Archeologia e Calcolatori
36.1, 2025, 109-128
doi 10.19282/ac.36.1.2025.06

REVEALING THE (UN-)KNOWN IN MARGINAL LANDSCAPES. MULTI-SCALAR LIDAR APPLICATIONS IN THE MOUNTAINOUS AREA OF MONTI AURUNCI (LATIUM)

1. Introduction

1.1 *Revealing the (un-) known: a fortified settlement in a marginal area*

The 'Monti Aurunci' mountain region, located in southern Latium between the Apennines and the Tyrrhenian Sea, falls largely within the Natural Regional Park, administratively divided between 10 municipalities of different sizes. The 'Monti Aurunci' are geographically and hydro-geologically divided into an eastern and a western part, the latter being the subject of a study project on ancient landscapes that began in 2021 ('Monti Aurunci Project', MAP: Saccoccio 2022; Vanni *et al.* 2023; Saccoccio, Zocco 2023; Vanni, Saccoccio in press) that aims to investigate the marginal ancient landscapes of this region with a diachronic and multi-thematic approach. The Aurunci Mountains are configured as a massif of predominantly calcareous nature, entirely within the orogenetic context of the central-southern Apennines and part of the Lazio-Abruzzo Apennine platform (Carrara 1995; Rossi *et al.* 2002). It is precisely the complex orogenesis of the area, with deformation events of various kinds occurring at different times and with different mechanisms, that is one of the elements underlying the region's particular ecological morphology, characterised by continuous erosive phenomena at the origin of its narrow valley bottoms, steep slopes, mountain massifs reaching over 1000 m above sea level and mountain passes connecting the main inland river corridors of the Liri valley to the east and the Garigliano valley to the S, with the coastal plains and the maritime landings of the Tyrrhenian coast (Fig. 1).

The historical region, still known today as 'Campello' and encompassing an area of approximately 15 km², lies in the centre of the western part of the Aurunci Mountains massif, and here, on the rise, is the medieval fortified settlement known today by the toponym 'Le Mura' of Campello (Fig. 1). This site was partly known to scholars of the Middle Ages (Crova 2005, 25; 2011, 27; 2018, 70) thanks mainly to the few mentions in ancient sources, particularly in the *Codex Diplomaticus Cajetanus* (CDC). The first attestation of the toponym *Campellum* comes from a document drawn up in Gaeta in 1036 (CDC I, 165). It is a donation of land and various agricultural outbuildings to the monastery of S. Giovanni di Fellino made by Leone Magnifico, son of Giovanni III Duke of Gaeta (CDC II, 196, year 1054), which would be founded as *montium nomine Campellum* (among the mountains – pertaining to – Campello). This mention would attest to the existence in this part of the

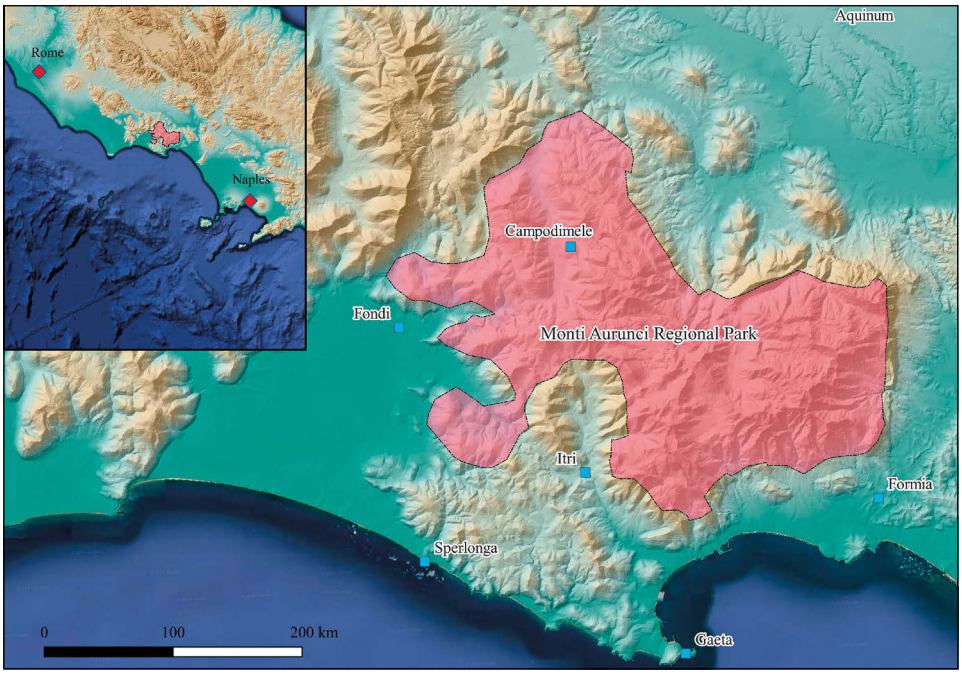

Fig. 1 – The Monti Aurunci Regional Park with some sites quoted in the text (elaboration E. Vanni).

'Monti Aurunci' of an administrative and land-owning entity, already at the beginning of the 11th century, ascribable to a political sphere different from that of the Duchy of Gaeta, the most important territorial entity of the area in this period, together with the papacy and the monastery of Montecassino (Delogu 1988, 191). The toponym *Campellu* also appears in the mid-12th century in a papal bull of Adrian IV (CDC II, 345, year 1152).

The document probably came to quell a situation of settling the territorial borders of the Norman dioceses and counties following the final conquest of the Duchy of Fondi and contemporaneous with the turbulent restructuring of the power of the Dell'Aquila counts (Quattrocchi 2017, 302). In the *Inventarium* (list of properties) of Onorato II Caetani d'Aragona, compiled between 1491 and 1493, the castle of Campello is already dilapidated and abandoned and its inhabitants are said to have moved to nearby Itri (Pollastri 2006, 4, 134): the rationale behind this move is unclear and would need targeted investigation and the contribution of other sources, especially archaeological ones.

Archaeologically, the vestiges of the settlement had always been visible, giving rise to the name 'Le Mura', which references the mighty walls surrounding the high ground on which the settlement is located. A few preserved

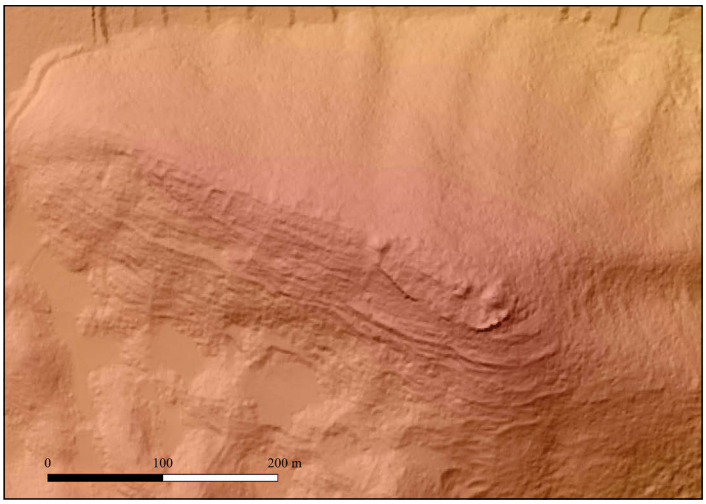

Fig. 2 – LiDAR image of 'Le Mura' site available from the Italian Ministry database (elaboration E. Vanni from http://wms.pcn.minambiente.it/ogc?map=/ms_ogc/WMS_v1.3/servizi-LiDAR/LIDAR_LAZIO.map&service=wms&request=getCapabilities&version=1.3.0).

sections of this wall circuit had been identified in elevation, as had an access gate. A tower and a church in the highest part of the settlement had possibly been reported (Crova 2005, 26, fig. 8). The retrieval of the satellite and LiDAR (1-2 m) imagery available for the region under investigation, provided by the Ministry for the Environment, had quickly identified the anomaly marking the site (Fig. 2).

