABAP Area Metropolitana di Napoli to establish a digital and open-access archaeological map of the remains of the ancient city and its territory. The project is conducted within the framework of a formal agreement between the Department of Humanities of the University of Naples Federico II (scientific coordinator: Prof. Rodolfo Brancato), the National Archaeological Museum of Naples, the SABAP for the provinces of Caserta and Benevento. The research is also part of the Atella Archaeological Project (MIC-MIC_SABAP-CE,26/06/2024-0013094-A), which aims to investigate the buried remains of the Roman city in order to understand its urban topography through an integrated approach, combining the digitization of legacy data and its integration with survey data.

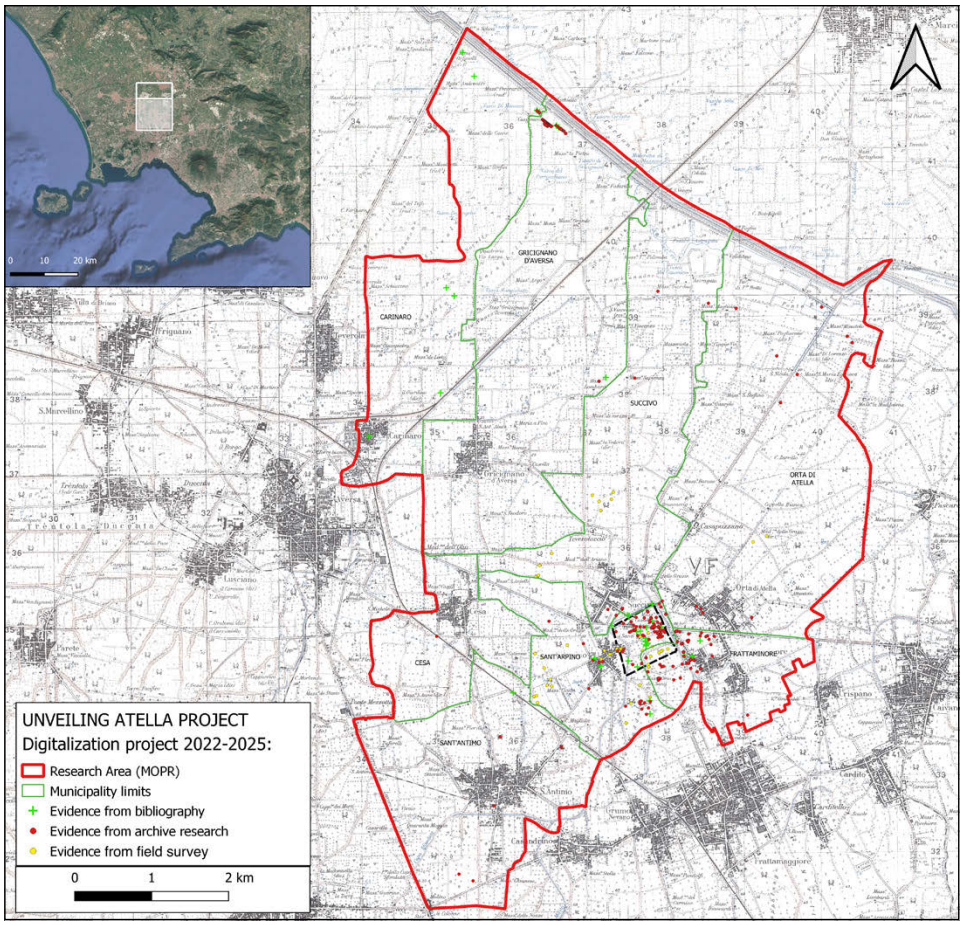


Fig. 1 – *Atella* and its territory within the Campanian Plain; project limits shown in red.

no ancient source mentions a theatre, Suetonius refers to an amphitheatre (Suet., *Tib.*, 75,3) in the context of AD 37. In late antiquity, the city suffered a major fire (late fourth-early fifth century AD) yet continued to prosper as an episcopal seat until at least the seventh century AD (De Caro 2012, 88). During the Roman period, *Atella* was linked to the main Campanian centres by roads whose courses relate closely to the centuriation of the alluvial plain (Quilici Gigli 2002, 2005, 2025). Comparative work in the Acerra area provides key points for discussing the chronological evolution of *Atella*'s rural landscape and its relationship to the *ager Campanus* (Giampaola 1997, 2002; Di Franco in this volume). S of the city walls, funerary contexts currently provide the most



Fig. 2 – Sant'Arpino (Caserta), aerial view of the project area.

substantial evidence for pre- and proto-urban phases: tombs from the late fifth-early fourth centuries BC are attested, while the bulk of material comes from the fourth-century BC necropolis (Bencivenga Trillmich 1984). SABAP investigations at Frattaminore (Orto dei Santi) in 1995-97 documented 76 tombs dated between the first and the fourth centuries AD, with varied orientations but predominantly E-W and consistent with a crossing road axis (De Caro *et al.* 1997, 815; De Filippis, Laforgia 2002, 144).

The delimitation of the centuriation in the SE sector of the *ager Campanus*, corresponding to the modern territories of Succivo and Orta di *Atella*, and its relationship with *Atella* remain largely unresolved (Monaco 1998; Soricelli 2001; Monaco, Clavel-Lévêque 2004; Taylor 2015). An orthogonal grid visible on aerial imagery – considered alongside the presumed centuriations of *Acerrae* and *Neapolis* – was assigned an Augustan date solely on the basis of module and orientation (Chouquer *et al.* 1987). Historical cartography and aerial photographs have been read to indicate overlapping field systems ('Acerrae-Atella I': Chouquer *et al.* 1987, 207, fig. 70; 226-227; 252; and 'Atella II': 208-209, fig. 71; 228-229), but these models are topographically inconsistent with the *ager Campanus* as a whole and remain unverified on the ground.

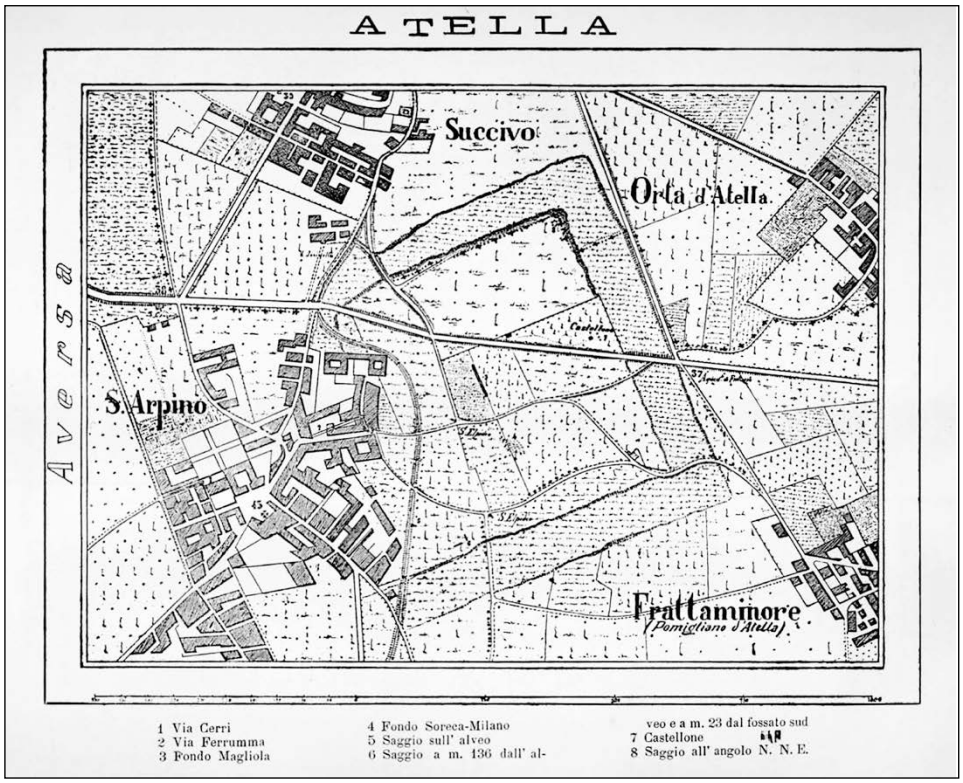


Fig. 3 – The archaeological map of *Atella* drafted by G. Castaldi (1908).

While 'Acerrae-Atella I' was originally attributed to the Augustan period on morphological grounds (Chouquer *et al.* 1987), excavations of canal and road sections argue for an earlier, second-century BC date (Giampaola 1997, 232). The AD 79 tephra mantled the centuriated landscape, and subsequent eruptions, most notably Pollena in AD 472, repeatedly sealed features; preventive archaeology has exposed ploughed fields and road surfaces preserved beneath these deposits that align with the centuriation, suggesting long-term cadastral persistence (Di Vito *et al.* 2021).

Explaining why elements of ancient rural and urban topography have endured, clearly visible today in historical aerial photography and LiDAR-derived digital elevation models, requires attention to the adaptive strategies of local communities and the role of political institutions. Accordingly, this paper tests the archaeological validity of earlier cadastral hypotheses while reporting the first outcomes of our integrated workflow. Since 2023 we have

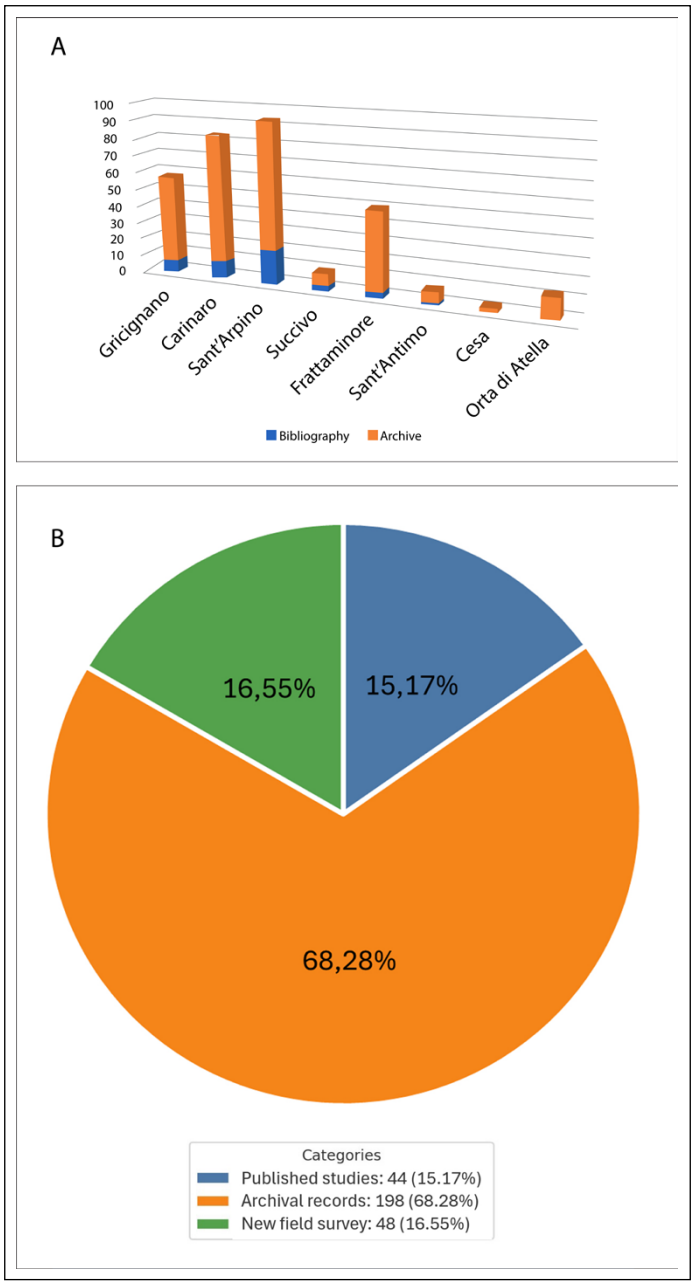


Fig. 4 – Percentage breakdown of archaeological sites identified from published studies, archival records, and new field surveys *(n = 285)*.

digitised legacy archival datasets and proceeded with systematic field survey and targeted excavations in selected urban and extra-urban areas (Fig. 4). We demonstrate how the integration of legacy sources and new observations refines the mapping of centuriation around *Atella* and frames specific, testable expectations for future field verification.

R.B.

2. Data from the archives

A systematic bibliographic review focused primarily on the scientific literature concerning *Atella* and its territory, with particular attention to the archaeological and historical-literary study of the centuriation system. Bibliographic data were managed using the open-source software Zotero (https://www.zotero.org/groups/5888666/in.res.agri/library) and stored in the Digital Groma repository (see Buono *et al.* in this volume), facilitating web-based access and integration among In.Res.Agri project participants.

A key part of the research involved collecting and digitizing archival archaeological data from the municipal territories of Aversa, Carinaro, Cesa, Gricignano di Aversa, Orta di Atella, Sant'Antimo, Sant'Arpino, Succivo (Caserta), and Frattaminore (Naples)[2], preserved across different collections at the National Archaeological Museum of Naples (Fig. 4A). Initial archival research, since 2023, included archaeological data from investigations carried out between 1995 and 2007, linked to major infrastructure projects such as the US Navy base in Gricignano di Aversa and the Rome-Naples high-speed railway (Brancato *et al.* 2024).

Archival research was crucial for retrieving and integrating topographic and semantic data from previous studies and excavations, including preventive archaeology, enabling a coherent reconstruction of the archaeological landscape. This sector of the Campanian Plain has undergone significant transformations over time, due to both natural processes and intensive human activity, which have deeply altered the historical landscape and affected the preservation and visibility of the surface archaeological records. To systematize archival data a spreadsheet was created, with fields structured according to taxonomic, typological, and spatial entities, based

[2] This work was initially conducted within the framework of a formal agreement between the Department of Humanities of the University of Naples Federico II (scientific coordinator: Prof. Rodolfo Brancato), the National Archaeological Museum of Naples (scientific coordinator: Dr. Emanuela Santaniello), the SABAP for the provinces of Caserta and Benevento (scientific coordinator: Dr. Ilaria Matarese). In 2024 a further formal agreement between the Department of Humanities of the University of Naples Federico II, the SABAP for the Metropolitan Area of Naples, the SABAP for the provinces of Caserta and Benevento, the National Archaeological Museum of Naples (MIC-MIC_MAN-NA-27/05/202-|0003279-P[28.34.04/245/2024]).

on standardized models developed by the Istituto Centrale del Catalogo e Documentazione (ICCD) and Istituto Centrale per l'Archeologia (ICA), subsequently integrated into the Digital Groma repository (see Buono *et al.* in this volume).

Preliminary analysis identified Gricignano as the municipality with the highest number of archaeological archival records (600 folders), followed by Sant'Arpino (204) and Frattaminore (160). Archival research allowed the identification of various types of archaeological interventions, mainly notifications, followed by requests for archaeological assessment. The collected data contributed to the reconstruction of the history of archaeological research in the *Atella*n territory. The earliest interventions for the study and conservation of the archaeological heritage in this area date back to 1792, with the unearthing of «columns and marbles exhumed in front of the Cathedral of Aversa» (AS-MANN, VI D5/17). A significant increase in discoveries occurred in the second quarter of the nineteenth century, particularly in the northern and southwestern sectors of the agro atellano (Aversa, Cesa, Parete, Sant'Antimo). These were mostly chance finds or discoveries made during infrastructure projects, such as the construction of the 'Direttissima' railway line segment between Aversa and Vico Pantano (AS-MANN, VI B7/48; Elia 1937).

After a decline in reporting during the post-WWII period, a resurgence of interventions occurred during the construction boom of the 1960s-1980s. The majority of archaeological finds, however, are attributable to the final two decades of the twentieth century, coinciding with the emergence of urban archaeology – still mostly conducted within the framework of rescue excavations. From the late twentieth century to recent years, archaeological discoveries have largely resulted from preventive archaeology (Brancato *et al.* in press), which led to the identification of extensive sectors of the eastern suburban area (Frattaminore). The earliest evidence dates to the Neolithic period, as indicated by the discovery of paleosols at Gricignano d'Aversa during construction work for the high-speed railway (Laforgia 2014b; Saccoccio *et al.* 2021). More substantial evidence emerges starting from the Early Bronze Age (Palma Campania cultural *facies*), particularly in the area later occupied by the eastern necropolises of Samnite-era *Atella* (De Caro 1992; Marzocchella 1997; Laforgia 2014a).

Early Bronze Age sites showed clear evidence of ploughing activity (AC-MANN, F 6/24) and included agricultural settlement features (e.g., canals, production structures, road surfaces, pits, ceramic dispersal areas, etc.) (AC-MANN, F 4/30 bis, F 6/23, F 6/24, F 8/14; De Caro *et al.* 1997; Marzocchella, Albore Livadie 1999). Iron Age sites are known, mostly located to the N and NW of the urban area of ancient *Atella* (Laforgia 2014b). These include areas with ceramic fragments, canalization

systems, and isolated burials, as well as the well-documented settlement at Gricignano d'Aversa (US Navy) (Saccoccio *et al.* 2021). Archaeological evidence increases significantly beginning in the Samnite period (the end of fifth century BC), when *Atella* assumed a recognizably urban character, as seen in the remains of necropolises in extra-urban and peri-urban areas, and the city walls.

Sections of the eastern and south eastern necropolis of ancient *Atella* were uncovered, dating to the Samnite period (mid of the fifth-third century BCE) (Patroni 1898; Elia 1937; Bencivenga Trillmich 1984; Marzocchella 1991, 1997; Marzocchella, Albore Livadie 1999; Laforgia 2007, 2014a)[3]. A widespread occupation pattern appears during the fourth-third centuries BCE, attested by small clusters of tufa cist or pit graves, likely associated with rural farmsteads, minor cultic sites, or small-scale rural settlements. These elements suggest a phase of intensive agricultural exploitation of the landscape during this period (Quilici Gigli 2025). Dating to the mid-fifth-century BC, a road surface, oriented SE-NW, has been found in Frattaminore (Bandolo property) (AC-MANN, F 6/16, Armadio ispettori). A marked rise in archaeological data is recorded during the Late Republican and Early Imperial periods, to which numerous burials (Bencivegna Trillmich 1984; De Caro *et al.* 1999; Guzzo 2016), public buildings (De Franciscis 1967; Johannowsky 1970; AC-MANN, S 6/35bis, S 6/43bis, S 6/47bis, 151/6), and private structures (Castaldi 1908; De Franciscis 1967; Johannowsky 1970; Bencivegna Trillmich 1984; AC-MANN, S 6/47bis, S 10/16, 151/6, Carta archeologica di Atella, n. 16) can be attributed.

The twentieth and twenty-first century excavations revealed several features associated with both intra-urban and extra-urban road systems, including what is likely the *cardo* and the *decumanus* of the ancient city of *Atella*, an E-W road parallel to the *cardo* of the centuriation system of the *ager Campanu*s (AC-MANN, F 4/31, F 6/16; De Filippis, Laforgia 2002, 144, fig. 21), and a segment connected to the *via Consularis Campana* (Melillo *et al.* 2009; AC-MANN, A 3/4, fasc. 4, A 4/14, A 5/17bis). Among the more recent discoveries, the 2007 excavation at Sant'Arpino – near the current cemetery in the northern sector – revealed the remains of a rural villa, evidenced by two *dolia* still on site and other pits likely intended for additional large containers. The site also yielded a kiln, presumably active between the twentieth and fifth and seventh centuries AD (Nava 2008).

[3] Frattaminore: AC-MANN A 4/14, F 4/19, F 3/25, F 4/23, F 4/24, F4/30bis, F 5/10, F 6/16, F 6/17, F 6/18, F 8/22; Orta di Atella: AC-MANN, O 1/2, fasc. 1, O 1/4, O 1/6, O 1/8, O 1/9, O 1/11, O 1/12, O 1/14, O 1/15, O 1/16. Sant'Arpino: AS-MANN, b. VI C3, 26, AC-MANN, F 4/17, O 1/2, fasc. 2, S 10/16; Carta archeologica di Atella (n.22); Sant'Antimo: AC-MANN, S 1/9, S 1/18, S 1/31 S 1/35, S 1/50, S 7/16, S 12/12. Succivo: AC-MANN, A 2-19, N 11/12, Carta archeologica di Atella (n. 31-32).



Fig. 5 – Sant'Arpino (Caserta), the paved road in via Cerri: A) photographed by G. Castaldi (1908); B-C) present remains.

Settlement dynamics between Late Antiquity and the Early Middle Ages remain poorly understood at present, apart from clear evidence of spoliation and/or reuse in several parts of the ancient city (Arenella *et al.* 2015) and the extra-urban area (Melillo *et al.* 2009).

T.T.

3. Data from the field survey

In light of the evidence emerging from the bibliographic and archival research, systematic surface surveys were initiated in the field. The investigations covered extensive sectors of the urban and extra-urban area of ancient *Atella*, within the municipalities of Sant'Arpino (CE), Succivo (CE), Orta

di Atella (CE) and Frattaminore (NA), for a total of c. 130 hectares. The design strategy phase, conducted entirely within a GIS environment, proved essential for the execution of the surveys. Using QGIS, a project was created to host and vectorise the collected legacy data, progressively integrated with the results of the archival research (cf. *supra*). This approach enabled the rapid identification of areas with the highest archaeological potential. In parallel, a layer was created for the vectorisation and recording of the survey areas, here termed Unità di Osservazione/Observation Units (UO), with an attribute table based on the standards and terminology proposed by the ICA (cf. *infra*). The project was subsequently deployed on a mobile device (iPad Pro) via the QField application (Montagnetti, Guarino 2021), allowing real-time visualisation, immediate localisation of sectors of greatest interest, and on-the-spot vectorisation and recording of the units during fieldwork.

In the first phase, surveys focused on the urban area of *Atella*, with particular attention to traces of fortifications and the road network already noted in the literature (Castaldi 1908; Bencivenga Trillmich 1984), also with the aid of photo-interpretation of historic aerial imagery (Brancato *et al.* 2023, 408-412). In this phase, the remains of the paved road already identified by G. Castaldi (1980, 84-85) in Sant'Arpino were documented and georeferenced: this is the best preserved trace of the extra-urban axis in line with *Atella*'s main *decumanus* (Fig. 5).

To understand the relationship between the urban space and its hinterland, investigations were extended into those sectors of the Campanian Plain where the supposed grids of agrarian divisions overlap (cf. *supra*). Few, however, are the published topographic plates at a legible scale that can be georeferenced in the GIS; consequently, the data derivable from such archaeographic material are not immediately integrable. In this area of research, an important role is played by research carried out by the Besançon School which, through the technique of so-called 'filtering' (Choquer *et al.* 1987, 60-61), identified traces interpretable as a palimpsest of agrarian systems ('Acerrae-Atella I' and 'Atella II'). However, their metrology and orientation are incompatible with those of the *ager Campanus* (Quilici Gigli 2025).

The 'Acerrae-Atella I' I system is particularly interesting, as it would seem to share the same orientation as *Atella*'s urban layout. However, the topographic reconstructions by French scholars of ancient cadastres lack reference points and thus proved unusable, as they could not be georeferenced. An exception is M. Monaco's (2004) contribution on the south-eastern boundary of the *ager Campanus*, provided with figures that report coordinates in the WGS 84/UTM 33N reference system. Once the tables had been positioned within the GIS environment, the traces of the ancient cadastral systems were vectorised, enabling the identification of targeted areas for survey validation.

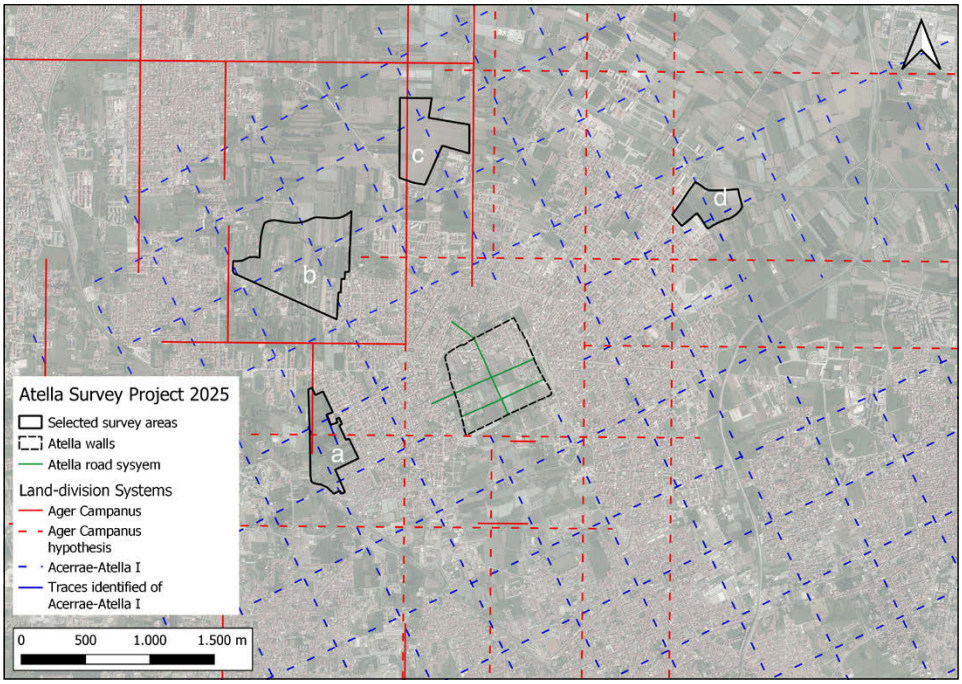


Fig. 6 – Campanian Plain (Province of Caserta), areas (a-d) identified as priority targets for archaeological survey, selected on the basis of archaeological visibility and the integration of legacy data (traces of ancient agrarian divisions).

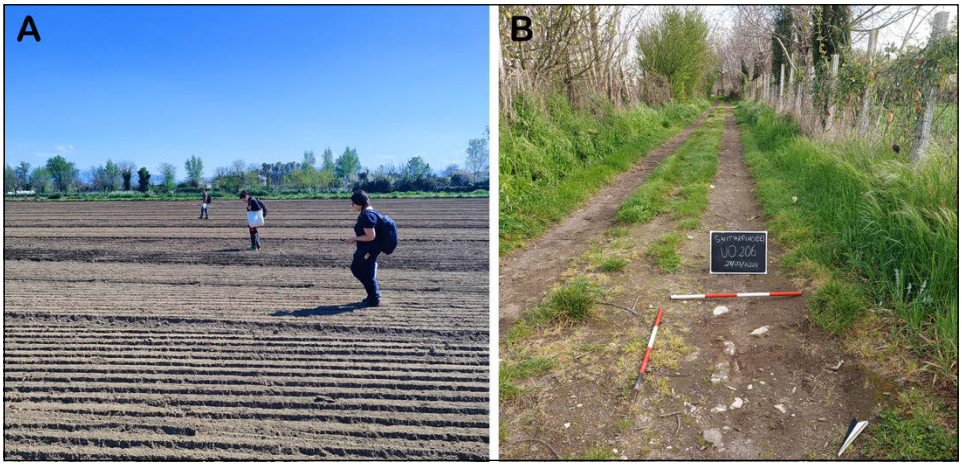


Fig. 7 – A) Succivo, Campanian Plain: the team during survey operations in a ploughed field (UO 223); B) Sant'Arpino, extra-urban area: view of UO 206.

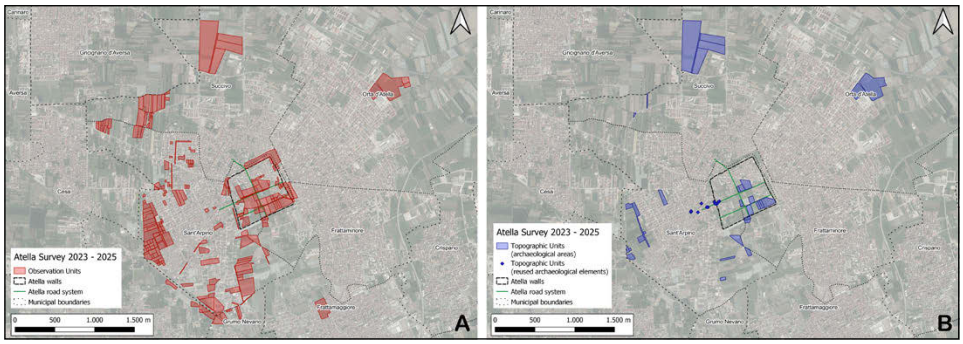


Fig. 8 – Campanian Plain (Province of Caserta): A) Observation Units and B) Topographic Units identified during the survey.

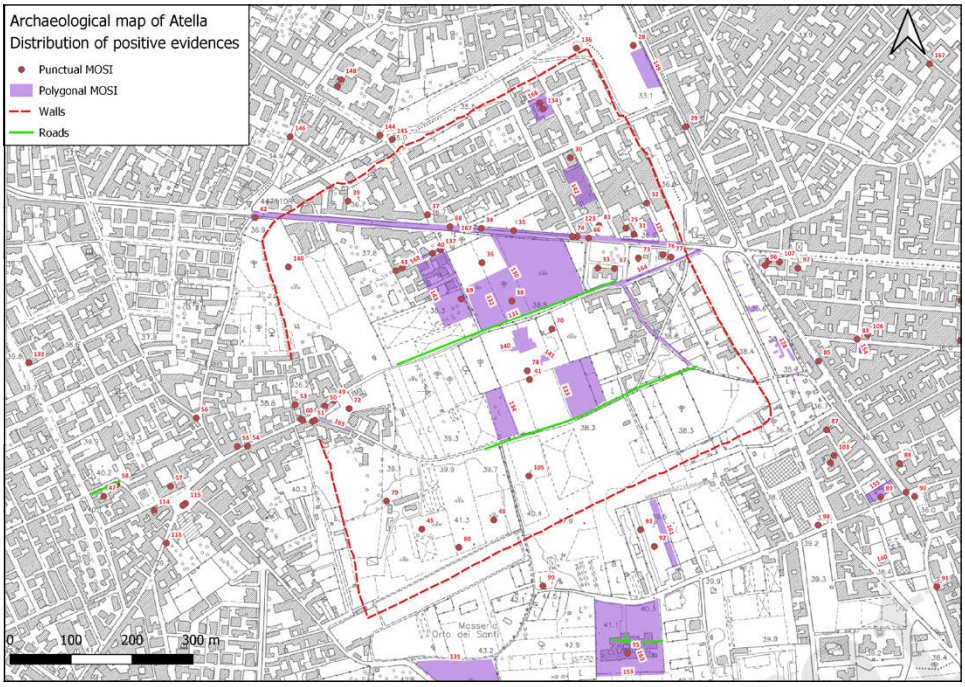


Fig. 9 – Archaeological map of the study area plotted on a 1:10,000 topographic base.

The vectorised traces were first compared with available historic aerial photographs (RAF sorties of 3 December 1943 and 10 March 1945; the Base Flight of 9 October 1954), available orthophotos (1988, 1994, 2012), and

satellite imagery from Google Earth (Brancato *et al.* 2023). This allowed positional error on the traces to be reduced; nevertheless, no previously unknown features were identified.

With the aim of recognising new topological relationships between systems of agrarian land-organisation, we sought to identify areas where the superposition of different centurial axes might be hypothesised, by projecting hypothetical extensions of the already vectorised traces. Four broad sectors thus emerged, characterised by large fields still under cultivation (Fig. 6): a) to the E, along the western boundary of the municipality of Sant'Arpino; b) to the NW, between Sant'Arpino and Succivo; c) to the N, within the territory of Succivo; d) to the NE, near Orta di Atella. These are not the only sectors marked by such superposition; however, intense urbanisation across the Campanian Plain has largely compromised archaeological legibility, and many other identified areas of interest are now largely built over or covered by extensive illegal waste dumps. In the NW sector in particular, the density of waste dumps was such as often to hinder survey operations, inevitably conditioning the results.

Even so, the surveys yielded new data (Fig. 7). In the SW sector (Fig. 6a), we identified the trace of a linear archaeological feature, a path with a compacted surface (UO 206), formed of re-used Roman age material (Fig. 7B); located in an extra-urban area of *Atella*, its orientation, inconsistent with the *ager Campanus*, appears rather to accord with the Acerrae-Atella I system (dotted line in blue in Fig. 6). In total, 260 Observation Units (UO) were identified (Fig. 8A), of which 43 Topographic Units (UT) can be defined as archaeological sites (Fig. 9B).

G.L.

4. The GIS integration

The geocoding of both legacy datasets and newly acquired archaeological data was carried out using the application developed by the ICA (Template GNA ver. 1.4.2; Calandra 2022). The application is based on a pre-configured project in the open-source software QGIS and employs two vector modules: Modulo Progetto (MOPR), which gathers general information and defines the project area, and Modulo Sito (MOSI), intended for the inventory of individual archaeological features identified (Fig. 9).

To optimise data management, we created a separate MOPR record for each municipality involved in the project (Fig. 1). This choice reflects the needs of the research, given that the case study spans territories falling within the provinces of Naples and Caserta and thus under the remit of two different heritage authorities (SABAP for the Metropolitan Area of Naples; SABAP for the Provinces of Caserta and Benevento). Eight distinct MOPR

records were therefore established, each aligned to municipal boundaries and assigned a unique code.

MOSI entries are positioned on the basis of historic and modern cartography where available, together with information gathered through bibliographic and archival research, including plans recorded on cadastral maps. Each feature is digitised as points, lines, or polygons according to its type and the reliability of its location, which may be exact, approximate, or symbolic (the latter used when precise placement is impossible but the general locality is known). In detail, polygon geometry was used exclusively for those features for which a plan exists and limits can be defined with confidence; the availability of a two-dimensional representation permits precise georeferencing of the topographic unit and consistent spatial placement. Where the plan documentation was absent or fragmentary, point geometry was adopted. This solution – consistent with ICA standards – still assigns a geographic location calibrated to the source's reliability, with the point acting as an indicator of archaeological presence for inventory and consultation purposes without generating forced or arbitrary spatial representations. Completing the representational toolkit, linear geometry was used for elongated or axial features, for which such a solution is graphically and analytically more appropriate. The use of lines affords a closer fit to the real development of structures and enables targeted spatial analyses, such as studies of territorial connectivity or reconstructions of urbanistic and infrastructural dynamics.

A central, strategic step in integrating archaeological data within the GIS environment was the precise positioning of trenches excavated as part of developer-led (preventive) archaeology. These were digitised as individual polygons corresponding to single MOSI records and grouped within the broader excavation area, for which an additional MOSI was created and labelled as a 'multi-stratified site'. This multi-level representation preserves the analytical detail of each intervention while restoring a coherent overview suited to interpreting settlement dynamics, reading stratified contexts, and comparing contiguous evidence. In parallel, the application also records preliminary exploratory sondages with negative results which, although devoid of material finds, are nonetheless significant for reconstructing the archaeology of the territory.

A.B.

5. Conclusions

In total, 290 MOSI have been entered to database. Of these, 44 sites (15.17%) derive from studies already published in the literature, 198 (68.28%) from the systematic review carried out in the historical archives of

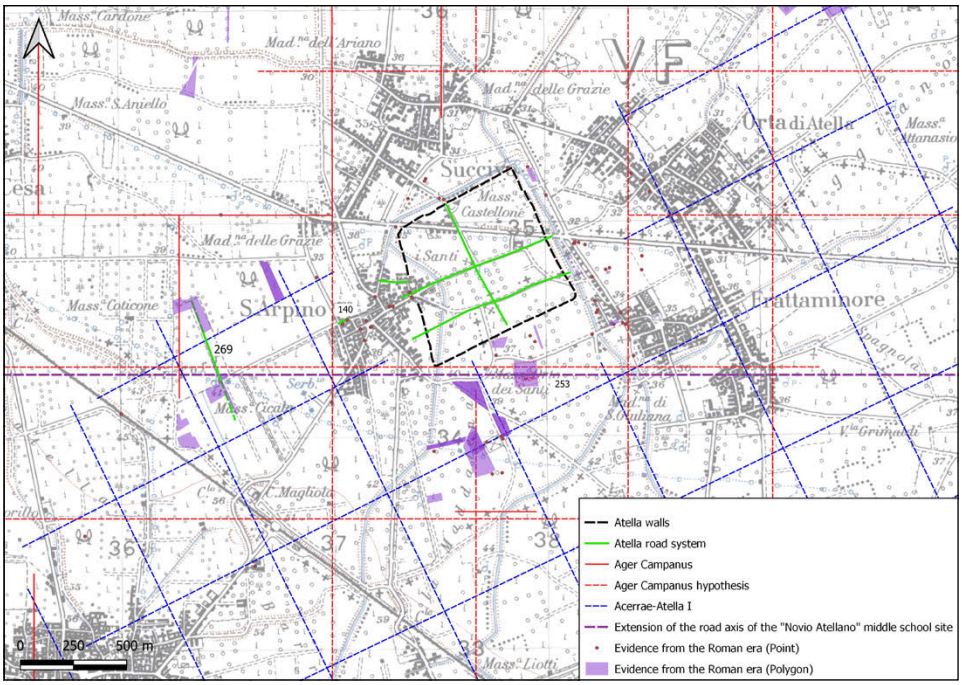


Fig. 10 – Extent of the road axis discovered during construction of the Frattaminore 'Novio Atellano' middle school, compared with the centuriation proposed by M. Monaco (1998).

the Soprintendenze, and 48 (16.55%) from the new surveys: the integration work has thus yielded an increase of approximately 548% in the archaeological knowledge of the area compared with the previously available picture (Fig. 4B). A notable datum concerns the provenance of the information: 139 MOSI (48.77% of the total) derive directly from trial trenches or sondages undertaken preventively in connection with building works; to these are added 21 MOSI (7.37%) relating to rescue excavations, conducted mainly in the 1970s and 1980s. In several cases, unfortunately, the structures found in such contexts have been partially or completely destroyed, precluding adequate documentation, as brought to light by the field surveys. Finally, MOSI originating from academic studies and research (4.21%), confirming the central role played by archival documentation in defining the current state of knowledge.

Among the sites of particular significance is the multi-stratified context investigated between 1996 and 1998 during construction of the Frattaminore middle school 'Novio Atellano'. The area does not display anomalies of archaeological interest in the aerotopographic analysis; the excavation data,

however, oblige us to treat the site as a meaningful case study for reconstructing the topographic configuration of *Atella*'s extra-urban area (Fig. 10). The correction in GIS of the orientation of the excavation drawings made it possible to highlight two road axes perpendicular to each other within the area of the largely unpublished necropolis (De Caro 2012). The E-W axis is the more significant, and may be referable to the ancient cadastral landscape: this axis shows two principal phases: a roadway (US 294), c. 3-4 m wide and datable to the first and second centuries AD, overlaid by the compacted surface of unpaved road (US 124), c. 6 m wide and datable to the 4th century AD, both sharing the same E-W orientation.

This finding invites reflection at a scale no longer limited to the site, but extending to *Atella*'s extra-urban organisation and its relations with the surrounding landscape. The orientation is consistent with the *ager Campanus*, hitherto undocumented archaeologically south of *Atella*: one may hypothesise its coherence with limits referable to a theoretical grid composed of *centuriae* whose *limites*' distance is ca. m 704-706 (Quilici Gigli 2025, n. 3; cf. Bencivenga Trillmich 1984; Monaco 1998) (Fig. 10). The relationship between these axes and the city's topography nevertheless remains problematic, as the locations of the city gates are not yet known.

The intersection of excavation data, surface evidence, and traces from aerial-photographic analysis together contributes to outlining a complex picture of *Atella*'s extra-urban landscape, whose *disiecta membra* (necropolis, farmsteads, traces of ancient roads) allow the history of continuity-and discontinuity-in the evolution of this sector of the Campanian Plain to be read, an area affected by the division of the *ager Campanus* that may have obliterated earlier cadastral organisations.

Thanks to the In.Res.Agri project, we now possess a solid informational basis for future research on the ancient topography of *Atella*'s agrarian landscape. At the end of the project, the geodata will be exported to the Digital Groma platform (see Buono *et al.* in this volume), but also to the National Geoportal for Archaeology via the dedicated ICA plugin (template version 1.4). In line with the data-sharing strategy, and in agreement with the relevant Soprintendenze, each MOPR – together with its associated MOSI – will be uploaded to the webGIS system and made immediately available online.

R.B.

