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From top to bottom

Multispectral Remote Sensing and Data Integration to Rediscover *Veii*

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L'applicazione del telerilevamento multispettrale da drone nell'ambito della ricerca archeologica rappresenta un'innovativa e promettente opportunità per la rapida identificazione su vaste estensioni di un numero consistente di evidenze archeologiche sepolte. L'utilizzo di camere multispettrali consente infatti di registrare la risposta spettrale delle piante in diverse bande dello spettro elettromagnetico ed elaborando le immagini mediante l'uso degli indici di vegetazione è possibile identificare le minime variazioni nelle condizioni fisiologiche delle piante prodotte da resti sepolti e invisibili all'occhio umano.
L'applicazione di questa tecnica a partire dal 2017 – e dal 2020 nell'ambito delle ricerche dell'Insegnamento di Civiltà dell'Italia preromana ed Etruscologia della Sapienza Università di Roma – presso l'area urbana di Veio, ed in particolare nella porzione nordoccidentale del plateau corrispondente al toponimo di Campetti, ha dimostrato come sia possibile identificare una notevole quantità di cropmark.
L'integrazione dei dati ottenuti tramite questa metodologia con quelli provenienti dal riesame degli scavi e ricerche pregresse, il cui studio è attualmente in corso mediante ricerche d'archivio, ha permesso di arricchire significativamente e approfondire la conoscenza e la comprensione dello sviluppo del paesaggio urbano in un'ampia porzione della città antica.

Introduction

From roughly the middle of the 3rd century CE onwards, the city of *Veii* (fig. 1) underwent a substantial decline in occupation for settlement purposes, with a shift almost exclusively towards agricultural exploitation. This makes the site a particularly suitable context for archaeological research and since 1996[1] a systematic programme of investigations, the "*Veii* Project", has been carried out at the *Sapienza Università di Roma* with the aim of improving our knowledge of the development and organisation of both the Etruscan and Roman settlement from a chronological and topographical point of view. A further objective has been the preservation of the site. The project has employed a wide range of investigative techniques to examine the site, including excavation, geophysical investigations, surveys, aerial photography – both historical and newly taken – as well as a reconsideration of the data that emerged from historical investigations that predated the project[2] and have made it possible to deepen our knowledge in relation to numerous aspects of the development of the city[3].

[1] On the targets of the "*Veii* Project" see DRAGO 1998.
[2] Among these, the "South Etruria Survey", the ground-breaking project of archaeological survey of a large portion of southern Etruria directed by John Bryan Ward-Perkins in the 1950s and 1960s, certainly deserves a special mention. It collected an extraordinary amount of data under review since the end of the 1990s as part of the "Tiber Valley Project", directed by Helen Patterson under the aegis of the British School at Rome. For the latest summary on the results of the project DI GIUSEPPE 2018 and PATTERSON *et al*. 2020.
[3] For the latest summary on "*Veii* Project" results CASCINO *et al*. 2015.

Fig. 1. The plateau of Veii *delimited with a white line with toponyms and the main waterways.*

This paper presents the results of research that forms part of the more general activity conducted by the Chair of Etruscology and Italic Antiquities at Sapienza Università di Roma in the area of *Veii*[4] and primarily uses a methodology that has been developed and refined since 2011[5], based on low-altitude use of multispectral sensors for the detection of vegetation anomalies caused by buried archaeological remains.

[4] MICHETTI *et al*. 2020. As part of this activity, since November 2021, a PhD project financed by the JP Droni company of Genoa, which is carried out by Filippo Materazzi, has also begun at the same University, aimed at executing systematic and repeated UAV remote sensing over the entire plateau area and the neighbouring portion of the territory, to collect and analyse the data with multi-spectral and thermal imaging and integrate it with the documentation of past investigations currently preserved in numerous archives, as well as to test and develop the methodology used. In 2022, a surface area of approximately 600 ha was covered repeatedly.
[5] FIORINI, MATERAZZI 2017.

In recent years, there has been an increasing interest in aerial archaeology[6]. This is due to the increased availability of UAVs (Unmanned Aerial Vehicles), which are advanced, low-cost tools that can easily capture high-resolution aerial images. These remotely piloted aircraft, universally known as drones, have reached high levels of both performance and reliability. There is currently a strong developmental trend underway towards the miniaturisation of drones, and in particular the payloads, while the technical features are constantly being improved. Sensors for drone photogrammetry can generally be divided into RGB, thermal and multispectral cameras, and all three are currently used to varying degrees of effectiveness in archaeology. The latter two, in particular, are employed for the detection of marks caused by underlying archaeology. The technique is the same as that used in the case of aerial or satellite photography, with the main difference being in terms of scale.