However, even though the settlement of 'Le Mura' was known – contributing to its exposure to constant and fierce depredation – the site has never been the subject of timely and systematic investigations. Consequently, the studies conducted in the past have also failed to provide an overall picture of the settlement with a detailed plan or at least a documentation of the surviving structures, contributing, together with the scarcity of archive sources, to an underestimation of the importance and role of this fortified settlement for the regional history of this area between the 10th and 14th centuries.

1.2 *The importance of an (un-) known site in the territorial context of Monti Aurunci*

The. renewed territorial research conducted on the landscapes of the Aurunci Mountains by MAP has brought to light the role of the fortified settlement of 'Le Mura' at Campello as a hegemonic centre during the Middle Ages. In particular, the field surveys carried out in the Piana del Campo – the latter

being the site of an extensive village of huts coeval with the final phases of the occupation of 'Le Mura' of Campello (Vanni, Saccoccio in press) – together with the stratigraphic excavation of the high ground site of Sant'Andrea, also fortified and not far from Campello (Vanni *et al*. 2023), as well as the presence to the W of another high ground site mirroring that of Sant'Andrea called Monte Castellone (Vanni, Saccoccio 2024, 83), have revealed a complex settlement and production structure and a consistency of occupation of these marginal mountain landscapes, particularly during the middle centuries of the Middle Ages. The site of Campello represents the most consistent settlement among those present, making it a centre of fiscal and territorial control around which the medieval settlement of this area seems to have been organised. Archive documentation, although scarce, also allows us to identify the presence of a settled community, at least for the middle and final centuries of the Middle Ages (CDC II, 282, year 1107; 355, year 1176; CDC III (2), 628, year 1329).

The research conducted so far has also made it possible to collect older material, which is a clear sign of the functional continuity of this place over a long period of time. In fact, its position allows for easy management of the entrances to the adjacent valleys and the transits of the mountain passes (San Nicola and the Forcella di Campello Vecchio), which are also the main access points between the region and coastal plains. The evident continuity of settlement would allow us to hypothesise for this region the existence of a true dwelling-unit ('Siedlungskammer') in which there are polycentric settlement systems interconnected by functional needs and control of the territory, organised by settlement cells (volcanic massifs, lake basins, etc.) and defined by the relationship between the unitary nature of the area, with its ecological and environmental peculiarities, and its propensity to establish relations with other altimetric belts. In this sense, the space thus articulated places this marginal area, in fact, at the centre of peculiar historical and ecological dynamics involving different and competing political and social entities. During the post-antique era, these socio-economic structures were alternately represented by the Byzantines, the Lombards, the Papacy, as well as the Duchy of Gaeta, the imperial structure as well as the territorial aristocracies (Saccoccio, Zocco 2023; Vanni, Saccoccio 2024, 83-84) (Fig. 3).

All these settlements would, therefore, be located along a border space, a space of contact and friction between areas of different influence, a sort of porous corridor created in all probability thanks to the peculiar ecological characteristics of this area. This area was likely the result of a stabilisation of the internal frontier during the 7th century between Lombards, placed firmly in the inland, and Byzantines, with main interests in the defense of the coastal shoreline (Delogu 1988, 191). The importance of studying this frontier corridor is essential not only for the understanding of the formation of state entities and landed aristocracies, but also for understanding the logic of the

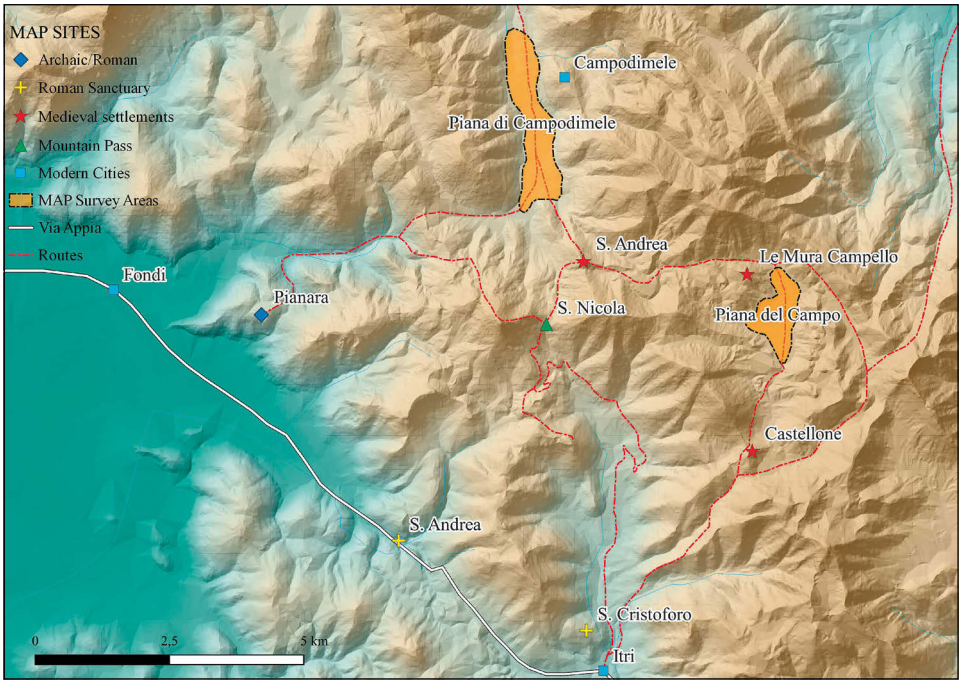

Fig. 3 – The sites investigated by Monti Aurunci Project through excavations and surveys (elaboration E. Vanni).

'incastellamento' of southern Latium (Toubert 1995, 23-43; Augenti 2018, 18-19) and centrifugal forces acting in competition with the formation of the Duchy of Gaeta, the promotion of ecclesiastical institutions (episcopal sees, parish churches, monasteries) as a model of territoriality (Violante 1991, 383), and the emergence of territorial and lordly aristocracies in conjunction with the dispersion of public and comital powers (Tabacco 2000, 109-110, 218-225).

Against this historical and archaeological backdrop, it was necessary to investigate the fortified centre of 'Le Mura' in Campello more thoroughly using innovative methodologies (LiDAR from UVA with high precise resolution) to assess its real material consistency and possible chronology through the available data and comparisons with similar coeval realities in southern Lazio, putting into perspective its importance as a hegemonic centre in the Aurunci Mountains[1].