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ABSTRACT

This paper presents preliminary results of the In.Res.Agri (PRIN 2022) case study on the ancient topography of *Atella* (Campania, Italy). We integrated legacy archival datasets – standardised to ICCD/ICA models – within a QGIS environment and guided systematic surface survey (c. 130 ha) using mobile mapping (QField). Preventive archaeology trenches and sondages were digitised as MOSI records alongside newly documented features, enabling multi-scale analyses of settlement and infrastructure. The database now comprises 285 MOSI (≈548% increase over the pre-existing picture), with c. 69% of entries derived from archival review. Fieldwork refined the mapping of extra-urban axes,

including the paved road at Sant'Arpino and a compacted path (UO 206) plausibly aligned with the 'Acerrae-Atella I' system. Re-oriented excavation drawings from the Frattaminore 'Novio Atellano' site reveal orthogonal roadways whose E-W axis accords with the *ager Campanus*, suggesting long-term cadastral persistence despite mantling by AD 79 and later tephras. The integrated workflow tests earlier hypotheses on centuriation, clarifies urban-rural relations, and delivers reproducible, georeferenced expectations for targeted verification. At project close, all geodata will be published via Digital Groma and the National Geoportal for Archaeology.

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MODALITÀ E FORME DI SFRUTTAMENTO AGRICOLO DEL TERRITORIO NAPOLETANO E DELLA PIANA CAMPANA MERIDIONALE TRA NEOLITICO ED ETÀ DEL BRONZO

Le estese indagini archeologiche condotte nell'ultimo trentennio nella Piana Campana e nel territorio napoletano, in relazione a imponenti opere pubbliche e private, hanno fornito moltissimi dati per la comprensione dell'evoluzione del paesaggio e delle modalità di sfruttamento agricolo del territorio tra il Neolitico Avanzato-Finale e l'età moderna. Si tratta di comparti territoriali fortemente interessati dall'attività eruttiva dei complessi vulcanici dei Campi Flegrei e del Somma-Vesuvio, attività che, se da un lato ha determinato significative cesure nell'occupazione, dall'altra, con la deposizione istantanea di coltri piroclastiche, ha permesso l'eccezionale e diffusa conservazione di tracce, spesso labili, relative a lavorazioni agricole e di veri e propri paesaggi agrari sepolti.

In questo contributo si fornisce un quadro sintetico degli elementi conoscitivi disponibili per la ricostruzione degli assetti agrari in età pre-protostorica nel territorio napoletano (Giampaola *et al.* 2019; Boenzi, Mancusi c.s. con bibl. prec.) e nel settore meridionale della Piana Campana compreso tra questo e i Regi Lagni (Di Vito *et al.* 2021 con bibl. prec.) (Fig. 1).

1. La stratigrafia

L'evoluzione del territorio è stata profondamente condizionata nel corso dei millenni dall'attività dei due principali complessi vulcanici ancora attivi: il Somma-Vesuvio e la caldera dei Campi Flegrei (Fig. 2A), caratterizzata, negli ultimi diecimila anni, dal verificarsi di eruzioni esplosive anche di elevata intensità, intervallate da più o meno lunghi periodi di quiescenza (Di Vito *et al.* 1999; Smith *et al.* 2011 con bibl. prec.). Il substrato dell'area è costituito dalla formazione del Tufo Giallo (TGN), al di sopra del quale si riscontra la deposizione di prodotti relativi a numerose eruzioni per lo più flegree e del Somma-Vesuvio (Fig. 2B).

Nelle fasi di quiescenza, di durata variabile, si sono formati consistenti paleosuoli, talora di tipo policiclico. Tra la prima (tra 15.000 e 10.600 anni BP) e la seconda epoca (tra 9600 e 9000 anni BP) di attività si assiste alla formazione del cd. Paleosuolo A; tra la seconda e la terza (tra 5500 e 3500 anni BP), quella del cd. Paleosuolo B, databile tra il Mesolitico e l'Eneolitico; al di sopra sono presenti, alternati a paleosuoli più o meno sviluppati, i prodotti di eruzioni avvenute nella terza epoca e databili tra l'Eneolitico e il Bronzo

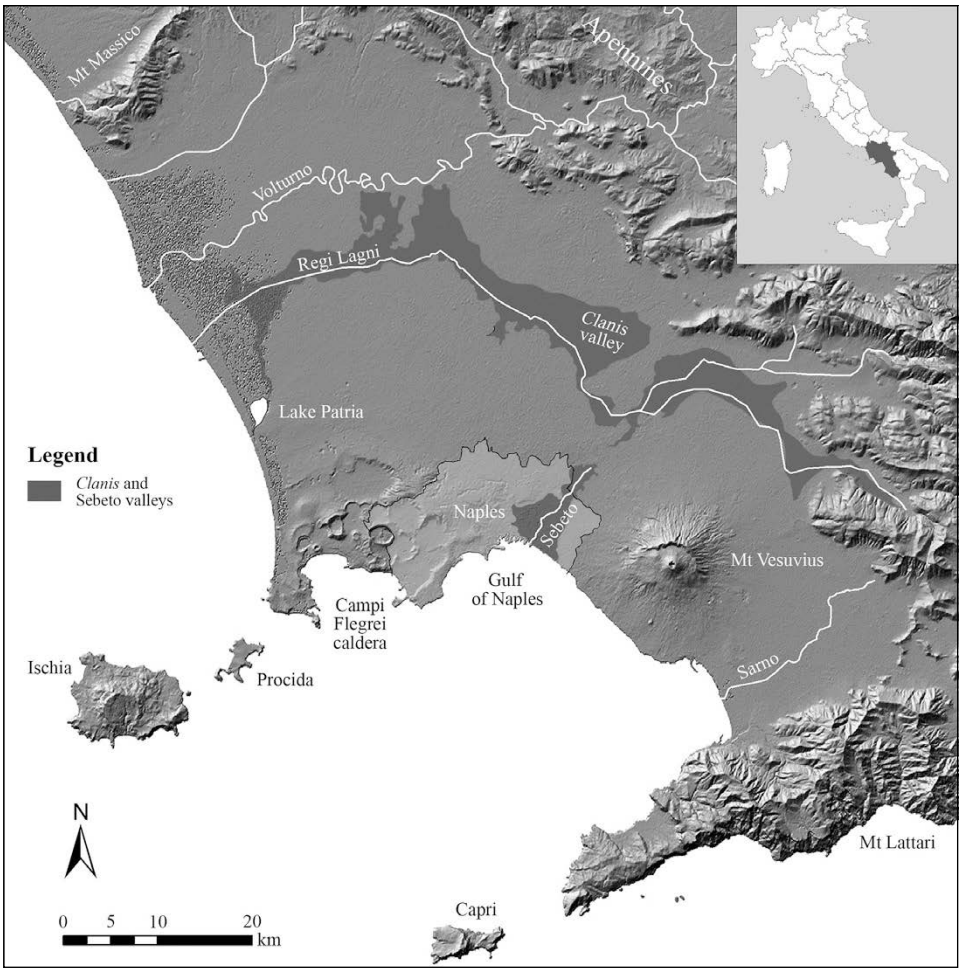


Fig. 1 – La Piana Campana e il territorio napoletano con i centri eruttivi dei Campi Flegrei e del Somma Vesuvio (rielab. da Saccoccio 2021).

Antico (Agnano 1, 2 e 3: >4757 cal BP, Paleoastroni 2: 4712-4757 cal BP, Agnano-Monte Spina: 4482-4625 cal BP, Paleoastroni 3, Solfatara, Averno 2 e Astroni: 4098-4345 cal BP). Nel territorio si rinvengono, infine, i depositi relativi all'eruzione vesuviana cd. delle Pomici di Avellino avvenuta in un momento finale del Bronzo Antico, agli inizi del II millennio a.C. (Sevink *et al.* 2011; Passariello *et al.* 2020 con bibl. prec.). I depositi vulcanici pertanto costituiscono, anche in assenza di elementi archeologici, importanti marker cronostratigrafici di riferimento. Durante i periodi di quiescenza tra le varie

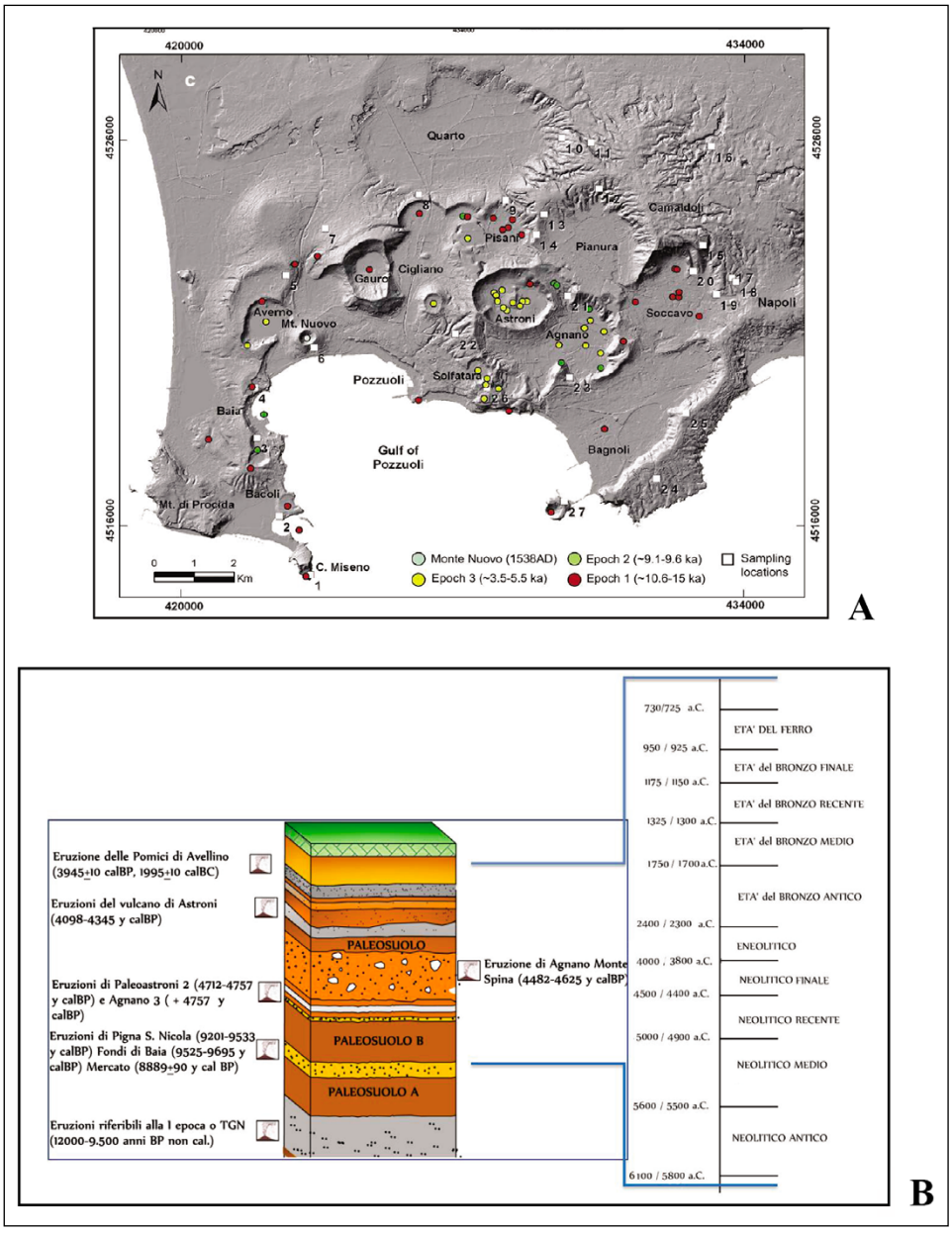


Fig. 2 – A) I Campi Flegrei e i centri eruttivi della III epoca (da Smith *et al*. 2011); B) sequenza crono-stratigrafica esemplificativa dell'area napoletana.

eruzioni, si assiste allo stabilizzarsi di insediamenti umani e alla diffusione di forme di sfruttamento del territorio, favorito dai suoli fertili e dalle condizioni climatiche favorevoli, ma anche dalla posizione geografica che facilitava scambi e interconnessioni con i territori vicini sia via terra che via mare.

2. Neolitico

Le più antiche evidenze di lavorazioni agricole, ben definite cronologicamente, sono state rinvenute a Napoli sul colle di Pizzofalcone (Boenzi, Mancusi c.s.), un promontorio proteso sul mare e delimitato a S da un paleoalveo ricalcato dall'odierna via Chiaia. Sulla superficie dell'eruzione di Pigna San Nicola (9201-9533 cal BP), alla base del Paleosuolo B, sono documentate buche di palo pertinenti a strutture a carattere temporaneo, la cui quota di partenza era verosimilmente superiore e non più riconoscibile, riconducibili a una frequentazione occasionale. Le evidenze sono obliterate da un suolo sulla cui interfaccia superiore sono state individuate evidenti tracce di lavorazioni agricole (zappettature?) sigillate da ceneri (Fig. 3A, B) probabilmente pertinenti all'eruzione ischitana di Piano Liguori (5200 y bp) (De Vita *et al.* 2011 con bibl. prec.); nel paleosuolo sono stati rinvenuti pochi frammenti ceramici in impasto e in argilla figulina per la maggior parte ascrivibili a una fase piena della *facies* di Serra d'Alto.

Analoga sequenza stratigrafica si riscontra sul pianoro di Capodichino, dove si individuano numerose buche per palo che sembrano delimitare, anche in questo caso, strutture temporanee a pianta semicircolare o ovoidale, lembi di battuto estremamente disturbati dall'azione degli apparati radicali e una fossa per combustione. Le evidenze testimoniano lo sfruttamento agricolo dell'area che gli scarsi frammenti ceramici presenti nel paleosuolo permettono di inquadrare in un momento avanzato della *facies* di Serra d'Alto.

Ad una fase ormai finale del Neolitico, invece, sono databili alcune evidenze, ancora relative a modalità di messa a coltura dell'area, attestate nella zona orientale della città, a Poggioreale ai piedi dell'omonima collina. È una porzione di territorio solcata da profondi paleoalvei sulle cui sponde sono state individuate, a partire da questo periodo, tracce di sistemazione e protezione. Meno costrette cronologicamente, e inquadrabili genericamente tra un momento avanzato e finale del Neolitico, sono le diffuse evidenze di sfruttamento agricolo documentate nel territorio cittadino e nella Piana Campana sia a ridosso del bacino del *Clanis* che del Sebeto. Si tratta di sporadici focolari, buche di palo relative a recinzioni o strutture leggere, arature incrociate che si intercettano sulla superficie dei depositi relativi all'eruzione di Pigna S. Nicola, obliterate dal cd. Paleosuolo B che ha restituito frammenti ceramici ascrivibili agli orizzonti di Serra d'Alto e Diana (Giampaola *et al.* 2018; Boenzi, Mancusi c.s.). Di contro a una apparente diffusa frequentazione



Fig. 3 – Napoli-Pizzofalcone: A) tracce di lavorazioni agricole sul paleosuolo sigillate dalle cineriti dell'eruzione di Piano Liguori; B) le tracce una volta asportato il deposito cineritico.

a scopi agricoli del territorio, ad oggi le uniche aree insediative sono documentate nel territorio di Acerra, in loc. Masseria Sanguigno (Talamo 1996), e ai margini della depressione del Sebeto, in loc. Botteghelle (Giampaola, Stanislao 2007) e a Volla.



Fig. 4 – Napoli-Pizzofalcone: arature a solchi e porche, tetto del paleosuolo sigillato dall'eruzione di Agnano 3.

3. Eneolitico

Per l'Eneolitico antico e medio, sia nel territorio napoletano che nella Piana Campana, sono attestate, su ampi areali, tracce diffuse di arature ad andamento perpendicolare (cd. arature incrociate) e subordinatamente a solchi e porche. Le prime, rinvenute sulla superficie del cd. Paleosuolo B e sui depositi eruttivi superiori, sembrano interpretabili come tracce residue di azioni di aratura succedutesi nel tempo (forse nell'arco di alcune stagioni). Le seconde, sigillate dai depositi piroclastici in giacitura primaria che ne hanno permesso la conservazione, rivelano l'ultima fase di lavorazione agricola dell'area prima dell'eruzione. A tal proposito risulta ancora una volta interessante l'analisi della sequenza intercettata nell'area di Pizzofalcone: le arature cd. incrociate presenti sul Paleosuolo B sono riempite dalle cineriti umificate ascrivibili all'eruzione di Agnano 1, sulla cui superficie sono invece attestate arature a solchi e porche, che testimoniano la presenza di campi forse già abbandonati al momento dell'evento eruttivo (Fig. 4). L'andamento dei solchi permette di ricostruire campi contigui con arature orientate perpendicolarmente. Tali



Fig. 5 – Napoli-Pizzofalcone: A) arature incrociate sull'interfaccia superiore delle ceneri di Paleoastroni 2; B) le evidenze di arature in sezione all'interno dei depositi di Paleoastroni 2; C) le evidenze di arature in sezione all'interno dei depositi di Agnano 3.

evidenze sembrano documentare la diffusione dell'uso dell'aratro a trazione animale almeno a partire da un momento non avanzato dell'Eneolitico.

Nella maggior parte dei siti, sia nel territorio napoletano che nella Piana Campana, è documentata una significativa continuità dello sfruttamento agricolo testimoniata dalla presenza di arature incrociate sulle superfici dei depositi di Agnano 3 e Paleoastroni 2 e a solchi e porche sui soprastanti e spesso sottili paleosuoli (Fig. 5). Questo dato appare particolarmente significativo e forse testimonia lassi di tempo brevi intercorsi tra le eruzioni che non hanno determinato, almeno nelle aree distali rispetto ai centri eruttivi, l'allontanamento per lungo tempo degli abitanti. Tale ipotesi sembrerebbe suffragata dalle scarse datazioni radiocarboniche disponibili (Passariello *et al.* 2010) e dalle poche evidenze dalle aree insediative (cfr. *infra*).

A Capodichino sulla paleosuperficie obliterata dai depositi di Agnano-Monte Spina si riscontra la presenza di tracce di passaggio di un carro o slitta



Fig. 6 – Napoli-Capodichino: sistemazione agricola sul paleosuolo sigillato da Agnano-Monte Spina.

costituite da sottili incisioni parallele con interasse 1,40 m che incidono due "bauletti" delimitanti un'area quadrangolare forse riservata a particolari colture (Fig. 6). Le indagini archeologiche documentano quindi ampi areali sottoposti con una certa continuità a sfruttamento agricolo; di contro rare, anche a causa della casualità della ricerca, sono le evidenze insediative e funerarie, attestate prevalentemente in prossimità del *Clanis*. Nel primo caso si tratta di due contesti di estremo interesse emersi nei comuni di Afragola e Caivano (Laforgia, Boenzi 2011): in entrambi i casi se le prime fasi di occupazione si individuano già sulla superficie del Paleosuolo B, l'insediamento sembra svilupparsi soprattutto nella fase successiva all'eruzione di Agnano 3 e perdurare anche dopo la deposizione delle ceneri di Paleoastroni 2, per essere abbandonato prima dell'evento di Agnano-Monte Spina.

Le testimonianze funerarie sono costituite da tombe a grotticella che attestano la diffusione della *facies* del Gaudo nel territorio napoletano e nella Piana Campana (Napoli, loc. Materdei: Marzocchella 1985; Acerra, loc. Parmiano: Giampaola, Ronga 1998; Caivano, loc. ASI: Laforgia, Boenzi 2009). Tra il Neolitico avanzato e finale e l'Eneolitico pieno la distribuzione delle evidenze indica l'occupazione e lo sfruttamento agricolo diffuso di un'ampia fascia a ridosso dei bacini idrografici del *Clanis* e del Sebeto e il progressivo rarefarsi dei rinvenimenti con l'aumentare della distanza. Parallelamente nel territorio cittadino sono oggetto di sfruttamento agricolo estesi settori come il pianoro del Pendino, il promontorio di Pizzofalcone, i versanti collinari compresi tra questi, ma anche la zona di Capodichino e di Piscinola.

Le successive fasi dell'Eneolitico avanzato e finale sono documentate sul paleosuolo presente al di sopra di Agnano-Monte Spina e obliterato dalle ceneri di Astroni (III mill. a.C.). In questo periodo sembrano subire un significativo cambiamento le dinamiche del popolamento e soprattutto dello sfruttamento agricolo del territorio. Le evidenze relative alla messa a coltura dei suoli diminuiscono infatti bruscamente (diminuzione resa forse ancora più evidente da problemi di conservazione e leggibilità del dato), testimoniando l'abbandono di ampi comparti come il promontorio di Pizzofalcone, il pianoro di Capodichino e quello del Pendino; parallelamente, a ridosso dei bacini idrografici del *Clanis* e del Sebeto, si assiste a una considerevole contrazione delle aree oggetto di frequentazione e di messa coltura, che sembrano concentrarsi in prossimità dei corsi d'acqua.

Negli stessi comparti è documentata la nascita di importanti insediamenti, generalmente di non lunga durata. In prossimità del *Clanis*, in un momento antico dell'aspetto culturale di Laterza, si struttura il sito monofase di Carinaro (Boenzi 2022, c.s.), al cui abbandono sembra seguire la nascita dell'insediamento di Gricignano US Navy (Fugazzola Delpino *et al.* 2003, 2007) inquadrabile in un momento più avanzato della *facies*. Procedendo verso S nel territorio acerrano (loc. Gaudello: Mancusi, Bonifacio 2020; Aurino, De Falco 2022), sempre in prossimità del *Clanis*, e poi in quello napoletano, ai margini della depressione del Sebeto (nei comuni di Casoria e Volla e nell'importante sito di Poggioreale: Boenzi, Mancusi 2022), si documenta una occupazione recenziore e riconducibile a un orizzonte ancora più evoluto della *facies* caratterizzato dall'ibridazione con altri aspetti culturali (Ortucchio, Cetina, il Pettine Trascinato) che segna un momento ormai di transizione dall'Eneolitico al Bronzo Antico. Allontanandosi dai bacini idrografici, il territorio appare interessato esclusivamente dalla presenza di battuti stradali anche di medio lunga durata, interpretabili come assi di collegamento nodali del sistema insediativo (Giampaola, Boenzi 2007).

Il nuovo assetto del popolamento sembra determinato, o comunque avvenire, in relazione agli esiti della crisi climatica cd. del 4200 bp e all'instaurarsi di un clima caldo e secco, ben testimoniato anche dalle caratteristiche pedogenetiche dei suoli immediatamente soprastanti le piroclastiti di Agnano-Monte Spina.

4. L'età del Bronzo

Nel corso del Bronzo Antico, prima il settore occidentale poi quello orientale del territorio vengono colpiti in maniera significativa dall'attività vulcanica della caldera flegrea e del Somma-Vesuvio. Gli eventi di forte intensità sembrano determinare estese e talora lunghe cesure nell'occupazione di ampi comparti territoriali. Ben documentati e oggetto di studi approfonditi

sono gli esiti dell'eruzione vesuviana delle Pomici di Avellino, avvenuta in un momento avanzato del Bronzo Antico. La messa in posto dei depositi eruttivi e post eruttivi ha determinato la conservazione, all'interno dei depositi stessi, delle impronte lasciate da capanne, magazzini, staccionate, recinti con i relativi arredi anche in materiale deperibile (ben documentati nei siti di Afragola e Nola-Croce di Papa: Albore Livadie, Vecchio 2020; Boenzi, Laforgia 2023 con bibl. prec.), ma anche di migliaia di impronte umane e animali che raccontano della fuga e dell'allontanamento dalle aree colpite di gruppi umani con al seguito animali e masserizie. L'evento ha permesso l'eccezionale ritrovamento di ampie distese di campi arati o sottoposti a lavorazioni agricole, in particolare nei comuni di Gricignano, Afragola e Acerra, prossimi al bacino del *Clanis*, e subordinatamente, nelle aree gravitanti sulla depressione del Sebeto.

Di particolare rilievo e oggetto di studi approfonditi sono i campi fossili emersi a Gricignano nell'area della base US Navy (Saccoccio 2021 con bibl. prec.), dove sono documentati solchi, canalette d'acqua poco profonde e bassi argini. È stato ricostruito un sistema agrario coerente di circa 60 ha di campi a pianta allungata, con larghezze ricorrenti, attraversati da una carrareccia. Si tratta della più ampia estensione di campi identificata nell'Italia centrale e meridionale e del più antico sistema agrario completo finora ricostruito per l'Italia per queste fasi. Sistemi analoghi anche se documentati su superfici limitate sono attestati nei comuni di Acerra, Afragola, dove i territori sembrano attraversati da battuti stradali talora di medio-lunga durata e in alcuni settori prossimi alla depressione del Sebeto. Decisamente sporadiche sono le evidenze dal territorio cittadino, concentrate nel settore orientale ai margini della depressione del Sebeto (Fig. 7).

L'analisi delle evidenze insediative, in particolare quelle emerse nel comune di Afragola, documenta periodiche dislocazioni degli insediamenti nell'ambito di areali comunque ristretti. Con l'eruzione delle Pomici di Avellino si assiste a una estesa e prolungata cesura nell'occupazione di ampi comparti della piana e del territorio napoletano che sembra estendersi almeno fino al Bronzo Medio 2-3. Diversamente, le aree costiere e quelle occidentali della città gravitanti sul comparto flegreo e meno toccate dall'eruzione sembrano conoscere un'occupazione precoce, a partire dal Bronzo Medio 1-2. Le dinamiche di formazione dei suoli al di sopra delle piroclastiti di Avellino, la lunga durata degli stessi e l'assenza di depositi vulcanici a sigillare fasi puntuali di frequentazione hanno determinato la scarsa o nulla conservazione di tracce spesso labili, relative alla messa a coltura dei suoli, riconducibili all'età del Bronzo.

Alcune evidenze non meglio definibili cronologicamente, se non in un momento avanzato dell'età del Bronzo e forse di passaggio all'età del Ferro, sono documentate ancora una volta nell'area orientale di Napoli; in queste



Fig. 7 – Napoli-Poggioreale: A) tracce residue di azioni di aratura a tetto dei prodotti dell'eruzione delle Pomici di Avellino in prossimità della sponda dell'alveo; B) sema individuato sulla superficie di uno dei livelli di riempimento del paleoalveo.

fasi sia i livelli superiori di riempimento del paleoalveo che la superficie delle piroclastiti di Avellino (Fig. 7A) che ammantano le sponde sono caratterizzati dalla presenza di solchi di aratura incrociati; nell'alveo, inoltre, su uno dei suoli sottoposti a lavorazioni agricole, è stato rinvenuto un sema litico di grandi dimensioni forse rotolato da quote superiori (Fig. 7B).

5. Conclusioni

La considerevole estensione degli areali interessati da lavorazioni agricole a partire dal Neolitico avanzato e finale, che vede un notevole incremento nel corso dell'Eneolitico, presuppone un precoce e forte impatto delle attività antropiche sull'ambiente naturale, con azioni di deforestazione funzionali alla messa a coltura delle aree. A partire dall'Eneolitico è attestato l'uso diffuso dell'aratro nelle zone sottoposte a coltivazione, che occupano ampie fasce

ai lati dei bacini idrografici e gran parte del territorio della città di Napoli. Sempre da un momento non avanzato dell'Eneolitico è testimoniato anche l'uso di carri e/o slitte grazie al rinvenimento di sottili solchi paralleli con interasse costante lasciati dal loro passaggio.

Una cesura sembra documentata nelle fasi successive all'eruzione di Agnano-Monte Spina nell'Eneolitico avanzato e finale, quando si assiste a una importante contrazione degli areali oggetto di lavorazioni agricole e di frequentazione diffusa, che si restringono in aderenza ai bacini idrografici del *Clanis* e del Sebeto. Nelle stesse aree è documentata la nascita di estesi insediamenti, talora monofase. A partire da queste fasi e poi soprattutto nel Bronzo Antico sembra diffondersi ulteriormente l'uso di carri da trasporto testimoniato dalla presenza di consistenti battuti stradali anche di medio-lunga durata, assi di collegamento tra siti o areali occupati con continuità, e di tracciati occasionali, di cui restano le carreggiate con interasse costante.

Non è difficile mettere in relazione il riassetto del popolamento e i cambiamenti nello sfruttamento agricolo del territorio agli esiti della crisi climatica cd. del 4200 bp che ha interessato l'Europa e il bacino del Mediterraneo in un ampio arco cronologico nel corso III millennio (Bini *et al.* 2019). Questa sembra peraltro aver determinato una forte mobilità delle popolazioni sul continente europeo e nel bacino del Mediterraneo la cui eco sul nostro territorio è documentata dalla presenza di materiali che indiziano ampie e forti connessioni da un lato con l'Europa occidentale dall'altro con l'area balcanica. Nello stesso tempo si assiste a una forte predilezione di siti prossimi a bacini idrografici o aree umide, sia in ambito laziale (Carboni 2020; Celant, Magri 2020), che nella Piana Campana (Amato, Salerno 2007; Di Vito *et al.* 2021; Boenzi 2022), ma anche nel territorio napoletano dove la depressione del Sebeto e quella di Bagnoli-Fuorigrotta (Boenzi, Mancusi c.s.) rappresentano dei polarizzatori del popolamento.

Nel corso del Bronzo Antico, anche grazie all'eccezionale conservazione delle evidenze determinata dalla messa in posto delle piroclastiti delle Pomici di Avellino all'inizio del II mill. a.C., è possibile ricostruire un tessuto insediativo piuttosto denso, caratterizzato da periodiche dislocazioni e un paesaggio agrario strutturato con campi allungati separati da canalette per il deflusso delle acque. Gli studi condotti nell'area di Gricignano di Aversa hanno permesso di proporre un «modello basato sulla mobilità, dove singoli lotti di terreno potevano essere temporaneamente attribuiti a membri della comunità» che «richiama alla mente casi di tipica economia strutturata, ma ancora mobile, come proposto dagli antropologi e dagli archeologi per le società stratificate ma sprovviste di proprietà privata» (Saccoccio *et al.* 2020, 249).

Nelle fasi successive all'eruzione e per i periodi seguenti estremamente rare sono le tracce di messa a coltura, a causa soprattutto della scarsa conservazione delle evidenze all'interno di suoli oggetto di frequentazione e

sfruttamento fino in età contemporanea. Ciò ha comportato, in assenza di coperture simultanee determinate dalla deposizione di depositi eruttivi e/o eluvio alluvionali, che si conservassero, solo alcune tracce in negativo (buche per palo, pozzi, etc.) e più raramente solchi di coltivazione.

L'eruzione delle Pomici di Avellino sembra aver determinato un abbandono anche di parecchi secoli delle aree più colpite e quindi un conseguente riassetto dell'insediamento. Questo di fatto precorre il più generale cambiamento delle dinamiche di occupazione e strutturazione del territorio che, a partire dal Bronzo Medio, vede la predilizione di siti naturalmente difesi e inseriti nelle dinamiche dei traffici sia via terra che, soprattutto, via mare (Giardino, Merkouri 2007; Pacciarelli 2016).

È solo a partire da un momento avanzato del Bronzo Medio e poi nel corso del Bronzo Recente che la Piana Campana a S del *Clanis* e parte del territorio napoletano sembrano nuovamente popolarsi. A tal proposito appaiono di rilievo le evidenze riconducibili ad aree insediative rinvenute nei territori di Gricignano, Caivano, Acerra e Afragola che documentano una diffusa rioccupazione dell'area a partire dal Bronzo Medio 3 e poi nel Bronzo Recente. In un momento successivo, tra il Bronzo Finale e il Primo Ferro, il territorio di Gricignano (Laforgia *et al.* 2011) continua a essere un polarizzatore del popolamento, mentre in quello napoletano sono documentati siti costieri legati allo sfruttamento delle risorse marine. Parallelamente le labili evidenze emerse dalle aree prossime alla depressione del Sebeto, e in particolare dal sito di Poggioreale, documentano fasi, purtroppo non meglio definibili cronologicamente, di occupazione legata allo sfruttamento agricolo del territorio.

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ABSTRACT

Archaeological investigations conducted over the last thirty years in the Campania plain and the Naples area have provided incredible insights into the evolution of the landscape and the agricultural practices of the land between the Late Neolithic and the modern era. This paper will attempt to provide a concise overview of the available knowledge for reconstructing pre- and protohistoric agricultural structures in the Naples area and the southern part of the Campania plain between it and the Regi Lagni. This area has been affected by the eruptive

activity of Somma Vesuvius and the Phlegraean Fields; it is characterized by eruptions of sometimes strong intensity punctuated by periods of quiescence. During the periods of quiescence between the various eruptions, human settlements stabilized and various forms of land use spread, favored by fertile soils and favorable climatic conditions.

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INTERACTION BETWEEN NATURAL DYNAMICS AND HUMAN SETTLEMENTS IN THE TERRITORY OF GRICIGNANO D'AVERSA (CAMPANIA PLAIN, ITALY) FROM THE NEOLITHIC TO THE ROMAN AGE

1. Introduction

This paper examines the changing topography of a sector of the Campania Plain, where the fertile volcanic soils of Gricignano d'Aversa have sustained continuous agricultural productivity and settlement from the Neolithic to the present (Laforgia, De Filippis 2002; Pizzano 2014; Boenzi in this volume). The area has been reshaped over time by natural dynamics (volcanic and alluvial) and human intervention; a notable example is the Clanio River, along the municipality's northern edge, whose course and drainage were substantially modified by seventeenth-century land-reclamation undertaken under the Spanish Viceroyalty. Our topographical and geoarchaeological reconstruction of northern Gricignano d'Aversa is grounded in the recovery and enhancement of legacy data generated by preventive excavations conducted in the late 1990s during construction of the Rome-Naples high-speed railway (TAV) (Brancato *et al.* 2024; cf. also Frandi, Ludovici 2020). These records enable a long-term reading of human-landscape relations in the alluvial plain, where stratigraphy around the Neapolitan volcanic centres preserves evidence of settlement and land use from the Late Neolithic through the historical period (Saccoccio *et al.* 2013; Brancato *et al.* in press). Despite the plain's extreme flatness and alluvial character, intensive occupation and cultivation were possible thanks to the fertility of volcanic-ash soils and to successive waves of ancient and modern reclamation, still legible in today's landscape.

The study adopts the concept of 'deep mapping' as a framework for diachronic geo-archaeological analysis within a GIS environment (Roberts 2016). Rather than a static map, the deep map is a digital workspace that integrates a wide spectrum of geo-referenced sources (archaeological, historical, environmental, and topographic) allowing layered visualisation and interpretation of material geographies. In this perspective, the intended outcome is an archaeological map of the municipalities of Gricignano d'Aversa and Carinaro: a diachronic, 'deep' representation of the historical landscape of the Campania Plain that encompasses both visible surface evidence and buried deposits revealed by large public-works projects. As highlighted by De Caro (2002), preventive archaeology and developer-funded investigations have transformed our understanding of the plain. The substantial,

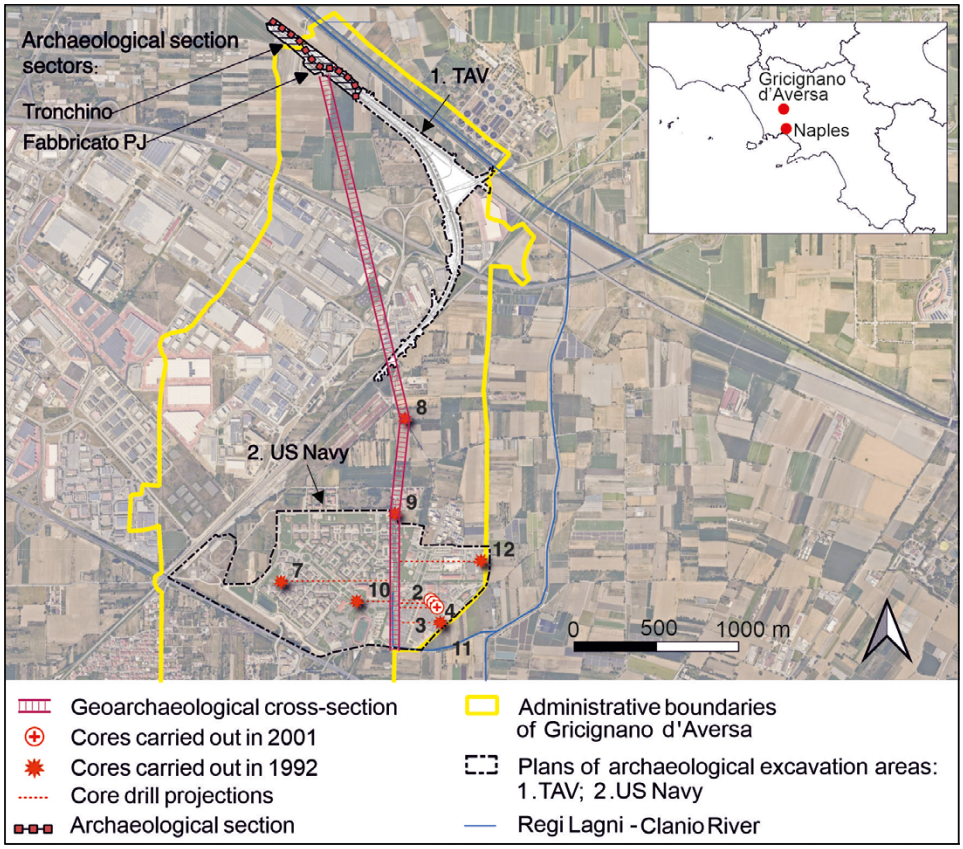


Fig. 1 – Location of the archaeological excavation areas in the Gricignano d'Aversa territory and profile of the geoarchaeological cross-section (cartographic base: Google Satellite).

heterogeneous corpus accumulated since the 1990s – managed at the time with early GIS, vector graphics, and cartographic platforms – now constitutes a crucial body of legacy data. Its systematic integration is essential not only for research, protection, and public value, but also for addressing the geoarchaeological visibility bias that often distorts surface-survey readings in alluvial contexts.

The following sections will contextualize the site and the environmental framework, illustrate the multidisciplinary approach adopted for the investigation, present the results and main interpretations, and finally, provide the conclusions.

R.B., E.R.E.

2. Site location

The study area is located in the Campania Plain and is configured as a flat territory, with altitudes ranging from 34 to 17 m above sea level (Fig. 1). The area is characterized by volcanic deposits, from the volcanic centres of Somma-Vesuvius and Campi Flegrei, and by the presence of the River Clanio-Regi Lagni canalization system. In particular, the most important chronostratigraphic marker in the area is the Campanian Ignimbrite (CI, ca. 40 ka; Giaccio *et al.* 2017), followed by the Neapolitan Yellow Tuff (NYT, 15 ka BP, Deino *et al.* 2004; De Vivo *et al.* 2010), and the Pomici di Avellino (ca. 3900 cal yr BP; Passariello *et al.* 2009). Historically and archaeologically, the area shows evidence of intense human activity from the Neo-Eneolithic period (Pizzano 2014; see also Boenzi in this volume) through the Roman period (Laforgia, De Filippis 2002) up to the present day. Regarding the archaeological context, Gricignano d'Aversa has been subject to two main preventive archaeology projects, conducted by A. Marzocchella (1998) and later by E. Laforgia and A. De Filippis (2002), between the mid-1990s and 2005: one for the US Navy base and the other for the aforementioned TAV works. In particular, the Tronchino and Fabbricato PJ investigated sectors are located in the northern part of the municipality of Gricignano d'Aversa (Fig. 1).

3. Methodology

Data collection was carried out through archival research conducted on several archival holdings kept at the National Archaeological Museum of Naples, which houses the archaeological and geological documentation produced during the preventive archaeology projects conducted between 1995 and 2005 in the province of Caserta. The need to recover and enhance these data, now largely inaccessible through modern software, emerged. The digitization process involved both textual and numerical data, categorized into the following types of documentation:

– scientific reports, cataloguing documentation, lists of materials;
– photographic documentation (B/W or color), slides, negatives;
– stratigraphic diagrams, drawings of archaeological materials;
– graphic documentation: phase plans, stratigraphic sections, general site plans;
– digital media: CD-ROMs and floppy disks.