Thermal cameras, on the other hand, capture thermal infrared images and can detect imperceptible differences between the thermal properties of soil or vegetation and buried archaeological remains[7]. Despite the long-term use of this technique, the results obtained from its use can still be quite variable and sometimes discordant, which is very often due to differences in use on vegetated or bare soil and the significant influence exerted by the weather, all factors that undoubtedly complicate its adoption[8].

Multispectral cameras simultaneously acquire several images in different bands of the electromagnetic spectrum, usually in the wavelengths between visible light and near-infrared (VIS + NIR). In archaeology, this technique has proven particularly fruitful in the identification of cropmarks[9]. Indeed, by analysing the information from the various sensors, it is possible to observe infinitesimal alterations in the vegetation invisible to the human eye that signal the presence of potential buried archaeological remains. There are numerous multispectral cameras available, ranging from modified RGB cameras that capture the NIR spectrum to those equipped with six or more sensors, each capable of acquiring different wavelengths and producing distinct results.

These techniques are nowadays often used simultaneously to try to increase the chances of finding anomalies[10], although it is often preferable to use them at different times or even periods in order to maximise their effectiveness.

Drone remote sensing, therefore, holds an important place among the non-invasive techniques available to archaeologists, especially due to the possibility of extensively analysing large areas in a large amount of detail. Indeed, it is increasingly used in conjunction with traditional geophysical techniques to increase the amount of information obtained on a site[11], albeit often still on an experimental level.

From a theoretical point of view, the methodology presented here is based on an agronomic approach, which focuses on an in-depth understanding of the complex relationships between the buried archaeological remains and the covering vegetation, starting with the study of the plant species. The manifestation of cropmarks is, in fact, closely dependent on a large number of factors that vary each time and that must be appropriately considered during the image processing phases[12]. Such an approach, therefore, allows for as much information as possible to be obtained and serves in this context as a basis for the development of both metho-dological and archaeological considerations. In fact, as has been aptly noted in the literature, "*In archaeological remote sensing, the focus of much research and publication work on technical issues and exemplars of methods and data, with less focus on understanding the past, is a notable characteristic of the last decade or more*"[13].

A further and fundamental support for the understanding of remote sensing data is provided by the integration with the results of previously published field investigations as well as unpublished reports conserved in archives. Maps, sketches and any other data that can be integrated into the GIS allow for correlation with the results of remote sensing in order to improve the understanding and consequently the interpretation of the anomalies detected.

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6 Adamopoulos, Rinaudo 2020, fig. 1.
7 Casana *et al.* 2017.
8 Casana *et al.* 2017.
9 Lehmann *et al.* 2015; Fiorini, Materazzi 2017; Fuldain González, Varón Hernández 2019; Uribe *et al.* 2021; Materazzi, Pacifici 2022.
10 Among the first Šedina *et al.* 2016.
11 Scudero *et al.* 2018; Pisz *et al.* 2020; Basso, Dobreva 2020; Uribe *et al.* 2021.
12 Czajlik *et al.* 2021.
13 Cowley *et al.* 2021: 1.