E.V.

[1] The data were acquired by Dr. V. Vitale and processed by Dr. G.P. Cirigliano. The flights and analyses were made possible thanks to funding from the CADMO (Centre for Archaeology of Diversity and Mobility in pre-Roman Italy) of the University for Foreigners of Siena (Italy).

2. The LiDAR analysis in a mountainous area

2.1 *Methodology and strategy*

The environment surrounding the site of Campello is characterised by dense vegetation, consisting of both tall trees and low shrubs typical of the Mediterranean scrub. This dense vegetation can pose a significant obstacle to identifying archaeological traces, making it challenging to conduct surveys through surface surveys and aerial imagery. Such conditions can severely limit the understanding of the historical and archaeological context under study and the various historical phases associated with it. In order to overcome these methodological challenges, LiDAR technology mounted on UAV platforms has been adopted. Thanks to LiDAR's operating principle, it is possible in some cases to penetrate the vegetation cover, allowing for a more accurate reconstruction of the terrain's morphology (DTM, Digital Terrain Model), as demonstrated by numerous previous studies (Doneus *et al.* 2008; Opitz 2013; Poggi *et al.* 2024).

The application of LiDAR has produced significant results in archaeological research since its early use (Holden 2001; Sittler 2004; Bofinger, Hesse 2011; Chase *et al.* 2011). However, as highlighted by recent studies (Vinci *et al.* 2024), the application of LiDAR systems in Mediterranean contexts still needs to be improved. This is primarily due to the challenges in penetrating the dense Mediterranean vegetation, which is characterised by multiple layers of cover. Despite these limitations, integrating advanced technologies, such as the combination of drones and LiDAR, presents a promising solution capable of expanding research prospects in wooded and hard-to-access environments. Recent developments and experiences confirm the potential of these methodologies (Campana 2017; Mazzacca *et al.* 2022; Štular *et al.* 2023), opening new possibilities for archaeological exploration and documentation in complex contexts.

2.2 *Data acquisition*

The field data collection phase was carried out using a DJI Matrice 300 drone, equipped with both a camera and a LiDAR system, operating at a constant altitude of 50 m. The automatic flight control and configuration of parameters parameters specific to archaeological research, such as flight altitude, speed, capture time, and image overlap for photogrammetry, ensured accurate data acquisition and uniformity. The survey was conducted with a DJI L1 laser scanner, which employs a technique known as 'online waveform processing'. This method allows for a complete analysis of the laser signal waveform and its real-time digitisation directly on the scanner, with the ability to record up to three echoes. The laser scanner is also equipped with a GNSS

RTK and PPK positioning system, used as a payload on the DJI Matrice 300 drone. The LiDAR acquisition covered a usable area of approximately 3 hectares. The flight was conducted at an altitude of 50 m above ground level (AGL), assisted by the digital elevation model (DEM) provided by Tinitaly (http://tinitaly.pi.ingv.it/). The flight speed was maintained at a constant 3 m/s, following a cross-grid acquisition mode facilitated by the DJI PILOT software. According to the LiDAR system's technical specifications, under ideal conditions, each individual acquisition produced a point cloud with a density of 142 points per square meter. However, it is important to note that this density is not uniform due to several factors: variations in the type and density of vegetation, which is denser in some areas than others; the morphology of the terrain; and, finally, the characteristics of the acquisition methodology, which followed a flight plan based on a cross-grid flight pattern.

2.3 *Data processing*

The processing of the collected data followed a structured workflow primarily aimed at creating a high-resolution Digital Terrain Model (DTM). This tool is essential in archaeological and territorial studies, as it accurately represents the terrain's morphology, isolating it from the complexities introduced by vegetation cover and anthropogenic elements. The generation of a DTM requires, as a fundamental step, the segmentation of the terrain, a process crucial for distinguishing ground points from other elements present in the LiDAR point cloud. This step not only ensures the reliability of the results but also enables the use of LiDAR data to create highly valuable scientific and operational products.

In the initial phase, GNSS data were corrected and integrated with the data collected during the flight using the Applanix POSPac UAV software, thus improving the positioning accuracy. Subsequently, DJI Terra software was used to transform the raw point cloud into a global coordinate system with the WGS 84 UTM Zone 33N reference system. Once the point cloud was generated, the data underwent a filtering and segmentation process using LiDAR 360 software, which enabled the separation of ground points from those associated with vegetation and anthropogenic elements, such as structures or artefacts. This step was critical for isolating the ground and obtaining an accurate and detailed DTM. In order to complete and verify the generated model, the processing was repeated using additional software to refine the result further. For example, CloudCompare software was employed to isolate ground points using the Cloth Simulation Filter (CSF) plugin, a particularly effective tool for handling complex datasets. Finally, the results were compared and integrated within a GIS environment using ArcGIS Pro, applying the Classify LAS Ground tool to validate and consolidate the ground classification.

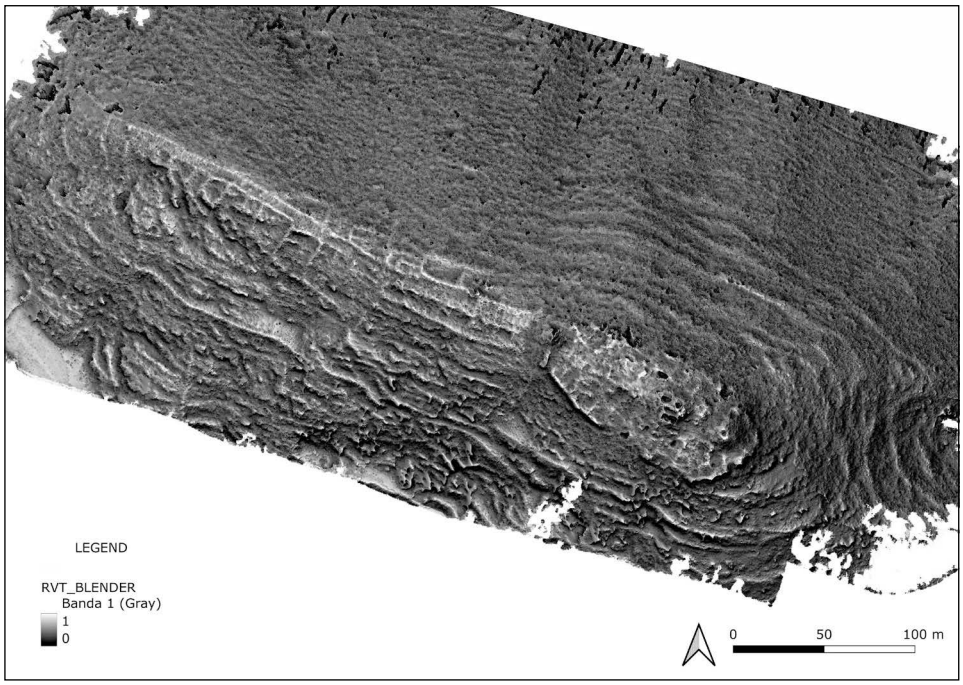

Fig. 4 – Results of the 'Blender' visualization analysis performed in a GIS environment using the RVT visualization plug-in (elaboration G.P. Cirigliano).