For the cartographic bases, WMS services, IGM maps at different scales, LiDAR products from the Campania Region, original site plans from the excavations (retrieved from the MANN Archives), and various historical cartographic sources were used. Based on this material, digitization began along two main directions: on the one hand, the implementation of data

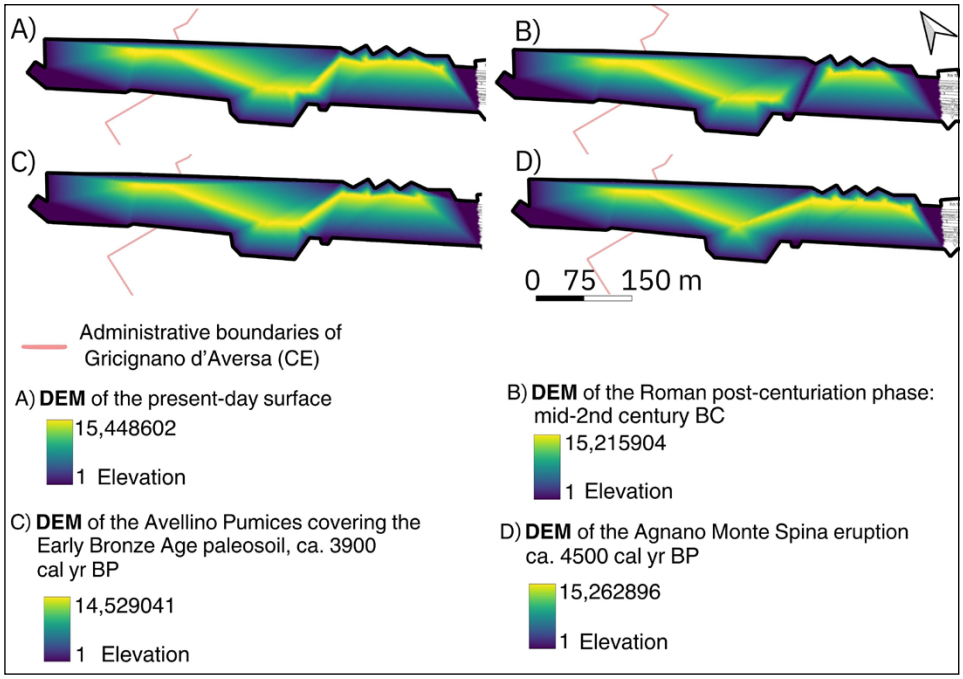


Fig. 2 – Digital Elevation Models (DEM) of the investigated archeological sectors.

in MOPR and MOSI formats within the Open Data application promoted by the Central Institute for Archaeology, i.e., the National Archaeological Geoportal, which allows the sharing and visualization of data produced from archaeological projects across Italy; on the other hand, the creation of a Territorial Information System (TIS). A central element of the latter is the stratigraphic unit sheets, associated with an average elevation and loaded into the GIS environment as georeferenced points. These data allowed for the creation of four Digital Elevation Models (DEMs) for the Tronchino and Fabbricato PJ areas (Fig. 2).

The models represent significant chronostratigraphic levels:

– the Agnano Monte Spina eruption (ca. 4500 cal yr BP; Smith *et al.* 2011);
– the Pomici di Avellino eruption (which cover the paleosoil of the Early Bronze Age, ca. 3900 cal yr BP; Passariello *et al.* 2009);
– the Roman post-centuriation phase (mid-2nd century BC);
– the present-day surface (for a comparative principle).

A further phase of analysis was conducted in AutoCAD, with the creation of a geoarchaeological section based on the recovery in the Archive

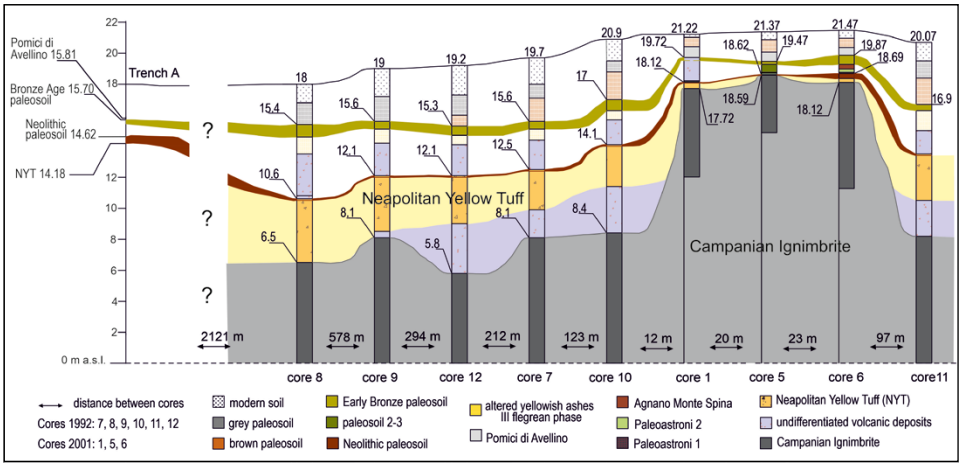


Fig. 3 – Geoarchaeological cross-section, not in scale (for location see Fig. 1).

of geological subsoil data, collected in 1992 and 2002 (Fig. 3a-b). Several core stratigraphies have been re-examined in order to identify the main chronostratigraphic levels recognized in the archaeological sections. This approach made it possible to compare the subsurface stratigraphy of the municipality (US Navy area) and the northern peripheral area (TAV area), highlighting the sectors where the lack of data would require further sampling.

4. Results and discussion

4.1 *The shaping of the landscape*

From the comparison of the DEMs for the Tronchino and Fabbricato PJ areas (Fig. 2) and the geoarchaeological stratigraphic reconstruction (Fig. 3), several significant observations emerged.

First, the formation of stratigraphic units in the area is mainly attributable to volcanic events, interspersed with phases of quiescence during which paleosoils developed, most of which were anthropized. The most significant eruptive events include the Campanian Ignimbrite (around 39,000 years ago), the Neapolitan Yellow Tuff (around 15,000 years ago), the Agnano Monte Spina eruption (around 4500 years ago), and the Pomici di Avellino (around 3900 years ago). The morphology of volcanic layers and paleosoils is strongly conditioned by the earliest eruption attested in the area, the Campanian Ignimbrite, which was deposited with considerable thickness across the entire Campania Plain during the last glacial period.

Subsequently, erosive processes shaped a varied alluvial landscape with hills and low-lying areas, showing greater differences in altitudes in older periods, which became less evident in more recent phases. Indeed, the erosion of heights and the progressive filling of lows, with both volcanic and colluvial-alluvial deposits, have led to a levelling of the area, which today appears almost flat. The TAV area is located at a lower elevation, around 18 m asl, compared to the U.S. Navy area, which is situated on a slight elevation, around 21 m a.s.l. This difference, slightly higher in ancient times, led to enhanced erosion on the hills. As a consequence, the stratigraphic levels (both volcanic and anthropic) in the US Navy area are thinner compared to those in the TAV area, where the stratigraphic thickness is greater (Fig. 3).

4.2 *Settlement choices*

From the comparison of anthropized paleosoils and archaeological traces found in the TAV area, and the sections cited before (Figs. 2, 3), some significant geoarchaeological and topographical observations emerge. The area shows sporadic settlement from the Final Neolithic period, with a more stable presence during the Late Neo-Eneolithic and Early Eneolithic. This is hypothesized based on the widespread presence of post-holes throughout the area, interpreted as remains of structures for housing or animal enclosures. The Early Bronze Age also shows evidence of frequentation, though with some inconsistencies compared to the general framework. While evidence of the Early Bronze Age in the TAV area is limited, numerous traces of an agrarian landscape dating back to this same period are documented in the US Navy area, as evidenced by the work of A. Marzocchella and A. Vanzetti. This discrepancy raised questions about the factors influencing the settlement choices of the communities of that time, especially considering that both areas were frequented during the Neo-Eneolithic period. One possible explanation emerges from the topography and hydrology of the region.

The Clanio River, which influenced the area's settlement choices, represents a significant ecological resource for those who inhabited the region. The proximity of the river during the Eneolithic period favoured settlements close to the waterway. Later, during the Bronze Age, the same river forced settlements to move to more elevated land to avoid flooding. This trend changed again during the Roman period, when the application of drainage techniques, such as canalization (Fig. 4) and embankments, allowed the establishment of settlements along the riverbanks. In fact, 21 canalization features were identified in the Tronchino and Fabbricato PJ areas, associated with traces of ploughing, as they share the same north-south orientation as the *decumani*. This designates a landscape fully consistent with the organization of the *ager Campanus* (between the 2nd and 1st centuries BC), which provides a *terminus post quem* for its realization.

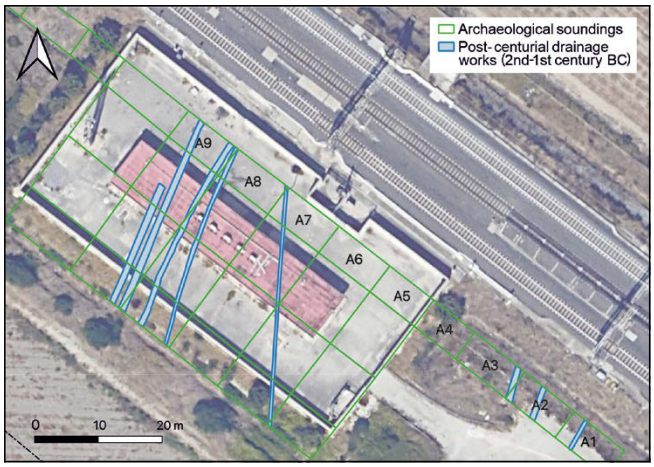


Fig. 4 – Post centurial drainage works. Focus on Fabbricato PJ (cartographic base: Google Satellite).

5. Conclusions and research perspectives

In conclusion, the territory of Gricignano d'Aversa reveals a profound and ongoing dialectic between humans and the environment, marked by eruptive events that have shaped its morphology and constitute the main character of the landscape, alternating with phases of settlement recovery and habitation. Future research perspectives focus on the need to deepen our understanding of the underground layers, particularly regarding the role of the Clanio River, whose presence before the flood control works has so far been poorly documented by historical and archaeological sources. Currently, the evidence of alluvial deposits is limited to two archaeological surveys in the T.A.V. area and is insufficient for a comprehensive reconstruction of the ancient river landscape, despite the undeniable historical and environmental importance of the Clanio River.

To fill this gap, it will be crucial to continue the research through a multidisciplinary approach that primarily involves new geological investigations. These would help better define the subsurface stratigraphy, identify ancient alluvial levels, and understand the geomorphological processes that have shaped the area over time. Such analyses could be conducted from new surveys at strategic points, particularly in areas that, according to the reconstructed geoarchaeological section, are currently lacking subsoil data for approximately one kilometre. In addition to new core drilling, another way to enhance the available knowledge is through the systematic consultation of municipal archives, where technical documentation related

to public or private construction works might be found. In many cases, building or infrastructure interventions include geotechnical surveys of the subsurface. If appropriately retrieved, analysed, and georeferenced, these could significantly enrich the stratigraphic framework and contribute to the paleoenvironmental reconstruction, while also reducing the costs and impact of new direct investigations.

At the same time, the new surveys would offer the opportunity for palynological analysis, should fine alluvial or peat layers be intercepted, which may have preserved pollen useful for paleoenvironmental reconstruction. Palynological studies would indeed allow for an integration of knowledge about the ancient environment, providing valuable information on vegetation, climate, and the impact of human activities over time. This approach, based on the integration of legacy data with new data from targeted core drilling, and ultimately, laboratory analysis, represents a promising direction for deepening our understanding of the ancient landscape of Gricignano d'Aversa and the complex relationship between human communities and the environment.

M.T.

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ABSTRACT

This study aims to reconstruct the long-term interactions between humans and the environment in the northern sector of Gricignano d'Aversa (CE), using historical data inte-

grated into a Geographic Information System (GIS). Legacy data from the Archaeological Museum of Naples were digitized as part of a project involving the National Geoportal and the development of a Territorial Information System (TIS). The latter is primarily based on the elevations of stratigraphic units, georeferenced in QGIS. The soil elevation data were obtained from both archaeological and geological surveys. These data sets allowed the development of a geoarchaeological section, created with AutoCAD, as well as Digital Elevation Models (DEMs) generated with QGIS. The results show that the site's geomorphology was mainly shaped by volcanic events, first the Campanian Ignimbrite eruption (39,000 years ago), which had a strong impact on settlement patterns. Topographical variations resulting from these events played a key role in settlement choices. Moreover, the proximity to the Clanio River influenced settlement choices, with communities preferring areas far from the river to avoid flooding. This trend changed by the Roman period, when drainage techniques, evidenced by canalizations, allowed settlement closer to the river.

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IL PAESAGGIO AGRARIO DI *ACERRAE* E *SUESSULA*: IL SISTEMA DELLE VILLE RUSTICHE

1. Introduzione

L'attuale territorio di Acerra, e in parte di Afragola, rientra nella *Campania Felix*, un'ampia pianura solcata da corsi d'acqua che rendono il terreno particolarmente ricco per l'agricoltura. Al centro della pianura era la città etrusca di Capua, attorno alla quale gravitavano altri importanti centri, la cui fondazione può essere talvolta coeva talaltra ben più recente: *Calatia*, *Suessula* e *Acerrae*, sul versante orientale del fiume *Clanis*, di *Atella* per quello orientale (Ruffo 2010, 152-244). La continuità abitativa in questi luoghi ha spesso inficiato la conoscenza delle antichità presenti, ma ha preservato molte tracce della divisione agraria, riconoscibile nelle centuriazioni di epoca romana. La vocazione agricola della piana, fino ad oggi pienamente riscontrabile, ha permesso di fornire un'identità precisa a questo territorio che, grazie alle nuove ricerche, può essere ancor più messa a punto.

In questa sede si presenteranno alcuni dei dati più rilevanti riguardanti la presenza da un lato di strutture romane di epoca primo imperiale di carattere produttivo, in particolare ville rustiche o loro annessi, utili a delineare lo sfruttamento agrario del territorio, dall'altro di sistemi di canalizzazioni per il drenaggio delle acque, campi coltivati, battuti e strade che forniscono informazioni importanti per la suddivisione delle aree e il collegamento tra esse[1]. Questo comprensorio, al di là della conoscenza dei centri urbani di *Acerrae*, *Suessula* e *Atella*, non ha restituito negli anni moltissimi dati di carattere archeologico che si unissero a considerazioni di tipo topografico. Gli scavi recenti dell'Alta Velocità Napoli-Bari, nel tratto Napoli-Cancello, che attraversa i comuni di Casoria, Casalnuovo, Afragola e Acerra per terminare appunto a San Felice a Cancello[2], hanno permesso di colmare questo gap e di offrire lo spunto per nuove riflessioni. La posizione di questo ricco bagaglio conoscitivo è quasi esclusivamente concentrata nel comune di Acerra e prevalentemente nell'*ager* appunto di

[1] I dati qui raccolti riguardano gli scavi più esaustivi e ampi, utili a comprendere fasi e sviluppo dei sistemi agrari; molti contesti dubbi o di piccola entità sono stati lasciati da parte.

[2] La divisione dei singoli segmenti dell'opera corrisponde in questo caso anche con il limite dell'area metropolitana di Napoli. La direzione scientifica delle operazioni di scavo è in capo alla Soprintendenza Archeologia, Belle Arti e Paesaggio per l'area metropolitana di Napoli, prima nella persona di Paola Aurino e in seguito di chi scrive. In tal caso si esprime un sentito ringraziamento agli archeologi che hanno lavorato sul campo, *in primis* alla coordinatrice scientifica Mariangela Moretti e al coordinatore della topografia Salvatore Borrelli.

Acerrae e *Suessula*, al di qua e al di là del corso del fiume *Clanis* e a poche centinaia di metri dall'antica *Acerrae*[3].

Primo elemento da evidenziare è il contesto geografico, anche con l'obiettivo di dissipare la non sempre facile sovrapposizione tra circoscrizioni moderne e organizzazione amministrativa antica. Le strutture archeologiche, con evidenze ad esse circostanti e annesse, ricadono in comuni la cui formazione è moderna. Il fiume *Clanis*, nelle cui vicinanze fu fondata *Acerrae* nel corso del IV sec. a.C., racchiudeva un'ampia valle, molto fertile per la presenza di acque sorgive, dominata fin dall'età del Ferro da *Suessula*. Al di qua del *Clanis*, nelle ampie circoscrizioni territoriali di Afragola e Caivano, non è noto alcun centro abitato, né *vicus* o *pagus*. Potrebbe indiziare la presenza di un qualche agglomerato il rinvenimento di una tomba a cassa dipinta del tipo sannitico proprio nelle vicinanze di Afragola (Benassai 2001, 21, n. A.1-2, e 127-129), cui si aggiungono negli ultimi anni altri nuclei di sepolture a cassa semplice trovati nei pressi della stazione AV, assimilabili per orizzonte culturale, la cui cronologia oscilla tra il IV e il II sec. a.C.

Dunque se non si può escludere la presenza di un qualche abitato in quest'area, forse a carattere sparso, è fuor di dubbio che il centro antico di maggior peso politico e territoriale fosse, fin dalla sua fondazione nel IV sec. a.C., *Atella* (Brancato, Kay 2024). Proprio le maggiori città di questo comprensorio, *Atella*, *Acerrae* e *Suessula* (Rescigno, Senatore 2009; Rossi 2011) hanno fortemente influenzato l'organizzazione agraria e, grazie a numerosi studi topografici, si possono oggi riconoscere con una certa chiarezza diversi reticoli di centuriazioni perduranti fino all'età imperiale romana (Chouquer *et al.* 1987, 207-208, fig. 70; Monaco, Clavel-Lévêque 2004, 188-200). Le scoperte qui presentate si inseriscono proprio a cavallo tra *Atella* e *Acerrae* e tra questa e *Suessula*, rientrando probabilmente nell'*ager* di *Acerrae*, ma in una dimensione assolutamente convergente con l'organizzazione stradale e territoriale comune alle tre città (sul territorio di *Acerra*, oltre alla bibl. citata, cfr. anche Amato *et al.* 2020).

È bene già preliminarmente sottolineare che tutti i contesti qui menzionati hanno una lunga vita che va dall'età augustea fino almeno al 472 d.C., data dell'eruzione vesuviana nota come Pollena, che ha obliterato in molti casi le strutture, benché di frequente vi sia una continuità che arriva fino al Medioevo. In questa sede, al fine di ricostruire il paesaggio agrario della prima età imperiale si presenteranno dati relativi alla prima fase di frequentazione dei contesti, pur accennando alla loro prosecuzione che, tuttavia, si sostanzia in

[3] È bene sottolineare che gli scavi di queste evidenze sono ancora parziali, poiché si è potuto indagare solo parte delle strutture, in attesa di futuri scavi complessivi, e soprattutto le indagini di questa fase, svoltesi tra 2022 e 2025, sono terminate da pochi mesi. Le prime tre ville sono state pubblicate in Di Franco 2025.

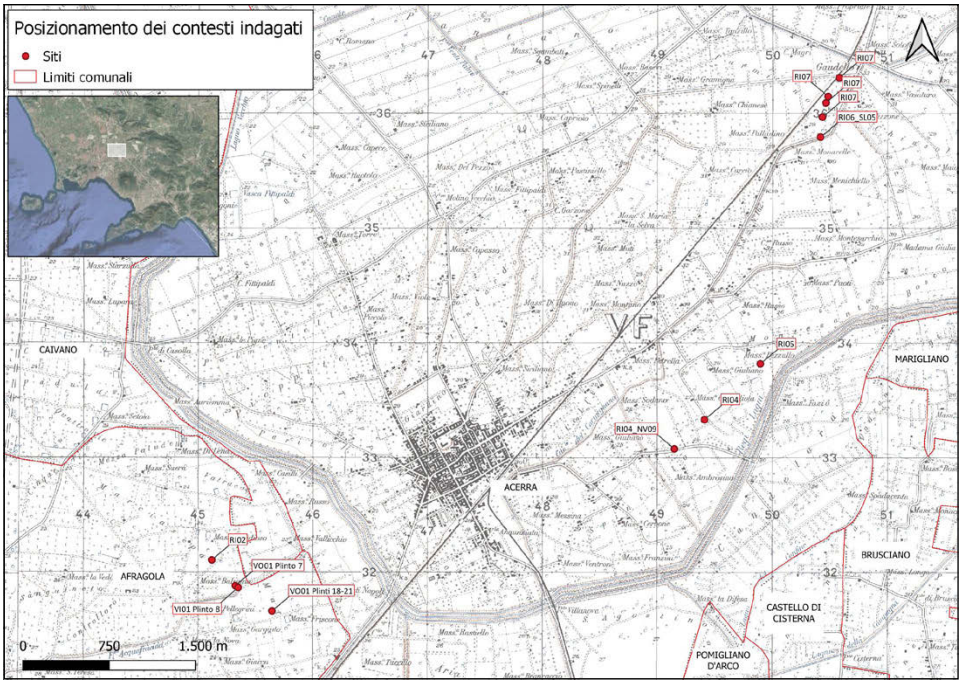


Fig. 1 – Tavola dei contesti.

molti casi unicamente in fasi di abbandono e spoliazione con l'impostazione di necropoli.

I risultati sin qui raggiunti hanno arricchito in maniera significativa il quadro conoscitivo sull'assetto topografico di questa porzione della Piana Campana, consentendo di delineare con maggiore precisione le dinamiche insediative e le trasformazioni del paesaggio nel tempo. A tal proposito, i dati sono stati raccolti all'interno dell'applicativo ICA del Geoportale Nazionale dell'Archeologia così da garantire la loro integrazione in un sistema informativo condiviso, favorendo la consultazione, l'analisi e la valorizzazione delle informazioni da parte della comunità scientifica e degli enti preposti alla tutela (Calandra 2022).

2. La villa di Afragola VI01, Plinti 18-21

Riguardo il posizionamento dei contesti indagati (Fig. 1), la prima struttura è emersa all'interno del Centro Commerciale "Le porte di Napoli", in un'area in cui indagini di archeologia preventiva propedeutiche alla costruzione del Centro avevano dato esito negativo. In quest'area, però, la previsione



Fig. 2 – Planimetria della villa VI01 Plinti 18-21.

di una linea ferroviaria viaggiante su viadotto (VI01), sorretto da plinti, ha permesso di raggiungere considerevoli profondità e quindi rintracciare le evidenze archeologiche della fase romana e protostorica. La realizzazione dei plinti prevede l'inserimento di pali di fondazione, la cui esecuzione precede i suddetti plinti. Tra il n. 18 e il n. 19 sono emerse strutture murarie riferibili per planimetria ad una villa rustica (Fig. 2), non interamente scavata poiché la porzione SO del complesso esce dai limiti dello scavo e l'ampliamento si prevede sarà realizzato solo dopo la messa in opera del viadotto per motivi logistici.

Le strutture indagate si pongono stratigraficamente al di sopra del livello eruttivo delle Pomici di Avellino, molto spesso utilizzato per le fondazioni poiché costituisce un piano coeso e solido, non drenante e quindi adatto a sostenere complessi costruttivi. Si tratta di una villa di carattere rustico a pianta rettangolare, organizzata con ambienti disposti intorno a un cortile centrale e di dimensioni ricostruibili di ca. 16×30 m. La tecnica edilizia utilizzata consiste in paramenti in opera incerta e reticolata composta da

tufelli non perfettamente regolari, il cui spiccato, in alcuni casi, presenta un marcapiano in tegole. Le murature rinvenute hanno uno spessore medio di 45 cm e si conservano in elevato per un'altezza compresa tra i 60 e i 20 cm. Una peculiarità costruttiva che pare contraddistinguere numerosi complessi edilizi extraurbani di questo territorio è l'altezza delle murature: anche in ragione di una totale mancanza di attestazione di crolli, il punto più alto dei muri, cioè i 60 cm descritti, corrisponde anche a una lisciatura delle creste, quasi a sottolineare un loro punto terminale piuttosto che un marcapiano. Ciò indurrebbe a ritenere che l'elevato fosse realizzato in materiali deperibili.

Per ciò che concerne invece i piani di calpestio, le stanze a N e a O della villa (ambienti A-C, D1-D4 nella planimetria) sono dotate di pavimenti poco elaborati costituiti da battuti di terra o da piani di calce collocati al di sopra di colmate di livellamento e in alcuni casi di rudimentali preparazioni in schegge tufacee. All'interno di questi ambienti sono state rinvenute anche due fosse circolari (vano D2), realizzate nel banco eruttivo di Avellino e utilizzate con ogni probabilità per l'inserimento di ceste in materiali deperibili o contenitori in ceramica per la conservazione di derrate alimentari, ma anche un pozzo (ambiente B), nel cui strato di obliterazione sono emersi 14 pesi da telaio. Gli ambienti F e H, posti sul fronte NO e SO, presentano una pavimentazione più ricercata, realizzata in un fine cocciopesto. Per quanto riguarda invece l'ambiente E, corrispondente al cortile centrale scoperto, il pavimento è costituito da una massicciata di schegge di tufo e frammenti di tegole. Nel mezzo del cortile dovevano trovare posto una vasca e dei *dolii*, di cui ancora uno *in situ*.

Gli elementi sicuri di questo edificio da un punto di vista planimetrico-funzionale sono costituiti, come anticipato, dal cortile interno utilizzato con scopo evidentemente produttivo, intorno al quale si dispongono ambienti di lavorazione, che fanno della struttura una villa rustica. Importante è l'ambiente D2, il più grande tra quelli messi in luce ed evidentemente assiale a quello che poteva essere l'ingresso al complesso, individuabile pertanto a SE. Gli ambienti posti a O sono di dimensioni comprese tra un massimo di 3×5,90 m e un minimo di 3,10×2,80 m, in cui si possono riconoscere vani di servizio e dove potevano trovare posto apprestamenti di carattere funzionale. Lo stesso ambiente D2, con le fosse per la conservazione delle derrate, era probabilmente il più grande di questo settore di lavorazione. Non è poi un caso che la vasca rinvenuta nel cortile sia annessa a questa parte e che nello spazio scoperto vi siano altri *dolii*, chiara testimonianza di un impianto produttivo. Indiziano verso attività di lavorazione anche i numerosi pesi da telaio già menzionati. A questo settore doveva corrispondere nel lato non scavato verso SO la *pars urbana*, il settore residenziale, già in parte indiziato negli ambienti F e H da una maggiore ricercatezza nella pavimentazione, cui dovrebbero riferirsi anche i numerosi residui di intonaco e un frammento architettonico fittile rinvenuti durante gli scavi.

L'edificio è impiantato tra la tarda età repubblicana e la prima età augustea e la sua fase di vita continuerà per tutta la prima età imperiale. A una seconda fase corrisponde la costruzione di un piccolo ambiente a NO che funge da ampliamento verso quel lato dell'ambiente D2 e nel quale è ricavata una delle fosse summenzionate. Nel corso dei secoli nel cortile interno e negli ambienti si accumulano strati contenenti lo smantellamento delle prime fasi dell'edificio, che coincide anche con un'attività di spoliazione degli elementi costruttivi ben ravvisabili in alcuni punti dove sono praticate fosse che arrivano fino alle fondazioni. Chiaro indizio di una defunzionalizzazione è la realizzazione di tre tombe, databili verosimilmente tra IV e V sec. d.C. Alla villa e alle tre sepolture prossime ad essa si possono poi collegare numerose altre sepolture rinvenute nello scavo vicino del plinto 20.

3. La villa di Afragola VI01, Plinti 7 e 8

A poche centinaia di metri più a O, nello scavo dei plinti 7 e 8, è emersa una struttura approssimativamente simile a quella descritta (Fig. 3). Cominciando dal plinto 8, vediamo che è stata intercettata una villa di impianto rettangolare, scavata solo per una piccola estensione relativa all'angolo meridionale, in attesa degli ampliamenti progettati per la fase successiva delle indagini. La tecnica utilizzata è l'opera reticolata con tufelli non perfettamente squadrati; le testate e le catene angolari invece sono realizzate in opera vittata di blocchetti di tufo. Lo spessore delle murature è di 45 cm, mentre l'altezza raggiunge i 60 cm. La forma degli ambienti è piuttosto disomogenea: tutti sono approssimativamente rettangolari, l'ambiente 6 è sicuramente il più esteso e non è stato rintracciato il limite N, mentre l'ambiente 5 è di ridotte dimensioni. Anche in questo caso la pavimentazione è costituita da un semplice battuto, in parte addensato con calce, per gli ambienti 2, 3 e 6, mentre gli ambienti 1 e 5 presentano un piano in buon cocciopesto. Il cortile centrale ha una pianta anomala trapezoidale e presentava una copertura lungo i margini, indiziata dalla presenza di almeno tre pilastri in *opus vittatum* posti lungo il lato meridionale e orientale dell'ambiente.

Relativamente alla funzionalità degli ambienti, quelli finora messi in luce sono distribuiti intorno a un cortile centrale, con il quale erano collegati attraverso aperture. Nell'ambiente 1, la presenza di un bancone in muratura e di un incasso circolare ricavato nel cocciopesto per l'inserimento di un dolio permette di dedurre che vi fosse una lavorazione per scopi produttivi legati a derrate alimentari. Senza alcun dubbio quindi questa parte dell'edificio si identifica nella *pars rustica* di una villa realizzata tra la tarda età repubblicana e la prima età augustea. La *pars urbana*, seppur non rintracciata, era particolarmente ricercata così come indiziato dal rinvenimento di frammenti di lastrine di marmo di rivestimento, intonaci dipinti e soprattutto frammenti

di pavimenti musivi in tessere bianche e nere, alcuni dei quali adoperati per la copertura della Tomba 7. La residenza doveva avere anche un impianto termale, come rivela la presenza di frammenti *tegulae mammatae* e di colonnine fittili per *suspensurae*, di comune utilizzo nei *balnea*.

L'edificio ebbe la sua continuità di vita per tutta l'età medio-imperiale. Durante quest'ultima la villa dovette subire interventi di diversa natura, rintracciabili soprattutto nell'innalzamento delle quote dei livelli di calpestio, ottenuti con parziali interri, fosse di scarico e altre attività legate, forse, al mutato uso di alcune parti dell'edificio. Immediatamente dopo si assiste a una fase di spoliazione della villa, indiziata dalla presenza di buche in alcuni ambienti e di crolli. Contemporaneamente la villa divenne poi sede di un sepolcreto, nel quale il materiale di spoglio è ampiamente adoperato.

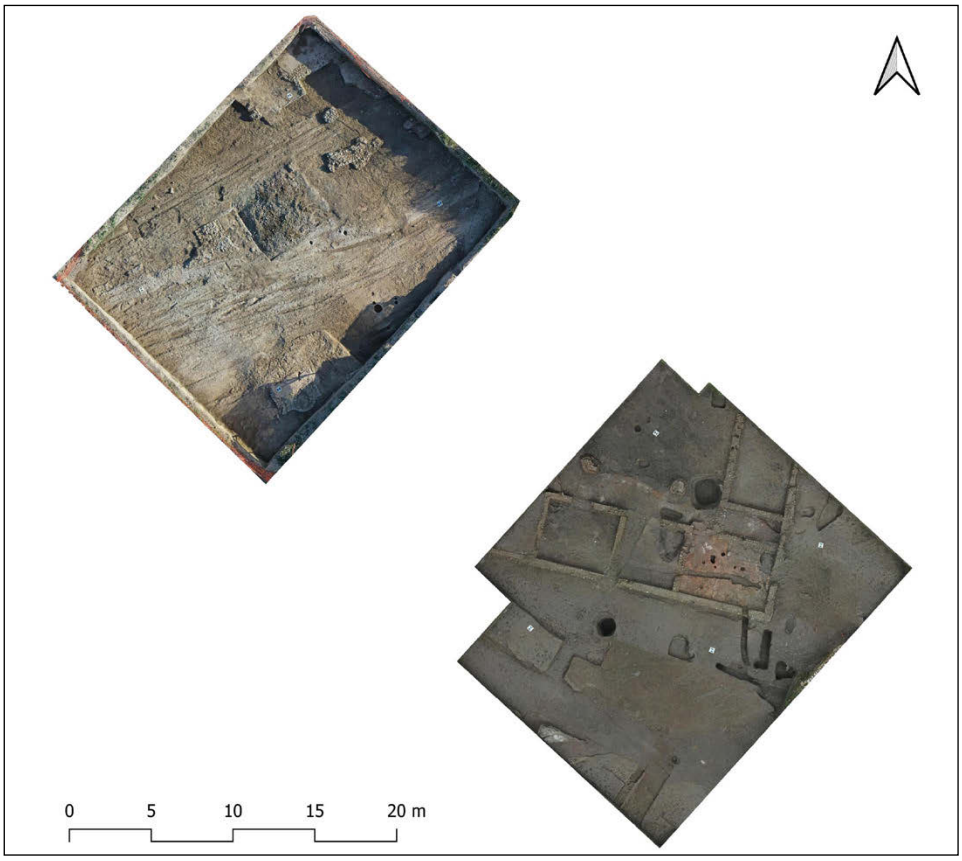


Fig. 3 – Ortofotomosaico della villa VI01 Plinti 7-8.

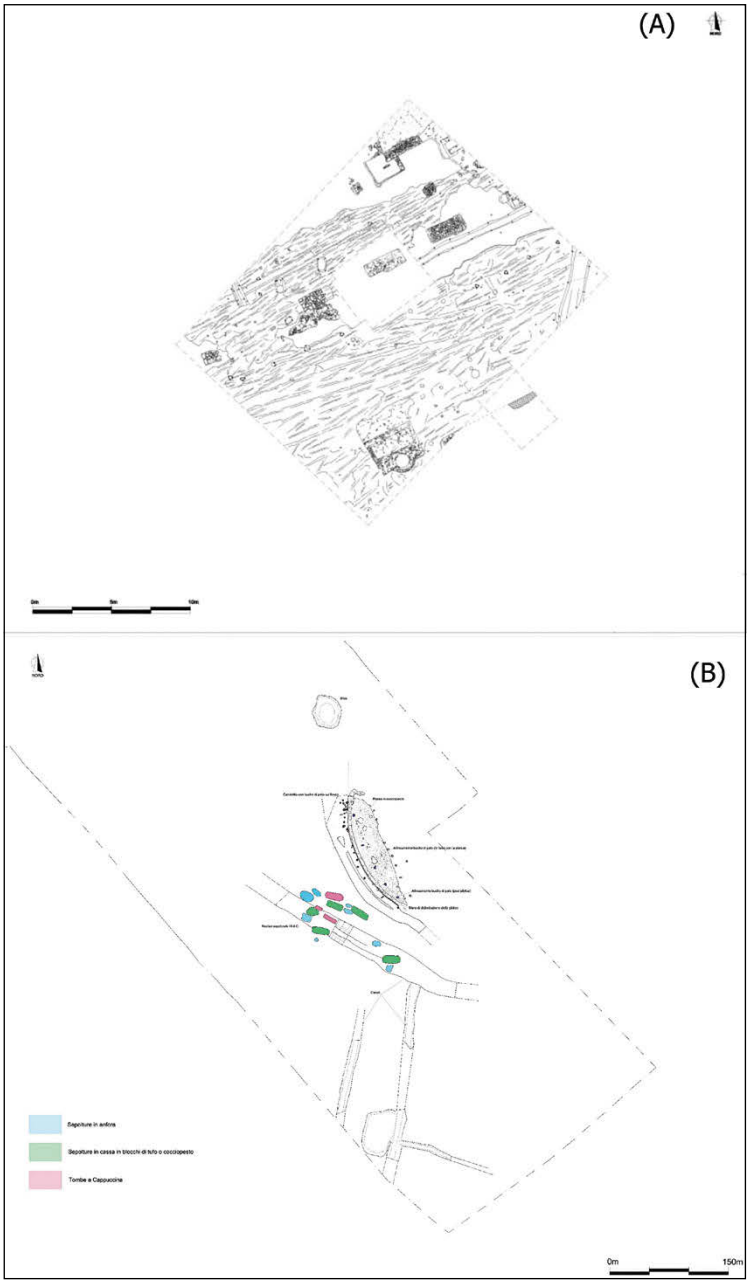


Fig. 4 – Planimetria delle evidenze romane dei contesti VI01 Plinto 7 (A) e RI02 (B).

Non è ancora chiaro il legame tra tali strutture e gli ambienti individuati nella vicina pila 7 (Fig. 4A). Qui, ai lati di un ampio e poderoso battuto stradale, si sono rintracciate a S alcune strutture (conservate a livello di fondazione) riferibili a un pavimento in cocciopesto a pianta rettangolare e a un pozzo costruito in muratura sul lato S, mentre un ulteriore strato di cocciopesto è visibile su un'area a pianta pseudorettangolare (4×1,50 m ca.). Lo scavo del riempimento del pozzo ha evidenziato la presenza di uno scarico omogeneo e sincronico di materiali, tra i quali sigillata africana o africana da cucina e vetri, inquadrabili tra la seconda metà del II e l'inizio del III sec. d.C. Sul lato N del battuto è stato rinvenuto un ampio piano pavimentale in cocciopesto che, a S, è fronteggiato da una vasca e da grossi basamenti di pilastri. Pare evidente quindi che su questo lato si conformasse un porticato. La datazione del complesso nella sua prima fase si colloca nella prima metà del I sec. d.C., cui seguono successive modifiche avvenute nel corso del I e del II sec. d.C. Senza alcun dubbio la fase di abbandono è determinata da strati contenenti ceramica di IV-V sec. d.C., obliterati dall'eruzione di Pollena.

Nel complesso edilizio sembra potersi riconoscere una villa rustica, alla quale, forse in un secondo momento, si affiancò una importante direttrice stradale che comportò la trasformazione dell'edificio in *statio* o *mansio*: la presenza infatti di pozzi e di vasche per l'approvvigionamento idrico, connessi a un porticato, pare compatibile con le funzioni di tali strutture. La direttrice stradale inoltre è particolarmente interessante perché pare uscire da *Acerrae* e dirigersi verso O, evidentemente per raggiungere *Atella* o un qualche *vicus* o *pagus* ad essa prossimo. Alla fase di vita della struttura seguì la sorte delle altre strutture coeve, vale a dire l'abbandono e la trasformazione in sepolcreto rinvenuto presso il plinto 6, poco più a NO, la cui vita ha una lunga durata tra la fine del I e il V sec. d.C., obliterate da Pollena, che si riallacciano alla fase di abbandono della villa rustica del plinto 8 e sono coeve al sepolcreto postovi all'interno.

4. La villa di Afragola RI02

Seguendo la direttrice della erigenda tratta ferroviaria, poco più a NO, lo scavo dell'interferenza Snam e l'attacco del viadotto VI01 con il rilevato RI02 e l'interferenza IN03 ha messo in luce parte di un'ulteriore villa romana (Fig. 4B). Nel primo scavo Snam è stato individuato un grande edificio, di cui rimane parte di uno spazio aperto pavimentato in finissimo cocciopesto e bordato sui lati da muri probabilmente in reticolato, di cui restano poche tracce a causa di una poderosa opera di spoliazione in epoca tardo-antica. Le indagini eseguite nell'area vicina hanno portato alla luce una struttura collegata alla prima, sempre in cocciopesto, ma bordata con blocchetti di pietra disposti a formare un semicerchio. Sulla faccia esterna del muretto si

conserva un rivestimento in malta idraulica e, oltre questo, è un taglio che segue l'andamento curvilineo del muro, probabilmente una canaletta. Sul fondo di quest'ultima si leggono buche di palo a pianta circolare che seguono l'andamento della struttura. Anche la pavimentazione in cocciopesto di forma semilunata è tagliata da numerose buche di palo: in particolare si individua un allineamento di almeno cinque buche, parallelo al muretto in blocchetti, ad una distanza di circa 2 m l'una dall'altra. Fosse subcircolari di dimensioni e forme diverse e buche di palo di dimensioni minori si dispongono su tutta la superficie del cocciopesto, senza un'apparente disposizione funzionale. Un allineamento più chiaro si legge in prossimità del margine E della platea dove si individua una serie di buche circolari di piccole dimensioni che seguono il profilo della pavimentazione. Sulla funzionalità della struttura restano molti dubbi. Si potrebbe ipotizzare che essa funzioni insieme alle buche di palo, apparentemente coeve, e l'insieme sia pertinente a pali per recinzioni o a un impianto di colture arboricole.

Potrebbe quindi trattarsi di un settore legato alla produzione e lavorazione agricola e quindi all'organizzazione degli spazi agrari di una grande villa latifondiaria. Inoltre nelle immediate vicinanze il rinvenimento di una fossa per silos e, un centinaio di metri più a NO, di un pozzo in muratura indizierebbe verso la vocazione agricola dell'area. La costruzione di tale edificio, di cui purtroppo mancano quasi totalmente l'elevato e il perimetro, si colloca tra la fine del I sec. a.C. e l'inizio del I d.C. Contemporaneamente si sviluppò nell'area vicina un sepolcreto a carattere sparso, la cui estensione è impossibile ad oggi circoscrivere, databile tra la fine del I sec. d.C. e il V sec. d.C.