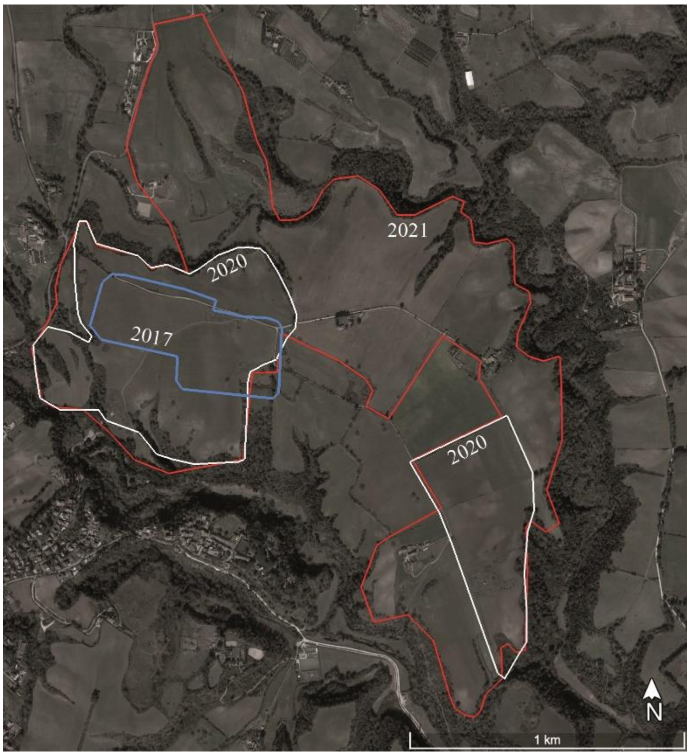

Fig. 2. Extension of the three remote sensing campaigns

By 2021, three distinct non-systematic multispectral remote sensing surveys with drones had been conducted (fig. 2). The first, with an experimental approach, was carried out in 2017 on a limited portion of the area identified by the modern toponym of Campetti in the north-eastern end of the plateau of *Veii*[14], while a second survey conducted in 2020 covered the entire area of the same toponym as well as a small burial area to the south-west of it, and part of Piano di Comunità on the south-east of the plateau. Finally, further data were collected in 2021 across almost the entire plateau of the ancient city, with the exclusion of some portions where the environmental conditions were unsuitable for the application of the technique. This survey also encompassed the Picazzano burial ground and the area to the south-west of Campetti, which had already been surveyed in 2020.

The results obtained in the Campetti area will be presented below through the integral analysis of all of the images obtained over the first three years of surveying and these will also be correlated with data from other sources and past investigations.

[F. M. - M. P]

Study area

Veii developed on a broad plateau of about 190 ha defined by the high natural cliffs that are formed to the south by the Piordo stream and to the north by the Valchetta (or Cremera), both of which merge to the south-east of the plain to become one of the tributaries of the Tiber[15] (fig. 1).

The plateau is characterised by a relatively flat, irregular central ridge, along which runs the rural route of the modern Vicolo Formellese, which follows the lay of the land and is located not far from the site of the ancient main road.

In addition to this, two further small plateaus should be considered as part of the ancient settlement. The most significant of these is the small hill located to the south-west, on which the modern village of Isola Farnese stands and where excavation has revealed the clear remains of a Bronze Age settlement[16], while to the south-east the hill called Piazza d'Armi, which although probably occupied contemporaneously with the rest of the inhabited area, would seem to have been abandoned around the beginning and the first half of the 5th century BCE, possibly as a consequence of social or political changes. It is only during the middle of the Republican Period that it was reoccupied for productive activities[17].

For the most part the surface of the plateau boasts natural defences, although where the cliffs are less steep different types of archaeological research have demonstrated the presence of strong defensive structures, initially of the so-called *aggere* type, subsequently replaced by tuff blocks[18].

[14] MATERAZZI, PACIFICI 2020; 2022.
[15] BARTOLONI *et al.* 2019: 1.
[16] See *infra*.
[17] BARTOLONI, ACCONCIA 2012: 12.
[18] WARD-PERKINS 1961: 32-39; BOITANI 2008; BOITANI *et al.* 2016.

At various points the cliffs were interrupted by natural rock-cut passages of varying sizes that led to the river valleys and probably served as access points. The main gates of the city were most likely located in correspondence with some of these passages. The layout of the ancient system of access to the plateau has mainly been hypothesed based on observations of the terrain morphology and the road network, as well as field survey activity[19]. It should be noted, however, that to date the only entranceway that has been identified through excavation is that located between the so-called North-West Gate and the *Caere* Gate[20].

It is highly likely that many of the funerary areas that have been discovered on the hill surrounding the plateau began to be used contemporaneously, from at least the beginning of the Iron Age – and perhaps even from the end of the Late Bronze Age[21] – during the process of city formation. Over time, the gaps in between these sites were filled in, forming a ring of tombs around the plateau[22].

It should certainly be remembered that the plateau as it appears today is the result of the various phases of use combined with the impact of natural factors, all of which must have led to profound changes to the area over time compared to its original natural morphology.

Evidence of this can be seen in the excavation carried out by La Sapienza in the upper part of Campetti which revealed that, in this area at least (but perhaps also across the rest of the plateau), the originally existing watercourse definitively dried-up at the beginning of the 8th century BCE, whereupon the route of the central main road was established in its place[23].

The modern toponym of Campetti refers specifically to the north-western sector of *Veii*[24]. The modern morphology (fig. 3) of the area is characterised by the presence of two continuous summit portions that are quite flat and wide, in correspondence with the previously mentioned central ridge on which the modern rural road runs. The slopes develop southwards from each of the two summit "planes" sloping gently at first, and then with an increasing gradient towards the limits of the plateau, thus forming a narrow and steeper valley in the middle. On the other side, to the north of the ridge, the two top portions develop for just a few tens of metres and then slope rapidly and steeply down to the limits defined by the gorge of the Valchetta stream.

Today the Campetti area is used exclusively for agricultural purposes. This portion of the plateau is probably also one of the most heavily investigated sectors of the site and has consequently returned the greatest amount of data so far. It is from this area that we have the most information regarding the earliest phase of occupation of the plateau. Indeed, although the only certain Late Bronze Age settlement is that one previously mentioned on the hillock of the modern village of Isola Farnese[25] – significantly located outside the area of the main plateau and connected to the coeval burial ground recently explored in the locality of Pozzuolo[26] – the very early occupation of this portion of the plateau is suggested by the antiquity of the defensive structures explored near the western edge. More specifically, these constitute a ditch and an *aggere* identified not far south of the North-West Gate that can be dated, thanks to pottery fragments, to a period of transition between the Late Bronze Age and the beginning of the Iron Age[27].