2.4 *Raster analysis and visualisation*

Once the segmentation and distinction between ground and non-ground points were completed and the Digital Terrain Model (DTM) was obtained, it was subsequently imported into a GIS environment for visualisation analysis. In particular, the QGIS software and the Relief Visualization Toolbox (RVT) plugin were employed (https://www.zrc-sazu.si/en/rvt). RVT is a tool developed to assist researchers in exploring and analysing raster datasets of elevation models (Štular *et al.* 2021). The Relief Visualization Toolbox is designed to maximise the visibility of small-scale features, a capability instrumental in the context of high-resolution digital models obtained from airborne LiDAR scans. This approach allows for applying well-established and optimised visualisation techniques for detecting topographic details that are often invisible using traditional methods. In order to ensure accurate and reliable analysis, various visualisation techniques were adopted, each providing complementary perspectives on the data. These techniques included Hillshade, Slope, Sky View Factor, Blender, and Local Dominance (Figs. 4-5). These

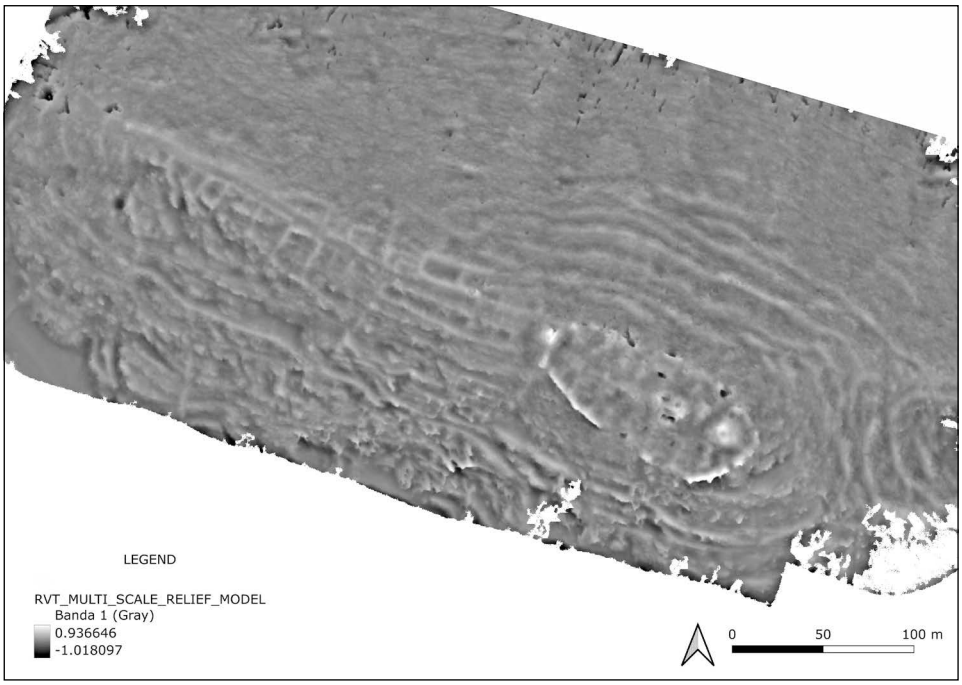

Fig. 5 – Another example of the visualization analysis results, in this case, a multi-scale relief model, performed in a GIS environment using the RVT visualization plug-in (elaboration G.P. Cirigliano).

techniques were employed in parallel to ensure a more robust comparison of the results. Only the features visible across multiple representations were considered valid, digitised, and subsequently interpreted. This digitalisation phase allowed for the transformation of visual results into vector data, thereby creating a reliable foundation for archaeological analysis and documentation of the study context.

2.5 *Data interpretation*

An analysis of the distribution of elements interpreted as archaeological traces reveals a significant concentration along the entire ridge of the hill, both on the northern and southern slopes and the summit. The presence of such a high density of potential archaeological traces suggests a long and intensive period of human occupation of the hill. A total of 110 elements have been identified and catalogued, representing various types of structures, including rectangular buildings, pathways, and fortified settlements on the summit, terraces, depressions, and walls.

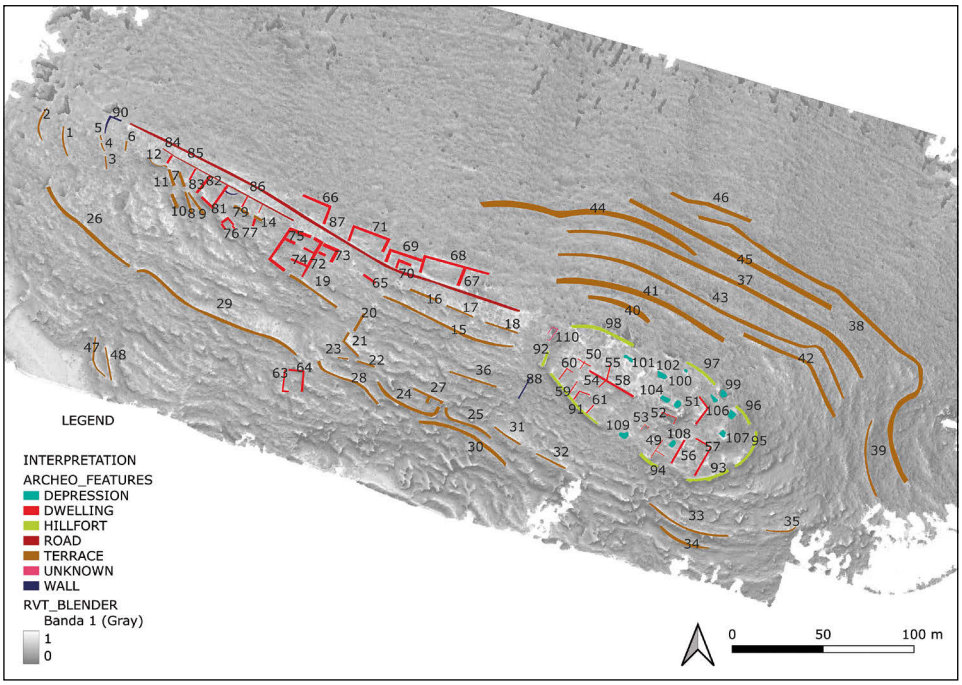

Fig. 6 – The image allows for the observation and localization of various archaeological structures identified during the analysis and study operations (elaboration G.P. Cirigliano).

In particular, a road (number 87), which connects the upper and lower parts of the hill, is clearly visible. Along this route, several architectural structures are located both to the S and N of it. A total of 11 structures have been identified along the central ridge, where portions of buildings can be recognized, such as numbers 12, 66, 67, 70, and 83. Other areas reveal more complex and complete structures, as evidenced by numbers 81-82, 72-73, 74-75, 63-64, 68, 69, and 7. Terraces are distributed along nearly all of the hill's slopes, while, at the upper part, a hillfort of about half a hectare surrounded by walls is observable. Within this fortification, various architectural structures are hypothesized.