5. La villa di Acerra NV09 (loc. Spiniello)

Verso Acerra, in località Spiniello, nell'area compresa tra *Acerrae* e *Suessula*, le indagini, realizzate in funzione di una nuova viabilità stradale (NV09), hanno portato alla luce un complesso pluristratificato frequentato tra il III sec. a.C. e il V sec. d.C. (Fig. 5A). La superficie indagata, pari a 1250 mq circa (50×25 m circa), ha restituito fasi di vissuto consequenziali e fra loro connaturate, frutto di interventi edilizi antichi di costruzioni, ampliamenti, demolizioni, ristrutturazioni, concentrati in uno spessore stratigrafico limitato e fortemente inficiato da interventi agricoli moderni. Il nucleo più antico, localizzato nel settore N dell'area, è costituito da tre ambienti a pianta rettangolare ed è caratterizzato da strutture murarie perimetrali in blocchi di tufo residuali nell'unico filare sotto fondante; tale nucleo risulta attribuibile, nel suo momento di edificazione, al periodo compreso tra il III e il II sec. a.C.

Tra la fine dell'età repubblicana e la prima età imperiale è possibile ascrivere un significativo intervento di riassetto/riqualificazione della realtà insediativa, mediante la realizzazione di un muro perimetrale in opera reticolata



Fig. 5 – Planimetria delle evidenze romane dei contesti NV09 (A) e RI04 (B).

che ingloba parte della più antica muratura in blocchi, chiudendo lungo i lati E e S l'intero complesso. A questa fase fanno capo una serie di operazioni di livellamento del piano di frequentazione, funzionali alla costruzione di pilastri in muratura a sostegno, presumibilmente, di un porticato gravitante intorno ad una vasca rivestita in cocciopesto. Lungo il lato orientale sono ricavati due ulteriori ambienti, anch'essi scanditi internamente da pilastri in muratura; quello meridionale è dotato, in un secondo momento, di un pozzetto e di un fognolo funzionale al deflusso verso l'esterno delle acque meteoriche dell'area porticata e/o di quelle provenienti dalla vasca centrale.

L'analisi preliminare dei materiali ceramici provenienti dai livelli di frequentazione del settore centrale sembrerebbe confermare una prevalente vivacità insediativa tra la fine del I e la metà del II sec. d.C., alla quale fa seguito il decremento della quantità degli indicatori cronologici. Nell'angolo esterno NO, inoltre, la presenza di una sepoltura infantile databile alla fine del II-III sec. d.C. lascia ipotizzare la continuità di utilizzo e frequentazione dell'area anche nella tarda età imperiale, seppur con dinamiche differenti rispetto alla fase precedente. È questo il momento al quale è possibile riferire gli ultimi interventi di ristrutturazione edilizia leggibili, in particolare, sulle strutture del nucleo più antico, caratterizzate dall'uso di materiali di risulta legati da malte poco tenaci.

La presenza antropica è attestata, ancora, nel IV-V secolo; a questo periodo possono essere ricondotte le attività di demolizione e spoliazione programmatica degli elementi murari ancora *in situ* e il recupero dei materiali fittili (ad es. tegole e coppi), come testimoniato dalla presenza di accumuli di elementi di risulta stoccati in più punti dell'area di scavo e/o in grosse fosse ricavate all'interno degli ambienti ormai defunzionalizzati. Nel caso dell'NV09 assistiamo all'unico caso finora documentato nella zona di un utilizzo continuativo di un complesso edilizio dall'età ellenistica fino al tardo-antico. Non è ben chiaro quale potesse essere la funzione del primo edificio, poi trasformato in una struttura produttiva. La presenza di tre vani, con un pronao di due file di pilastri sembrerebbe ricondursi a edifici di culto, benché non si possa escludere una continuità funzionale e la demolizione di murature più antiche nelle fasi più recenti. I dati cronologici però ci permettono di accrescere le informazioni sulle fasi immediatamente successive alla conquista romana nel territorio di Acerra.

6. La villa di Acerra RI04

Sempre nel comune di Acerra, a E del centro antico, è stato individuato lungo il tracciato ferroviario RI04 (Fig. 5B) un edificio a pianta quadrangolare, composto da quattro ambienti (sul versante occidentale), prospicienti su un ampio cortile dotato di un pozzo (situato nella parte N-NO). L'edificio

era costituito da un'ampia fondazione, larga da 1 a 0,60 m circa, ricavata all'interno di un taglio con pareti verticali e rastremate, su cui poggiavano gli alzati, poco conservati, costituiti da blocchi squadrati in tufo giallo tenuti da un nucleo in cementizio. All'esterno, sono state intercettate tre strutture di forma quadrangolare, interpretabili come basi per pilastri, che lasciano ipotizzare che almeno una parte del cortile in origine fosse dotata di una copertura. La cultura materiale indica un periodo di vita della struttura tra I sec. a.C. e I sec. d.C. Una sepoltura a *enchytrismos* rinvenuta poco fuori l'edificio data la frequentazione ancora al II sec. d.C., che continuerà fino al tardo-antico prima della consueta spoliazione e all'obliterazione da parte dell'eruzione di Pollena.

Si tratta anche in questo caso di una villa rustica con ambienti, molti non conservati, distribuiti intorno ad un cortile interno. A differenza dei casi finora citati non vi è alcun utilizzo quale sepolcreto all'interno della struttura.

7. La villa di Acerra RI05 (loc. Masseria Montesanto)

Un'altra importante villa, la più estesa finora rintracciata, è emersa in località Masseria Montesanto, nella periferia NE di Acerra, lungo il tratto ferroviario RI05 (Fig. 6A). Dell'impianto sono riconoscibili i muri perimetrali settentrionale, orientale e occidentale, oltre ad alcune partizioni interne. Le murature risultano tutte rasate poco al di sopra del piano di spiccato. Tecnicamente si è di fronte a costruzioni in conglomerato cementizio che vedono l'impiego di paramenti sia in opera reticolata sia in blocchetti di tufo. I piani pavimentali presentano sia cocciopesto, sia superfici calpestabili in semplice terra battuta. A livello di organizzazione degli spazi, sul fronte settentrionale, si dispongono sei ambienti a pianta rettangolare delle dimensioni medie di 4×5 m, verosimilmente vani di servizio a giudicare sia dalla semplicità dei rivestimenti pavimentali, sia dalla prossimità in alcuni casi con ambienti forse a carattere produttivo. Questi ultimi vengono a comporre il quadro architettonico del fronte occidentale dell'edificio. All'estremità settentrionale di quest'ala si trova il vano E (7×10 m) che ospita una vasca in cocciopesto con dolio interrato, destinato forse a contenere liquidi (olio, vino?) o adibito a pratiche di altra natura, come ad esempio attività connesse alla tinteggiatura di tessuti. Più ampia è, invece, la superficie occupata dall'ambiente D (ca. 49 m²), un vano rettangolare, con un dolio interrato.

Maggiormente elaborata è la configurazione del fronte meridionale del complesso. È qui presente una doppia fila di ambienti, di forma sia rettangolare che quadrata, pavimentati in cocciopesto, di superficie compresa tra 25 e 14,30 m². Il settore centrale è un'area scoperta, forse una sorta di impluvio, come sembrerebbe suggerire la configurazione morfologica del terreno connotata da un pronunciato avvallamento. A presunte modifiche successive

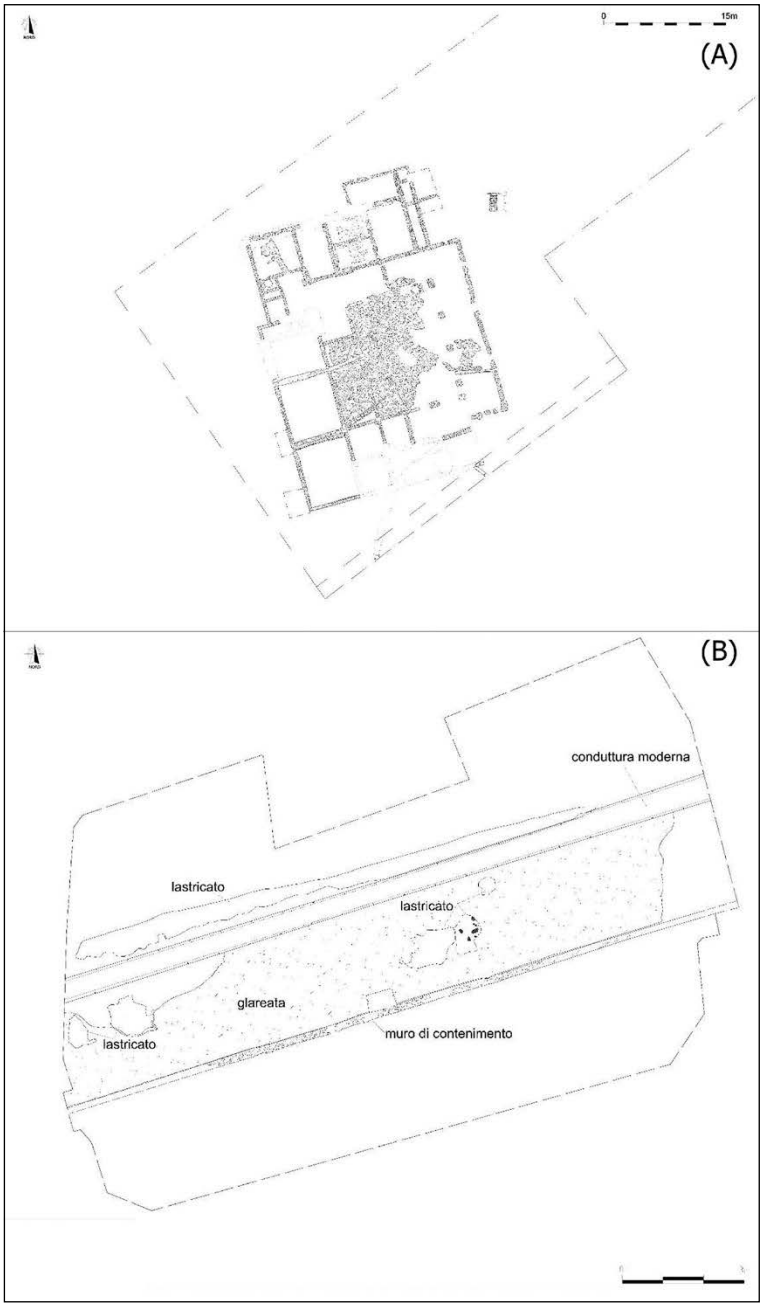


Fig. 6 – Planimetria delle evidenze romane dei contesti RI05 (A) e SL05 (B).

potrebbe, invece, essere attribuito l'allestimento dei vani S e C, situati rispettivamente sul fronte settentrionale e meridionale della villa. Si tratta di ambienti che si discostano dall'impianto originario o per tecnica edilizia (ambiente S), o per orientamento (vano C). La viabilità di servizio rinvenuta subito all'esterno del fronte orientale della villa è costituita da una percorrenza in terra battuta creata, probabilmente, sia per consentire l'ingresso all'edificio sia per metterlo in comunicazione con il territorio circostante.

Importante è anche segnalare che negli scavi preventivi antecedenti al rinvenimento della villa sono state trovate tracce del paesaggio agrario circostante. A E è emersa una serie di incisioni lineari che descrivono articolate configurazioni planimetriche in cui è, forse, plausibile riconoscervi sistemi di piantumazioni e organizzazioni di "aree verdi". Ad implementare un simile scenario concorrono anche alcune fosse rettangolari disposte su file parallele con andamento N-S e scavate ad intervalli regolari. La loro distribuzione spaziale e la configurazione morfologica mostrano singolari corrispondenze con quanto, ad esempio, prescritto da Columella (*Res rust.*, V, 53) a proposito delle tecniche di coltivazione della vite.

La non perfetta convergenza d'orientamento tra le strutture della villa e l'andamento di alcuni dei diversi sistemi di piantumazione potrebbe suggerire un assetto non creato sincronicamente, ma che per un certo periodo ha comunque convissuto e quindi partecipato ad un univoco paesaggio. La villa e la sistemazione agraria risultano, infine, obliterate dalla formazione eruttiva dell'Unità di Pollena.

8. La strada SL05 di Acerra (loc. Gaudello)

Nel settore più a NE di Acerra, in località Gaudello, tra via dei Sanniti e via Benevento, è emersa una importante direttrice stradale, nello scavo SL05 (Fig. 6B); è stata identificata un'articolata stratigrafia di battuti stradali orientati, approssimativamente, EO e riferibili ad un ampio arco cronologico compreso tra l'età romana e moderno-contemporanea. Nella prima fase, la pavimentazione appare costituita da ciottoli di pietra calcarea, di medie dimensioni nella sua parte centrale; mentre in ghiaia sub-centimetrica e centimetrica e sabbia nella parte laterale che costituisce una via glareata. Nella seconda fase, il fondo stradale è realizzato con blocchi di travertino. Tale tracciato stradale sarebbe interpretabile, in via del tutto preliminare, come un diverticolo della via Appia o della Capua-Reggio.

9. La villa e le divisioni agrarie RI07 di Acerra (loc. Gaudello)

Un ultimo settore, tra i tanti, pare essere interessante ai fini della ricostruzione del sistema agrario di epoca romana nella bassa Piana Campana. Presso l'ultimo tratto ferroviario, nominato RI07, in località Gaudello, nelle

prossimità della stazione di Cancello, è stata rinvenuta parte di una struttura forse ascrivibile a una villa rustica molto mal conservata. Più importante però è rilevare la stratificazione del territorio a S di essa. Nella parte più alta sono emersi tre assi viari in terra battuta, in differente stato di conservazione e orientamento, ma convergenti. Il primo percorso attraversava diagonalmente il saggio, dalla sezione O alla sezione N, ed era costituito da diversi cordoli di terreno; il secondo risultava ben conservato, ad eccezione di due crasi registrate nella porzione centrale e centro meridionale del suo sviluppo. In via del tutto preliminare e in attesa dei dati cronologici provenienti dallo studio del materiale ceramico si propone una loro datazione in una fase posteriore al IV d.C.

Al di sotto di questi battuti e di sepolture a cappuccina, l'indagine ha messo in luce il piano di frequentazione databile alla prima età imperiale, consistente in un complesso sistema di canalizzazioni presenti su tutta l'area di scavo, di dimensioni e profondità diverse che si affiancano o si incrociano ad angolo retto secondo uno schema piuttosto complesso, probabile risultato di azioni e interventi diacronici. Oltre ai canali, che hanno restituito materiali che ne datano l'abbandono al IV sec. d.C., vi sono anche grosse fosse di forma subcircolare, con probabile uso di pozzi.

10. Conclusioni

Dalla documentazione qui presentata, sintesi di una complessa stratigrafia archeologica di un territorio abitato fin dall'età del Bronzo, emerge un quadro interessante della frequentazione di epoca romana, tardo-antica e medievale. I processi di formazione degli insediamenti e la loro trasformazione paiono essere univoci: la fertile Piana Campana, sul finire del I sec. a.C., probabilmente a seguito della pace seguita agli sconvolgimenti che il territorio aveva subito con le guerre civili, viene capillarmente occupata da edifici di sfruttamento del territorio, la cui vita può seguirsi fino al medio-impero. L'impianto planimetrico pare seguire quello canonico noto anche dalle ville rustiche della vicina Valle del Sarno (Esposito 2020, 2021), con un cortile centrale e ambienti su esso affacciati con scopi prettamente funzionali. Alla *pars rustica* si affianca una *pars urbana* contraddistinta anche da una certa ricercatezza, come dimostrano il materiale decorativo e la suppellettile rinvenuti. L'intenso sfruttamento del territorio comporta evidentemente anche un certo numero di lavoratori e abitanti delle strutture che portano in una fase avanzata dell'età imperiale alla predisposizione di sepolcreti privati, fortunosamente rintracciati per tutte le ville qui presentate. La parabola discendente dell'ordinamento socio-politico dell'impero romano e forse anche la trasformazione del sistema di sfruttamento del territorio verso una struttura maggiormente latifondista portano a un progressivo abbandono e smantellamento delle ville rustiche, che appare in tutti i casi netto, sincronico e radicale. Le fondazioni

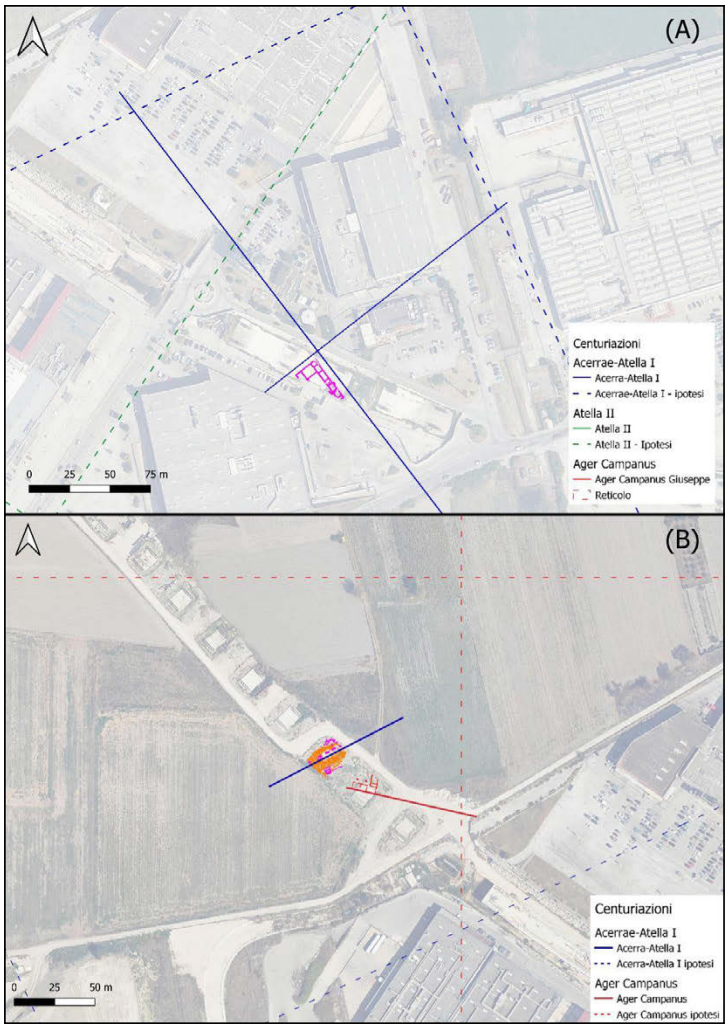


Fig. 7 – VI01 Plinti 7-8 (A); 18-21 (B).

o le basi dei muri delle ville vengono sfruttate per collocarvi sepolcreti più o meno organizzati, che però si pongono anche in continuità con le sepolture precedenti poste in spazi definiti e in luoghi prossimi alle residenze.

Un elemento appare però importante per la definizione degli assetti organizzativi del territorio. È ben noto come l'area tra Acerra e *Atella* sia stata interessata da importanti studi sulle centuriazioni, grazie alla continuità d'uso con finalità agrarie delle sue fertili pianure e anche di una densità abitativa molto

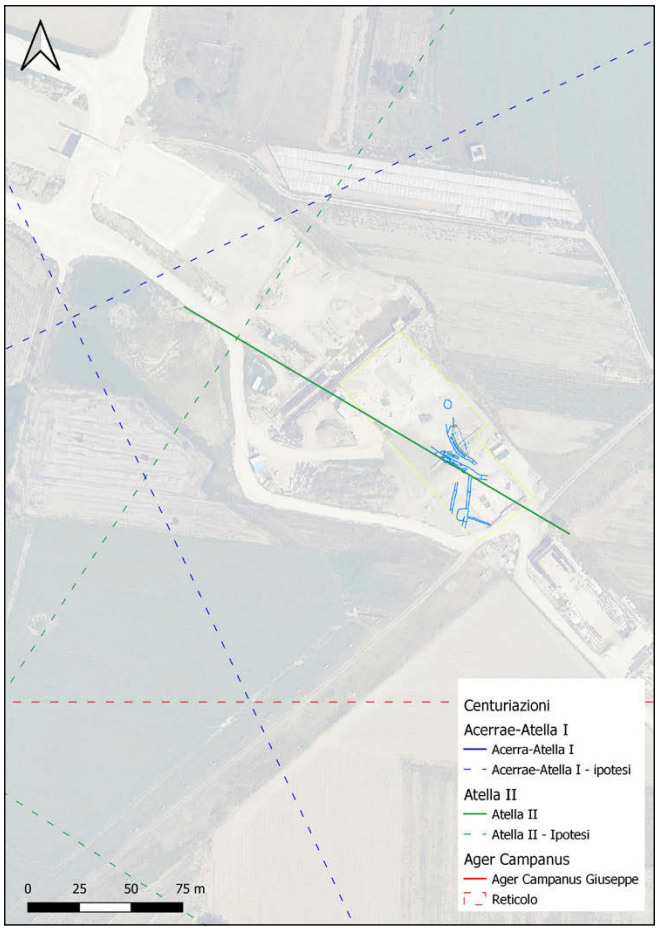


Fig. 8 – Osservazioni sulla villa RI02.

minore rispetto ad altre aree della Campania antica. Sono state individuate principalmente due divisioni agrarie: la prima denominata "Acerrae-Atella I" è stata datata o in età augustea (Chouquer *et al.* 1987, 90, 207) o al II sec. a.C. (Giampaola 1997, 231-232); la seconda è chiamata "Atella II" ed è stata collocata in un periodo posteriore a Silla (Chouquer *et al.* 1987, 90, 208-209). Volendo tentare ora di collegare i nuovi dati alle conoscenze già sedimentate nel corso degli studi di settore si arriva ad alcune conclusioni importanti.

La villa di Afragola VI01, Plinti 18-21, presenta un orientamento dell'edificio a prima vista non coincidente con gli orientamenti delle divisioni agrarie note. Tuttavia, prolungandone i lati, ci si rende conto che l'unica

possibile affinità potrebbe esservi con il sistema "Acerrae-Atella I". Nel caso di VI01 Plinto 7, molto vicino al precedente, si nota innanzitutto la presenza di un asse viario, perfettamente orientato secondo il sistema "Acerrae-Atella I", che conferma quanto asserito per la struttura dei Plinti 18-21 e la loro interconnessione (Fig. 7A).

La villa cui si lega l'asse viario del Plinto 7, vale a dire il Plinto 8, non sembra rispetti alcun orientamento in particolare. Il prolungamento di uno dei lati permette forse di ipotizzarne qualche leggera affinità con il sistema "Ager Campanus" (Monaco, Clavel-Lévêque 2004, 188-200). Dal momento che le due strutture sono intimamente interconnesse, appare chiaro come la villa rustica sia stata realizzata dopo secondo il sistema "Ager Campanus" e si sia adeguata all'avancorpo porticato che intercettava l'asse stradale orientato secondo il sistema "Acerrae-Atella I", trasformando l'edificio in una possibile *statio* o *mansio* (Fig. 7B).

Rimanendo sempre ad Afragola, per le strutture di RI02 il dato più rilevante è che l'evidenza centrale risulta perfettamente orientata secondo il sistema "Atella II" (Fig. 8). Passando ad Acerra, la villa rustica RI04 presenta un orientamento dell'edificio, seppur non perfettamente allineato, affine alla

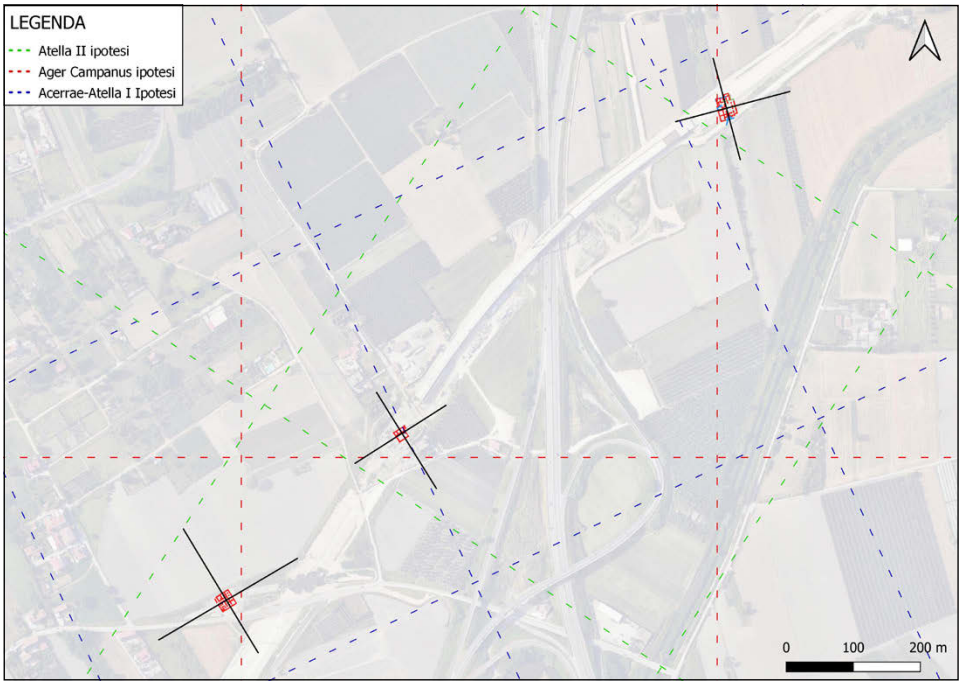


Fig. 9 – Osservazioni sui contesti RI04, RI04-NV09, RI05.

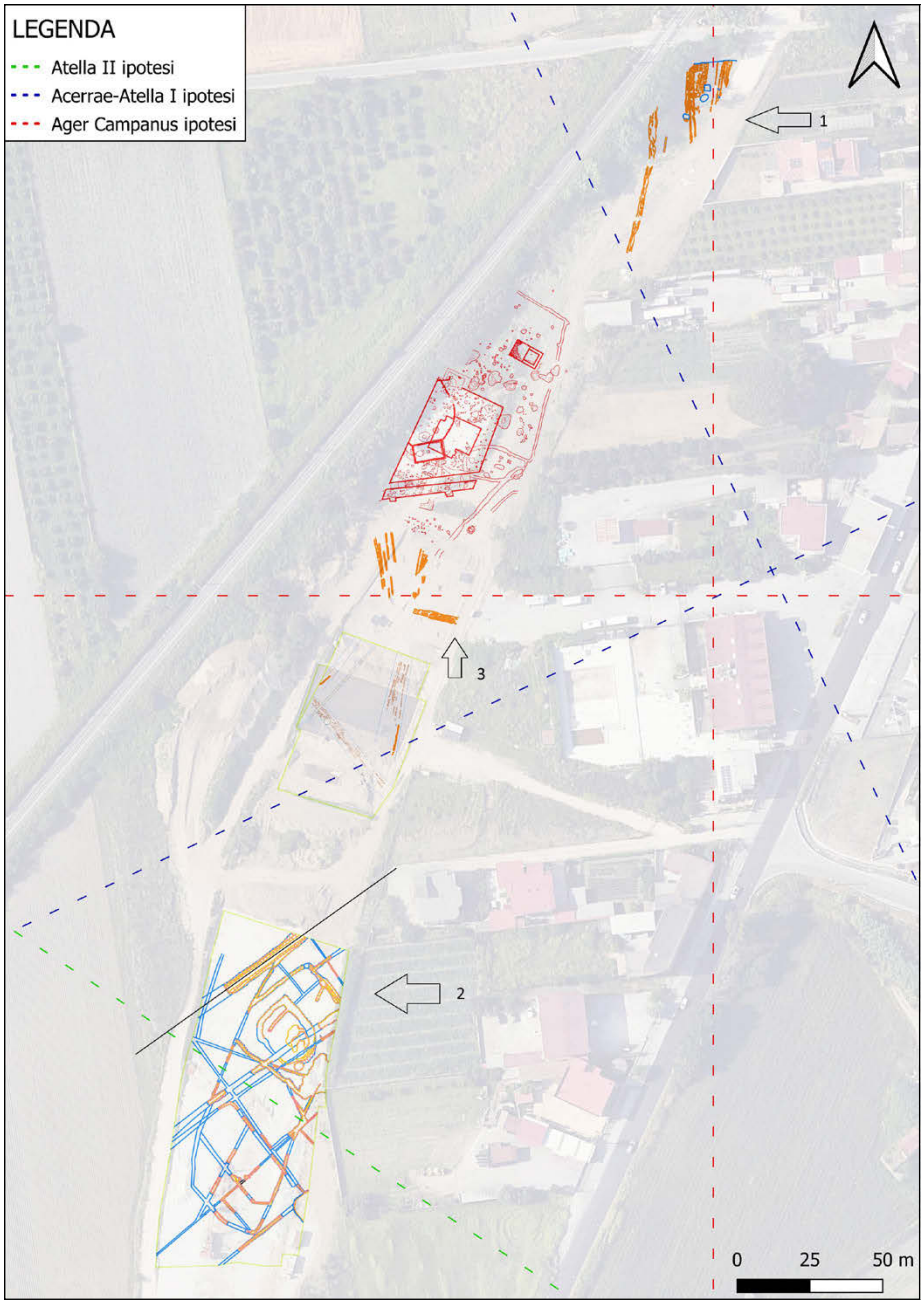


Fig. 10 – Osservazioni sui contesti RI07, RI06-SL05.

divisione agraria "Acerrae-Atella I" (Fig. 9). Secondo la ricostruzione un asse centuriale sembrerebbe passarvi nelle immediate vicinanze. Ciò perché la ricostruzione è prettamente teorica, basata sulla divisione in quadrati regolari di 16×16 *actus* (568×568 m). La villa rustica, con prima fase al III sec. a.C. ma funzione probabilmente differente, di NV09 mostra un orientamento coincidente con la centuriazione "Acerrae-Atella I". In effetti, data l'area in cui esse si trovano, è altamente probabile il loro inserimento in quel sistema (Fig. 9). La grande villa rustica di RI05, come per le due vicine strutture precedenti, mostra un orientamento dell'edificio, anche questo non perfettamente allineato, coincidente con la divisione agraria "Acerrae-Atella I" (Fig. 9). Possiamo invece raggruppare insieme la strada glareata e poi lastricata di SL05 e le divisioni agrarie di RI07, che sono quasi perfettamente coincidenti con il sistema "Acerrae-Atella I" (Fig. 10), mentre i battuti di epoca tardoantica sembrano coincidere con l'orientamento della centuriazione "Ager Campanus". Ciò che si evince quindi è una netta prevalenza dell'assetto agrario di "Acerrae-Atella I" per le ville rustiche e le canalizzazioni di sicura impostazione augustea o primo imperiale. Se così fosse i dati qui presentati dovrebbero confermare una datazione di tale sistema all'età augustea, benché NV09 presenti lo stesso orientamento già nel III sec. a.C. Un dato importante è anche riservato alla presenza del sistema dell'"Ager Campanus" che in VI01 Plinti 7-8 si associa all'assetto "Acerrae-Atella I", denunciando chiaramente una diacronia tra asse viario e struttura produttiva e anche una precisa scelta divergente nella costruzione del nuovo ampliamento.

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ABSTRACT

The fertile plain of Acerra, within the Campania Felix, has yielded significant new data from the preventive excavations carried out along the Naples-Bari high-speed railway. The discoveries – mainly rustic villas and related agrarian structures – provide an unprecedented picture of the rural organisation between *Acerrae*, *Suessula*, and *Atella*. These settlements, dating from the late Republican to the early Imperial period and often lasting until Late Antiquity, illustrate the intensive agricultural exploitation of the area through integrated systems of villas, drainage canals, roads, and centuriations. Stratigraphic and spatial analyses reveal the coexistence of different cadastral grids, particularly the 'Acerrae-Atella I' and 'Ager Campanus' systems, testifying to successive phases of Roman territorial planning. The villas, later abandoned and reused as burial areas after the 4th century AD, mark the transformation of the rural landscape in response to broader socio-economic and political changes in the Roman Empire.

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UOMO E AMBIENTE A NOLA: I CASI DI VIA FEUDO E MASSERIA CIANCIULLI

1. Introduzione

L'area della città antica di Nola e il suo *ager* sono stati interessati dagli effetti dell'eruzione subpliniana cd. di Pollena, evento del Somma-Vesuvio datato al 472 d.C., che ha investito il territorio posto a NNE e a NNO dell'edificio vulcanico, con un deposito di caduta spesso tra 20 e 40 cm e con riporti alluvionali post-eruttivi il cui volume varia tra 60 cm e 15 m. Tale evento catastrofico ha sigillato il paesaggio tardo-antico, permettendo così di ricostruire aspetti dell'economia e della società del periodo. In particolare, le indagini archeologiche condotte nel corso degli ultimi decenni in area nolana hanno portato in luce un paesaggio caratterizzato dall'abbandono e defunzionalizzazione di alcuni dei più importanti edifici cittadini, tra i quali l'anfiteatro, dalla presenza di ville sia in ambito urbano che suburbano (Sampaolo 1986, 113-116; 1991, 162-168; 1996, 33-35; Lubrano *et al.* 2012; Cesarano 2018), alcune delle quali al momento dell'eruzione già in stato di abbandono e in parte spoliate (Cesarano 2018), nonché di complessi residenziali e produttivi come la villa in loc. Starza della Regina a Somma Vesuviana, dove al momento dell'eruzione alcuni ambienti risultano già abbandonati e in parziale stato di crollo, mentre altri erano obliterati da un terreno humificato e arato (Cesarano 2018). In generale, le testimonianze che vengono per così dire "fossilizzate" dalle coltri eruttive mettono in evidenza una società in crisi, priva delle risorse utili a mantenere in esercizio gli edifici pubblici e caratterizzata da una netta prevalenza delle attività agricole, che spesso subentrano obliterando strutture e anche aree destinate a necropoli.

Nel corso di campagne archeologiche condotte tra la fine del 2024 e il 2025, sotto la direzione scientifica della Soprintendenza Archeologia Belle Arti e Paesaggio per l'area metropolitana di Napoli, nel territorio di Nola (NA), sono state rinvenute tracce di occupazione databili tra la tarda età repubblicana e l'epoca tardoantica. Le aree oggetto di studio ricadono in proprietà private e precisamente la prima, in corrispondenza della frazione di Piazzolla, lungo via Feudo, la seconda presso la località Masseria Cianciulli. I dati ricavati testimoniano le trasformazioni e la continuità di vita del territorio di Nola fino ai nostri giorni.

Presso via Feudo è stato portato in luce un asse viario in terra battuta, che ha subito numerosi rifacimenti e interventi di manutenzione nel corso dei secoli. La strada, collocata nell'area suburbana a S della città antica, attraversava campi arati ed era affiancata da una piccola area necropolare.

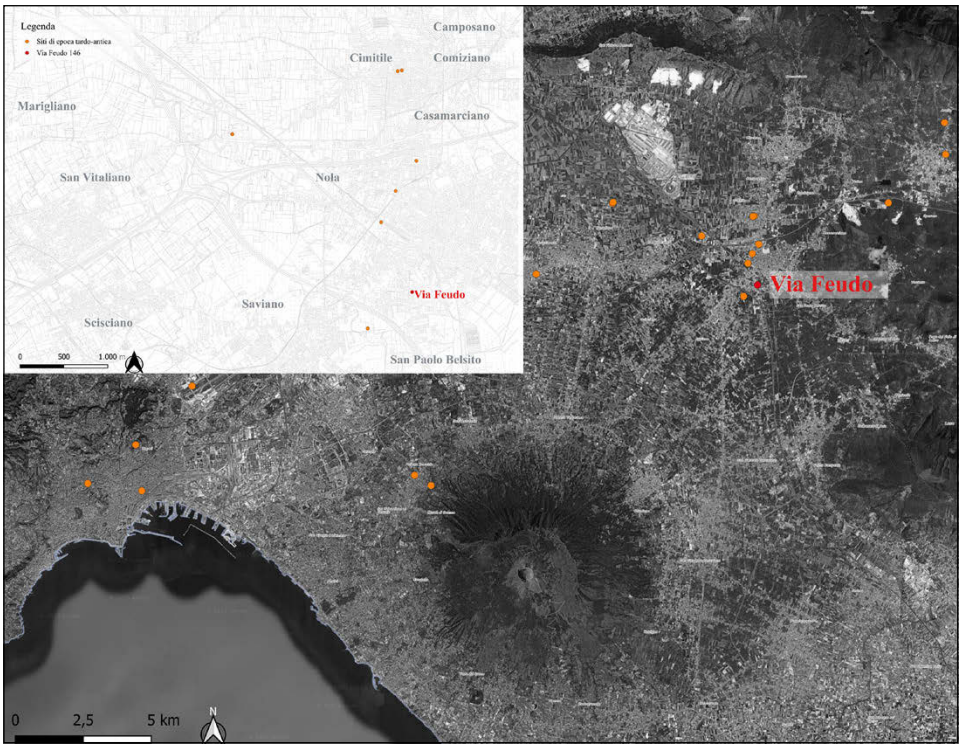


Fig. 1 – Nola (NA), via Feudo. Panoramica da Google Satellite: in arancio, i siti nel territorio di Nola in epoca tardoantica e ubicazione dello scavo in via Feudo.

Anche in località "Masseria Cianciulli", ubicata sempre nell'area suburbana ma a NO, le indagini preliminari ai lavori per la realizzazione di un impianto fotovoltaico, hanno permesso di intercettare una sequenza di campi arati e un battuto stradale. I due siti risultano frequentati dal II sec. a.C. al V sec. d.C., come testimoniano le diverse fasi occupazionali, scandite da una successione di livelli vulcanici e alluvionali.

In questa sede si presentano sinteticamente le fasi di occupazione di tale porzione di territorio provando ad inserire i siti nel quadro più generale di Nola e della Campania tardo-antica (Fig. 1).

2. Lo scavo in via Feudo: descrizione delle evidenze geo-archeologiche e della sequenza di occupazione

Già nel mese di giugno 2024, una serie di saggi preliminari aveva permesso di individuare una sequenza di cinque battuti stradali, frequentati in un

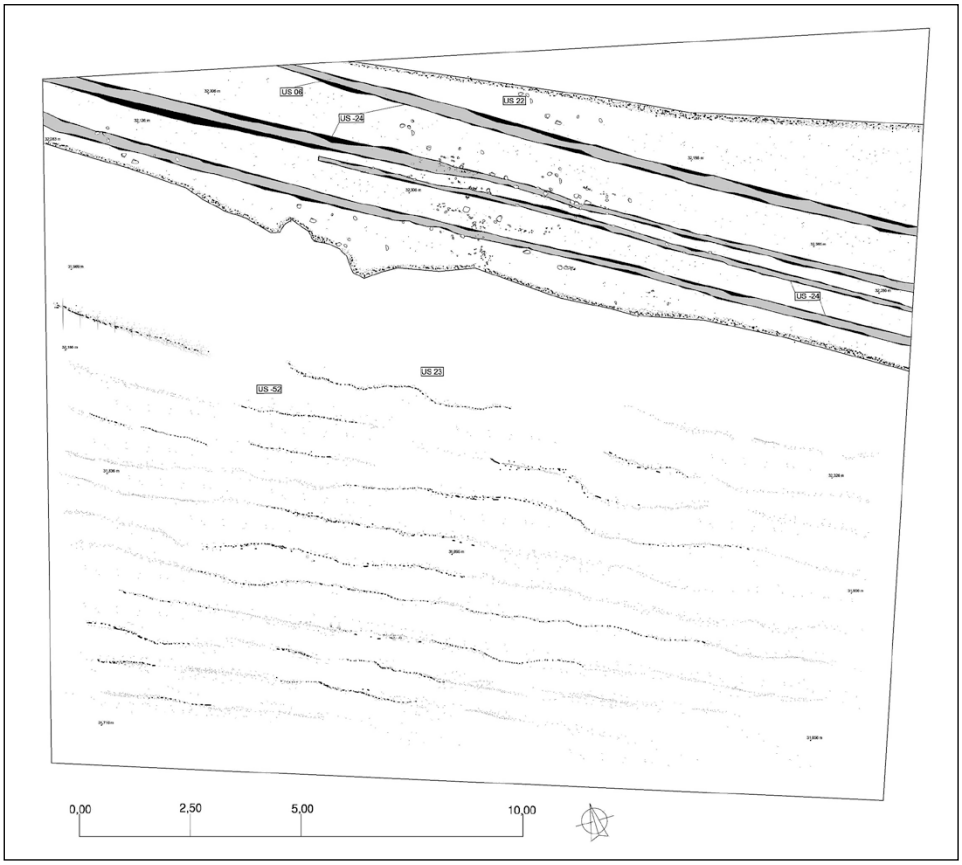


Fig. 2 – Nola (NA), via Feudo. Pianta di fase con solchi di aratura e battuto.

arco cronologico compreso tra la fine del II sec. a.C. e la fine del V sec. d.C. In considerazione di tali primi rinvenimenti, l'attività di scavo archeologico è proseguita in estensione, portando alla scoperta anche di un'area necropolare tardo-antica e di una frequentazione di età moderna. L'area oggetto di studio risulta occupata, senza apparente soluzione di continuità, dal II sec. a.C. all'età contemporanea, come testimoniano numerose evidenze antropiche pertinenti ad una frequentazione anche in epoche recenti.