During the Iron Age, there was intense occupation of Campetti for settlement purposes, characterised by oval hut-type structures, as attested by numerous anomalies that were revealed both near the western edge of

[19] WARD-PERKINS 1961: 3-20.
[20] BIAGI *et al.* 2020.
[21] This might be suggested only by the unique Late Bronze Age tomb from the burial ground of Casal del Fosso (BARBARO 2010: 321, n. 219) and a number of objects of that can only be loosely dated to the Late Bronze Age from Quattro Fontanili (*Ivi:* 321, n. 218). The recently explored burial ground of Pozzuolo, on the other hand, is most likely connected to the Late Bronze Age settlement at the modern village of Isola Farnese (NOMI *et al.* 2020).
[22] For a general overview of the necropolis of *Veii* BARTOLONI *et al.* 1994.
[23] JAIA, CELLA 2015: 35.
[24] A reconstruction of the toponymic development of the plateau is in the process of being drawn up, through the systematic analysis of the archival documentation within the framework of the doctorate being carried out. See *Introduction*.
[25] BARTOLONI 2012.
[26] NOMI *et al.* 2020.
[27] BOITANI *et al.* 2016: 24. From the Campetti also comes an isolated fragment collected during survey activities that can be dated during the initial phases of the Late Bronze Age (BARBARO 2010: 321, n. 217). On the subject SCHIAPPELLI in CASCINO *et al.* 2012: 329 and PATTERSON *et al.* 2020: 78.

the plateau, in connection with an artisanal area for the production of pottery[28] as well as by the less-preserved structures in the central portion close to the paleochannel of the watercourse, which during this phase must have still been active on the summit portion in a more articulated manner than today[29]. A number of remains of similar structures have also emerged in the oldest layers of the large sanctuary of in the southern area of Campetti, which have been investigated along the southern margin[30].