The terraces, numbering 48, span almost the entire slopes of the hill and appear to follow the natural inclination of the slopes. Thirty-four wall elements, all part of rectangular buildings (numbered 49 to 83), were also identified. Among these, a notable structure composed of elements 74 and 75 stands out; it has a rectangular layout and a division into at least three internal spaces. This building is located to the south of a probable pathway (no. 87) that connects the upper and lower parts of the hill. Its dimensions are approximately 20×18 m.

Additional rectangular buildings were identified to the N of pathway no. 87, with approximate dimensions of 20×8 m. Another significant finding is the presence of fortified structures located at the upper part of the hill, numbered from 91 to 98. These appear to consist of boundary walls defining an area of approximately 0.6 hectares. Within this area, walls and depressions in the ground have been observed, which could indicate the presence of settlement environments such as dwellings and other functional structures, including possible cisterns or production spaces (Fig. 6).

At present, it is not possible to assign a definitive and certain interpretation to all these traces, with the exception of the settlement's perimeter walls, the access road from the W, the many depressions within the walls mostly pertaining to water cisterns and the collapse of a tower located in the upper eastern part of the hill clearly visible both from LiDAR anomalies and from a 1942 aerial photo taken by the RAF (Royal Air Force; see *infra*). Further field investigations will be necessary to confirm hypotheses and enhance our understanding of these structures.

G.P.C.

3. Putting anomalies in the historical and archaeological context

3.1 *Comparing settlements in southern Lazio*

The new remote sensing analysis has produced new information on the structures and plan of the castle of 'Le Mura' of Campello that previous autoptic observations did not detect in detail. The visible anomalies have made it possible to recognise buildings whose shape is comparable to that of known and studied settlements in southern Latium, providing important information on their possible function and chronology. The immediately recognisable element is the town wall, which defines the plan of the *castrum*. Campello is in line with many *castra* in southern Lazio, particularly in the Frusinate area. The walls follow the natural orography of the mountainous relief, creating an elliptical geometry that can also be found in other uninhabited *castra* in the area, such as Acquaviva and Ambrifi (province of Latina) in the nearby Ausoni mountains, but also in *castra* with continuity of life such as Leopoli/Traetto (modern Minturno), Lenola, Monte San Biagio, Itri, Campodimele (province of Latina), Pofi and Vallecorsa (province of Frosinone) (Fiorani 1996, 208-235). In the settlements with continuity of life, it is complex to reconstruct the original road network. In the other uninhabited *castra*, no exhaustive research has been carried out. However, the results that have emerged from the new LiDAR flights indicate of a regular road network, composed of a main artery connecting the access gate to the square tower and a network of secondary axes that intersect perpendicularly to the former, along which all the public and private buildings of the *castra* must have developed.

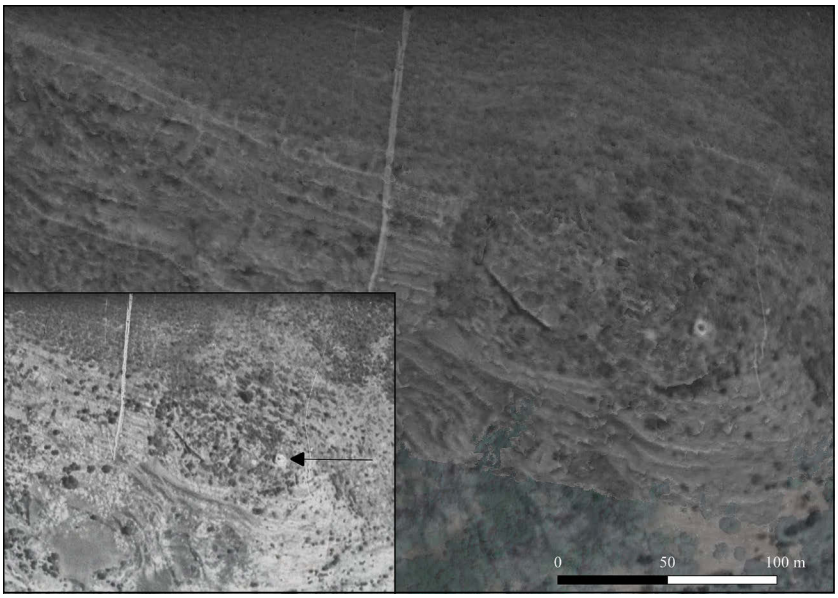

Fig. 7 – Our LiDAR image processed with the Royal Air Force image taken in 1942 in transparency (in the left box below), showing the tower still standing (elaboration E. Vanni after IGM archive aerial photos from RAF flights year 1942, swipe 13).

The main gateway is composed of a central body, thus a very deep entrance, flanked perhaps by a circular tower. There are no direct comparisons in southern Latium, but the most striking analogy is with the Frederician gate at Capua (CE) (Crova 2015, 140), composed precisely of a quadrangular central architectural element and two lateral circular towers. One certainly recognisable element is the secondary access, which today appears as a simple opening in the walls. An example of a side door in the walls is at the castle of Acquaviva, where there was a 'portella', a toponym used locally to indicate the presence of secondary access doors (Pesiri 2015, 99 -100, 106-107).

LiDAR also made it possible to detect two internal buildings, one of which can be referred to as a square tower, still visible in elevation in aerial photographs taken during the Second World War by the RAF, and now completely collapsed (Fig. 7). The use of square geometric shapes for the construction of towers, 'donjons', and bell towers seems to be a peculiarity of Norman-Swabian influenced areas, with a conspicuous presence of comparative elements in southern Latium and upper Campania: the fortresses of Minturno and Maranola (LT), the Roccaguglielma in Esperia (FR) (Crova 2015, 135-138), the main towers in the aforementioned *castra* of Ambrifi and Acquaviva (LT), the towers of the city walls of Sessa Aurunca (CE); the same geometries can

also be traced in the palatial complex of the city of Capua (CE) and the Norman cistern at the base of the Mastio di Fondi (LT) (Crova 2016, 79-84). The interpretation of the second building (anomaly 104), which could be the *castrum*'s main church or a quadrangular residential building with side towers, is complex. The presence of churches in Campello is certainly ascertained by documentation (De Santis 1971, 107-115), and even though LiDAR analyzes a plan that resembles an apsidal building, the true nature of this building can only be further investigated with more invasive archaeological investigations.

Inspecting the site made it possible to observe some of the wall facings in the castle. Although the vegetation prevents a clear view of the masonry, at least two techniques were identified along the walls: the first is in limestone blocks, arranged in irregular horizontal rows, with the presence of large or medium-large blocks, alternating with flakes and smaller pieces and referable to class A3, group II, chronologically dated between the 12th and first half of the 13th century (Fiorani 1996, 125-129); the second, referable to a chronological span between the end of the 13th and the 14th century, is in irregular flakes, interspersed with fictile elements, such as bricks and tiles, and with an abundant presence of white mortar, attested in Acquaviva, but also in various buildings in Minturno/Traetto and Maranola (LT), interpreted as extensions and restorations that occurred under the Caetani family (Crova 2005, 89-90).

A.C.