Gli strati post antichi sono tagliati dalle fosse di fondazione di muri in blocchi di tufo riferibili al primo impianto di una masseria moderna e da fosse riempite con materiale di scarto, databile al XVII-XIX secolo per il rinvenimento di ceramica diagnostica e di una moneta del Regno di Napoli di Ferdinando IV di Borbone (1759-1816). Alcune di queste grandi fosse, di

forma circolare[1], individuate presso il lato O e SO dell'area, sembrano essere state realizzate con l'intento di intercettare strutture/tombe antiche e hanno infatti tagliato quattro delle sepolture indagate, di cui due del tipo a cappuccina (T1 e T6), una in muratura (T5) e una a *enchytrismós* (T2). Tali interventi di spoliazione, come anche le attività agricole ivi condotte nel corso degli ultimi secoli, rendono talvolta problematica l'interpretazione delle evidenze archeologiche, avendo intercettato i tagli e rimaneggiato i riempimenti delle sepolture, come pure gli strati di terra battuta che costituivano l'asse stradale.

Lo strato vulcanico che sigilla l'ultima fase di vita tardo-antica è il deposito piroclastico riferibile all'eruzione di Pollena del 472 d.C., che si è adagiato sulla morfologia naturale del terreno e sulle tracce antropiche, quali strade, solchi di carro e arature. Rimossa la crosta eruttiva, infatti, è stato messo in luce un battuto stradale orientato NO-SE, sul quale risultano ancora visibili lievi solchi di carro, orientati NO-SE e riempiti dalla porzione basale del deposito di Pollena. Gli elementi diagnostici associati si datano entro la prima età imperiale.

La strada, che presentava nella sua fase originaria un'ampiezza di circa 5 m, era stata leggermente ridotta nell'ultima fase di occupazione precedente l'eruzione di Pollena, a vantaggio di un'area agricola caratterizzata da solchi di aratura paralleli a quelli impressi dal transito dei carri (Fig. 2). I materiali diagnostici associati si datano tra la tarda età repubblicana e la prima età imperiale. La rimozione dello strato di frequentazione agricola ha permesso di riportare in luce il battuto, delimitato da un cordolo, forse interpretabile come una sorta di stretto separatore dalla necropoli adiacente, databile dal I al V sec. d.C.

Al di sotto di questa strada in terra battuta ne è stata individuata un'altra, segnata da solchi regolari orientati NO-SE[2]. I materiali associati si datano tra la fine del I secolo a.C. e l'inizio del I secolo d.C. L'asse viario era servito da un profondo canale posto sul lato S che tagliava i precedenti battuti stradali. Tale apprestamento risulta essere stato colmato prima dell'impianto della necropoli: le sepolture, infatti, sono posteriori al suo riempimento. L'unico elemento diagnostico rinvenuto è un'olletta monoansata integra in ceramica di uso quotidiano (Fig. 10), simile ad un frammento proveniente dalla villa di Somma Vesuviana, nel contesto contemporaneo all'eruzione del 472 d.C. (Mukai 2010, 471-472, fig. 5, n. 23). Il fatto che il recipiente sia intero e contenga un chiodo in ferro e una moneta in bronzo induce a pensare che debba essere considerato come pertinente al corredo di una sepoltura, forse T19, del

[1] UUSS -20, 21, -36 e 37.

[2] I solchi, con interasse di circa 0,35/0,40, presentano dimensioni costanti: larghezza superiore ca. 0.2 m, larghezza inferiore 0,12, profondità tra 0,05 e 0,08 m.

tipo a *enchytrismós* datata tra la fine del II e la metà del III secolo d.C., nelle cui prossimità è stato rinvenuto (Ceci 2001, con bibliografia precedente).

Immediatamente al di sotto dello strato di battuto, ne è stato individuato un altro, con lo stesso orientamento, sul quale sono stati osservati solchi irregolari orientati NO-SE[3]. I materiali diagnostici rinvenuti nel corso dello scavo, concentrati nella parte più convessa della carreggiata a schiena d'asino, si datano entro il I secolo d.C. e sono soprattutto di natura edilizia (frammenti di intonaco e cementizio a base fittile con inserimento di tessere di marmo), forse provenienti dalla dismissione di edifici circostanti. Rimuovendo questo livello di battuto, è stato individuato un sottilissimo strato di terreno sabbioso grigio, che non ha restituito materiali e che potrebbe essere interpretato come uno strato di abbandono, testimonianza del fatto che la strada non è stata frequentata per un breve lasso di tempo. Al di sotto dello strato di sabbia, infatti, è venuto alla luce un altro strato di terra battuta, caratterizzato da solchi molto irregolari e poco leggibili, orientati NO-SE[4]. Dalla sua preparazione, spessa 0,20 m, proviene un frammento di ceramica a vernice nera di età tardo-repubblicana. Tale strato livellava l'irregolarità del piano e colmava il salto di quota del battuto precedente, caratterizzato da una marcata pendenza verso SE e da solchi regolari, conservati su tutta la superficie esposta e orientati nella stessa direzione[5]. Rimosso questo livello stradale, è stato individuato il sesto battuto, con tre evidenti solchi regolari[6], che ne copriva un altro, caratterizzato dalla presenza di scorie metalliche, che avevano verosimilmente la funzione di rendere più stabile e compatta la strada, anch'essa segnata da solchi regolari. I pochi materiali diagnostici associati a questi ultimi due battuti si datano alla tarda età repubblicana (II-I a.C.).

Adiacente e in fase con quest'ultimo livello, a S, è venuto alla luce un campo a destinazione agricola, caratterizzato dalla presenza di ampi e profondi solchi di aratura, con orientamento NS. Un approfondimento effettuato presso il settore N dell'area di scavo ha permesso di individuare altri due battuti stradali sovrapposti, il primo dei quali è percorso da solchi orientati NO-SE. Dall'ultimo battuto della sequenza stratigrafica provengono frammenti di ceramica a vernice nera e una moneta bronzea poco leggibile.

[3] I tagli hanno dimensioni variabili: larghezza superiore 0,25/0,20 m, larghezza inferiore 0.08/0.1 m e una profondità tra gli 0,08 e 0,05 m. Essi sono concentrati e ben evidenti a N, mentre sul resto della superficie sono meno leggibili in quanto intercettati dai solchi del battuto che lo copre.

[4] Larghezza superiore 0,30/0,25/0,20 m; larghezza inferiore 0,06/0,08/0,10 m; profondità tra 0,13 e 0,09 m.

[5] Larghezza superiore 0,25/0,2/0,16 m; larghezza inferiore 0,04/0,07/0,8 m; profondità tra 0,07 e 0,05 m.

[6] I solchi presentano dimensioni piuttosto regolari con una larghezza superiore di circa 0,25/0,20 m.

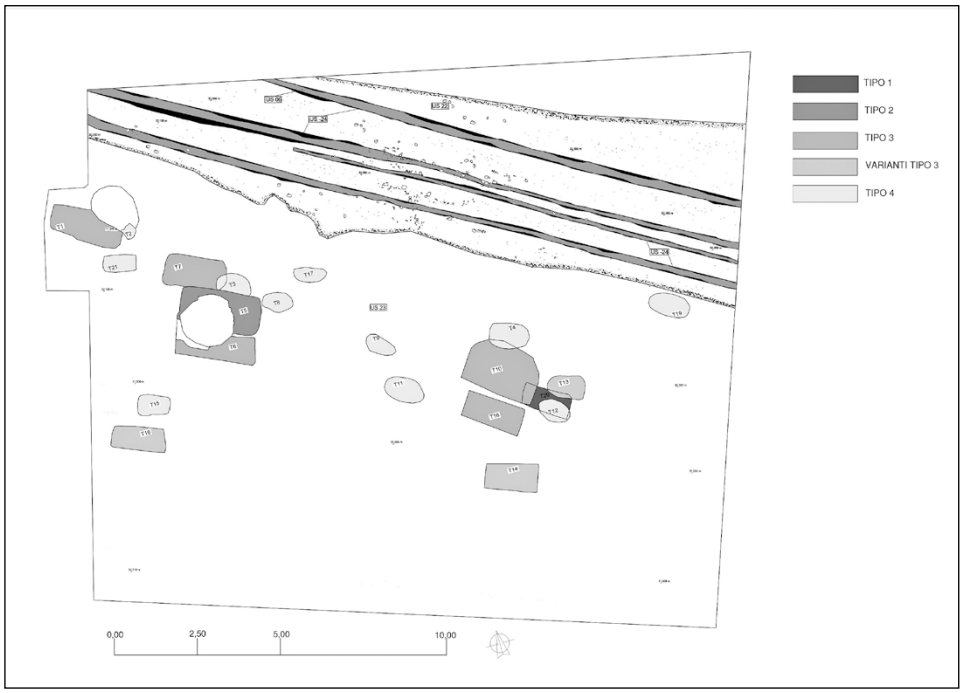


Fig. 3 – Nola (NA), via Feudo. Pianta di fase con asse viario in terra battuta fiancheggiato dall'area necropolare.

3. La necropoli tardo-antica in via Feudo

Tra il III e il V secolo d.C. l'asse viario in terra battuta viene delimitato da un cordolo di terreno e fiancheggiato da sepolture a inumazione, rinvenute in tutta l'estensione del tratto indagato. Sulla base della stratigrafia e del materiale associato, sono stati individuati almeno tre nuclei di deposizioni, forse a carattere familiare (Fig. 3). Lo scavo ha messo in luce tombe di diversa tipologia, ricorrenti in età romana e tardo-antica (Costantini 2008, 154), caratterizzate dall'impiego di materiali non necessariamente di risulta. Tutte le tombe sono orientate E-O, con la maggior parte dei defunti deposti con il cranio a O, tranne rari casi (T18 e T20).

L'analisi preliminare ascrive la maggior parte delle sepolture a infanti e sub-adulti, mentre solo due sembrerebbero di adulti (T1 e T7). Il piano deposizionale è generalmente realizzato con tegole poste di piatto, o in alcuni casi rivestito d'intonaco chiaro. Quattro tombe presentano un *pulvinus* (cuscino), in due casi realizzato in malta, altrove costituito dalla modanatura di una tegola. Nelle inumazioni di sub-adulti e adulti, il corpo è generalmente



Fig. 4 – Nola (NA), via Feudo: a) nucleo di deposizione a carattere familiare (T3, T5, T6) e tipologie di tombe; b) tomba in fossa terragna (T20); c) tomba alla cappuccina probabile sub-adulto (T13); d) tomba in cassa di laterizi (T5); e) tomba alla cappuccina con corredo (T7); f) tomba a *enchytrismós* (foto B. Musella).

in posizione supina, con le mani convergenti sul pube. La disposizione delle sepolture suggerisce una organizzazione pianificata iniziale, concentrata soprattutto lungo il fossato che fiancheggia la strada. Le tombe più antiche risultano più distanziate, mentre le più recenti sono disposte in modo più fitto e caotico, negli spazi liberi. Il progressivo affollamento, peraltro, ha determinato talvolta la sovrapposizione di deposizioni diverse e, di conseguenza, il danneggiamento delle fosse, dovuto anche alla probabile assenza di segnacoli duraturi in superficie. Le 21 sepolture si differenziano in quattro tipologie principali: una in semplice fossa terragna (tipo 1), una in cassa di laterizi (tipo 2), otto alla cappuccina (tipo 3) e 11 sepolture d'infanti in anfora, o *enchytrismós* (tipo 4) (Fig. 4).

Se per le sepolture infantili in anfora è evidente l'*upcycling* (riciclo) del contenitore, per le tegole, in alcuni casi analizzati, è probabile un impiego

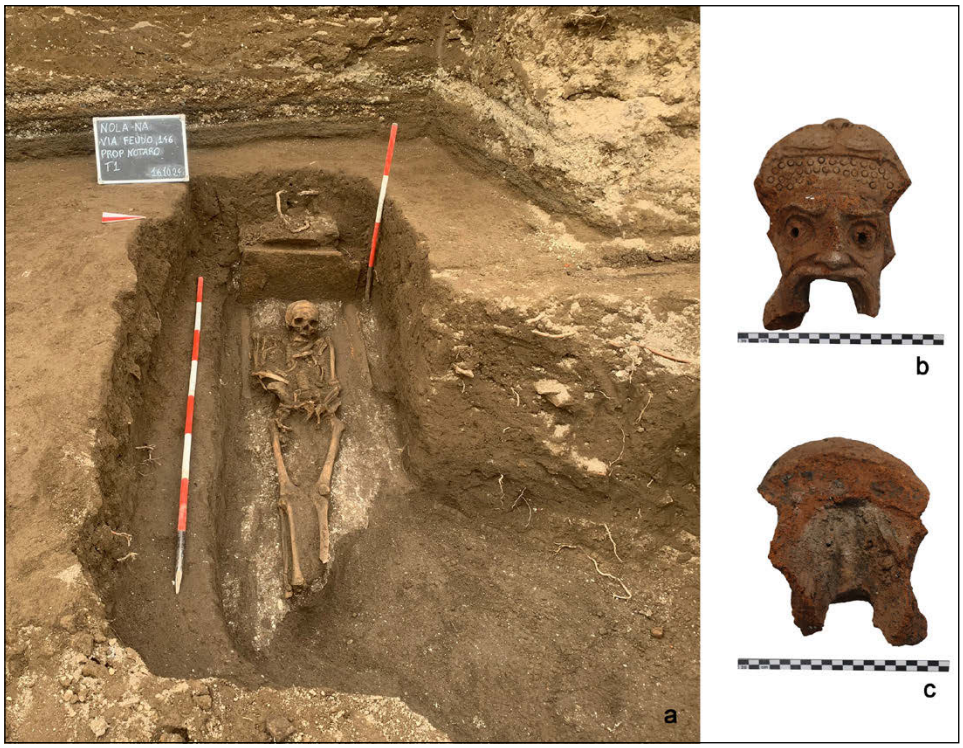


Fig. 5 – Nola (NA), via Feudo: a) tomba 1 alla cappuccina con cuscino (*pulvinus*) in malta (foto B. Musella); b-c) corredo della tomba 1: maschera fittile raffigurante Ercole (foto S. Piccolo).

primario per la costruzione della cassa e della copertura, secondario ovviamente nel caso di laterizi frammentari utilizzati per colmare vuoti. Le otto sepolture alla cappuccina (tipo 3) presentano una copertura a doppio spiovente, talvolta poggiante su una cassa in tufelli legati con malta. Tra queste, la T1 si distingue per il ritrovamento di una maschera fittile interpretabile come gocciolatoio, raffigurante Ercole: si riconoscono, infatti, la *leonté*, i capelli ricci e la barba (Fig. 5). Della maschera leonina sono raffigurati il naso, la bocca con i baffi e i denti, tra i quali sono evidenziati i due canini (Fig. 5b). In base al confronto della tecnica di esecuzione dei riccioli, simile ad antefisse da Pompei, il manufatto si data al I secolo d.C. (https://pompeiicommitment.org/en/inventario/masks-and-faces/). Le tombe T6 e T7, che affiancano la T5 (tipo 2) forse a formare un nucleo familiare, hanno restituito elementi di corredo in una piccola nicchia: una brocchetta acroma contenente un chiodo di ferro e una moneta di bronzo (Fig. 6c, d). La T18 ha restituito il corredo più ricco (olletta, lucerna bollata,



Fig. 6 – Nola (NA), via Feudo: a-c) deposizione, letto funebre e tegole con impronte di felino della tomba 7; d) olletta potoria globulare dalla T6 (foto S. Piccolo); e-f) copertura alla cappuccina e deposizione della tomba 10 con tegola utilizzata come cuscino (*pulvinus*) (foto B. Musella).

chiodo e moneta; Fig. 7) ed è costituita da tegole bollate poste a copertura (CA– PAEI NEREI, VITALIS GALLICI e ACVTI), che trovano confronti con i fittili di Pompei datati alla prima età imperiale (Fig. 8a, b, c). Sono inoltre state riconosciute varianti costruttive con cassa in muratura (tipo 3a; T13), doppia copertura piana (tipo 3c; T14) o copertura rinforzata con coppi (tipo 3b; T16).

La tipologia a *enchytrismós* (tipo 4), con undici deposizioni infantili, per i rapporti stratigrafici, sembra pertinente all'ultima fase di frequentazione della necropoli (Fig. 9). I contenitori riutilizzati per la sepoltura sono soprattutto anfore cilindriche di produzione africana (T2, T4, T9), datate tra il IV e il V secolo d.C. Sono attestate, tuttavia, anche anfore iberiche tipo Almagro 51/ Keay XIX, datate tra la seconda metà del III e il V d.C. (T3, T12) e il tipo Almagro 51C, datata tra il IV e il V d.C. (T11). Tra le produzioni sicule si annovera l'anfora tipo Ostia I 453-453, datata tra il III e l'inizio del V d.C.



Fig. 7 – Nola (NA), via Feudo: a) tomba 18 alla cappuccina con coppo utilizzato come cuscino (*pulvinus*) (foto B. Musella); b-d) corredo della tomba 18: olletta con coperchio al cui interno erano stati deposti una lucerna bollata, un chiodo e una moneta in bronzo (foto S. Piccolo).

(T8). La T9, costituita da un'anfora africana tipo Keay XXV, potrebbe essere pertinente ad un neonato, probabilmente di pochi giorni, seppellito all'interno del vaso tagliato a metà e chiuso con una pentola vera e propria, utilizzata come tappo, con la funzione di proteggere il corpicino, bloccandolo tra puntale e fondo della pentola. La pentola, di produzione locale, a imitazione della forma Hayes 197 in Africana da cucina, è a sua volta sigillata/coperta da una tegola frammentaria con aletta.

Alcune deposizioni sono più antiche, a giudicare dai contenitori impiegati: la T15 riutilizza un'anfora africana tipo Dressel 30, datata al III secolo d.C.; T17 e T19 reimpiegano anfore olearie africane cilindriche tipo Africana IB databile tra la metà del II e la metà del III secolo d.C. La T17 è notevole per l'ottimo stato di conservazione e per la presenza di elementi di corredo, ha restituito infatti un'olletta monoansata che conteneva un chiodo di ferro ed era sigillata da un coperchio rovesciato (Fig. 10).



Fig. 8 – Nola (NA), via Feudo. Tegole bollate: a, b, c, d) T18; e) T20 (foto S. Piccolo).

4. Lo scavo di Masseria Cianciulli

Le indagini condotte in località Masseria Cianciulli hanno permesso di intercettare una sequenza di campi arati databili dall'epoca romana sino a quella contemporanea, e un battuto stradale in uso fino all'arrivo dell'eruzione di Pollena, nel 472 d.C. La strada, orientata EO, larga 5,20 m e indagata per 12 m di lunghezza, risulta ben conservata con la tipica conformazione convessa a schiena d'asino e i solchi impressi dal transito dei carri. Lungo le estremità N e S, il battuto appare maggiormente alterato, con solchi meno marcati, mentre in alcuni punti è visibile una sovrapposizione di più carriaggi. È possibile notare, inoltre, la presenza di pietre calcaree inglobate, e che parzialmente rivestono i solchi dei carri, probabilmente con una funzione di rinforzo statico.

In questa fase, il tracciato doveva apparire come un percorso rurale alberato, di non poca rilevanza. Infatti, ai bordi della strada, dovevano essere collocati degli alberi, i cui negativi sono stati rinvenuti all'interno di cavità poste alla base del deposito eruttivo di Pollena. Le cavità, riconducibili al



Fig. 9 – Nola (NA), via Feudo. Tipologia di tombe a *enchytrismós*: a) T4: anfora cilindrica di produzione africana databile tra il IV e il V secolo d.C.; b) T8: anfora tipo Ostia I 453-453, databile tra il III e l'inizio del V d.C.; c) T12: anfora tipo Almagro 51C, databile tra il IV e il V d.C.; d, e) T19: anfora tipo Keay XXV, databile tra l'inizio del IV secolo e la seconda metà del V secolo d.C. tagliata a metà e chiusa con una pentola, utilizzata come tappo (foto B. Musella).

sub-fossile di un albero formatosi per il deterioramento del legno, conservano l'impronta della corteccia impressa nelle ceneri dell'eruzione. Rimosso il primo battuto è stata indagata una precedente sistemazione, leggermente traslata a S e ristretta rispetto alla precedente con un'ampiezza di 4,10 m e un interasse di 1,50 m, che si è rivelata risistemata più volte nel corso del tempo.

La strada, che risulta impiantata all'interno di un taglio concavo, realizzato probabilmente come cavo di fondazione e rivestito da uno strato dalla matrice argillosa, da una prima analisi dei materiali risulta cronologicamente inquadrabile all'età sillana, tra la fine del II secolo a.C. e il I a.C. (Fig. 11).

5. Considerazioni conclusive e accenni di ricostruzione storica

Le indagini condotte nell'*Ager Nolanus* hanno restituito un quadro di straordinaria continuità insediativa e di evoluzione del paesaggio rurale,



Fig. 10 – Nola (NA), via Feudo. Tomba 17: a-b) anfora olearia africana cilindrica tipo Africana IB databile tra la metà del II e la metà del III secolo d.C. (foto B. Musella); c) corredo T17: olletta monoansata con coperchio; d) olletta monoansata in ceramica di uso quotidiano dal riempimento del canale (foto S. Piccolo).

svelando assi viari in terra battuta in uso ininterrottamente dalla tarda età repubblicana (II-I sec. a.C.) fino al V secolo d.C. Questi rinvenimenti, sebbene frammentari, risultano fondamentali per affrontare il complesso tema della suddivisione agraria, soprattutto in un territorio reso notoriamente illeggibile dalle spesse coltri piroclastiche, dove solo lo scavo, talvolta, può fornire dati certi (Ruffo 2012, 86).

La persistenza e la cura di questi percorsi, evidenti nei molteplici rifacimenti e manutenzioni, appaiono in netto contrasto con il progressivo disinteresse per le infrastrutture che si registra nel tardo antico. Le strade, ampie circa 5 m, con la tipica conformazione convessa "a schiena d'asino", dimostrano una realizzazione accurata. La loro storia è una testimonianza di resilienza e adattamento: in via Feudo, ad esempio, i nove battuti sovrapposti raccontano di interventi che vanno dall'uso di scorie di ferro per stabilizzare



Fig. 11 – Nola (NA): a) via Feudo, panoramica da drone; b) Masseria Cianciulli, panoramica asse viario; c) catasto di Nola I-Abella su tavoletta IGM in scala 1:25.000, con indicazione dei casi studio.

la carreggiata, al ripristino con materiale edilizio, fino allo scavo di un canale in età augustea per ovviare agli allagamenti. Questa cura per l'asse viario si scontra con le profonde trasformazioni del tardo antico. Il canale di via Feudo, ormai colmato e defunzionalizzato, accoglie infatti sepolture databili tra il III e il V secolo d.C. L'impianto di aree di sepoltura ai margini dell'abitato di età classica si inserisce nel più generale fenomeno di trasformazione delle dinamiche occupazionali in età tardo-antica. In particolare, la distribuzione diffusa dei nuclei sepolcrali, che costituisce un segno peculiare di queste nuove modalità insediative, ben si colloca nella topografia coeva, caratterizzata da un nuovo modo di vivere il paesaggio urbano, la viabilità, la tipologia e la funzione degli edifici circostanti (Ebanista, Rotili 2016, 285).

Il dato più significativo è che, immediatamente prima dell'eruzione di Pollena, si registra una riduzione della carreggiata a favore di un'area di coltivazione che oblitera anche la necropoli, segnando chiaramente il definitivo prevalere dell'aspetto produttivo su quello funerario/sacro. L'inquadramento

di questi due assi nel reticolo centuriale offre risultati disomogenei e stimolanti per la ricerca futura. La strada rinvenuta a Masseria Cianciulli (loc. Camposano), con i suoi due livelli orientati EO, presenta una potenziale coerenza con una delle griglie del sistema Nola I-Abella (Chouquer *et al.* 1987, 209-210). Questo catasto sillano principale, la cui influenza è certificata anche dalla diffusione di toponimi "prediali" nell'area, tra cui Camposano (Ruffo 2012, 118), sembrerebbe quindi aver plasmato in modo duraturo l'assetto viario.

Di tutt'altro tenore è il risultato emerso per la strada di via Feudo. Nonostante si tratti di un diverticolo fondamentale per i campi arati, collegato a un asse principale basolato orientato NS (Cesarano 2021, 58-60; 2023), il suo orientamento NO-SE risulta completamente estraneo a tutti e quattro i sistemi di suddivisione agraria finora noti nell'*Ager Nolanus* (Nola I-Abella, Nola II, Nola III, Nola IV). Infatti, si registra solo una parziale e generica sovrapposizione con i cardini o decumani di alcuni sistemi, come Nola II o Nola IV, senza una chiara compatibilità (Chouquer *et al.* 1987, 210).

In conclusione, sebbene la strada di Masseria Cianciulli si integri nel sistema agrario di Nola I-Abella, il tracciato di via Feudo, con la sua eccezionale durata e il suo orientamento anomalo, solleva la necessità di considerare una maggiore complessità nella divisione agraria nolana. I dati archeologici ci spingono a ipotizzare l'esistenza di assi viari e trame parcellari che, pur non allineandosi alle griglie maggiori, erano essenziali per l'organizzazione produttiva del territorio, sopravvivendo e adattandosi per secoli alle mutate esigenze del paesaggio rurale.

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ABSTRACT

The contribution aims to present the unpublished data collected during a preventive archaeology excavation carried out in Nola-via Feudo, a suburban area S of the ancient city. The investigation shed light on a succession of dirt roads, dated from late republic to the end of the 5th century A.D., lined with graves. In the most recent phase, sealed by the so-called eruption of Pollena (472 A.D.), the beaten track was flanked by a ploughed field, covering partially the necropolis area along the street. The necropolis, partially violated in modern times, consisted of twenty-one burials with inhumation 'alla cappuccina', *enchytrismós* and in earthen pits. The preliminary study presented here increases our knowledge of the *ager Nolanus* to Late Antiquity, in the wake of the studies carried out in last decades.

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THE RESILIENCE OF ANCIENT LANDSCAPES THROUGH THE ANALYSIS OF CERAMIC ASSEMBLAGES: THE CAMPANIAN PLAIN AS A CASE STUDY

1. Introduction

When applied to ancient landscapes, the concept of resilience refers to their capacity to adapt and respond to environmental, climatic, socio-political, and cultural challenges. Historical ecology provides a valuable perspective through which to understand resilience in ancient societies by employing approaches such as Resilience Theory or Theories of Chaos, Complexity, and Complex Adaptive Systems (Holling 1973, 2001; Redman, Kinzig 2003; Redman 2005; Grimm *et al.* 2017). This paper explores the resilience of ancient landscapes by analyzing ceramic assemblages. These contexts are a key archaeological source that can provide crucial insights into the relationship between past societies and their environments. As a fundamental component of daily life, pottery is a marker of economic practices, exchange networks, social transformations, and technological adaptation. Studying ceramic artifacts can help us understand how ancient societies adapted to climate change, resource availability, and the impact of human activities. This can reveal how they responded to periods of crisis or drastic change. Thus, ceramic data offer a distinct perspective on landscape resilience, which is understood not only as a reaction to external events but also as an intrinsic component of the long-term processes that shaped ancient societal development (Mentesana *et al.* 2024).

The Campanian Plain is a particularly rich case study, given its complex and layered landscape history. This paper focuses specifically on ceramic materials from the central sector of the plain, which corresponds to the *Atella* territory and its hinterland. Proximity to both the *Clanius* River and Mount Vesuvius significantly influenced the landscape and human activities in this area (Brancato *et al.* 2024). Analyzing material culture, particularly ceramic finds, can provide valuable insights into human-environment interactions in this region, which is characterized by the successive landscape transformation at multiple scales over a long period. The presence or absence of specific ceramic classes can help detect historical, cultural or economic transformations over time. Furthermore, the ceramic record may reveal so-called 'ghost activities', that are not visible in the archaeological evidence (Tescione in preparation). In this sense, the ceramic analysis is integrated with archaeological, paleoenvironmental, geomorphological, climatic, and historical data, following a multi- and interdisciplinary approach.

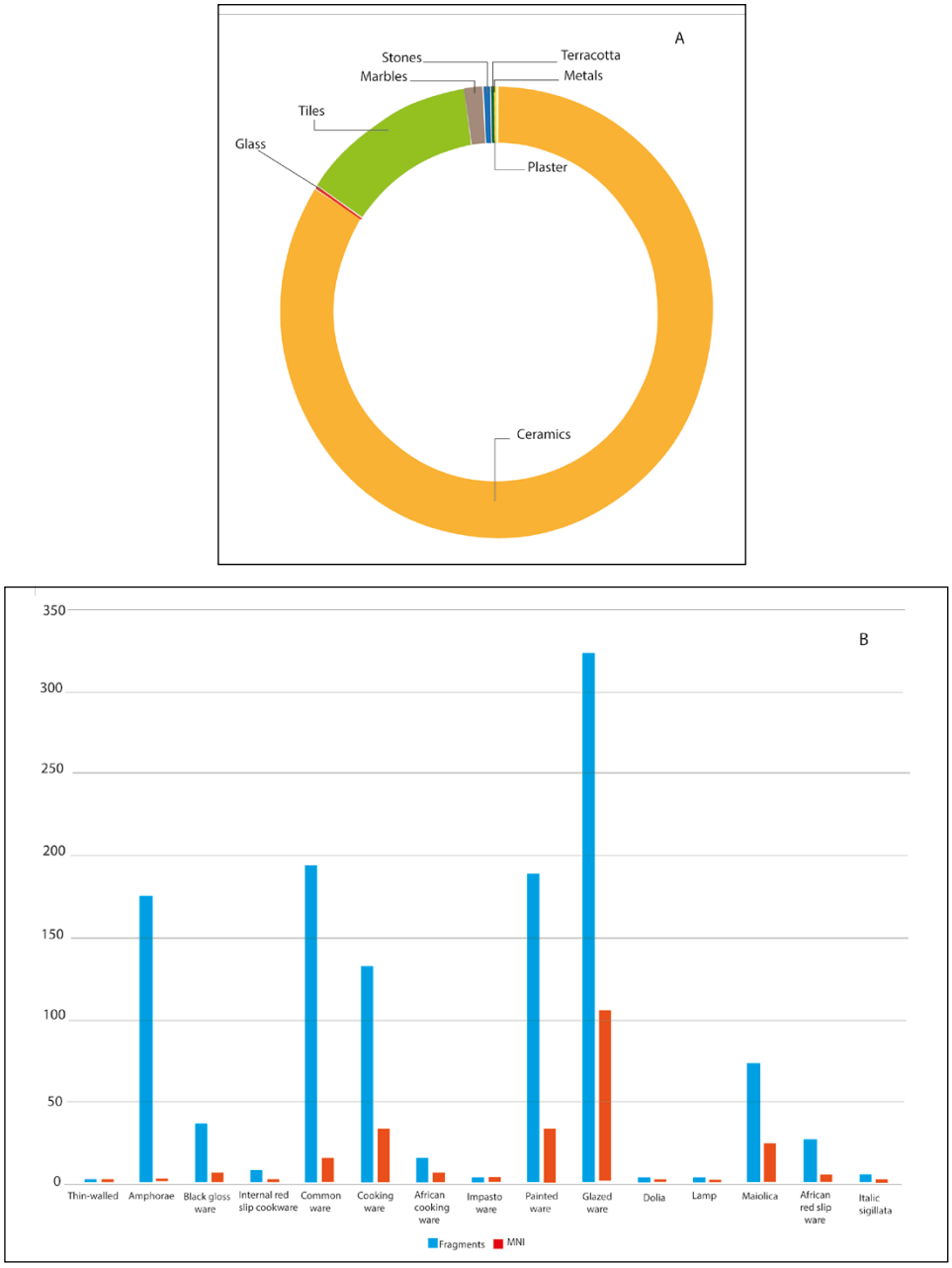


Fig. 1 – A) Quantitative analysis of the archaeological records from the Survey Topographic Units; B) quantitative analysis of the ceramic classes from the Survey Topographic Units.

The analysis has been carried out on ceramic records recovered during the non-invasive survey campaign conducted in 2024 and 2025 within the territory of ancient *Atella* (Brancato *et al.* in this volume). These archaeological records were catalogued according to the standards established for the MINP[1] and MINV[2] modules developed by the ICCD, within the framework of the SiGECWeb system framework. A spreadsheet was developed and integrated in the Digital Groma repository (see Buono *et al.* in this volume). Quantitative analyses have identified approximately 1185 records, belonging to various material categories, of which around 84% consist of ceramic artefacts (Fig. 1A). Within these materials, the morpho-typological and functional repertoire appears highly heterogeneous, spanning a long chronological range from the Samnite age to the contemporary era. The most represented class is that of glazed ceramics, followed by common ware (in terms of fragments), painted and cooking ware (as individuals) (Fig. 1B).

2. The pre-Roman age

Although there is documented prehistoric evidence (Early Bronze Age) in the Atellan hinterland (Gricignano, Succivo, Aversa) (see Brancato *et al.* in this volume), data from the recent field surveys do not allow us to confirm this presence with certainty[3]. Currently, this phase appears as a 'ghost landscape' in the surface archaeological record. Available documentation allows us to reconstruct the settlement dynamics beginning from the second half of the fourth century BC. This is evident from the discovery of black gloss ware that can be clearly linked to morpho-typologies (Fig. 3, 1) known in the Campania region (Ferrara 2016, 85-100). This change in material culture can be understood in the context of new historical developments: *Atella* received *civitas sine suffragio* after 338 BCE (Fest., 50, 126). The introduction of Roman-Latial ceramic types in *Atella* after the end of the fourth century BC reflects change in material culture and the activity of urban craftsmen and traders adapting to new political and economic conditions (Flohr, Wilson 2016). From the mid of the third century BC onward, a marked increase in available data indicates a widespread distribution of coarse wares (Fig. 3, 6-9), associated to Graeco-Italic amphorae (Fig. 3, 5), and black gloss ware (Fig. 3, 2-4), across multiple sites (Fig. 2). This evidence supports the hypothesis of rural farmsteads, or small-scale rural settlements related to the intensive agricultural exploitation of the

[1] http://www.iccd.beniculturali.it/it/ricercanormative%20/156/minp-modulo-per-l-inventariazionepatrimoniale-4_00.

[2] http://www.iccd.beniculturali.it/it/ricercanormative/234/minv-modulo-per-l-inventariazione-4_01.

[3] Three fragments from UO 225 (Gricignano d'Aversa) and UO 179 (Sant'Arpino) could be referred to Archaic age impasto pottery.

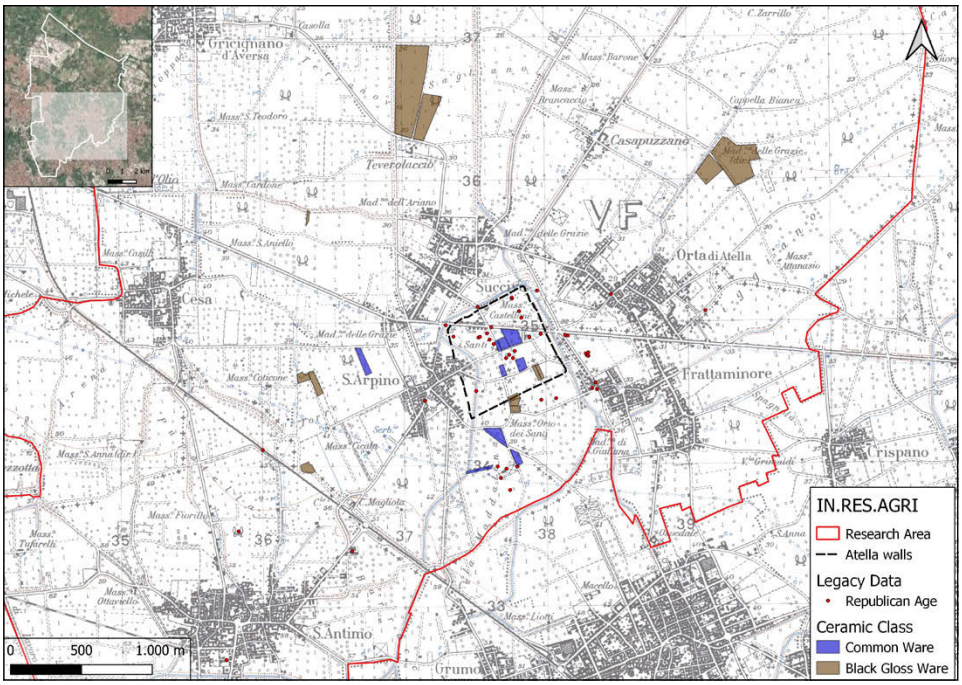


Fig. 2 – Spatial distribution of Republican age sites from legacy data, spatial distribution of black gloss ware and mid-Republican common ware in the Survey Topographic Units.

landscape during this period (Quilici Gigli 2025). Imported materials, such as *unguentaria* and black gloss ware, from northern Campania (*Cales*, Capua, Teano) and the Bay of Naples attest to the city's prosperity. This wealth was likely supported by road networks documented as early as the fifth century BC, as evidenced by the legacy data (see Brancato *et al.* in this volume). Of particular interest are the fine and coarse wares dating to the mid-Republican period found in the eastern (Orta di Atella, UO 229 and 232) and northern (Succivo, UO 225 and 233) sectors of the Atellan territory. Currently, no legacy data is available for these areas (Fig. 2).

3. The Roman period

Following the Hannibalic defeat in the second century BC, the city entered a phase of growth and prosperity, fostered by its strategic position within the regional road network (Laforgia 2014). The presence of imported black gloss ware types, documented in the Vesuvian area (Morsiani 2017, 575) and the Phlegraean region (Esposito 2017, 77), attest to this (Fig. 5,1).

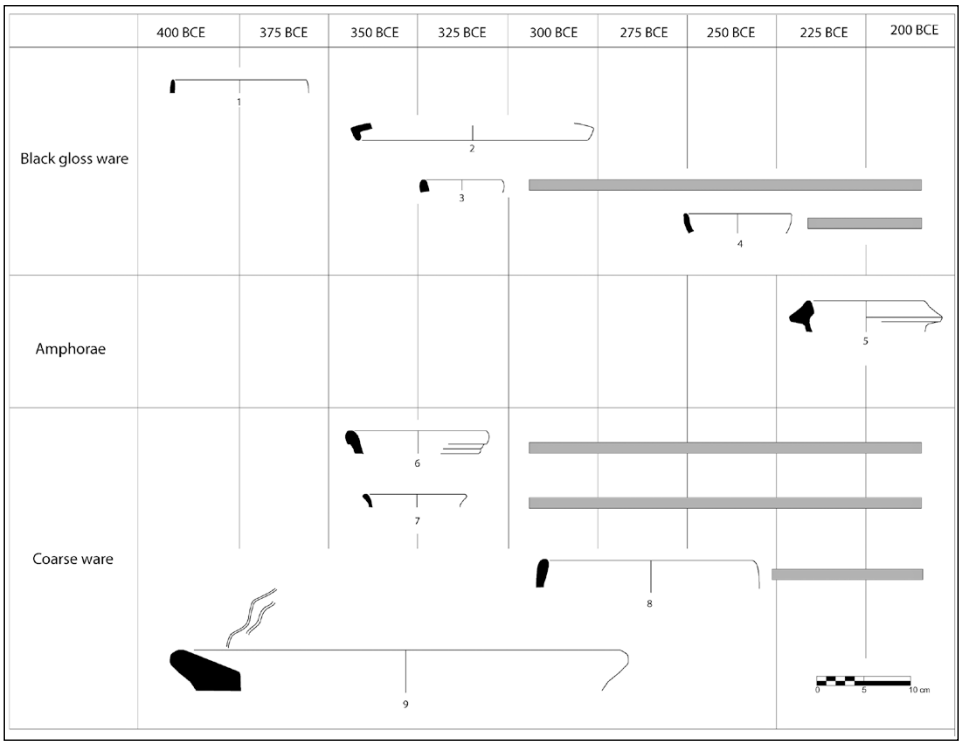


Fig. 3 – Chronotypological graph of mid-Republican ceramic. Black gloss ware: 1) *skyphos* Morel 4380 (Sant'Arpino UO 91); 2) lid (Frattaminore UO 16); 3) cup Morel 2420 (Frattaminore UO 16); 4) cup Morel 2970 (Sant'Arpino UO 65); amphorae: 5) Gr.-Ita Vc (Sant'Arpino UO 91); coarse ware: 6-7) pots (Frattaminore UO 32); 8) situla (Sant'Arpino UO 90); 9) basin (Frattaminore UO 16) (drawings by E. Canciello; re-elab. by Author).