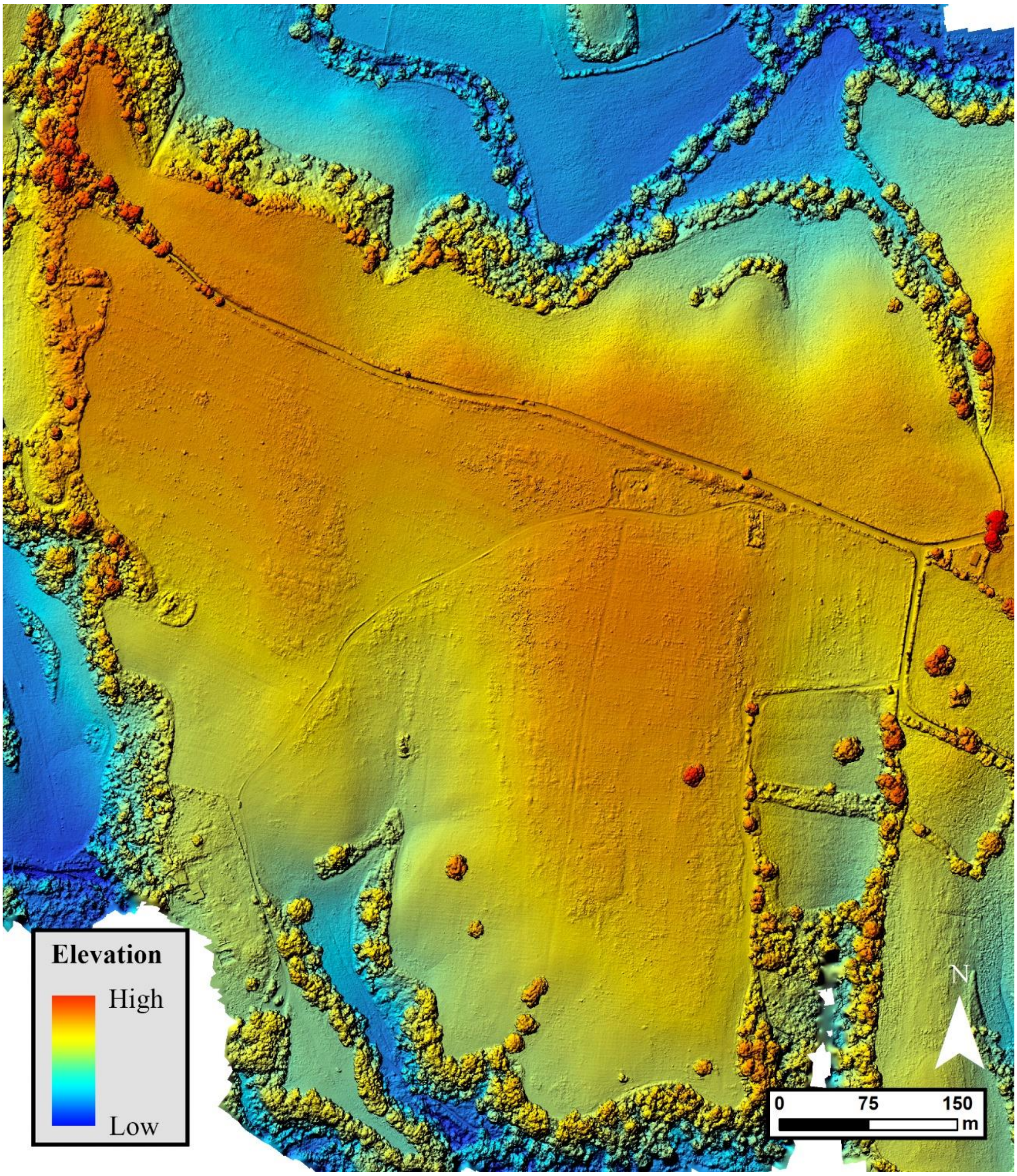

Fig. 3. Digital surface model of Campetti.

[28] The so-called "Circular Hut" excavated by Ward-Perkins just north of the North-West Gate (WARD-PERKINS 1959: 52, fig. 6a; VAN KAMPEN 2003: 26; CASCINO 2015: 105-106) and, next to the rampart, structures to produce pottery at first and then metal associated with an oval hut with a portico (BOITANI *et al.* 2016: 26-27).

[29] JAIA, CELLA 2015: 36-37. On the circulation of water in *Veii* and in this area, see lastly the short note MAGGI, LATINI in FUSCO 2015: 45-48.

[30] FUSCO 2015: 41.

Despite the particularly limited number of finds relating to the Orientalizing period, most likely due to the impact of later occupation[31], it appears that the hut structures were generally reorganised through the introduction of rectangular timber buildings[32] and the appearance of stone walls in the second half of the 7th century BCE[33].

At the end of the 7th century BCE the most complete and clearly evident organisation of the large sanctuary area of Campetti South took place near the so-called Portonaccio Gate[34], in line with a combination frequently attested at *Veii* of cult areas located close to the entrances[35]. What is less clear, however, is the function of a poorly preserved building that occupied the area investigated near the central summit of Campetti[36].

The considerable amount of evidence available for the Archaic period is consistent with the assumed maximum occupation of the entire urban area that was achieved during this phase[37]. Indeed, it is around the middle of the 6th century BCE that the defensive rampart was replaced with a wall made of tuff blocks[38]. Between the end of the 6th and, more probably, the beginning of the 5th century BCE, the rebuilding of the entranceway identified between the North-West Gate and *Caere* Gate also took place[39]. Near the western edge of the plateau, a little south of the North-West Gate, there is also evidence for structures of a monumental nature, possibly with a public function[40].

The data concerning the cult areas during the Archaic Period are also particularly plentiful.[41] Indeed, while the development of the sanctuary of Campetti South continues on two terraces and is equipped with structures that reveal the central role of water[42], a second sanctuary, not far from *Caere* Gate, must have been located on an artificial platform contained to the south and east by walls of tuff blocks built between the end of the 6th and the beginning of the 5th century BCE[43].

The foundation of a shrine in the sacred area known as Campetti North, in the northern portion of the area, could also be dated to the last thirty years of the 6th century BCE. Although investigations in the sanctuary over the years have been plagued with problems and less than perfectly documented, it is quite likely that the shrine was initially constituted by buildings in perishable materials and only equipped with masonry structures at a later point, along with an artificial cave containing a pillar that was created near a naturally occurring height difference in the north-eastern portion of Campetti[44].

During this same phase a very large building was in use in the central portion of Campetti, occupying an artificial terrace supported by a substantial wall facing the summit path, which during this period was gravelled. Despite the fact that, at the current state of knowledge, the building layout is only partially known, the theory that it was a temple is supported by the finds from a cistern investigated within the area of the building and used for the dumping of waste material during the building's decommissioning following the Roman conquest of the city.