3.2 *Towards a chronology for 'Le Mura' of Campello site*

Over the years, the monumentality of the castle and the presence of elevated structures have attracted illegal looting activities that have caused damage to the stratigraphy, especially outside the boundary wall, where building collapses are less substantial and, therefore, easier to remove manually. Precisely from the area outside and inside the boundary wall comes a group of metal finds[2] and these are now being studied by the MAP team. The group of artefacts is quantitatively important and remarkably heterogeneous, both in terms of typology and chronology: it is mostly made up of numismatic finds (around 1200 coins), while smaller quantities are mainly instrumental, ornamental, clothing accessories, and objects related to the religious and cultic sphere.

Despite their decontextualisation, which makes it impossible to understand the spatial distribution and characterise the roles and functions of certain sectors of the settlement, the materials are nonetheless of great interest

[2] The group comes from a recovery carried out by the Local Police of the Municipality of Campodimele. The report was drafted by Dr. Antonio Silvestro Picano, whom we thank. We would also like to thank SABAP Frosinone and Latina officials, particularly Dr. Gianluca Melandri, for their ever-ready availability and cooperation.

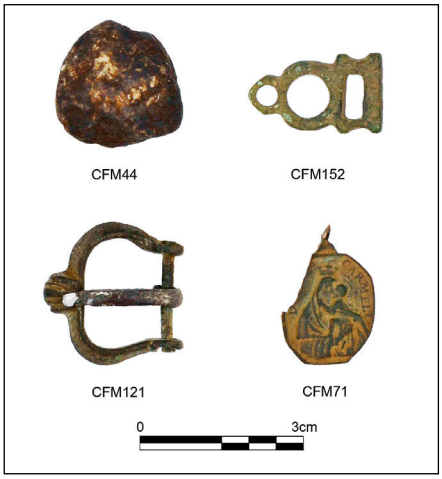

Fig. 8 – A group of metal finds from Campello. CFM44: Roman shell; CFM152: early medieval necklace element; CFM 121: late medieval buckle; CFM71: modern votive medal (elaboration S. Zocco).

both for understanding the phases of the site's occupation and because they contribute decisively to enriching our historical-archaeological knowledge of the Aurunci Mountains.

The materials suggest that Le Mura was frequented in Roman times. The most ancient finds are some coins from the Republican and Imperial periods, weights, and shells (Fig. 8, CFM44) , the latter very similar to those found at the sanctuary of San Cristoforo (De Spagnolis 2019) and perhaps linked to cultic forms common in the mountainous area. The Late Antique period (4th-6th century) is represented only by numismatic material, which is much more abundant than the Republican-Imperial period. A small set of objects probably from a burial context can be dated to the 7th century (Fig. 8, CFM152). Early medieval material documentation becomes more conspicuous only between the 10th and 11th centuries: in particular, there is a group of imperial coins from the Pavia mint (*ottolini*; Rovelli 1995) and ducal coins (*folles*) from Gaeta (Vanni *et al.* 2023, 12). In terms of quantity, there is a clear predominance of late medieval coins and metal elements (12th-14th century) related to the castle's phases of life, such as different types of buckles (Fig. 8, CFM121), women's belt elements and applique with heraldic symbols.

Following the castle's abandonment, the site appears to have been visited on several occasions during the modern period (15th-17th centuries), as reflected by the discovery of a votive medal (Fig. 8, CFM71) and numerous

buttons. However, based on these sporadic data, it is difficult to establish the extent of post-medieval frequentations, which may be related to the persistent activity of the castrense church, the unstable occupation of the high ground, and the phenomena of transhumance.

On the basis of these initial considerations, judging by the broad chronological horizon of the finds, a prolonged occupation of the site since Roman times and – hypothetically – without hiatuses until its abandonment, to be placed between the 14th and 15th centuries, can be noted. Whilst the Roman period remains problematic and nebulous despite the presence of elements with a marked cultic character, the late antique and early medieval finds would seem to delineate the existence of a stable settlement that became increasingly important, at least from the 6th to 7th century, several centuries before the *castellum* of Campello is mentioned in historical sources (CDC II, 282, year 1107). The cataloguing and precise study of the finds will allow, in the coming months, to give historical depth to a hitherto little-known site and mountainous area.

S.Z.

4. Conclusion

From the methodological point of view, this study has demonstrated the effectiveness of data acquired using drones equipped with LiDAR technology, which allows for the optimisation of acquisition parameters, such as flight altitude and speed, to enhance the readability of the archaeological landscape. By comparing these data with satellite imagery (Fig. 9) and aerial photogrammetry results acquired simultaneously, it has been shown that the presence of vegetation heavily influences the visibility of the terrain and it represents a significant limitation for identifying archaeological traces on the ground. It is only through the use of LiDAR that a more precise and more detailed view of the archaeological record on the ground has been obtained. An exciting aspect of this study was the comparison with LiDAR data provided by public agencies, specifically regional datasets. These datasets, acquired using lower-resolution aerial platforms, allowed for identifying certain archaeological features but were limited to highly visible elements, such as hilltop fortifications. In contrast, the use of drones provided higher-resolution data, enabling the identification of even subtler and less obvious traces. The results obtained significantly contribute to ongoing research at the Campello site and open up promising prospects for future investigations across a broader area, such as the Aurunci Mountains. This methodology thus proves to be a valuable tool for expanding our understanding of the archaeological landscape and further enhancing the region's historical heritage.

From an archaeological point of view, although it appears in the sources as both an *oppidum* (CDC II, 345, year 1152) and a *castellum* (CDC II, 282,

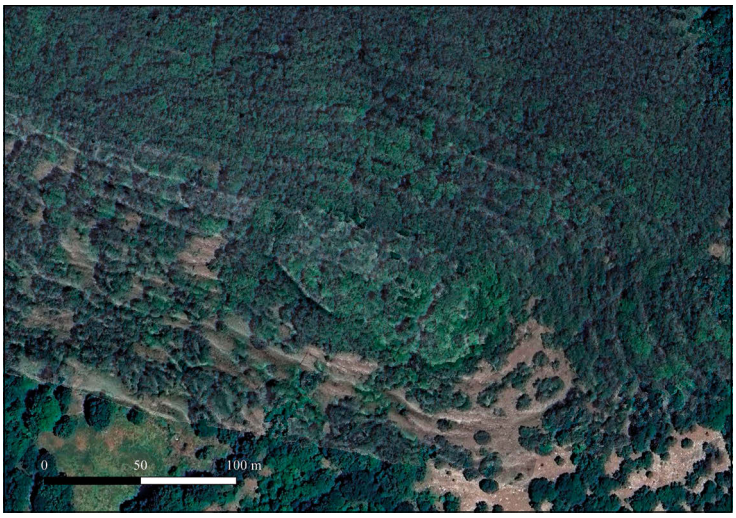

Fig. 9 – The site of Campello as seen from satellite imagery covered by dense vegetation and the LiDAR RTV Blender in transparency (elaboration E. Vanni).

year 1107), the site of 'Le Mura' would present, in its current form of settlement, all the elements proper to a medieval castle. The site, with a surface area of approximately 0.6 ha within the wall perimeter and approximately 15 ha in all its external structures, clearly stands as the main seat of a seigniorial power whose contours, still very uncertain, seem to be defined above all in the relationship with the resources fundamental to the economic activities of the area (Saccoccio 2022, 74-76). The numerous cisterns and wells for collecting rainwater are of particular interest, and these have been identified thanks to LiDAR images. In an area with a scarce presence of springs, the monopoly on controlling water resources, on the one hand, and the ability to put in place an efficient and capillary system of water regimentation structures and maintain it becomes crucial. This is evident from what was recorded in the surveys of the 'Piana del Campo', the village most probably dependent on the centre of 'Le Mura' of Campello, where numerous canalisations and collection systems for runoff water of various sizes and types (wells, pit-cisterns, cisterns) were recognised. As the fortified site within the walls awaits detailed data, it can be noted that several remodulations of the citadel layout, composed of rather heterogeneous elements, are evident, which would highlight the complexity of the settlement as well as a continuity of its role as the administrative centre of the district, played at least until the mid-15th century (Fig. 10).