This economic vitality persisted until the end of the first century BC, as evidenced by the short- and medium-range imports of terra sigillata originating from the Bay of Naples (Soricelli 2004) and central Italy. The coarse ware assemblages follow Italic traditions and feature cooking pans with bifid rims, Internal Red Slip cookware, and pots with almond and everted rims (Fig. 5, 5-7), some of which may have been brought to *Atella* from the Vesuvian and/or Phlegraean areas alongside wine transport containers.

Imperial expansion promoted market-oriented practices, amplifying pre-existing local dynamics. By the first century BC, these local responses had contributed to the formation of new food distribution system. Rising expectations and growing demand led to the development of a supply network that was resilient to moderate environmental fluctuations, yet vulnerable to extreme events. For example, the major volcanic eruption of the 79 AD that

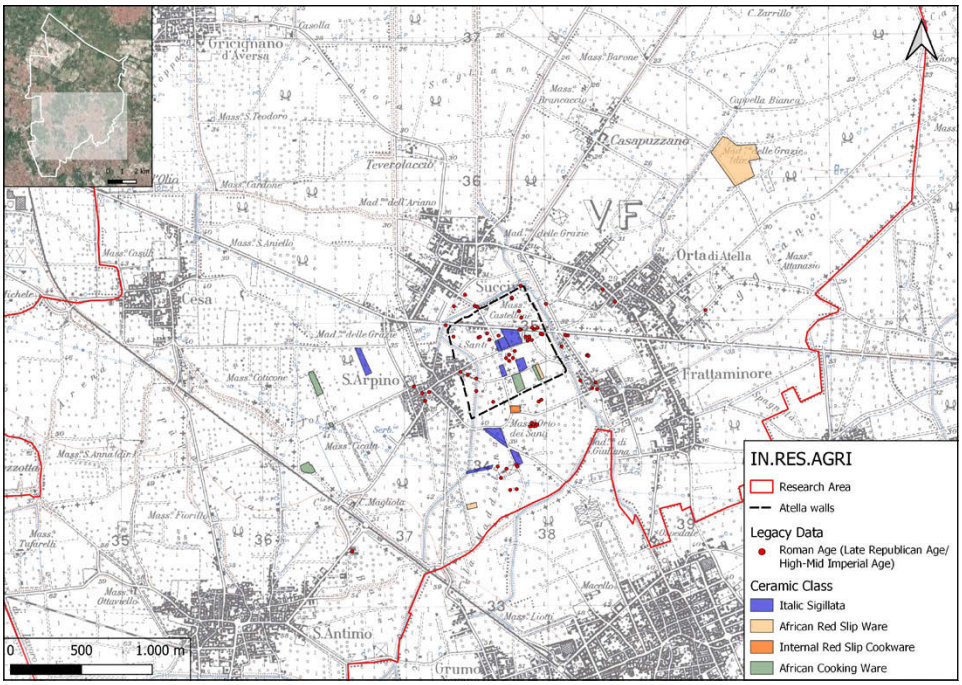


Fig. 4 – Spatial distribution of Roman age (late Republican age/high-mid Imperial age) sites from legacy data, spatial distribution of Italic Sigillata, Internal Red Slip ware, African Red Slip ware, African Cooking ware in the Survey Topographic Units.

may have triggered a sudden period of global cooling at the end of the Republic (Bernard *et al.* 2023). This environmental pressure may also help explain the emergence of new food storage strategies, such as the use of large containers (*dolia*), as evidenced by two sites in the NE (Orta di Atella UO 229) and SE (Frattaminore UO 32) of *Atella* territory (Fig. 4). From the second century AD onwards, there is an increase in ceramics and products from the North African coast, as evidenced by transport containers, fine ceramics, such as African Red Slip Ware, prod. A (Fig. 5, 2-3), and cooking wares (Fig. 5, 4).

4. The late Roman-high medieval age

A chrono-distributive analysis of late Roman to high medieval age ceramic classes reveals interesting perspectives. According to legacy data, sites from this period are scarcely reported in the urban area, except for traces of spoliation or road infrastructure (see Brancato *et al.* in this volume). However, whereas data from field surveys highlight a concentration of Late Roman African Red

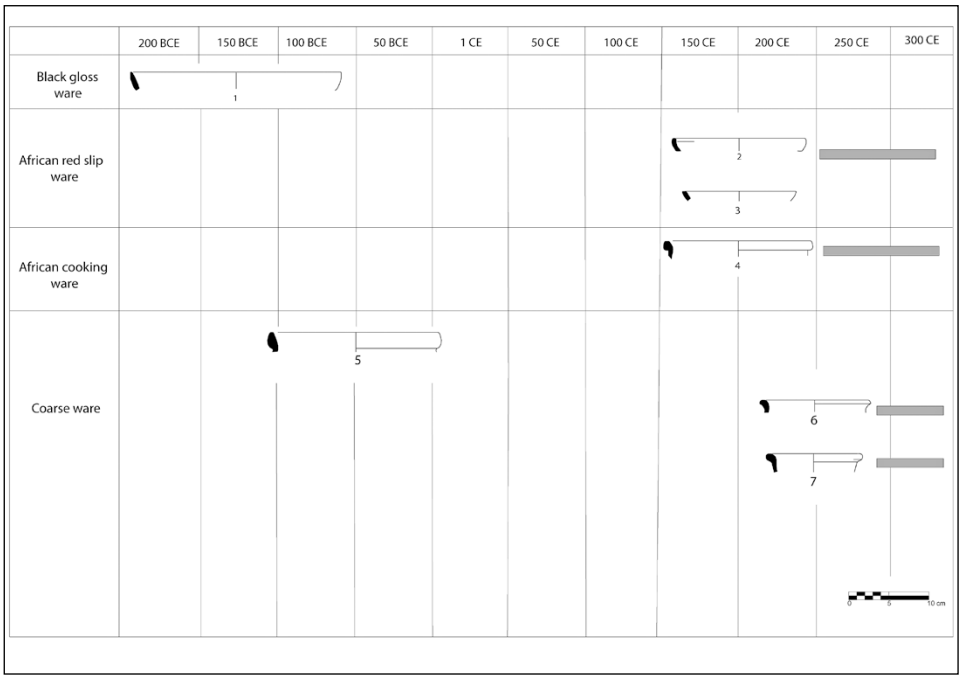


Fig. 5 – Chronotypological graph of late Republican and Imperial age ceramic. Black gloss ware: 1) dish Morel 2280 (Frattaminore UO 16); African Red Slip ware: 2) cup Hayes 26 (Frattaminore UO 32); 3) cup Hayes 14a (Frattaminore UO 32); African cooking ware: 4) Pan Hayes 197 (Frattaminore UO 32); Coarse ware: 5) pot with almod rim (Frattaminore UO 32); 6-7) pot with everted rim (Sant'Arpino UO 94; Frattaminore UO 32) (drawings by E. Canciello; re-elab. by the Author).

Slip ware in this sector (Fig. 6). This finding corroborates the hypothesis of a collapse in the influx of North African imports, which impacted rural areas more than the urban sector because they were increasingly excluded from established commercial networks (Tortorella 1998). Although still in its early stages for certain categories, particularly those related to the late Roman to early medieval phases, spanning the fifth to seventh centuries AD, the qualitative analysis reveals strong correlations with the material culture documented in the 2010 excavation of the forensic baths (Arenella *et al.* 2015).

Between the fifth to seventh centuries AD, imports of ceramics (African Red Slip ware, prod. D, Fig. 7, 1-2) and foodstuffs from *Africa Proconsularis* continued, alongside goods from the Eastern Aegean (common ware, Fig. 7, 3) and the Calabrian-Sicilian regions (e.g. Pantellerian ware). Imported ceramics were gradually imitated in local ceramic repertoires, as seen with Pantellerian (Fig. 7, 11-12) and African cooking ware (Fig. 7, 10). This phenomenon is already well known in Campania (Toniolo 2020) and in the rest of the

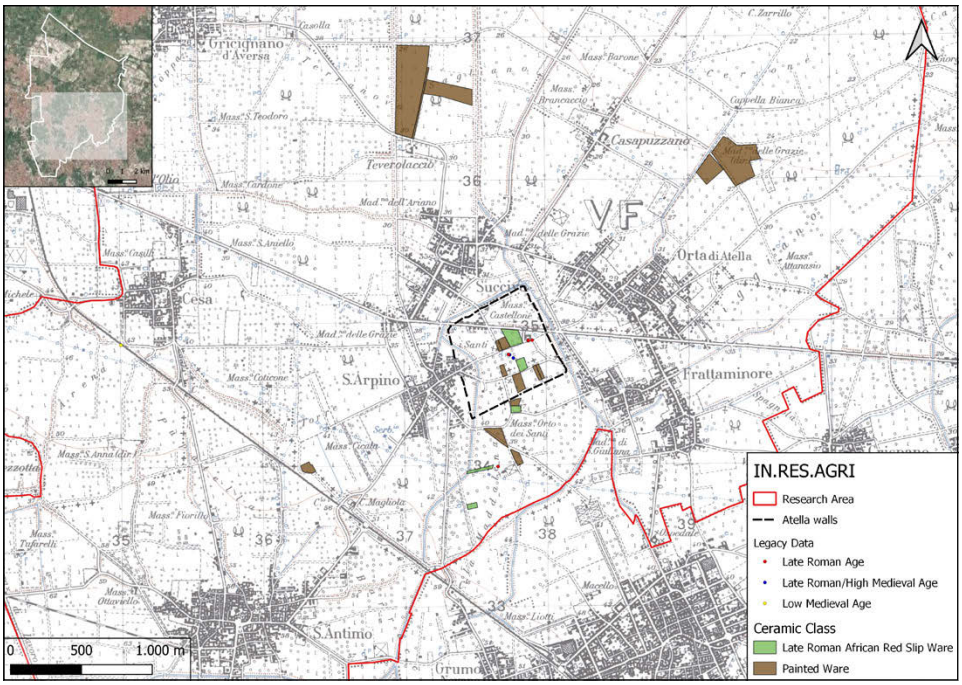


Fig. 6 – Spatial distribution of late Roman and medieval age sites from legacy data, spatial distribution of late Roman African Red Slip ware and painted ware in the Survey Topographic Units.

peninsula. Interestingly, ceramic materials were produced not only in the Bay of Naples but also in inland and central-northern Campania (colour coated ware, Arthur, Soricelli 2015; Fig. 7, 4, 6-8) and in the Vesuvian area (as demonstrated by the so-called burnished ware, Benková 2017; Fig. 7, 5) appears to be interesting. Painted ware is well attested, particularly in the form of open vessels, such as basins with thickened and variably profiled internal rims (Fig. 7, 6-8). These types are present in contexts from the Bay of Naples dating from the late fourth century AD. They remain fairly frequent through the sixth century AD, and continue to be commonly found into the seventh century AD (about the circulation see Toniolo 2020). During this period, the road network connecting *Atella* to Naples and to Capua was subject to numerous interventions, highlighting the vitality and continued efficiency of the *ager Campanus*'s road network even in the fourth century AD (Quilici Gigli 2005). The ceramic evidence from this period indicates the circulation of products and formal repertoires, which was likely supported by a system of highly frequented periodic markets (*nundinae*), characterized the Roman period (Storchi 2000; Toniolo 2020).

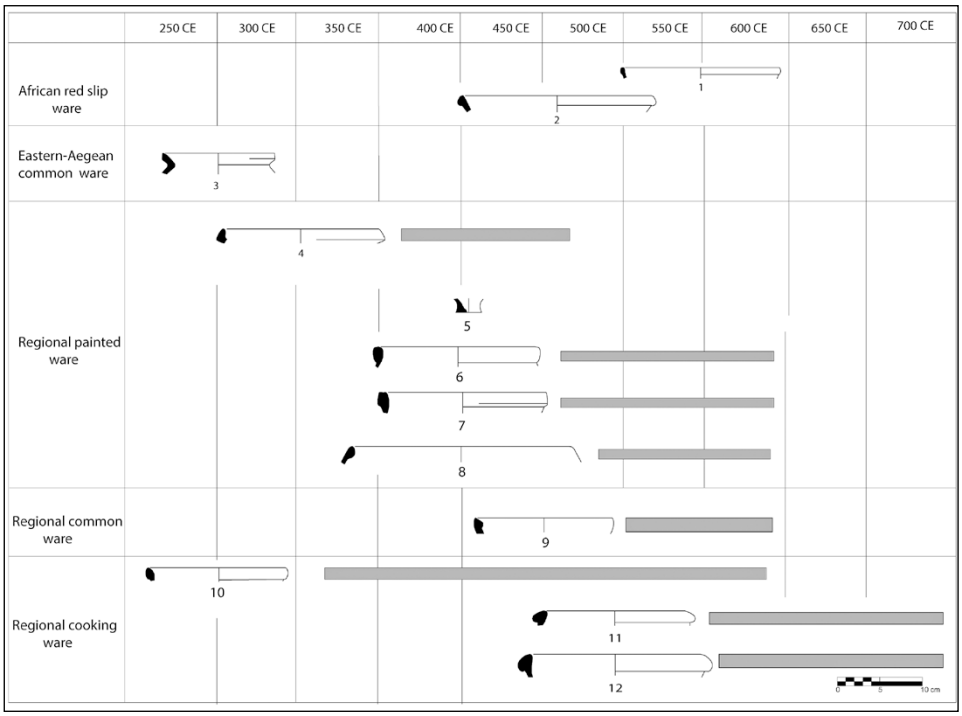


Fig. 7 – Chronotypological graph of late Roman and high Medieval age ceramic. African Red Slip ware: 1) bowl Hayes 88b/90 (Frattaminore UO 32); 2) bowl Hayes 61C (Sant'Arpino UO 94); Aegean-Eastern common ware: 3) pot (Frattaminore UO 32); Regional painted ware: 4) bowl (Sant'Arpino UO 65); 5) jug (Sant'Arpino UO 65); 6-8) basin (Sant'Arpino UO 90; Frattaminore UO 32-UO 43); Regional common ware: 9) cup (Sant'Arpino UO 65); Regional cooking ware: 10-12) pot (Frattaminore UO 32; Frattaminore-S. Arpino UO 52; Sant'Arpino UO 94) (drawings by E. Canciello; re-elab. by the Author).

Additionally, changes in the cooking ware repertoire can be traces, such as the prevalence of lug-handled casseroles. This shift has been linked to changes in dietary habits, which may be due to a decline in global temperatures and subsequent climate deterioration. This climate change may have led to an increased demand for semi-liquid foods, for which casseroles are particularly well-suitable. Dietary variation at other sites in Campania (Naples) is also associated with an increased consumption of goats and sheep, as suggested by archaeozoological evidence (Arthur 2007, 2010)[4].

[4] The results of archaeozoological and paleoenvironmental analyses could provide further confirmation of this hypothesis.

Late Roman evidence represents a substantial revision of previous interpretations that attributed the scarcity of ceramic records from the middle and late Imperial periods primarily to a significant demographic decline in the urban area (Bencivenga Trillmich 1994). However, documentary sources confirm that the city persisted into the sixth century AD, despite being devastated by the Vandals and continued to function as an episcopal seat throughout the early Middle ages (Greg. M., *Epistulae*, IX, 142).

5. The modern and contemporary age

Medieval and modern phases up to the eighteenth century do not appear to be documented, which likely confirms the abandonment of the city. Notably, the episcopal seat was transferred to Aversa in the eleventh century (Bencivenga Trillmich 1994). During the modern period, glazed tableware and cooking pottery is attested, referring to typologies typical of the eighteenth century-twentieth century CE. The documented maiolica ceramics appear to belong to a relatively recent period, dating between the eighteenth century and twentieth century.

6. Final remarks

Archaeological evidence from the Atellan hinterland provides a detailed picture of human settlement and landscape use from the Samnite to the present. While pre and proto-historic presence remains elusive and appears as a 'ghost landscape' within the surface record, the documented material culture from the beginning of the fourth century BCE onwards clearly indicates increasing settlement complexity and economic vitality. The significant raise in ceramic finds between the fourth and third centuries BCE supports the hypothesis of a rural landscape characterized by small farmsteads reflecting intensive agricultural exploitation. The city's prosperity during the Roman period, sustained by its strategic location along major roadways and evidenced by imported fine wares and productive villa estates, underscore its integration into broader regional and Mediterranean trade networks.

Continuities and transformations in material culture from the late Roman to early medieval periods reveal sustained trade connections extending from North Africa to the eastern Mediterranean, as well as within Campania itself. The circulation of goods through periodic, highly frequented markets (*nundinae*) likely facilitated social and economic resilience in this changing historical context. The apparent abandonment of the area during the medieval period, culminating in the transfer of the episcopal seat to nearby Aversa, marked a significant shift in the local settlement pattern. However, the subsequent re-emergence of glazed ceramics and maiolica in the modern era testifies to renewed activity and changing cultural dynamics in the area.

Overall, the ceramic record not only provides crucial insights into settlement dynamics, economic practices, and trade relations, and serves as a valuable proxy for understanding the broader processes of adaptation, resilience, and transformation within the Atellan landscape over millennia. The recurrence or disappearance of particular morpho-typological forms or fabrics may be interpreted as responses to historical, cultural, environmental and climatic changes. Further investigation is required in order to better understand these underlying dynamics and their broader implications.

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ABSTRACT

This paper examines the resilience of ancient landscapes by analyzing ceramic assemblages from the Atellan hinterland in the central Campanian Plain. Using a multidisciplinary approach based on historical ecology and resilience theory, the study examines how pottery reflects adaptive responses to environmental, climatic, and socioeconomic changes over a long period of time, from the Samnite age to the contemporary era. The ceramic record, collected during recent non-invasive surveys (2024-2025), includes over 1100 artifacts cataloged using the Digital Groma standards. The results suggest a substantial increase in rural settlement and agricultural activity between the fourth and third centuries BC, accompanied by evident integration into regional trade networks. Late Roman assemblages demonstrate continued vitality, challenging earlier hypothesis of urban decline. The presence of North African and eastern Mediterranean imports alongside local imitations highlights sustained economic activity and adaptability. Changes in cooking ware types, notably the increase in casseroles, may indicate dietary shifts related to climatic deterioration. The apparent absence of medieval phases, followed by the reappearance of modern ceramics, suggests discontinuities in settlement. Ultimately, ceramic evidence provides a valuable perspective for understanding long-term human-environment interactions, resilience strategies, and cultural transformations within the Atellan landscape in the *longue durée*.

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ASH: ARCHAEOLOGY AND SOIL HERITAGE. A PRIN PNRR RESEARCH PROJECT ON THE ROLE OF ANDOSOLS FROM LATE PREHISTORY TO ANTIQUITY

1. Introduction

The interaction between ecosystem peculiarities and use of land resources by human communities in the past is a relevant – but yet underdeveloped – field of research. Among the disciplines eligible for collaboration in this perspective are territorial-scale archaeology (often referred to as 'landscape archaeology' and related to survey projects and archaeological topography), pedology, geomorphology, and bio-archaeology (paleobotany, archaeozoology, etc.). The PRIN PNRR two-year ASH research project – scheduled for completion in February 2026 – aims to investigate one of the most promising aspects of this interdisciplinary approach: the historical role played by Andosols, a very fertile type of soils generated by the pedogenization of volcanic ashes. The ASH Project aims at improving – with specific regard to Central Mediterranean – the diachronic archaeological knowledge, in part already established, on the relation between the Andosols distribution, their fertility and the development of dense, complex and long-lasting settlement patterns from Late Prehistory to Antiquity. This improvement in knowledge is intended as a means to investigate and demonstrate the relevance of these soils as a strategic natural resource that has supported dense human populations for millennia, highlighting the need for their conservation and proper management.

2. State of the art

Although volcanoes have often had negative and even catastrophic consequences – e.g. in the well-known cases of Vesuvius (Costa *et al.* 2021) and Etna (Chester *et al.* 2011) – the ash ejected during eruptions often resulted in the development of extremely fertile soils, generating significant long-lasting benefits for human communities (Fiantis *et al.* 2019). Volcanic soils – often classified as Andosols (Soil Taxonomy USDA) – have unique physical, chemical and biological properties which make them among the most fertile soils. In the last decades, research highlighted the occurrence of these soils also far from volcanic ecosystems (Iamarino, Terribile 2008), due to the wind-driven transport of fine ashes. These soils cover approximately 124 million hectares: 0.84% of the world's land surface; while representing a relatively small extent, they are a crucial land resource, as demonstrated by the high human populations density in these regions. This human concentration and

the lack of awareness of their importance, unfortunately led in several cases to a degradation or destruction of these soils. Recent research carried out in Italy on the intense soil sealing and its impact over land capability classes has assessed that, during the last 60 years, this process mainly affected the most fertile soils (e.g. Terribile *et al.* 2013; Vingiani *et al.* 2018).

Among the peculiar soil properties of Andosols there are (i) high porosity, (ii) friable consistency, (iii) high water retention capacity, (iv) large reserves of easily weatherable mineral and glass components (Nanzyo 2002). All these properties make Andosols very suitable for agriculture, even in prehistoric times. In this regard, paradigmatic cases come from the Andosols of the Poro highplain in Calabria (Pacciarelli 2013) and of the Campanian Plain (Talamo 2013; Minieri *et al.* 2020). In the first area archaeological surveys identified an exceptional high density of pre- and protohistoric settlement remains (Pacciarelli 2001), dating to a very long time-span covering several millennia (at least from Late Neolithic to the Iron age, that's to say from 4300 to 700 BC). The human presence and impact in the Poro highplain from Middle Copper age (3300-2800 BCE) to Final Bronze age (1150-925 BCE) was also investigated through the study of a pollen core (Di Lorenzo *et al.* 2021). In the Campanian plain, in the last decades, an extraordinary spreading and development of pre- and protohistoric settlements and ploughed fields was recognized in Rescue Archaeology excavations (Laforgia, Boenzi 2011). In both regions, however, historical rural occupation remains to be systematically investigated. In other areas the relation between volcanic environments and intensive occupation of the territory have been observed but never systematically investigated.

Interdisciplinary studies combining humanistic and scientific methodologies have been carried out regarding the relationship between Andosols and ancient human settlements systems in some geographical district around the world, such as central Arizona (Nakase *et al.* 2014) or Costa Rica (Ruiz *et al.* 2018), but only few and limited attempts in this regard have been made in Italy. ASH aims to change this scenario, by an organic and integrated study of relevant sub-regions of the central Mediterranean, in the context of a scientific project taking into account archaeological, pedological, archaeobotanical and remotely-sensed data, in order to investigate the connection between Andosols and settlement patterns of ancient societies. In doing so, the project will also demonstrate the urgency to preserve this crucial resource for the future society and human wellbeing.

3. The project

Within the ASH Project, the integration of legacy data (archaeological, environmental, pedological, remotely sensed) from selected sub-regions with new fieldworks aims to expand our archaeological diachronic knowledge on

the interaction between past Mediterranean communities and volcanic soils (Bonnier *et al.* 2019; Brancato 2019). Andosols have a brown (often dark, sometimes reddish) color and a powdery appearance when dry: from the point of view of agricultural use, they are characterized by a very high porosity and fertile structure, high permeability and water retention. The high content of organic matter, its stability given by the presence of low crystalline material and the high cation exchange capacity contribute to the marked fertility of these soils. Thanks to their high fertility, due to the characteristics highlighted above, flourishing crops often develop on these soils in spring, summer and autumn, in a non-irrigation regime.

Since late prehistoric times onwards, areas such as the Campanian Plain, where soils of this type are attested, were widely exploited for agriculture, as is demonstrated not only by the cited protohistoric ploughed fields found under the Vesuvian and Phlegraean Fields eruption levels, but also by traces of Roman centuriation frequently identified in modern landscape. Also the available palynological data, mainly coming from the Sarno Plain and the coastal areas of the Campanian Plain, indicate the occurrence of crops since protohistoric times (Vignola *et al.* 2021 and references therein).

In the Tyrrhenian Calabria region, an archaeological survey revealed an intensive occupation of the Andosols of the Poro highplain over a period of almost four millennia (Pacciarelli 2001), between the late Neolithic (last centuries of the fifth millennium BCE) and the Iron age/Archaic period (first half of the first millennium BC). Also significant is the study of a pollen core taken on the highplain, which reveals a landscape largely deforested and anthropized between the third and second millennia BCE (Di Lorenzo *et al.* 2021). Nevertheless, in both areas the presence of complex settlement patterns of the historical age linked with Andosols has been poorly investigated. ASH therefore aims at developing this research theme by fully highlighting the agricultural potential of these soils as a primary resource in subsistence and a crucial factor in the emergence of complex settlement systems. This goal is urgent considering that, according to specific studies, these types of soils, due to their morphological, physical, and chemical properties, induce a considerable soil fertility but also a great vulnerability to land degradation (James *et al.* 2000).

4. Case studies

The project will focus on the systematic collection and elaboration of heterogeneous evidence to analyze the human occupation and use of volcanic ash landscapes in four selected areas of Italy: Southern Etruria (especially Bolsena lake surroundings), Campanian Plain, Tyrrhenian Calabria (especially Poro highplain) and Ionian-Etnean Sicily (Fig. 1). These case-studies (hereafter, CS) were selected for: 1) the presence of Andosols generated by ash deposits



Fig. 1 – ASH Project: case studies.

from both nearby (e.g. Campanian plain) and distant (e.g. Poro highplain) volcanoes; 2) the advanced archaeological knowledge on the evolution of the settlement systems; 3) the advanced state of soil research, in particular regarding the distribution of Andosols.

CS 1: Southern Etruria (Northern Latium). The landscape of Southern Etruria is characterised by extensive deposits resulting from the activity of volcanoes during the Pleistocene (Bolsena, Vico, Bracciano, etc.). In this area numerous territorial research have been carried out, including those led by the RU 1 (e.g. Pacciarelli *et al.* 2022), aimed at understanding the territorial dynamics through the mapping of settlements especially since Bronze age times. Our research will start from legacy data (of both archaeological and paleobotanical interest) harvesting and digitization of previous studies on areas west of the Bolsena Lake (especially near Gradoli and Piansano), where Andosol concentrations are located (Napoli *et al.* 2019) (Fig. 2). New archaeological surveys will be also carried out.

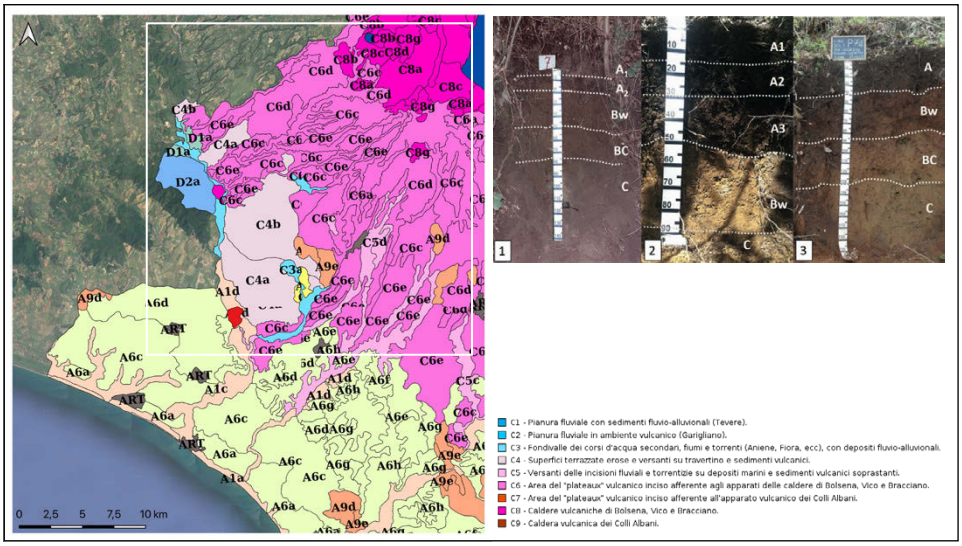


Fig. 2 – Distribution of Andosols and other volcanic-ash deposits in Lazio and a section for pedological analysis (after Napoli *et al.* 2019).

CS 2: the Campanian Plain (about 392 kmq), a wide Plio-Pleistocene tectonically depressed area (graben) bounded by Mesozoic and Cenozoic carbonate mountains, is subdivided by the Vesuvius volcano into the Volturno Plain to the NW and the Sarno Plain to the SE. The history of the interaction between human communities and volcanoes is preserved in the Campanian plain's stratigraphy, where systematic or preventive excavations have led to define the framework of settlements and human activities between the Late Neolithic and the historical era (Di Vito *et al.* 2013, with previous bibliography). One of the most important achievements emerging from these excavations is the widespread presence of settlement remains and well-preserved cultivated areas dated mainly between the Late Neolithic and the Bronze age (Di Vito *et al.* 2013; Taylor 2015). Despite the widespread distribution of archaeological evidence, very few are the studies devoted to the reconstruction of the environment and land use history of this territory, especially in its central area, where the ancient urban center of *Atella*, with its centuriation, is located (Figs. 3-4).

Some scattered pollen data come from the Iron age levels of the Longola site (Di Maio *et al.* 2012). More recently, a pollen sequence from Pompeii allowed reconstructing the environmental evolution and the plant landscape of the Sarno floodplain between 900/750 cal BC and AD 79 (Vignola *et al.* 2021), highlighting the occurrence of pasturelands, cultivated fields and olive groves, as well as the introduction of cabbage cultivation in the fourth

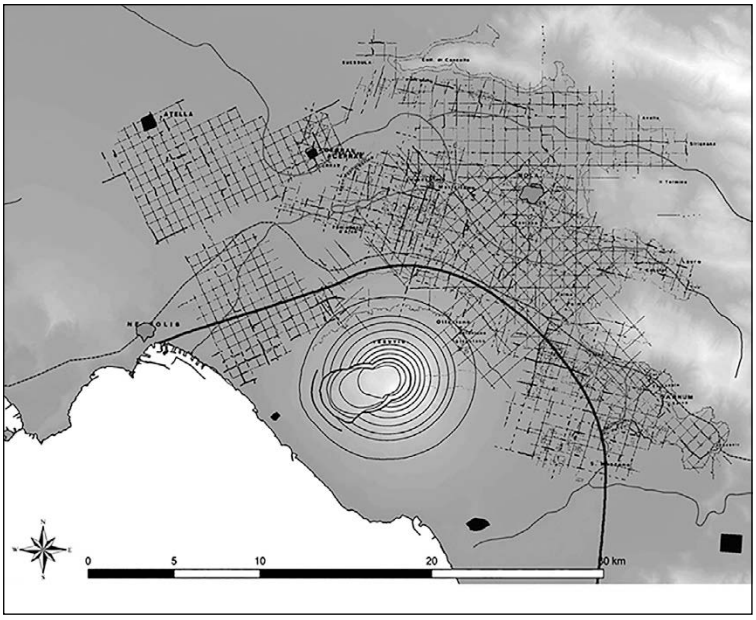


Fig. 3 – Digital reconstruction of Roman agrarian landscapes affected by the AD 79 Vesuvius eruption (after Taylor 2015).



Fig. 4 – Campanian Plain, aerial view of the agrarian landscape at the boundary between the provinces of Caserta and Naples, the present location of the Archaeological Park of *Atella*.



Fig. 5 – View of the Poro highplain (Tyrrhenian Calabria).

century BC. Concerning the Volturno Plain, no pollen data is available from the internal areas, but some interesting pollen sequences come from the coastal lakes of Averno and Literna Palus (Lago Patria). This was surrounded by a mixed deciduous and evergreen forest with local exploitation of olive, grapevine, walnut, and chestnut from the eighth century BC (Di Rita *et al.* 2018). Other data come from Neapolis (1st century BC to 5th century AD), where tree crops and cabbages were cultivated around the Graeco-Roman harbour (Russo Ermolli *et al.* 2014).

CS 3: the Poro highplain (Tyrrhenian Calabria) (Fig. 5) represents a key territory for the development of human communities through Prehistory and Protohistory (Pacciarelli 2001). The intensive archaeological surveys of the last decades demonstrate that this territory was continuously and intensively settled at least from the Late Neolithic to the Iron age (Pacciarelli 2001). The economic reason for this continuous occupation can be found both in the favourable agricultural predisposition of the Andosols, present mainly on the Tropea Promontory top surface (Poro highplain), and the availability of pastures. Archaeological surveys document many phases of human settlement on the Poro highplain dating to the Late Neolithic, to the Copper, Bronze and Iron ages (Pacciarelli 2001, 2017), that is, from the end of the fifth to the beginning of the first millennium BC. Recent pollen analysis highlighted that the Poro Plateau was exploited for agricultural practices (cereal cultivation) and livestock grazing between ca. 3000 and 1000 cal BCE (Di Lorenzo *et al.* 2021). One of the main reasons for this long-lasting – and in some phases very intense – occupation of the highplain is the presence of very light and fertile Andosols, quite suitable for primitive agriculture with wooden plow.

CS 4: the Etnean region in Sicily (Fig. 6), with an extent of 500 kmq, is a perfect case study due to its geographical characteristics and the number of archaeological projects (both excavations and surveys) carried out within it



Fig. 6 – Plain of Catania, agrarian fields seen from the Roman site of Castellito di Ramacca.

in recent decades. The landscape and soils of the Etnean area (Catania, Sicily) have been shaped by the intense activity of Mount Etna, one of the world's most active volcanoes (Branca *et al.* 2015). Etnean volcanic soils supported an intense agricultural exploitation throughout millennia: as the field-use research history has highlighted, here agricultural economy, land colonization and urbanism flourished on the lower slopes of the mountain toward the Ionian Sea and the broad Plain of Catania (Sorbello 1992). The traditional historiography described the Etnean region as capable of producing wheat and other agricultural products in quantities well beyond the consumption requirements of its population. In this area several researches have been carried out, including those led by members of the RU 1 (Brancato 2020), aimed at understanding the settlement systems evolution through field survey research, archaeological mapping and legacy data digital integration. However, for this area research project focused on palaeoenvironment are scarce, with a few exceptions (Brancato 2022; cf. also Castiglioni 2018).

5. Methodologies

ASH project investigates CS areas through the combined use of innovative technologies for the digital recovery, interpretation and management of archaeological, pedological, topographical, environmental legacy data, integrated through new field research and remote sensing. The pedological work in each CS aims at identifying new portions of Andosols starting from the study of remote data (high spatial and temporal resolution - Copernicus, Prima, QuickBird and MIVIS dataset) and the analysis of soil and vegetation index, carrying out specific surveys and taking pedological samples. Archaeological field surveys and excavations scheduled within the project aim at collecting information about the location, distribution and organization

of human settlements. The information about archaeological artefacts and sites found during field researches is systematically recorded and implemented within an open geographical information system infrastructure. The datasets and the relational database are also implemented with all the archaeological legacy data obtained starting from archive research and continuing with bibliographic analysis of previous findings.

Palynology is widely recognized to be one of the most appropriate methods for reconstructing past landscapes and their changes over time, related to natural phenomena or the impact of human activities (Mercuri *et al.* 2019). In particular, the latter can be detected through the careful definition of the anthropogenic indicators (ruderals, crops, etc.) and a quantitative analysis of microcharcoals that can help to understand the regime of fires in the past. Remote sensing (RS) analysis (Lasaponara *et al.* 2007; Forte, Campana 2016, 2017; Traviglia, Torsello 2017; Verhoeven 2018; Argyrou, Agapiou 2022; Wang, Liu 2024) is planned for all study areas. The RS method is aimed to a better understanding and characterization of buried elements in different archaeological sites; in particular relevant archaeological features have been pointed out in several studies making use of optical multi-spectral remote sensing sensors, such as WorldView and Pléiades.

Archaeological proxies, such as soil and crop marks, can be depicted from multispectral datasets due to their different spectral signature in comparison to the surrounding area (Fig. 7). For this purposes, WorldView-2, WorldView-3 (see Di Palma, Merola in this volume), Pléiades-1A, Pléiades-1B, Pléiades Neo (Di Palma *et al.* 2023; Cozzolino *et al.* 2025), Sentinel-1 and -2 images, Prima image, QuickBird images are inspected for each CS (Schreier 2020). Copernicus Sentinel-1 data were acquired in interferometric wide swath (IW) mode, with a 250 km swath, processed to Level-1 ground range detected (GRD) at a resolution of 10 m, orthorectified at VV intensity (vertical transmit and vertical receive) and VH intensity (vertical transmit and horizontal receive) polarisation (Lasaponara, Masini 2020). The VV and the VH polarisations were also extracted from the herein featured Copernicus Sentinel-1 image. The high- and very high-resolution multispectral satellite images (0.50-0.30 m on the ground) are processed, analysed and interpreted using ENVI 4.5, QGIS and a very performant artificial intelligence (AI) software, such as eCognition (see Di Palma, Merola in this volume), with the aim of detecting, identifying and analysing anomalies and traces of archaeological interest (Fig. 8). The methodology integrates traditional topographical analysis, including historical cartography, aerial photographs (see Ditaranto, Giordano in this volume), and historical space photos, with semi-automated and fully automated Machine Learning (ML) and Deep Learning (DL) techniques. This includes the training of convolutional neural networks (CNNs) to detect specific patterns in the landscape.

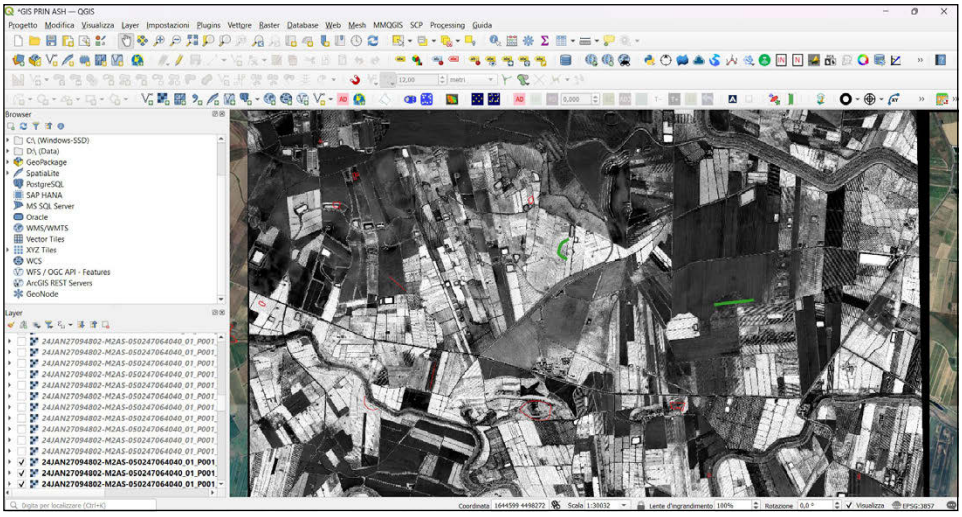


Fig. 7 – Application of the Normalized Difference Water Index (NDWI) to the WorldView-3 satellite image (27/01/2024), with subsequent vectorization of potential dump-marks and their integration in the QGIS platform.