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31 See *infra*.
32 Two 'Rectangular Timber Buildings' were discovered on both sides of the North-West Gate. For the northern one WARD-PERKINS 1959: 52, fig. 6b; MURRAY-THREIPLAND 1963: 47-49; VAN KAMPEN 2003: 26; CASCINO 2015: 106, for the other one BOITANI *et al.* 2016: 27. On this subject see also BARTOLONI 2017.
33 This is the 'Rectangular Stone Building' that replaces the wooden hut identified by Ward-Perkins (WARD-PERKINS 1959: 53, fig. 6c; VAN KAMPEN 2003: 26; CASCINO 2015: 106)
34 FUSCO 2015: 43.
35 FUSCO 2011: 382, footnote 9.
36 JAIA, CELLA 2015: 37.
37 GUAITOLI 2016: 212.
38 BOITANI *et al.* 2016: 28; BIAGI *et al.* 2020: 439.
39 BIAGI *et al.* 2020: 440. However, the excavation, which is still not completed, would seem to suggest the presence of the gateway as early as the late 10th century BCE (*Ibid*.). Moreover, the access is again significantly modified shortly before the mid-5th century BCE.
40 BOITANI *et al.* 2016: 27-28.
41 While reaffirming the uniqueness of the excavation of the gate along the western edge of the plateau in the overall framework of the accesses to the ancient city, Ward-Perkins postulates the presence of four probable gates in this area, all connected to points of natural depression on the edge of the plateau. These are, proceeding counter clockwise from the north, the *Formello* Gate, which exploits a deep and long gully, the North-West Gate, which would seem to trace the access to the plateau of the modern *Vicolo Formellese*, the *Caere* Gate, certainly confirmed by the morphology of the edge of the plateau, and the *Portonaccio* Gate, which, heading southwards, also guaranteed access to the sanctuary area (WARD-PERKINS 1961: 3-20).
42 FUSCO 2015: 43. For the definition of the names of the sanctuaries in the Campetti area COLONNA 2014: 61.
43 TORELLI, POHL 1973: 42-53.
44 On Campetti North Sanctuary CAROSI 2002 and COLONNA 2014: 61-68. For the edition of the findings see VAGNETTI 1971 and COMELLA, STEFANI 1990. For the hypothesis of two other areas of worship in the portion of the plateau north of the summit field road, suggested by questionable data, see COLONNA 2014: 69-71.

The presence of defective ceramic pieces also suggests the possible presence of a pottery workshop in the vicinity.

The Roman conquest of the city, which according to tradition took place in 396 BCE, brought about a change in the layout and occupation of the plateau[45]. Starting from the 4th century BCE, there were intense periods of demolition or spoliation associated with the important buildings attested in the Campetti area during the previous century. It is in this phase that we witness the dismantling of portions of the defensive walls near the western slopes of the plateau[46], as well as of the large temple in the central apex[47] and the destruction of at least the known elements of the sanctuary near the *Caere* Gate[48].

There is, however, no lack of evidence of continuity of use of the area, in particular with regard to cult practices, as demonstrated by the offerings relating to some kind of renovation of the sanctuary of Campetti North at the end of the 4th century BCE[49].

On the other hand, the Roman occupation of the site found new vigour, albeit to a lesser degree than in the Etruscan phase, starting from the second half of the 1st century BCE when the sanctuary of Campetti South was renovated and the cultic and therapeutic complex reached its maximum extension[50].

These are the decades in which an initial allocation of plots of land under Caesar was followed by the Augustan foundation of the *Municipium Augustum Veiens*, at an unspecified moment after 27 BCE[51]. Although our knowledge is particularly fragmentary, the data make it possible to observe an overall reorganisation of the entire plateau surface, with the definitive filling in of the rough areas of terrain that remained and the preparation of a road system with paved paths that almost certainly followed the course of the oldest routes – certainly the main road on the top of the plateau – and that were provided with all of the necessary associated services (sewerage ridges, containment works, sidewalks, etc.)[52].

Despite the fact that the urban area of the Roman municipality was concentrated exclusively in the central portion of the plateau, the known evidence seems to reveal the planning for infrastructure that extended over a large part of the plateau. Evidence of this at Campetti is provided by the presence of funerary monuments overlooking the main paved road that connects the entire plateau[53] contextually to the significant amount of evidence for dwellings with various functions that can be placed in this phase. These include the *domus* and the two-storey building with stables overlooking the main road[54], the Roman villa of Quarticcioli – a toponym referring to the northern portion of Campetti, to the north of the main road axis[55], from which comes the mosaic with a scene of an elephant being boarded onto a ship[56] –, another building along the main road axis to the west of the previous one[57], and the generically named 'Roman houses' from the Pallottino excavations at the sanctuary of Campetti North[58].