From a historiographical point of view, this settlement becomes a privileged place in which to observe the local and peculiar characters of *incastellamento*,

Fig. 10 – A photo of the collapsed southern tower (photo A. Cammisola).

generated by different historical circumstances, where castles are often the point of arrival of the interaction of different dynamics and actors (Augenti 2018, 21-23). Moreover, the presence of fortified points in the rural landscape is a sign of the unfolding of political programs, often wide-ranging, of which fortresses are often ephemeral and mobile elements aimed at the implementation of certain settlement and economic arrangements (Cortese 2018, 58). In the absence of elements, however, it appears more problematic to place the castle of Campello within one or the other process. Campello could be part of a scheme linked to the affirmation of non-ecclesiastical military elites within the Lombard principality – a phenomenon that seems to have mainly affected the border areas (Di Muro, Loré 2018, 397) – or it could be part of a scheme of royal or public property management with a rural structure more closely linked to *curtensi* models (Loré 2019, 40-46, 64-65; Wickham 2019, 416) and in which the role of the Ottonian dynasty may have played a decisive role. Nor can we exclude the strong imprint of the Duchy of Gaeta – and the 'Byzantines' of Naples – in structuring this border landscape.

However, the specific affirmation of the castle of Campello from the 12th century onwards raises further questions about its relationship with its appurtenances. The latter probably included a series of sites identified in the Campello district and subjected to various methods of investigation. Sant'Andrea and Monte Castellone established a clear hierarchical and dependency relationship with the castle of 'Le Mura', but they were also strategic places of control of the routes that crossed the Aurunci from the Liri valley towards Gaeta and

vice versa. As the epicentre of political and economic activities and as a centre holding primary resources such as water, its investigation appears fundamental for understanding the dynamics and relations with the forms of peopling implemented in the inland area of the Aurunci Mountains until the late Middle Ages.

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REFERENCES

Augenti A. 2018, *Castelli, incastellamento e archeologia*, in Augenti, Galetti 2018, 17-37.

Augenti A., Galetti P. (eds.) 2018, *L'incastellamento: storia e archeologia. A 40 anni da Le Structures di Pierre Toubert*, Spoleto, CISAM.

Bofinger J., Hesse R. 2011, *As far as the laser can reach … laminar analysis of LiDAR detected structures as a powerful instrument for archaeological heritage management in Baden-Württemberg, Germany*, in D.C. Cowley (ed.), *Remote Sensing for Archaeological Heritage Management, Proceedings of the 11th EAC Heritage Management Symposium (Reykjavík 2010)*, Bruxelles, Europae Archaeologia Consilium (EAC), 161-171.

Campana S. 2017, *Drones in archaeology. State-of-the-art and future perspectives*, «Archaeological Prospection», 24, 4, 275-296 (https://doi. org/10.1002/arp.1569).

Carrara C. 1995, *Elementi di geologia regionale,* in *Lazio Meridionale. Sintesi delle ricerche geologiche multidisciplinari*, Roma, Enea, Dipartimento Ambiente, 23-33.

CDC I 1969, *Tabularium Casinense, Codex Diplomaticus Cajetanus*, t. I, Montecassino.

CDC II 1981, *Tabularium Casinense, Codex Diplomaticus Cajetanus*, t. II, Montecassino.

CDC III (2) 1960, *Tabularium Casinense, Codex Diplomaticus Cajetanus*, t. III, pars II, Montecassino.

Chase A.F., Chase D.Z., Weishampel J.F. *et al.* 2011, *Airborne LiDAR, archaeology, and the ancient Maya landscape at Caracol, Belize*, «Journal of Archaeological Science», 38, 2, 387-398 (https://doi. org/10.1016/j.jas.2010.09.018).

Cortese M.E. 2018, *Una convivenza difficile: castelli e città nell'Italia centro-settentrionale (sec. X-XII)*, in Augenti, Galetti 2018, 81-97.

Crova C. 2005, *Insediamenti e tecniche costruttive medievali. Il Latium adiectum e la Terra Laboris,* Montecassino, Archivio Storico di Montecassino, Archivio Storico del Lazio Meridionale Monografie, 1.

Crova C. 2011, *Sistemi insediativi nell'Italia centro-meridionale (IX-XIV secolo)*, «Castellum», 52, 17-40.

Crova C. 2015, *Castelli e territorio fra Normanni e Svevi. La Terra di Lavoro nel Lazio meridionale e in Campania settentrionale*, in F. Marazzi (ed.), *Civitas Aliphana, Alife e il suo territorio*, Isernia, Volturnia Edizioni, 127-143.

Crova C. 2016, *Lo sviluppo urbanistico di Fondi nel Medioevo*, in M. Gianandrea, M. D'Onofrio (eds.), *Fondi nel Medioevo*, Roma, Gangemi Editore, 79-90.

Crova C. 2018, *Sistemi insediativi del Latium Adiectum: caratteri costruttivi dell'urbanistica medievale*, in D. De Meo (ed.), *Formia e il suo territorio. Storia e archeologia, Atti del Convegno (Formia 2017)*, Minturno, Armando Caramica Editore, 63-82.

De Santis A. 1971, *Le chiese di Itri e Sperlonga nel Settecento*, «Bollettino dell'ISALM», 7, 107-122.

De Spagnolis M. 2019, *Itri. Il santuario romano in località San Cristoforo*, Gaeta, Ali Ribelli.

Delogu P. 1988, *Il Ducato di Gaeta dal IX al XI secolo. Istituzioni e società*, in G. Galasso, R. Romeo (eds.), *Storia del Mezzogiorno, 2.1. Il Medioevo*, Napoli, Edizioni del Sole, 191-236.

Di Muro A., Loré V. 2018, *L'incastellamento in Campania*, in Augenti, Galetti 2018, 391-404.

Doneus M., Briese C., Fera M., Janner M. 2008, *Archaeological prospection of forested areas using full-waveform airborne laser scanning*, «Journal of Archaeological Science», 35, 4, 882-893 (https:// doi.org/10.1016/j.jas.2007.06.013).

Fiorani D. 1996, *Tecniche costruttive murarie. Il Lazio Meridionale*, Roma, L'Erma di Bretschneider.

Holden N. 2001, *Digital airborne remote sensing: The principles of LiDAR and CASI*, «AARGNews», 22, 23.