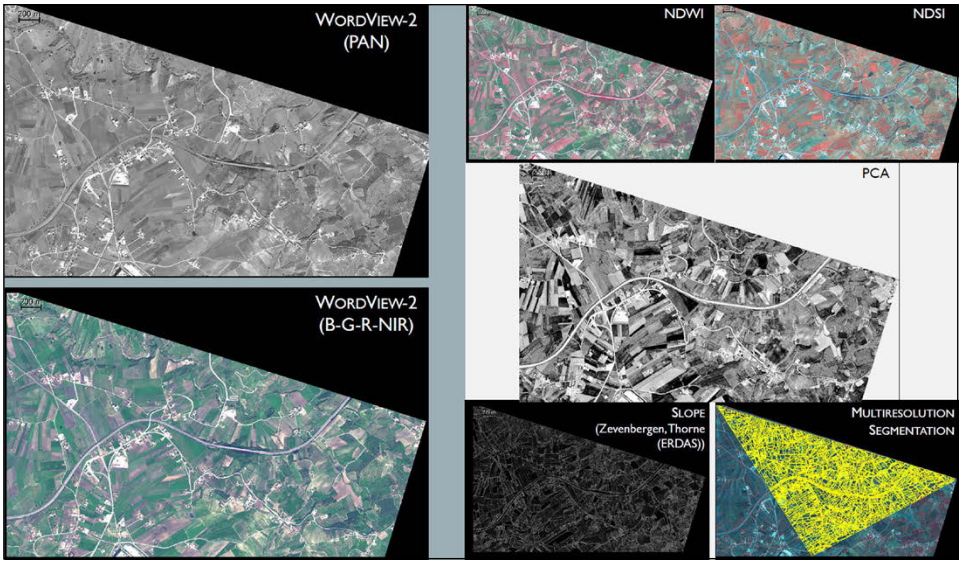


Fig. 8 – The eCognition experiments involved processing, analysis, and evaluation, including spectral index calculation (NDWI, NDSI in false colour), Principal Component Analysis (PCA), slope estimation using ERDAS, and segmentation.

The systematic collection, integration, and publication of heterogeneous sources are managed within a dedicated geographic information system designed *ab initio* to comply with the Istituto Centrale per il Catalogo e la Documentazione (ICCD) standards and the Istituto Centrale per l'Archeologia (ICA) principles (Calandra 2022). The geodatabase (PostGIS) is structured around core archaeological entities – sites, findspots, survey units, features, cores/samples, and interventions – whose descriptive, spatial, chronological, and bibliographic attributes adopt ICCD Normativa semantics and authority lists to guarantee terminological consistency and catalogue interoperability at national level. This modelling enables the harmonisation of legacy datasets with newly acquired field observations and laboratory outputs, following a workflow for heterogeneous-data integration already tested in Mediterranean landscape archaeology (Brancato 2019), where archival records, survey evidence, and remote-sensing proxies converge in a single, queryable analytical space.

Within the ICA Geoportale Nazionale per l'Archeologia (GNA) application for archaeological data management, descriptive and authority information is encoded using the ICA's standards (Brancato *et al.* 2024). ISAD(G) (i.e. General International Standard Archival Description) specifies which elements (fields) are used to describe archival units – for example title, dates, scope and content – so that every dataset or collection record exposes a predictable set of metadata. ISAAR(CPF) (i.e. International Standard Archival Authority Record for Corporate Bodies, Persons and Families) defines authority records for the agents involved (survey teams, institutions, individual researchers), ensuring that names, roles, and histories are recorded once and reused consistently across records. Each operation across the data lifecycle – digitisation, georeferencing, classification, sampling, laboratory analysis, and interpretative synthesis – will be uploaded in the GNA as a discrete event with explicit paradata. Descriptive metadata will be also exposed according to standards, facilitating data provision to Italian and European e-infrastructures for archaeology and digital cultural heritage (Richards *et al.* 2021; Caravale *et al.* 2024). Interoperability/FAIR are ensured through standardised exports and crosswalks, open long-term formats (e.g., GeoPackage), metadata APIs, and authority control (DOI for publications; ORCID/VIAF for agents). In line with the dissemination plan and the decision to avoid a public WebGIS, discovery and preservation rely on deposition to the ICA GNA via automated end-of-project batch upload, guaranteeing citability and governance consistent with ICCD/ICA compliance. The bibliography is curated in Zotero and exposed as Linked Open Data (LOD) in CSL-JSON, JSON-LD, and RDF with stable identifiers; GIS records link back to the specific sources underpinning each interpretation. The LOD bibliography is accessible via the project website (https://archeomaplab.it/progetti/progetto-ash-prin-2022-pnrr/), which also hosts open-access reports and publications.

6. Objectives

This standards-based, provenance-aware infrastructure provides the analytical backbone for organic comparisons across the case studies. By integrating legacy archives, field-survey outputs, pedological and palynological datasets, and remote-sensing interpretations within a single environment – together with authoritative cataloguing (ICCD), archival accountability and linkage, automated deposition on the GNA, and LOD-based bibliographic exposure – the project ensures methodological transparency and long-term reusability. Following an interdisciplinary approach, ASH pursues the following objectives:

– reconstruct settlement dynamics by integrating legacy and newly collected survey data with remote sensing in the sample areas, mapped against multi-layer cartography (soil, topographic and geological maps, digital elevation models);
– detect and characterise Andosols using multi-temporal Copernicus imagery, evaluating their influence on vegetation phenology and productivity through NDVI-derived metrics;
– undertake pedological sampling to reconstruct some of the principal pedogenetic factors and properties of Andosols;
– compile and analyse pollen-core legacy data, to reconstruct major palaeoenvironmental trends;
– compare the distribution of volcanic soils with settlement (and socio-economic) systems and land uses across regions and periods.

Results to date are substantial but currently under analysis; publications in preparation will present the full datasets, methods, and implications for the project objectives.

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ABSTRACT

ASH investigates the role of Andosols, i.e. volcanic-ash soils, in four case studies in central and southern Italy (Southern Etruria/Northern Latium, the Campanian Plain, the Poro highplain in Calabria, and the Ionian–Etnean area of Sicily). It studies how the distribution and properties of these soils shaped agricultural productivity, settlement systems, and long-term landscape use from Late Prehistory to Antiquity. The research combines archaeological records (new fieldwork and legacy data) with pedological and archaeobotanical studies and multi-temporal remote sensing (historical satellite images, multispectral imagery, spectral indices mapping, sampling, integrated machine-learning and deep-learning analyses). A standards-based GIS supports cross-domain integration and spatial modelling. The project advances knowledge of human-environment relations, highlighting the strategic importance – and vulnerability – of volcanic-ash soils as a crucial subsistence resource. It also establishes a basis for transdisciplinary work linking archaeology, remote sensing, pedology, and environmental research, and provides evidence to inform responsible management of soil and landscape heritage today. Newly collected datasets and GIS mapping enable reproducible analyses and open deposition to benefit future research and heritage governance.

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THE NORTH VULSINIAN SURVEY: DIGITAL MAPPING, SYSTEMATIC TERRITORIAL RESEARCH, AND THE PROBLEM OF PROTOHISTORIC OCCUPATION AND LAND USE IN SOUTHERN ETRURIA

1. Territorial processes in protohistoric Etruria and the problem of sparse settlements[1]

An important contribution to the study of the forms and dynamics of settlement evolution in Southern Etruria comes from protohistoric studies, which have had the merit of building up a broad base of knowledge, result of intense territorial research activity (Cardarelli *et al.* 1980). These investigations, anticipated by the research of F. Rittatore Vonwiller (1951 with bibliography), led to the acquisition of a vast amount of data (Belardelli *et al.* 2007) and the reconstruction of settlement dynamics in the region (di Gennaro 1986; Pacciarelli 2001; di Gennaro, Peroni 1986; Schiappelli 2008; Barbaro 2010). This research culminated in the definition of the process of social, economic, and territorial transformation which, between the end of the Bronze Age and the Early Iron Age, reached its full expression in the formation of proto-urban centers (Pacciarelli 2001).

Despite Southern Etruria being one of the best-known areas with respect to protohistoric territorial processes, some aspects remain to be defined. Two points in particular stand out. The first concerns models of land occupation. The wealth of available data clearly demonstrates the consolidation, during the Bronze Age, of the settlement pattern based on well-defended hilltop, often corresponding to plateaux of several hectares (typically up to about a dozen), made defensible along all or much of their perimeter by steep slopes or rocky cliffs. On these reliefs developed nucleated villages (probably numbering several hundred inhabitants), often occupied for centuries. These centers are distributed at intervals of a few kilometers (typically at least three or four), a fact linked to the formation of territories stably controlled by the villages. Less well-known are other forms of settlement that certainly coexisted with defended villages, especially in the Early and Middle Bronze Age. A clear example is that of lakeshore settlements, a model, however, well known thanks to underwater archaeology. Another important, though less systematically recorded, phenomenon is that of small open settlements (or those on minor, undefended hilltop), often short-lived and located at short distances from one

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another. In certain areas, these settlements seem to reflect a pattern of sparse occupation by small human groups with only limited prospects of stability. This 'sparse settlement' pattern remains less documented and studied, also due to methodological problems connected with archaeological survey.

The second aspect concerns precisely the methods of systematic archaeological field survey, which will be discussed later in the context of a comparison between some of the largest systematic surveys conducted in Southern Etruria.

2. The North Vulsinian Survey: methodological aspects

The North Vulsinian Survey was carried out between 2017 and 2019 in the territories of Grotte di Castro and S. Lorenzo Nuovo, located on the northern side of Lake Bolsena. The study formed part of an 'industrial' doctoral project at the University of Naples Federico II, aimed at producing an updated archaeological map – including evidence from prehistory through late antiquity – intended to contribute both to research progress and to the knowledge and protection of archaeological heritage[2] (Fiorillo 2020; Fiorillo, Scardozzi 2023).

An intensive and systematic survey method was adopted (an example of the field-by-field method in Bintliff *et al.* 2007), with a team of 4-5 surveyors positioned in parallel lines at regular 5 m intervals (Pacciarelli *et al.* 2022). At the outset, the project aimed to cover the entire territory without preliminary sampling. This approach was deemed functional for future use of the map in archaeological heritage protection and territorial planning. As the research progressed, this objective, as usual, had to deal with visibility limitations, which ultimately allowed for the coverage of 7 km² (11%) out of a total area of about 53 km² (Fig. 1).

The main factors that resulted in zero or very low visibility were woodland cover (27%), uncultivated rural areas (18%), dense vegetation in pasturelands (13%), private properties (8%), and stubble fields (11%). Some obstacles (woods, private property, built-up areas) will likely remain a limitation in the future, while others, depending on land use, may not reoccur in future investigations. In this perspective, the mapping of not-visible areas provides a reliable basis for planning future work.

[2] New research was conducted in the autumn of 2025 in the territory of Gradoli, NW of the lake. These investigations are part of a broader PRIN PNRR research project aimed at the archaeological study of Andosols and their importance in the formation of complex settlement systems from prehistory to antiquity. 'ASH PRIN 2022 PNRR Archaeological investigation of Soil Heritage: the case of Andosols. An integrated and open IT approach to investigate a crucial agricultural resource in Central-Southern Italy (Latium, Campania, Calabria, and Sicily) through archaeology, pedology, archaeobotany, and remote sensing'. Project Code 2 P2022NNE72.

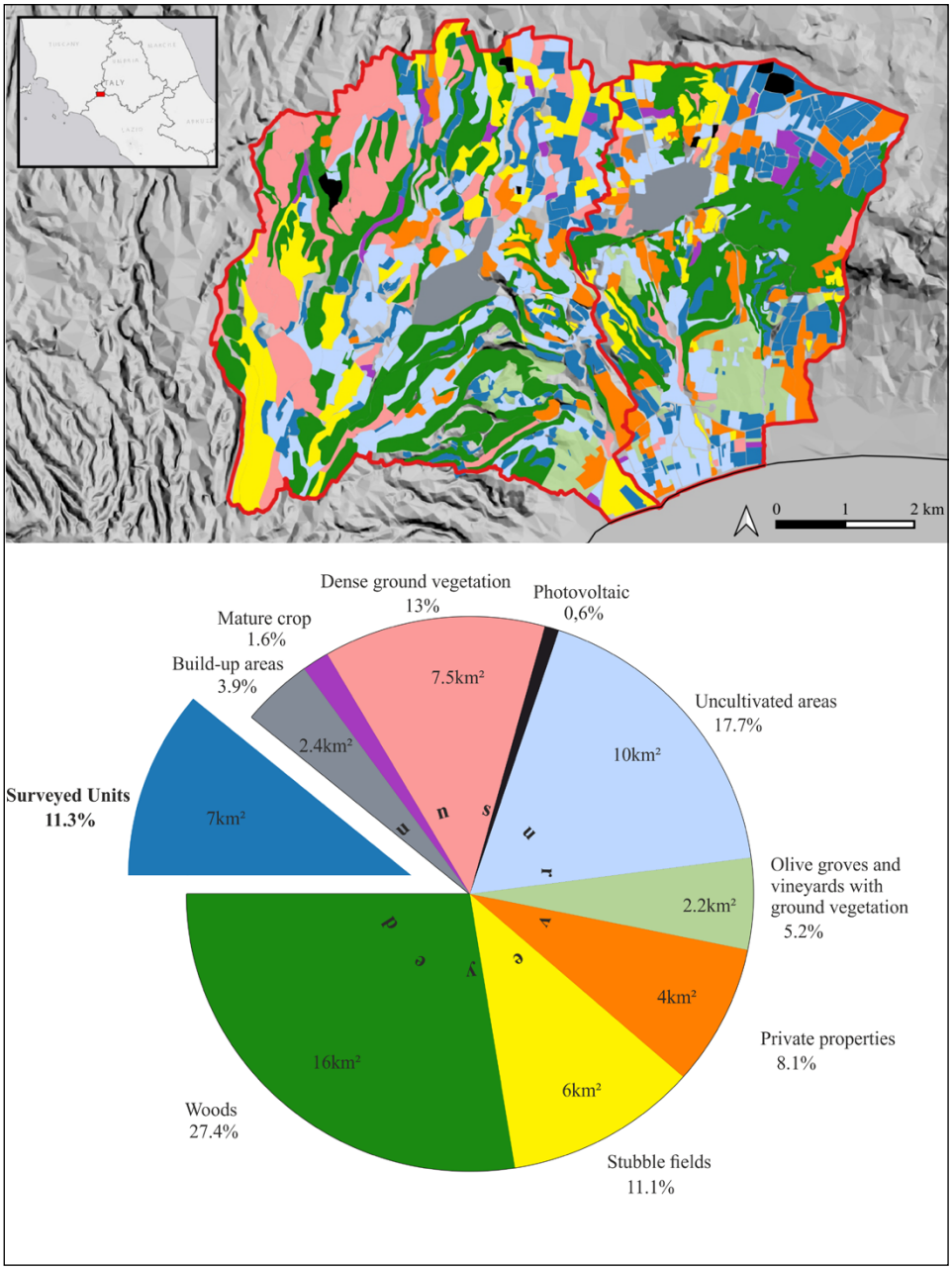


Fig. 1 – Thematic map of land use and comparison between the percentages of visible (surveyed) and non-visible (non-surveyed) areas.

3. The webGIS

One of the goals of the project was to provide a tool for archaeological heritage protection and urban-territorial planning. To this end, a freely accessible webGIS was implemented (https://qgiscloud.com/lorenzofiorillo/WEBGIS). Since the entire GIS project for the survey had been developed using QGIS software, the online version was implemented with the QGIS Cloud plugin, which ensures smooth navigation and compatibility with all layers. As the available space on the free QGIS Cloud server is limited, the online map is an excerpt of the complete version produced during the research. It includes layers useful for the geomorphological framework of the territory (altimetry taken from the CTRN 5000 of the Lazio Region), polygons of the surveyed units, polygons and points for archaeological evidence (pottery scatter-sites, point elements), and archaeological protected areas.

4. Morphology of the territory

The geomorphology of the area is characterized by the succession of three distinct landscapes along the N-S axis (Fig. 2). The northernmost consists of a broad zone of moderate undulation forming the southern limit of the Alfina Plateau (450-500 m a.s.l.). Further S, the landscape consists of volcanic reliefs shaped and bounded by watercourses. Still further S, the orography softens, reaching elevations between 310 and 304 m a.s.l., corresponding to the lake-shore zone of the Val di Lago. The dominant orographic feature is Monte Landro (585 m a.s.l.), from which not only the entire lake basin is visible, but the view extends further, from Monte Cimino to the SE, to the Monti Canino and Doganella to the SW. To the S, the relief gently slopes into the S. Angelo-Mezzagnone area (400-320 m a.s.l.), rich in light and fertile soils belonging to the pedological class of andosols (Napoli *et al.* 2019, 108-111; see also Pacciarelli 2013, for the importance of these soils in the development of pre-protohistoric extensive settlement systems), derived from volcanic activity of the Vulsini complex (Cerilli 2012). In the territory of Grotte di Castro, the central hilly belt extends also to the NW. Much of the landscape, except for the Val di Lago and part of the northern plateau, shows a sequence of reliefs of varying orientation, alternating with sinuous valleys. The northwestern ones correspond to the final outliers of the northeastern slope of the Latera caldera.

5. Previous finds in the survey area and its surroundings

Several pre-protohistoric finds around the Bolsena lake occurred over the last decades (Belardelli *et al.* 2007; Persiani 2009). The main investigations focused on the archaeological complexes of La Capriola (Cazzella, Moscoloni 1992), Civita di Arlena (Raddatz 1983), Fondaccio-Casale Marcello

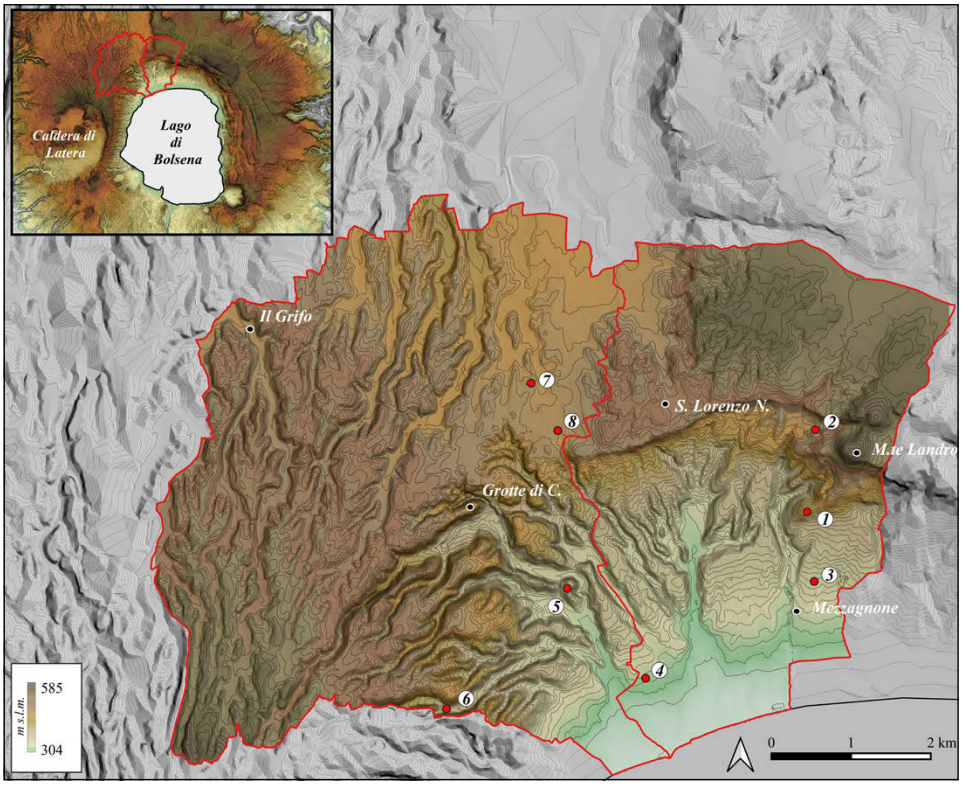


Fig. 2 – Morphology of the territory within the municipalities of Grotte di Castro and S. Lorenzo Nuovo, with indication of pre-protohistoric sites. Pomele (1), Pantanicce (2), S. Angelo-Mezzagnone (3), Quarti (4), Monte Maiulo (5), Butuni (6), Faciano (7), Pianinciano (8).

(Persiani 2009), and Montefiascone-Rocca (Barbaro 2010). At the same time, underwater research conducted by A. Fioravanti in Lake Bolsena (Fioravanti 1993 with bibliography) brought to light numerous findings, including the Ragnatoro and Monte Senano Sub sites on the western lakebed (Gradoli) and the remains of the Villanovan settlement of Gran Carro on the eastern lakebed (Tamburini 1995), where the SABAP VT-EM has recently set up a new program of systematic research (Barbaro 2021). Further discoveries over the last twenty years have involved Monte Segnale and La Montagna hills (Casi, Tamburini 1999) and the Capodimonte promontory (Persiani, Conti 2016).

Other significant data were gathered in the Latera caldera (Conti *et al.* 1993), where the identification of numerous archaeological sites spanning from the Paleolithic to the Late Bronze Age, combined with the excavation of some of these sites and the integration of available paleoenvironmental studies for

Mezzano lake (Sadori *et al.* 2011 with bibliography), led to a comprehensive synthesis on landscape evolution (Petitti, Rossi 2012). In this panorama of widespread protohistoric evidence, the absence of finds in the territory N of the Bolsena lake – between the municipalities of Grotte di Castro, San Lorenzo Nuovo, and Bolsena – appeared striking. The only certain data concerned a few fragments of protohistoric pottery from Monte Landro (Casi, Tamburini 1999; Maggiani, Pellegrini 2012) and the flask-shaped vase near the boundary between Grotte di Castro and Onano, in the locality Il Grifo (Bertolani *et al.* 1993). Further data are related to the discovery of ceramic fragments (not collected), tentatively attributed to the Iron Age, from Colle Mortaro and S. Maria delle Colonne in the territory of Grotte di Castro (Belardelli *et al.* 2012). In addition to the absence of documentation concerning these artifacts, a high incidence of later materials, particularly Roman, was observed in the pottery scatter areas. This Iron Age presence should therefore be considered at least doubtful.

6. Newly recorded sites in the survey area

The archaeological map of the territories of Grotte di Castro and S. Lorenzo Nuovo includes legacy data and the evidence recovered during the survey, dating from prehistory to late antiquity. For all the topographic units of archaeological interest – 68 in total, including new finds and bibliographic or archival data – detailed datasheets were prepared, including the topography of the scatter-sites, cadastral data, coordinates, and drawings of monuments (e.g. tombs) and diagnostic ceramic artifacts useful for chronological attribution (Fiorillo 2020).

The research provided significant insights for the Etruscan and Roman periods (Fiorillo, Tescione 2024) and allowed the discovery of new Bronze Age sites, the focus of this contribution. Eight impasto pottery scatter-sites can be attributed to the protohistoric period (Fig. 2), corresponding – according to the reconstruction presented here – to small settlements dating from the Early to the Middle Bronze Age 1-2 (21st-15th centuries BC), except for one context attributable to the Late Chalcolithic. These new finds, while leaving the gap regarding the Early Iron Age and the Late Bronze Age unchanged, significantly increase knowledge of protohistoric settlement in the northern sector of Bolsena lake, suggesting that the previous lacuna in documentation was due more to the lack of systematic research than to specific settlement dynamics (Persiani 2009).

6.1 *Pomele*

The hill, characterized by steep slopes on the NW and SW sides, has a summit area extended slightly beyond one hectare (Fig. 2, n. 1). On one of the hill's flanks, ceramic fragments were collected, some of which are datable to the Early Bronze Age (Fig. 3A).

6.2 *Pantanicce*

Fragments of impasto pottery were found in a narrow strip of land at the base of a modest relief at the northwestern extremity of Monte Landro (Figs. 2, n. 2, 3B). Some forms are datable to the Early Bronze Age.

6.3 *S. Angelo-Mezzagnone*

The S. Angelo-Mezzagnone (Fig. 2, n. 3) area corresponds to part of a large terrace descending from the southern side of Monte Landro with moderate slopes toward the Val di Lago (Fig. 4A). Protohistoric finds indicate phases of the Early and Middle Bronze Age 1-2.

6.4 *Quarti*

The Quarti archaeological site (Fig. 2, n. 4) is located at the beginning of the Val di Lago, about 700 m from the shore, at the transition between the inner hilly landscape and the lakeside plain (Fig. 4B). Ceramic fragments indicate occupation between a late phase of the Early Bronze Age and the Middle Bronze Age 1-2.

6.5 *Monte Maiulo*

Monte Maiulo (Fig. 2, n. 5) is a small hill with a settleable summit area of about 1.5 hectares. It is isolated along all its perimeter by steep slopes (Fig. 5A). Few finds were recovered due to low visibility, among which is a fragment of a carinated bowl generically attributable to the Middle Bronze Age.

6.6 *Butuni*

Fragments of impasto pottery were scattered in a narrow strip at the northern base of a tuff ridge elevated about 30 m above the valley (Figs. 2, n. 6, 5B). The fragments are partially attributable to the Middle Bronze Age 1-2, but the presence of Early Bronze Age material is also attested.

6.7 *Faciano*

The Faciano archaeological site (Fig. 2, n. 7) was identified on the plateau NE of Grotte di Castro. Pottery fragments, found at high density and datable to the Early Bronze Age, covered an area of about 3,000 m² (Fig. 6A). In 2023, a stratigraphic excavation carried out by a research team from the University of Naples Federico II revealed the poor state of preservation of the site, reduced to a few centimeters in thickness and preserved in secondary deposition only due to a slight depression in the geological substrate (preliminary reports in Fiorillo *et al.* 2024).

6.8 *Pianinciano*

Pianinciano site (Fig. 2, n. 8) lies less than 1 km from the previous site, near the southern edge of the plateau. The pottery scatter-site extended 200 m in a NS direction over an area of 5,000 m² (Fig. 6B). Some fragments suggest a Late Chalcolithic date for the context.

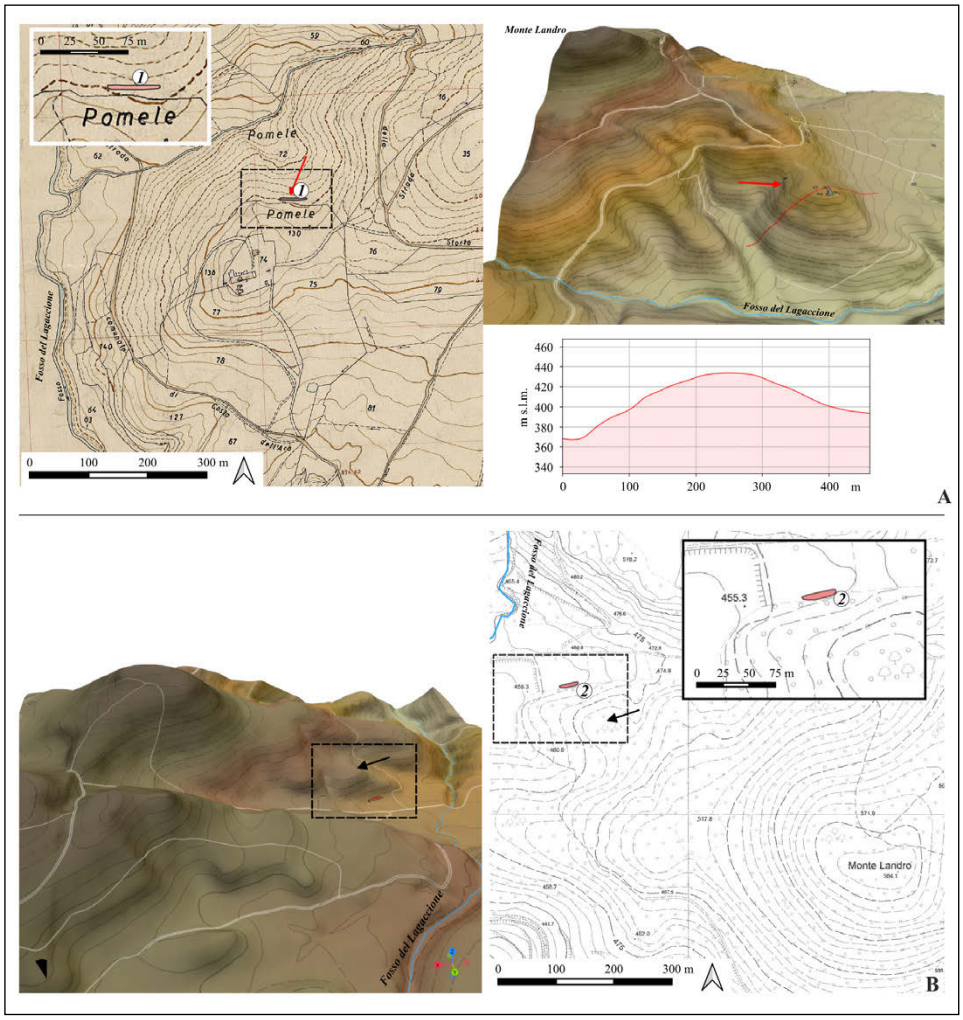


Fig. 3 – Location of protohistoric pottery scatter-site on Pomele hill (A) and at Pantanicce (B). The arrow highlights the hypothetical original location of the site.

7. Integration of the new finds into the Vulsinian context

The survey carried out between 2017 and 2019 in the territories of Grotte di Castro and S. Lorenzo Nuovo greatly increased the knowledge of protohistoric settlements in the northern sector of Lake Bolsena. Most of the pottery scatter-sites, as noted, can be assigned to the period between the Early Bronze Age and the Middle Bronze Age 1-2. Only Pianinciano belongs to an earlier phase, corresponding to the Late Chalcolithic. Six settlements can be referred to the Early Bronze Age (Fig. 2, nn. 1-4, 6 ,7). For three of

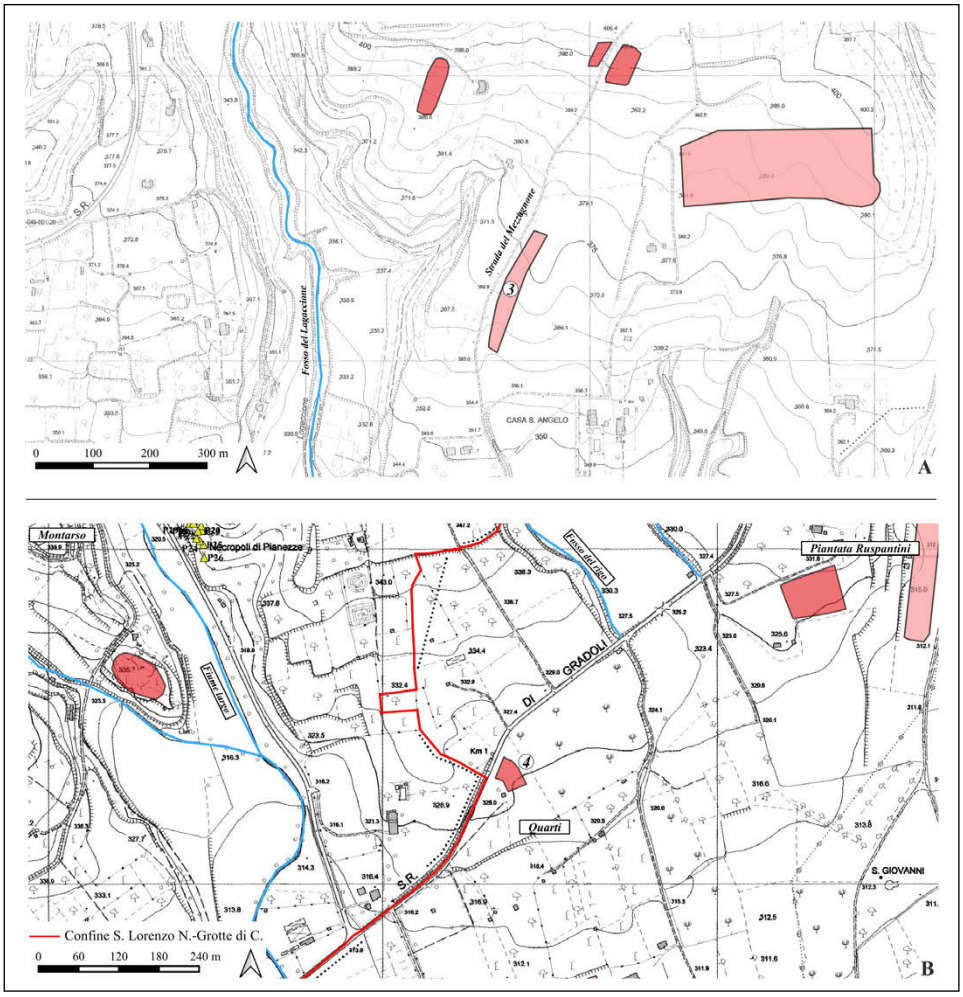


Fig. 4 – Location of protohistoric pottery scatter-site at S. Angelo-Mezzagnone (A) and Quarti (B).

these sites (Pomele, Mezzagnone, and Butuni), the Early Bronze attribution, although probable, remains uncertain. The limited extent of the pottery scatter-sites suggests the presence of small settlements, generally extended less than 1 hectare, located mostly in open landscapes. Exceptions are Pomele, on a small hill partially isolated by steep slopes, and Butuni, occupying an isolated position within a sequence of reliefs ad valleys.

An approximately 1 km equidistance separates the three sites of Pantanicce, Pomele, and Mezzagnone (Fig. 2). This could suggest a dense and

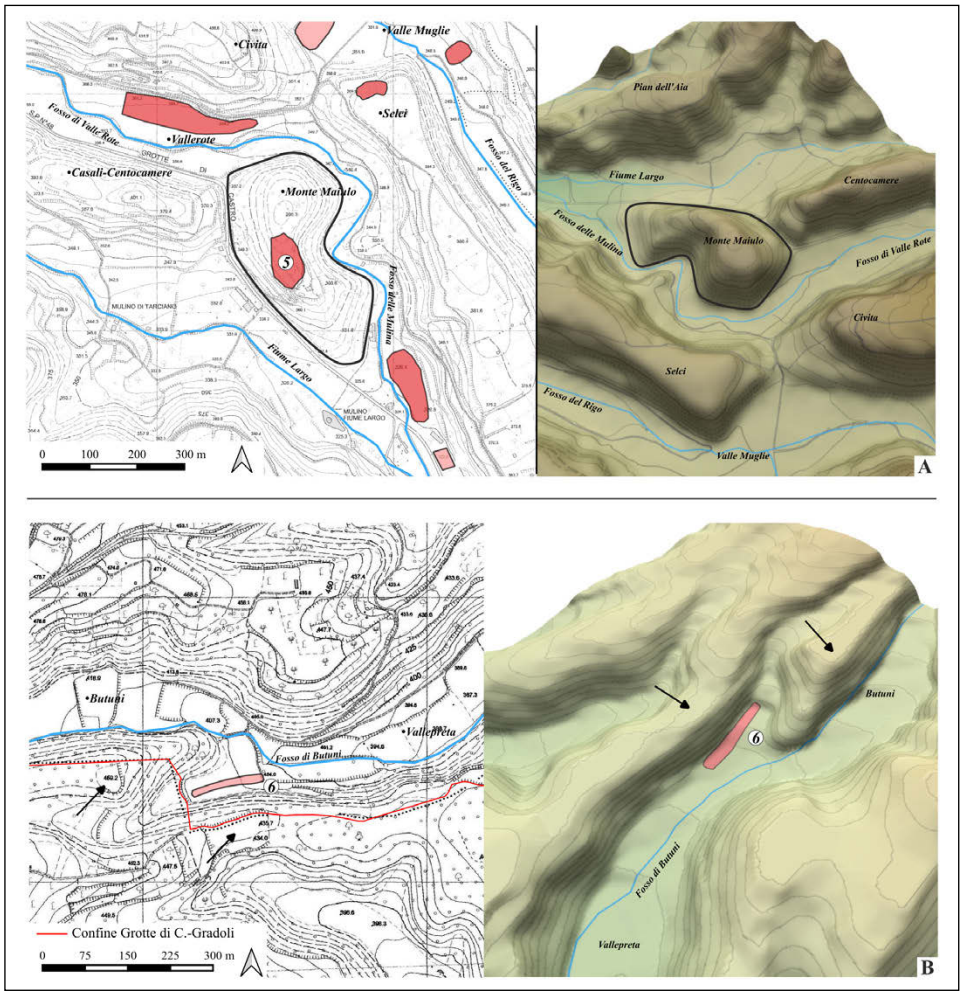


Fig. 5 – Location of protohistoric pottery scatter-site on Monte Maiulo (A) and in Butuni valley (B).

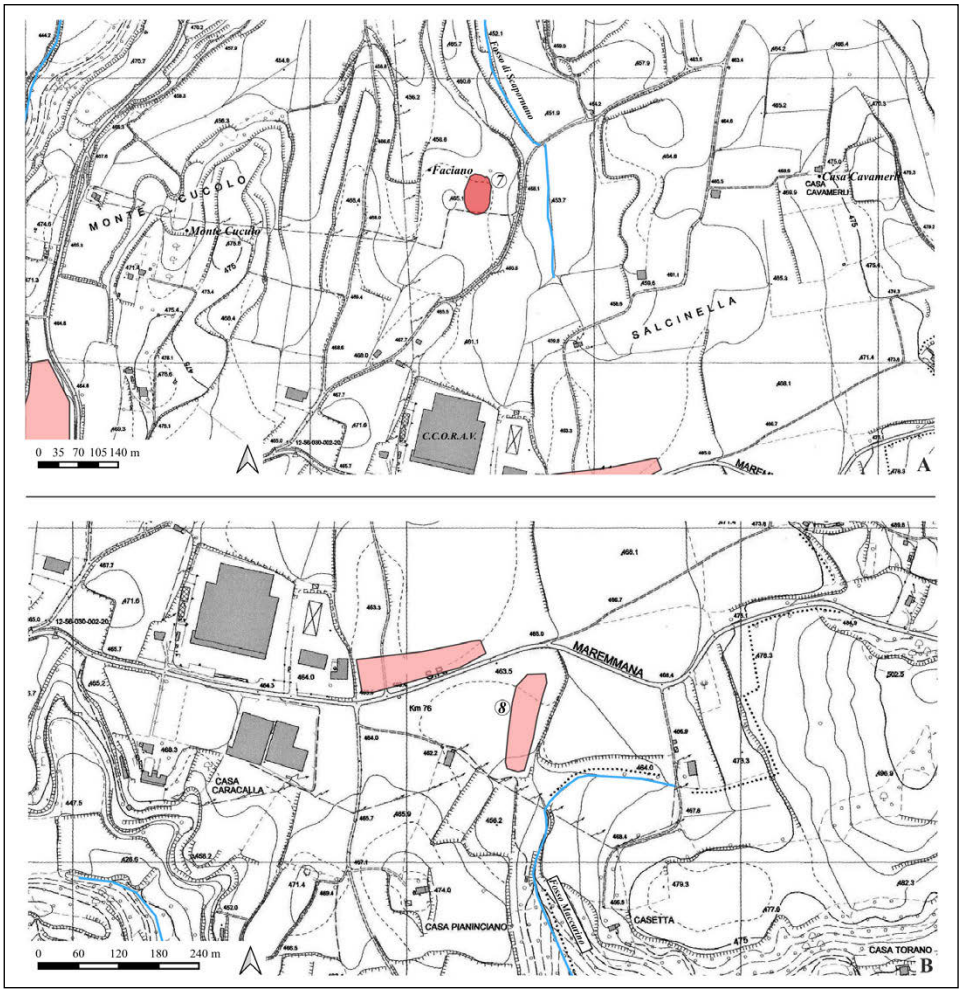


Fig. 6 – Location of protohistoric pottery scatter-site at Faciano (A) and Pianinciano (B).

somewhat regular occupation of the territory, of which only a limited portion has been revealed by research[3]. At the same time, it cannot be excluded that this topographic feature represents not a dense and regular settlement

[3] From this perspective, the greater distance between Mezzagnone and Quarti could be explained by the failure to identify a contemporary site midway, which, however, might be suggested by sporadic fragments of impasto pottery found in correspondence with a Roman *villa* at Piantata Buccelli (Fiorillo 2020, 136, fig. 3.61), a location just over 1 km from both Quarti and S. Angelo-Mezzagnone.

system, but rather the cumulative outcome of short-lived settlement forms. Early Bronze Age settlement pattern thus consisted predominantly of open sites, without defensive potential, oriented toward exploitation of available agricultural resources. Proximity to a watercourse is also notable for the sites of Pantanicce, Pomele, and S. Angelo-Mezzagnone, located near the Lagaccione stream. There is also a correspondence between the settlements and volcanic andosols, such as those at Quarti, S. Angelo-Mezzagnone, and Faciano, which represented a primary agricultural resource.

In this context, the settlement on the Pomele hill could have had a distinct character, situated on a relief that, while not completely isolated, provided stronger defensive potential and some degree of strategic relevance. Although a more extensive data set is needed for reliable reconstructions, the protohistoric sites identified N of Lake Bolsena suggest a sparse settlement model, consisting of small settlement clusters at short distance, largely oriented toward exploitation of primary resources. This organization may either represent a system of intensive occupation and land use, anticipating the 'polynuclear' settlement model proposed for the Middle Bronze Age (Peroni, Di Gennaro 1986; Pacciarelli 2001, 94), or, alternatively, a proliferation of small short-lived sites.