Given the present state of knowledge and data it is difficult to define a precise layout of the Campetti area during the whole period of the Roman colony's life – the only certain evidence is the sharp decline in the use of the sanctuary of Campetti South [59]. This is even more the case for the following centuries. However, around the

[45] Liverani 1984; Michetti 2021.
[46] Boitani *et al.* 2016: 28.
[47] The dismantling affects the building right down to the foundations as well as the structures of the terrace on which it stood (Jaia, Cella 2015: 38). See also Colonna 2014: 63.
[48] Torelli, Pohl 1973: 49-53.
[49] Carosi 2002: 366. Also, Michetti 2021: 27-29.
[50] Fusco 2015: 44. In this phase, the 'very poor' Roman structure at the investigated portion of the sanctuary of Campetti *Caere* Gate is also realised (Torelli, Pohl 1973: 54-55).
[51] Liverani 1987: 143-162.
[52] Jaia, Cella 2015: 39.
[53] *Ivi*: 35-36. Sporadic finds of sarcophagi in Campetti, in the area just north of the central road route, are also worth mentioning. (Liverani 2015: 102-103).
[54] *Ivi*: 35-36, 39.
[55] See footnote 24.
[56] Ward-Perkins 1961: 68, fig. 18. For the correct position of structures Liverani 2015: 101-102.
[57] Ward-Perkins 1961: 69, fig. 19a; Cascino *et al.* 2012: 41, Area 20.
[58] Pallottino 1938: 403. Also, Colonna 2014: 69.
[59] Fusco 2015: 44.

middle of the 3rd century CE both this area and the plateau as a whole almost certainly witnessed the definitive end of the previous occupation system[60].

[M. P.]

Materials and methods

Compared to the 2017 flight campaign[61], as part of which a Sequoia multispectral camera was used, 2020 saw the first use of the Phantom 4 Multispectral, a newly-developed drone made by DJI specifically for precision agriculture surveying. The main features that make this one of the best solutions for low-altitude remote sensing are the integrated, six-band, 12bit, gyro-stabilized multispectral camera with a sensor for radiometric calibration and the GNSS RTK that ensures high accuracy in positioning during flight as well as the georeferencing of the images produced. The six available sensors are divided into five monoband and one RGB sensors, all of which are 2.1 MP. Thanks to these features, flying at an altitude of 110 m above the ground with 80% frontal overlap and 70% side overlap, it is possible to cover about 15 ha with a GSD (Ground Sampling Distance) of about 6 cm/pixel in circa 20 minutes real flight autonomy, which means that it is possible to land with more than 20% of battery level remaining.

For automatic flight planning and execution, the DJI GS Pro App was tested in 2020, followed by the UgCs software in 2021. Although the latter is more complex to use due to its many functions, it allows for the employment of advanced mission settings, but more importantly, it makes it possible to create flight plans with the terrain ground awareness function, in which the drone modifies its flight altitude autonomously to maintain approximately the same overlap between shots and the same GSD. In order to address this important shortcoming in an area with complex orography such as Campetti, in 2020 multiple flight plans were planned with different altitudes to try to keep the drone at the same distance from the ground as much as possible. This resulted in a considerably greater amount of time being required to plan the missions and to carry them out in the field, leading to less than perfect results.

The surveys were carried out on 16 May 2020 and 18 May 2021. In both cases the flights were performed in the central hours of the day, between approximately 10 am and 3 pm in order ensure that the sun was as close to its zenith as possible and thus minimize the projection of shadows on the ground surface[62].

In order to monitor the weather conditions in the days prior to surveying and to record the data at the same time as the remote sensing was carried out, information available freely online from two weather stations installed a short distance to the south-west of the limits of the plateau near the town of La Storta (Rome) was used[63].

Meteorological conditions were particularly favourable for remote sensing purposes in 2020, with uniform stratiform cloud cover and almost no wind during the flight. However, data acquisition was more problematic in 2021 due to suboptimal weather conditions. Indeed, the 18 May was characterized by irregular cloud cover associated with strong winds, with a significant presence of gusts of moderate intensity. The combination of these factors resulted in highly irregular and variable brightness, even over a short period of time, and also caused a large amount of movement in the plants, a phenomenon that is evident in the images obtained and that necessitated careful evaluation in both the reading and interpretation of the photos.

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[60] LIVERANI 1987: 161-162. The renovation of the Villa of Quarticcioli, carried out in the 4th c. CE, is attested in this phase in Campetti, as evidenced by the already mentioned mosaic of a pachyderm boarding, while the area of the sanctuary of Campetti South, abandoned in the mid-3rd c. BCE, is still occupied for residential purposes in a small part at the end of the 4th c. BCE (FUSCO 2015: 42, period VI).

[61] MATERAZZI, PACIFICI 2020.

[62] For 2017 flight data: MATERAZZI, PACIFICI 2020: 100-101.