Loré V. 2019, *Curtis regia e beni dei duchi. Il patrimonio pubblico nel regno longobardo*, in F. Bougard , V. Loré (eds.), *Biens publics, biens du roi. Les bases économiques des pouvoirs royaux dans le haut Moyen Âge. Beni pubblici, beni del re. Le basi economiche del potere reale nell'alto Medioevo*, Turnhout, Brepols, 33-78.

Mazzacca G., Grilli E., Cirigliano G.P., Remondino F., Campana S. 2022, *Sensing among foliage with LiDAR and machine learning: Towards transferable archaeological pipeline*, «International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences», XLVI-2/W1-2022, 365-372 (10.5194/isprs-archives-XLVI-2-W1-2022-365-2022).

Opitz R.S. 2013, *An overview of airborne and terrestrial laser scanning in archaeology*, in D.C. Cowley, R.S. Opitz (eds.), *Interpreting Archaeological Topography: 3D Data, Visualisation and Observation. Interpreting Archaeological Topography*, Oxford, Oxbow Books, 13-31.

Pesiri G. 2015, *Pergamene nell'archivio del Capitolo Cattedrale di San Pietro in Fondi (1140-1494),* Roma, Istituto Storico per il Medioevo.

Poggi G., Dallai L., Volpi V. 2024, *Mining under the canopy: Unveiling the archaeo-mining record in the Colline Metallifere with LiDAR analysis and multidisciplinary studies*, «Quaternary International», 705, 16-36.

Pollastri S. 2006, *Inventarium Honorati Gaietani: l'inventario dei beni di Onorato II Gaetani d'Aragona (1491-1493)*, Roma, L'Erma di Bretschneider.

Quattrocchi C. 2017, *Santa Maria della Rocca: testimonianze della frequentazione del Monte Arcano dal Paleocristiano al Quattrocento*, in M. Gianandrea, M. D'Onofrio (eds.), *Fondi nel Medioevo*, Roma, Gangemi Editore, 301-308.

Rossi D., Bigi S., Del Castello M., Di Manna P. 2002, *The structure of the Aurunci Mountains (southern Lazio): A balanced cross-section and its restoration*, «Bollettino della Società Geologica Italiana», 1, 151-159.

Rovelli A. 1995, *Il denaro di Pavia nell'alto Medioevo (VIII-XI secolo)*, «Bollettino della Società Pavese di Storia Patria», 47, 71-90.

Saccoccio F. 2022, *Campello nei Monti Aurunci: osservazioni preliminari sui sistemi di gestione delle acque nella Piana del Campo*, in T. Baronti, F. Gizzani Marcia, R. Marcheschi, L. Marchisio, A. Monticolo, S. Rojo Munoz, F. Saccoccio, F. Sala, J. Tasselli, S. Vagnuzzi (eds.), *AMNIS. L'acqua dalla materialità alla parola, Atti del Convegno Internazionale di Studi (Pisa 2021)*, Firenze, All'Insegna del Giglio, 67-77.

Saccoccio F., Zocco S. 2023, *Gaeta preducale delle aristocrazie invisibili*, «Stratigrafie del Paesaggio», 6, 84-99.

Sittler B. 2004, *Revealing historical landscapes by using airborne laser scanning. A 3-d model of ridge and furrow in forests near Rastatt (Germany)*, in M. Thies, B. Koch, H. Spiecker, H. Weinacker (eds.), *Proceedings of Natscan, Laser-Scanners for Forest and Landscape Assessment - Instruments, Processing Methods and Applications*, XXXVI, 258-261, Freiburg, International Archives of Photogrammetry and Remote Sensing Part 8/W2, 258-261.

Štular B., Eichert S., Lozić E. 2021, *Airborne LiDAR point cloud processing for archaeology. pipeline and QGIS toolbox*, «Remote Sensing», 13, 16, 3225 (https://doi.org/10.3390/rs13163225).

Štular B., Lozić E., Eichert S. 2023, *Interpolation of airborne LiDAR data for archaeology*, «Journal of Archaeological Science: Reports», 48, 103840 (https://doi.org/10.1016/j.jasrep.2023.103840).

Tabacco 2000, *Dai re ai signori. Forme di trasmissione del potere nel Medioevo*, Torino, Einaudi.

Toubert P. 1995, *Dalla terra ai castelli. Paesaggio, agricoltura e poteri nell'Italia medievale*, Torino, Einaudi.

Vanni E., Saccoccio F. 2024, *Redescobrint el paisatge medieval del Laci du sud (Italia). El Monti Aurunci Project (MAP)*, in L. Palahí Grimal, M. Bouzas Sabater (eds.), *De la tardoantiguitat a l'alta edat mitjana: una visió arqueològica, MONACRA*, Girona, Universitat de Girona, 34-51 (https://doi.org/10.33115/c/9788499846156_05).

Vanni E., Saccoccio F. in press, *Marginality on the stage: The Monti Aurunci Project (MAP)*, «Rassegna di Archeologia», in press.

Vanni E., Saccoccio F., Zocco S. 2023, *Monti Aurunci Project: il sito altomedievale di Sant'Andrea*, «FOLD&R Italy», 568 (https://www.fastionline.org/docs/FOLDER-it-2023-568.pdf).

Vinci G., Vanzani F., Fontana A., Campana S. 2024, *LiDAR applications in archaeology: A systematic review*, «Archaeological Prospection», 1-21.

Violante C. 1991, *La signoria rurale nel secolo X: proposte tipologiche, in Il secolo di ferro: realtà e mito del secolo X, Atti della XXXVIII Settimana di Studio (Spoleto 1990)*, Spoleto, Fondazione CISAM, 329-385.

Wickham C. 2019, *Beni Pubblici: A provisional typology*, in F. Bougard, V. Loré (eds.), *Biens publics, biens du roi. Les bases économiques des pouvoirs royaux dans le haut Moyen Âge. Beni pubblici, beni del re. Le basi economiche del potere reale nell'alto Medioevo*, Turnhout, Brepols, 413-422.

ABSTRACT

The Monti Aurunci Regional Park, located in southern Lazio, Italy, is renowned for its geological and naturalistic features as well as its archaeological significance. This area hosts a wealth of archaeological sites covering from pre-Roman and Roman periods to the modern era, many of which remain largely unexplored. These sites are currently being investigated as part of the Monti Aurunci Project (MAP, https://www.archeologiadiffusa.org/2022/09/17/map/), an initiative led by the University for Foreigners of Siena. Among the notable sites in this region is the multi-layered and abandoned hillfort known as 'Le Mura di Campello'. However, dense forest cover significantly hinders the identification, interpretation, and mapping of archaeological remains in the area. Furthermore, the lack or low quality of existing datasets limits their usability for archaeological purposes. To address these challenges, a drone-based LiDAR survey was conducted in the winter of 2023, yielding high-resolution data that has proven invaluable for archaeological analysis. With an average point density of 142 points per square meter, the LiDAR data facilitated the identification of numerous archaeological features, enriching the understanding of the Monti Aurunci's cultural heritage. Over 100 previously undocumented features were mapped, including terracing systems, hillforts, dwellings, walls, and road system. The results obtained have refined our understanding of the historical settlement dynamics in the Monti Aurunci area and opened the door to new methodological approaches, offering promising future research directions.