During the Middle Bronze Age 1-2 four sites are attested (Fig. 2, nn. 3-6), of which Monte Maiulo is uncertain. Open-position sites such as Quarti and S. Angelo-Mezzagnone continue, while Pantanicce and Faciano seem to have been abandoned. Pomele also shows no evidence of continued occupation, though its strategic relevance suggests that this absence may be merely apparent, reflecting the random nature of surface survey results. Notable is the new occupation of Monte Maiulo, which, although only generally attributable to the Middle Bronze Age, may be part of a process of progressive selection of sites with high defensive potential, beginning in Southern Etruria from this period onward (Di Gennaro, Barbaro 2008). Middle Bronze Age 1-2 settlement pattern appears aimed both at exploiting fertile plains and at occupying strategic positions. In summary, despite the limited sample area, the identification of eight pre- and protohistoric sites corresponding to small settlements is significant, with an average density of 1,14 sites per km² over the 7 km² systematically surveyed. Another notable element is the presence of five open-type settlements, a still poorly known class compared to hilltop sites, likely underrepresented due to the lack of high-intensity systematic surveys.

Chronologically, the Early and Middle Bronze Age phases are the most attested, with communities organized into small settlements distributed at short intervals. Later Bronze Age phases have not yet been documented; while partial population contraction cannot be excluded, it should also be considered that sites of this period may simply not have been identified due to the small extension of the surveyed area.

8. Identification of protohistoric surface evidence: comparative experiences in Southern Etruria

From the second half of the 20th century onward, the progressive increase in discoveries of protohistoric settlements in Southern Etruria reflects both the development of autonomous research – sometimes locally rooted – and the broader historical academic context, which, beginning with the pioneering South Etruria Survey (Potter 1979), witnessed a growing interest in surface archaeology, field methodologies, data collection and analysis, and, ultimately, the reconstruction of ancient landscapes (Cambi, Terrenato 1994).

The more structured survey projects (Stoddart *et al.* 2020, 2, fig. 1) have often been conducted on a broad diachronic scale, starting with the contributions of *Forma Italiae*, based on the 1:25.000 topographic sheets of the Istituto Geografico Militare, and continuing with large-scale projects carried out through different territorial sampling strategies. Among these, the most extensive ones in Southern Etruria (Fig. 7) were the South Etruria Survey (Potter 1979), later re-examined within the Tiber Valley Project (Patterson *et al.* 2020; Witcher 2020), the Tuscania Survey Project (Barker, Rasmussen 2023), and the research project covering the area between the Albegna and Fiora river valleys (Carandini, Cambi 2002).

The latter, carried out between the late 1970s and the 1980s, investigated a total surface area of 330 km² in which 1650 topographic units were identified. However, the publication, focused on territorial development from the Etruscan to the Modern Age, excluded the pre and protohistoric periods from its analysis. The South Etruria Survey, conducted between the mid-1950s and the mid-1970s, according to the synthesis by T. Potter (1979), yielded approximately twenty sites datable to the Bronze Age across an investigation area of about 1000 km². This corresponds to an unrealistically low density that cannot be explained solely by the adopted methodology. Since the survey was extensive and widely spaced (with surveyors set 20 m apart), it is likely that smaller scatters often went unnoticed (see also di Gennaro, Pacciarelli 2024). On the other hand, it should be noted that surface deposits between the 1950s and 1970s, when the South Etruria Survey took place, were in much better condition than today. At that time, artifacts freshly brought to the surface by the first mechanical agricultural ploughing would have been highly visible, whereas today they are often reduced to modest scatters of small fragments, progressively dispersed and broken by agricultural activities, and hardly detectable except through very intensive survey (with spacing no greater than 5 m between surveyors).

It is therefore plausible that the investigations carried out within the South Etruria Survey was better suited to identifying remains from the historical periods, particularly Etruscan and Roman. This, combined with the low survey

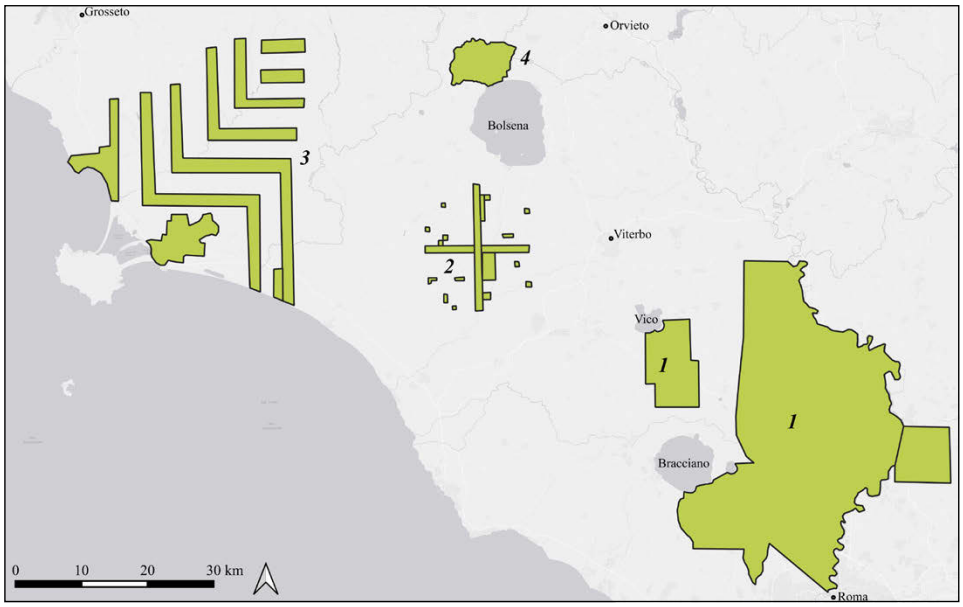


Fig. 7 – Location of survey projects mentioned in the text. South Etruria Survey (1, adapted from Patterson *et al.* 2020), Tuscania Survey (2, adapted from Barker, Rasmussen 2023), Albegna Survey (3, adapted from Carandini, Cambi 2002), North Vulsinian Survey (4).

intensity and the likely greater difficulty in recognizing protohistoric ceramics compared to Roman or Etruscan productions, may partly explain the gap in protohistoric data. Partial confirmation comes from the re-examination of a sample of sites identified by the South Etruria Survey in the *ager Veientanus* (Stoddart, Di Gennaro 1982). This study highlighted the presence of some sites which, although identified, had not been classified as protohistoric. The scatters with diagnostic elements mainly date between Middle Bronze 3 and the Recent Bronze Age, while for other sites, lacking characteristic forms or decorations, only a generic attribution to pre- and protohistoric age can be suggested. Similarly, the Tiber Valley Project, in re-examining the South Etruria Survey documentation, concluded that the number of sites attributable to the Bronze Age was about twice the original estimate (Di Giuseppe 2020). Overall, these data confirm that the settlement density indicated by T. Potter (1979) should be regarded as underestimated (albeit to a lesser extent than might be assumed). Given the great extent of the territory explored, it is therefore reasonable to assume that many sites went undetected.

A different case is represented by the Tuscania Survey Project (1986-1991), whose data collection method allows for a more precise comparison

with the results of the North Vulsinian Survey. The research in the Tuscania countryside, based on a sampling strategy combining transects and squares (both targeted and random), enabled systematic investigation of an area of 41,5 km², with a fixed distance of 15 m between surveyors. The chronological attributions proposed by the authors are not detailed (Barker *et al.* 2023), grouping the finds into two broad phases: an 'Earlier Bronze Age', covering both Early and Middle Bronze Age (21st-14th centuries BC), and a 'Later Bronze Age', including the Recent and Final Bronze Age (13th-10th centuries BC). No drawings of the material from each site are presented, which prevents chronological cross-checking.

For the Earlier Bronze Age, 62 sites are reported: only one considered as definite, 25 as probable, and 36 as possible, yielding a density of about 1,5 sites per km². This estimate is not very distant – considering the differences in survey area – from that recorded N of Lake Bolsena (1,14 sites per km²). However, it should be noted that among the 62 sites of the Tuscania Survey attributed to the Early-Middle Bronze Age, some consist of just a few sherds, sometimes only one or two (Barker *et al.* 2023, 96, tab. 4.5). Such low-density scatters were considered sporadic and were not included in the distribution maps of the North Vulsinian Survey, as they were regarded as of little significance. Consequently, the difference in site density may depend on this methodological divergence. It should also be emphasized that the settlement recorded by the Tuscania Survey appears concentrated around the Tuscania center itself, both in the earlier and later Bronze Age phases. This pattern does not allow for the reconstruction of a widespread territorial occupation of the kind proposed for the northern area of Lake Bolsena.

This brief comparison, clearly not exhaustive, is simply intended to examine, through three of the most extensive surveys conducted in Southern Etruria, the varying capacity to detect protohistoric surface evidence (especially the smaller sites) in the territories explored. At the same time, it aimed to check whether in survey areas much larger than the North Vulsinian one, there were indications of a sparse settlement system consisting in small, predominantly open sites similar to those observed in the northern area of Lake Bolsena. The results show that for two projects (Albegna Valley, South Etruria Survey) the available data are insufficient, while the Tuscania Survey produced a significant number of records for which, however, neither graphic documentation of finds nor a precise chronological framework is available. Considering the historical context of these research projects and the broader evolution of archaeological practice, including field survey, clear divergences emerge in the approaches to detecting and studying protohistoric settlement. These differences stem not only from methodological choices but also from the varying preparation of individual surveyors (Bintliff *et al.* 1999) and, of course, from the overall design of the projects.

Finally, it should be highlighted that reconstructing the nature of protohistoric minor sites requires targeted archaeological excavations, such as the one recently carried out in 2023 at the Early Bronze Age site of Faciano (Fiorillo *et al.* 2024). This excavation confirmed that the site was a small, short-lived settlement, while also revealing that the archaeological deposit had been subject to erosion and colluvial transport and was largely damaged by mechanical agricultural ploughing – factors which over time have likely compromised the preservation of many remains of small sparse settlements.

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ABSTRACT

A recent systematic survey project, carried out between 2017 and 2019 in the North Vulsinian area (territories of Grotte di Castro and San Lorenzo Nuovo), has partially filled the previous lack of data in the northern sector of the Lake Bolsena. The investigation, based on an intensive and systematic approach, covered about 7 km² (11% of the total area), revealing numerous new archaeological sites dating from Prehistory to Late Antiquity. This paper focuses on new settlement evidence attributable mainly to the Early and Middle Bronze Age. It clearly emerges that in order to achieve a more comprehensive understanding of protohistoric settlement patterns – particularly for the earliest phases of the Bronze Age – intensive and systematic territorial surveys are required, as they are the only means capable of detecting the most fragile and now largely eroded traces of small settlements. A similar observation also arises from the Tuscania Survey Project, while the comparison with other past survey projects highlights less attention to the issue.

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AN OPEN DIGITAL ARCHIVE FOR THE INTEGRATION OF HETEROGENEOUS DATA FOR TOPOGRAPHICAL RESEARCH

1. Introduction: the Digital Groma platform

The project In.Res.Agri – Investigating Resilient Roman Agricultural Landscapes in Southern Italy, funded under the PRIN 2022 program[1], involves the integrated use of traditional and innovative methods for the documentation, interpretation, and dissemination of archaeological and topographic information related to Roman land division in Southern Italy, based on selected case studies located in the Campania and Puglia (Brancato *et al.* 2024). To support data collection, organization, and analysis activities within the project, a dedicated IT platform has been developed, named Digital Groma. This platform consists of three modules: a database with its open repository – composing the In.Res.Agri digital archive – and a geodatabase. This article aims to describe the approaches which guided the CNR-ISPC research unit in the modeling of the archive as a tool capable to integrate a whole range of heterogeneous data coming from different types of sources – topographical, archaeological, environmental and textual – and designed according to FAIR principles.

I.R.

2. The In.Res.Agri archive

2.1 *The applications – with a view to FAIRness*

The In.Res.Agri archive is built on a relational database designed for the recording, manipulation, and integration of both new and legacy data concerning archaeo-topographical research. The database builds upon an application, named Racoon, developed by the IT specialist V. Bellucci for archaeological databases, which has been customized to meet the project's specific requirements, both in terms of logical structure and table fields, and of data-entry and administrative functionalities. The application is based on a PostgreSQL relational database with the PostGIS extension, installed on a cloud server. This configuration is well established in the management of geospatial data, enabling direct upload of shapefiles and interoperability with the geodatabase (Guarnieri *et al.* 2016; Berzellini *et al.* 2024, 239-241)[2]. The

[1] Project code 2022SMJCHX. The project is coordinated by the University of Naples Federico II, in collaboration with the research units of the Institute of Heritage Science of the National Research Council (CNR-ISPC) and the University of Salento.

[2] The development of the geodatabase is under the responsibility of the research unit at the University of Naples. It will enable geospatial analysis and visualization.

web interface for data entry (https://digitalgroma.cnr.it/) was developed using PHP on the server side and JavaScript, HTML5, and CSS3 on the client side.

A public version of the archive has been also developed to enable the automatic publication of validated database records as static HTML pages, provided with a set of metadata tracking scientific responsibility, usage conditions, authorship and chronology of content, thus ensuring transparency and citability[3]. Although such public version was not a requirement of the project in this phase[4], it was deemed important to allow prompt accessibility to the project's archival data. Moreover, as an API endpoint was developed to ensure that the data collected could be reused by similar initiatives, associating each database record with a public URL allowed the necessary stable referencing for identification and linkability across machine-interoperable environments.

2.2 *A model for the integration of heterogeneous data*

The core of the In.Res.Agri informative system is concerned with topographical entities and the related archaeological features, including both movable and immovable monuments, as well as environmental and geomorphological features. These data primarily derive from the fieldwork conducted by the units involved in the project. However, a distinctive aspect of the project is the particular attention devoted to legacy data derived from pre-existing documentation, such as archival materials, and to the history of research available through previous publications, which often include a wide range of visual or, more broadly, multimedia content – especially maps and photographs, both aerial and satellite. Finally, textual information derived from epigraphic and literary sources was deemed essential for a complete reconstruction of the topographical landscape.

The implemented data model follows a relational structure organized around seven entities: Topographical Entity, Project, Archaeological Materials Table, Geomorphological Entity, Monument, Literary Source, and Archival Document (Fig. 1). Within this architecture, the Topographical Entity represents the central core and is responsible for collecting and organizing topographical information (Brancato 2020, 70-72). It maintains: recursive relations with itself, useful to represent possible connections and hierarchies among multiple topographical entities; many-to-many relations with the entities Monument, Literary Source, and Archival Document; a many-to-one

[3] Each record in the system is associated with an operational status (draft, private, public), defining its level of validation and visibility within the platform. An authentication system implements user profiling with differentiated roles (Admin, Read/Write, Read/Write Own Records, Read Only). This setup supports a workflow based on distributed responsibility, ensuring traceability, version control, and data integrity throughout the entire processing cycle.

[4] Contents will be publicly accessible and queryable through the geodatabase.

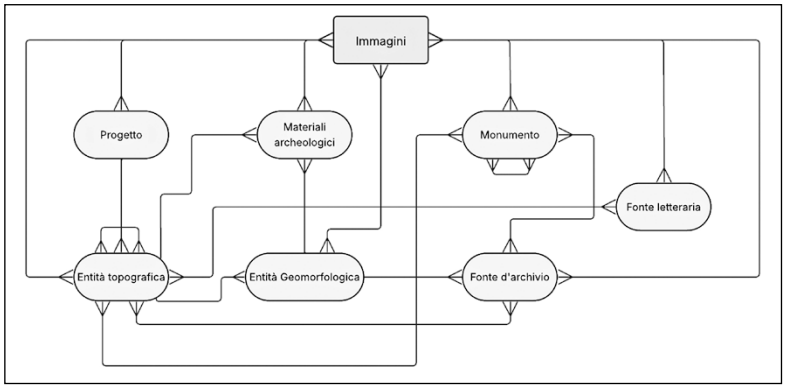


Fig. 1 – Model of the In.Res.Agri database.

relation with the Project entity; and one-to-many relations with the Archaeological Materials Table and Geomorphological Entity.

The Project entity is understood as the territorial reference unit within which field activities are organized – corresponding, in the context of the In.Res.Agri project, to the areas selected as case studies. Monument, Archival Document and Literary Source contribute to documenting the different interpretative dimensions of the Topographical Entity through material, archival and literary sources.

The Monument entity is conceived for the analytical characterization of both immovable and movable evidence; it includes a recursive relation useful for modelling hierarchical configurations among objects (for instance, the inclusion of an inscription on a wall within the relevant architectural unit).

The Archival Document entity, on the other hand, is devoted to integrating materials derived from previous research, including maps, drawings, written documents, as well as digitized or born-digital resources, not only in relation with Topographical Entities but also with Monuments and Geomorphological Entities.

One of the distinctive aspects of In.Res.Agri is its attention to the analysis of textual sources. For this reason, an autonomous Literary Source entity was defined to provide a structured description of textual attestations, following an information model consistent with the specific characteristics of this documentary typology. This results in a catalogue of sources related to Roman centuriation in the study areas. Textual sources which are not literary but epigraphic are described within the Monument entity (see *infra*).

The Archaeological Materials Table allows for the structured recording of material movable finds of a given Topographical Entity, while the Geomorphological Entity documents data obtained from coring carried out in

the relevant context. Both contribute to building an integrated and coherent interpretive and chronological framework of the associated Topographical Entity.

Within the relational database developed according to this model, the relationships among most entities are implemented through join tables, designed not only to formally link records but also to qualify semantically the nature of those relationships. Although the database does not formally adopt a semantic model, each join table is enriched with descriptive attributes that explicitly specify the type of relationship between connected entities. For instance, the recursive relationship between two Monument records can specify that an element classified as an 'inscription' *is included* within an 'architectural structure'. Further specifications of the relationships can be recorded as well: for instance, a Literary Source can be linked to a Topographical Entity by specifying as attributes of the join table the relevant toponym mentioned in the Source, where a citation of the textual passage containing the toponym appears. In this way, the system supports semantic traceability of connections, enhancing the integration of material and documentary evidence.

The system also includes bibliographic information and multimedia content. While technically treated as accessory components (see *infra*), they are fundamental from an informative perspective: the latter allows to integrate visual materials on monuments, archival documents, maps, aerial and satellite images, etc., while the former ensures to reference existing literature and trace the history of studies concerning a given territory.

I.R.

3. Selecting and organizing information

Since the outset, the project focused on designing a model able to address the diversity of the available information and bring it together within a coherent conceptual frame. Two were the principles guiding the organisation of information within the seven main record types described above: first, the effectiveness in the representation of the actual data produced and gathered by the In.Res.Agri project and the responsiveness to the project's research aims; second, the compliance with standards in view of interoperability – a commitment to ensuring that the dataset could be reused and extended within a broader research environment. The data were deliberately organised with the prospect of integration into the Geoportale Nazionale per l'Archeologia (GNA: https://gna.cultura.gov.it/; Calandra *et al.* 2021) and, wherever possible, aligned with the standards of the Istituto Centrale per il Catalogo e la Documentazione (ICCD, http://www.iccd.beniculturali.it/; Mancinelli 2018). To this aim, the adoption of controlled vocabularies has been a structural component of the data model, designed to guarantee descriptive

coherence, interoperability, and semantic quality. In total, 46 vocabularies have been integrated. A significant portion derives from nationally recognized repositories, such as those of the ICCD and the GNA, which together represent over three quarters of the total. To a lesser extent, vocabularies from the epigraphic domain were also included, notably from the Europeana Network of Ancient Greek and Latin Epigraphy (EAGLE) and the Epigraphic Database Roma (EDR). About one sixth of the vocabularies were newly developed by the project's research units in response to specific needs that emerged during the modelling process. Although the system is not formally based on an ontological model, the selection of vocabularies was guided by compatibility with existing information standards, making the model potentially alignable with infrastructures adopting semantic approaches.

3.1 *Project*

The Project table was developed to bring together the key information relating to the study area as a whole. For the In.Res.Agri project, this meant providing a concise framework for the selected case studies contributed by the various research units. The information is arranged into seven sections, grouped into three broad categories. The first category gathers general and administrative details, setting out the institutional and territorial framework of the project. The second one addresses methodological and technical aspects, describing the process of identifying study areas and the georeferencing methods applied. The third one presents descriptive and documentary information, ranging from the historical and archaeological overview to environmental and geomorphological features.

The structure closely follows the Modulo Progetto (MOPR) adopted by the GNA, which is used to record initiatives that have an impact on the territory (https://gna.cultura.gov.it/wiki/index.php/Compilare_il_MOPR). Nearly two-thirds of the fields of the relevant In.Res.Agri database table correspond directly to those defined in the MOPR, both in nomenclature and in the controlled vocabularies employed (see *infra*). At the same time, some modifications were introduced to the original specifications to better meet the research project's requirements (Fig. 2). These included the addition of fields, such as a numerical code assigned to the geometry of the study area to manage spatial information within the system[5], as well as fields allowing for the specification of the geometry type to represent geographical features and the coordinate reference system used, derived from the ICCD Modulo Sito/Area (MOSI) along with their associated vocabularies (https://iccd.beniculturali.it/getFile.php?id=9512). Other controlled vocabularies were

[5] It is comparable in function to the GEI code used in SIGECweb.

In.Res.Agri DB: Project entity		
Section	**Field**	**GNA MOPR / ICCD correspondence**
Identificazione		
	Codice progetto	GNA
	Ambito di applicazione	GNA (with vocab)
	Denominazione	GNA
	Modalità di individuazione	GNA (with vocab)
Localizzazione		
	Regione	GNA
	Provincia	GNA
	Comune	GNA
Georeferenziazione		
	Identificativo Geometria	
	Tipo di localizzazione	GNA (with vocab)
	Tipo di georeferenziazione	ICCD vocab
	Sistema di riferimento	ICCD vocab
	Tecnica di georeferenziazione	GNA (with vocab + new values)
	Grado di precisione del posizionamento	GNA (with vocab)
	Base cartografica di riferimento	GNA (with vocab + new values)
	Note al posizionamento	GNA
Opera in progetto		
	Categoria opera	GNA (with vocab)
	Fase di progetto	GNA (with vocab)
	Data della relazione archeologica	GNA
	Data della campagna di ricognizione	GNA
	Descrizione	GNA
Descrizione		
	Geomorfologia	GNA
	Caratteri ambientali storici	GNA
	Caratteri ambientali attuali	GNA
	Sintesi storico archeologica	GNA
	Note	GNA
Riferimenti		
- Bibliografia		
	Id record in Zotero	
	Riferimento	
- Risorsa esterna		
	URL	
Certificazione e gestione dei dati		
	Responsabili della redazione della scheda	GNA
	Responsabili del progetto e contenuti	GNA
	Data di redazione della scheda	

Fig. 2 – The Project table and its correspondences with the GNA 'MOPR' module and ICCD vocabularies.

also expanded to include additional georeferencing techniques and types of cartography employed, which are not provided in the MOPR module but reflect the operational practices adopted by the research units[6].

3.2 *Topographical Entity*

The Topographical Entity table was conceived to organise contextual information. It arranges data across thematic sections, covering the location and georeferencing of evidence, the methods applied to identify them, and their nature, all framed within their chronological setting (Fig. 3). Its design draws on the MOSI module of the GNA. Much of the architecture of MOSI is retained – over two-thirds of the fields correspond directly – yet the schema was not applied rigidly and was adapted and extended to address the specific

[6] The additional terms include georeferencing techniques such as 'Base rover, RTK, and TS', and reference cartographic bases such as 'Tavoletta IGM'.

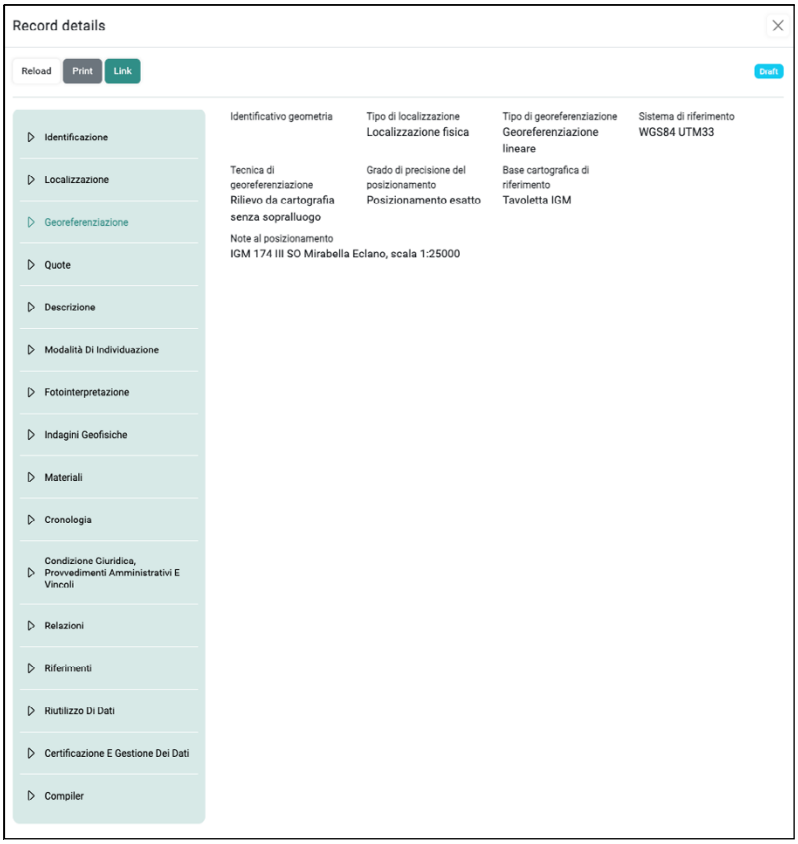


Fig. 3 – Example of a Topographical Entity record (Località Baricella) showing georeferencing information.

needs of the project. The photointerpretation section illustrates this balance between continuity and adaptation. The reliability field and its vocabulary were kept unchanged, while the existing field for type of image was preserved and its vocabulary broadened to better reflect the work in the field[7].

At the same time, new fields were introduced to record the type of traces and their visibility on the terrain, using vocabularies developed specifically for the project[8]. Other additions include a field recording the *Regio Antiqua*

[7] Values of 'Tipo di immagine' vocabulary: foto da drone, foto aerea, immagine satellitare.

[8] Values of the 'Tipologia di traccia' vocabulary: traccia da umidità, traccia da alterazione della composizione del terreno, traccia da anomalia, traccia da microrilievo, traccia da sopravvivenza, traccia da vegetazione; vocabulary of 'Situazione sul terreno' field: visibile, non visibile.

to which a site once belonged, with controlled terms taken from the corresponding field in the Epigraphic Database Roma (EDR, http://www.edr-edr.it/Download/EDR%20-%20Manuale%20v.1.pdf). Moreover, this table introduces a completely new section on geophysical surveys where it is possible to specify the methods applied by the research team.

3.3 *Archaeological material recovered during fieldwork*

This table was created to record the movable finds connected with the topographic entities investigated during the project. In shaping its structure, inspiration was drawn from two national standards: the Tabella Materiali Archeologici (TMA, version 3.0, https://iccd.beniculturali.it/getFile.php?id=207) and the Modulo per la Schedatura Preliminare dei Materiali Archeologici (https://iccd.cultura.gov.it/getFile.php?id=8936) developed by the ICCD. Both were originally designed to allow the rapid cataloguing of finds recovered during fieldwork, whether from surveys or excavations. From these models, a substantial set of fields was selected, to which a handful of additional ones were added in order to complete the framework.

The resulting table is organised into nine sections. These range from general and identifying information on the categories of material, to details of their location and discovery, chronology, and contextual information. A dedicated section is reserved for typological and quantitative description, designed to accommodate composite or complex collections.

3.4 *Geomorphological data*

As part of the In.Res.Agri project, selected areas were explored through pollen corings to identify indicators of past agricultural activity. A dedicated table was developed to document these interventions systematically. It records key information for each investigation, including location, elevation, depth, and geographic coordinates. A stratigraphy section enables each layer to be numbered and described in terms of relative elevation, thickness, and composition[9].

3.5 *Monuments (including inscriptions)*

The Monument table was developed to provide a detailed framework for describing monuments directly or indirectly associated with the topographic entities under study. Its design draws on a reasoned combination of three ICCD models: Monumenti Archeologici (MA, version 3.0, http://www.iccd.beniculturali.it/it/ricercanormative/38/ma-monumenti-archeologici-3_00),

[9] This table was specifically developed for this study by a group – coordinated by Prof. Elda Russo Ermolli – of the research unit of the University of Naples.

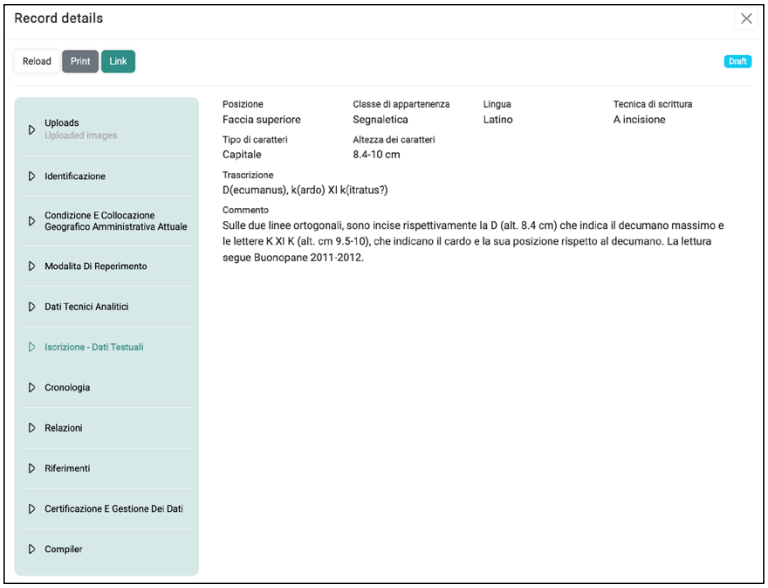


Fig. 4 – Example of a Monument record with inscription (Cippo RPAA-2010/11-326 = AE 2010, 00353).

Reperti Archeologici (RA, version 3.0, http://www.iccd.beniculturali.it/it/ricercanormative/4/ra-reperti-archeologici-3_00) and Beni Numismatici (NU, version 3.0, http://www.iccd.beniculturali.it/it/ricercanormative/18/nu-beni-numismatici-3_00). Information is organised into sections covering identification, location, circumstances of discovery, description of the monument, and chronological attribution. Terminology follows ICCD vocabularies wherever possible, complemented in some cases by other standards, such as the one provided by the Europeana Network of Ancient Greek and Latin Epigraphy (EAGLE) project for material classification (https://www.eagle-network.eu/resources/vocabularies/material/).

A particular focus is placed on epigraphic data, reflecting one of the broader aims of the In.Res.Agri project: to advance knowledge of Roman agrarian landscapes through an integrated approach that also includes literary and epigraphic sources. Inscriptions are recorded directly within the Monument, rather than as a separate entity, preserving their connection to the physical support (Fig. 4). This follows the ICCD RA model, which already includes a dedicated section for epigraphic information. Fields allow for the specification of inscription type, language, script, and text, and terminology in this section relies primarily on ICCD vocabularies, with additional terms introduced where necessary.



Fig. 5 – Example of a Literary source record (Cic., *De Lege Agraria*, II) with transcription of the relevant text passage.

3.6 *Literary sources*

In contrast to epigraphic data, which for their partly-material nature are described by means of the Monument table – a dedicated table was created for literary sources, with the aim of integrating ancient texts into the broader documentation framework of the project. It is organized into three principal sections, enabling the systematic recording of essential information for each work, including author, title, original language, and chronological framework. A dedicated field allows for the transcription of relevant textual passages, with particular attention to those containing toponymic references (Fig. 5). These references are systematically associated with the Topographic Entities, allowing textual evidence to be interpreted in relation to the geographical context under study.

3.7 *Archival sources*

Archival research constitutes a significant component of the project; accordingly, a dedicated table was developed to meet the specific requirements of documenting these sources. It is organised into sections for identification and general description, including fields for the type of support, the documentary unit, and chronological information. Particular attention is given to the archival location, with fields to record, for example, folder, file, and shelf, which enables precise tracing and referencing of the materials.

3.8 *Common features*

The tables share a number of structural features that strengthen the coherence of the overall modelling framework. For instance, a section for data

certification and management is systematically included, ensuring traceability, scientific accountability, and transparency in the process of compilation. Moreover, specific fields are provided for entering links to external digital resources matching the present record, thus allowing, for example, to associate the record describing an inscription with the relevant record in a specialized database such as EDR, or to connect a site to its corresponding entry in a gazetteer such as ToposText, Pleiades, or Geonames.

Bibliographical references are a key informative component of the archive; they are not recorded in an autonomous table but as attributes within each table, pointing to a widely-used external application, Zotero. Each publication retains complete metadata within the Zotero open library of the In.Res.Agri project (https://www.zotero.org/groups/5888666/in.res.agri) and is referenced in the database via its unique identifier given in the Zotero library. The effectiveness of this approach, chosen to facilitate data interoperability and reuse, was validated in previous experiences within the H2IOSC project (see *infra*), such as H-SeTIS (https://h-setis.cnr.it/; Scarpa, Valente 2024) and EpiHub (https://open-epihub.cnr.it/; Rossi, Salvador 2024).

Finally, the management of multimedia content, mainly images, is handled through a dedicated internal library; each file can be associated with one or more database records and described through a structured set of metadata documenting its content and context (Type, Year, Scale, Description), possible bibliographic references, and usage or reuse conditions (Rights, License).

G.B.

4. Final remarks

These final remarks focus on two key aspects of the information system described above: one looking back at automated cataloguing in Italy and its long-term observation by A&C, and a second focused on current perspectives in digital archaeology, which place data sharing and interoperability between systems at the core of research practices. The relational database created as part of the In.Res.Agri project, as noted, was designed in accordance with ICCD cataloguing standards, developed to ensure uniformity, coherence and interoperability among the different institutions involved in heritage management, through descriptive models, controlled vocabularies, and shared data structures. These standards are the result of a long and complex process, undertaken in the mid-1970s, aimed at progressively harmonizing documentation practices and establishing a common language for cataloguing Italian cultural heritage. Terminology played a central role in this process, being essential for achieving descriptive coherence and standardization, and leading to the establishment of controlled vocabularies and shared tools for semantic definition (Caravale 2022).

From its earliest stages, this process was designed as a comprehensive framework for knowledge, enabling each catalogued object to be placed within its historical, cultural, spatial, and temporal context, and in relation to other artefacts. From this perspective, cataloguing serves as an active interpretative tool, capable of reflecting the complexity of heritage objects and their relationships within broader systems of reference. A&C closely monitored ICCD's activities, documenting their progression over time, up to the most recent developments and the new opportunities offered by the Semantic web, with interoperability and data sharing playing an increasingly central role in the construction of archaeological knowledge (cf. e.g., Ferrari 1991; Papaldo, Ruggeri 1993; Mancinelli 2004; Mancinelli, Negri 2016; Moro *et al.* 2017). In this context, the In.Res.Agri database represents a recent example of the practical application of ICCD criteria in national projects, capable of managing multiple and heterogeneous cataloguing entities and providing effective tools to support the study and understanding of archaeological heritage.

Data sharing and resource interoperability have become fundamental principles for fostering truly collaborative knowledge, reflecting a research paradigm increasingly oriented toward cooperation among institutions, projects, and scientific communities. Within this framework, the In.Res.Agri digital archive was conceived in full compliance with established standards and with a strong emphasis on interoperability, aiming to facilitate its integration into broader research ecosystems, such as the GNA. At the same time, efforts are being made to connect the archive with one of the platforms developed by the CNR-ISPC research group Open Data, Open Knowledge, Open Science within the PNRR H2IOSC project (https://www.h2iosc.cnr.it/). More specifically, reference is made to the Open Digital Archaeology Hub (ArchaeoHub, https://open-archaeohub.cnr.it/), an advanced digital archaeology platform conceived as one of the pilot of Work Package 7 of the project (Caravale *et al.* 2025). Designed as an open and extensible environment, the system aggregates and interlinks metadata from collections of textual, visual, and bibliographic materials, digital archaeological projects, datasets, and interactive resources, providing access to information through a geographic interface. In its prototypical version, the platform has been populated with texts, bibliographic records, and images from A&C, as well as data from DHeLO (Digital Heritage Landscaping platfOrm; https://chloe.cnr.it/s/DHeLO/page/home), another H2IOSC digital product (Mancuso 2025). Following the recent TNA call (Trans-national and National Access to the H2IOSC RIs Cluster Services, July 2025), which promoted the advanced digital services developed within the PNRR project and aimed to gauge the level of interest among research communities, efforts are now underway to connect and integrate the datasets of ArchaeoHub and In.Res.Agri, advancing interoperability and promoting the coordinated use of the digital resources

produced. Moreover, some of the ArchaeoHub resources, particularly visual ones, have already been structured for harvesting by Europeana, the European digital library. This opens up broader perspectives for our project, which could benefit from integration into wider transnational infrastructures, further enhancing the visibility, accessibility, and reuse of its data within the European research landscape.

A.C.

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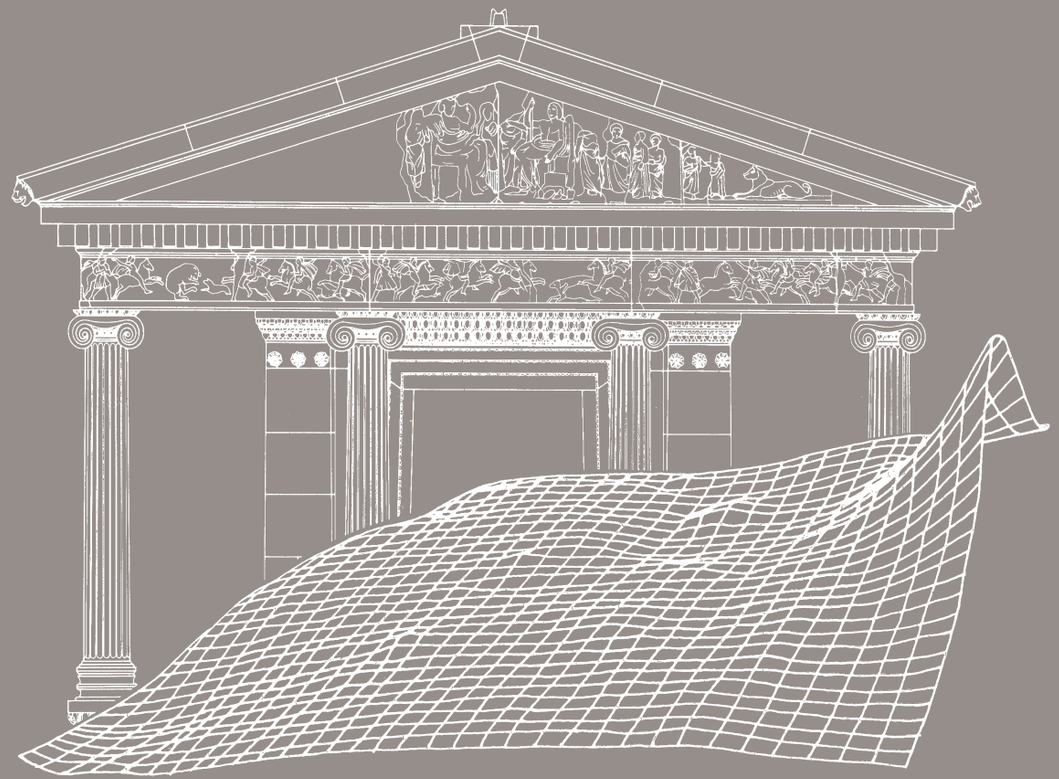
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ABSTRACT

This paper presents the In.Res.Agri digital archive, developed within the PRIN 2022 project In.Res.Agri – Investigating Resilient Roman Agricultural Landscapes in Southern Italy. Conceived as part of the Digital Groma platform, the archive provides an open and FAIR-compliant environment for managing heterogeneous data related to topographical resources. Built on a PostgreSQL relational database, it integrates information from diverse sources – archaeological, geomorphological, textual, and archival – within a coherent data model structured around seven core entities. The system adopts national documentation standards to ensure semantic coherence, interoperability, and long-term sustainability.

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