[63] The data of these two private weather stations are available at the link: http://www.lineameteo.it/index.php.
The first one "Roma - Spizzichino" is a Neatmo model placed on the roof of a building (41,997 No., 12,393 E°) at an elevation of about 148 m a.s.l., while the second one "Roma - La Storta" is an Oregon Scientific WMR300 model installed in a private garden (41,999 No., 12,378 E°) at an elevation of 145 m a.s.l. The two instruments are respectively approximately 2070 and 2700 m from the nearest offshoot of the plateau, and they are approximately 1250 m apart with an elevation difference of about 3 m, circumstances that allow for a valid comparison and possible integrated use of the data.

For the georeferencing of the images we relied on the real-time corrections offered by the P4 Multispectral GNSS RTK. To test its accuracy, at a later stage, in November 2021, the coordinates of a number of fixed points in the area were taken and used in the image processing as control points. The results obtained for both years is almost identical and confirms an average accuracy of about 15 cm on the x- and y-axes and about 1 m on the z-axis, which is to be expected in a context characterized by numerous variations in elevation and is considered sufficient for the purposes of this project.

Numerous tests were carried out to choose the most suitable software for the image processing. Since Pix4D Mapper, which had previously been used with the Sequoia camera in 2017, resulted in alignment problems between the individual reflectance maps, two software programmes specifically designed to process multispectral images were first chosen: DJI Terra and Pix4D Fields. Both produce good results in a very short space of time while proceeding with an extremely simplified processing mode that does not produce a point cloud. However, it must be noted that when the overlap and GSD of the images are not homogeneous, they produce numerous errors in the mosaic that affect the final result. The images were therefore reprocessed with Agisoft Metashape, which despite its longer processing time, allows for the advanced management of structure-from-motion processing settings. The reflectance maps, RGB orthophotos, and DEMs from each survey were managed separately on ArcMap GIS software. The single-band reflectance maps were first ratioed pixel by pixel using vegetation indices (VIs), which are mathematical formulas used in agronomy to analyse certain plant characteristics and that are useful in highlighting cropmarks. The spectral characteristics of the new camera used allowed for the application of 38 VIs (tab. 1). Each VI, therefore, underwent a process of contrast enhancement through the application of specific tools within ArcMap in order to emphasize the cropmarks as much as possible, following which the VIs that had the potential to guarantee better results were then finally imported into a general GIS project.

In terms of anomaly detection, due to the considerable complexity of the context and the regular presence of marks produced by agricultural practices, VI maps were carefully compared with each other within each year. The identified anomalies were digitised on two vector layers, with the best-defined cropmarks assigned to the first and those anomalies for which a complete perimeter could not be drawn assigned the second those. A different colour was chosen to identify each feature group.

Once the anomalies from each of the years had been digitized, they were then compared once again to create two overall layers that included all of the identified features from each of the various years (2017 included[64]) and that will be constantly updated in the future after each new acquisition process. These levels also include the most basic interpretations inferred from the trends of the cropmarks, but which it was deemed useful to add for the purpose of reading the data more easily (fig. 4).

As has previously been presented on a preliminary basis[65], this work was guided by an interdisciplinary approach that combines archaeology primarily with agronomy and aims to achieve an understanding of the complex relationships between buried remains and the environmental context in which they are embedded. The starting point was an understanding of use of the VIs, following which it was necessary to undertake an agronomic analysis of the plant species present at the time of the flights. Thus, an attempt has been made to take a step forward in understanding the dynamics of the occurrence of cropmarks by analytically considering and comparing the large number of variables that characterise the process of cropmark formation[66].

The main elements under discussion can be divided into four groups: buried anthropogenic contexts, soil, weathering and vegetation. The first includes the type of buried evidence, the morphological and chemical-physical characteristics of the materials from which they are composed, as well as the state of preservation and the depth at which they are buried. To the second group belong the chemical-physical parameters of the soil, especially permeability, but also its temperature and moisture. The third group relates to the temperature and humidity of the air and the atmospheric phenomena that have occurred both over the longer period since the plants were sown as well as in the period immediately preceding the flights. Finally, the fourth group is concerned with the

[64] Materazzi, Pacifici 2022.
[65] Fiorini, Materazzi 2017: 2-3; Materazzi, Pacifici 2022: 5.
[66] Czajlik *et al.* 2021.

plant species present and their variety associated with genetic characteristics and needs, phenological stage at the time of flights, health status, and specific agricultural practices[67].

From this brief outline, it is clear that there are numerous possibilities involved in the data obtained and that consequently what is presented here must necessarily be considered within the limits of the case study proposed and cannot pretend to be exhaustive. The intent, therefore, is to try to find plausible answers to explain the numerous anomalies that have been found through different techniques and at different times in the context of *Veii*, which is undoubtedly a site that is equally complex from both an environmental and archaeological perspective.

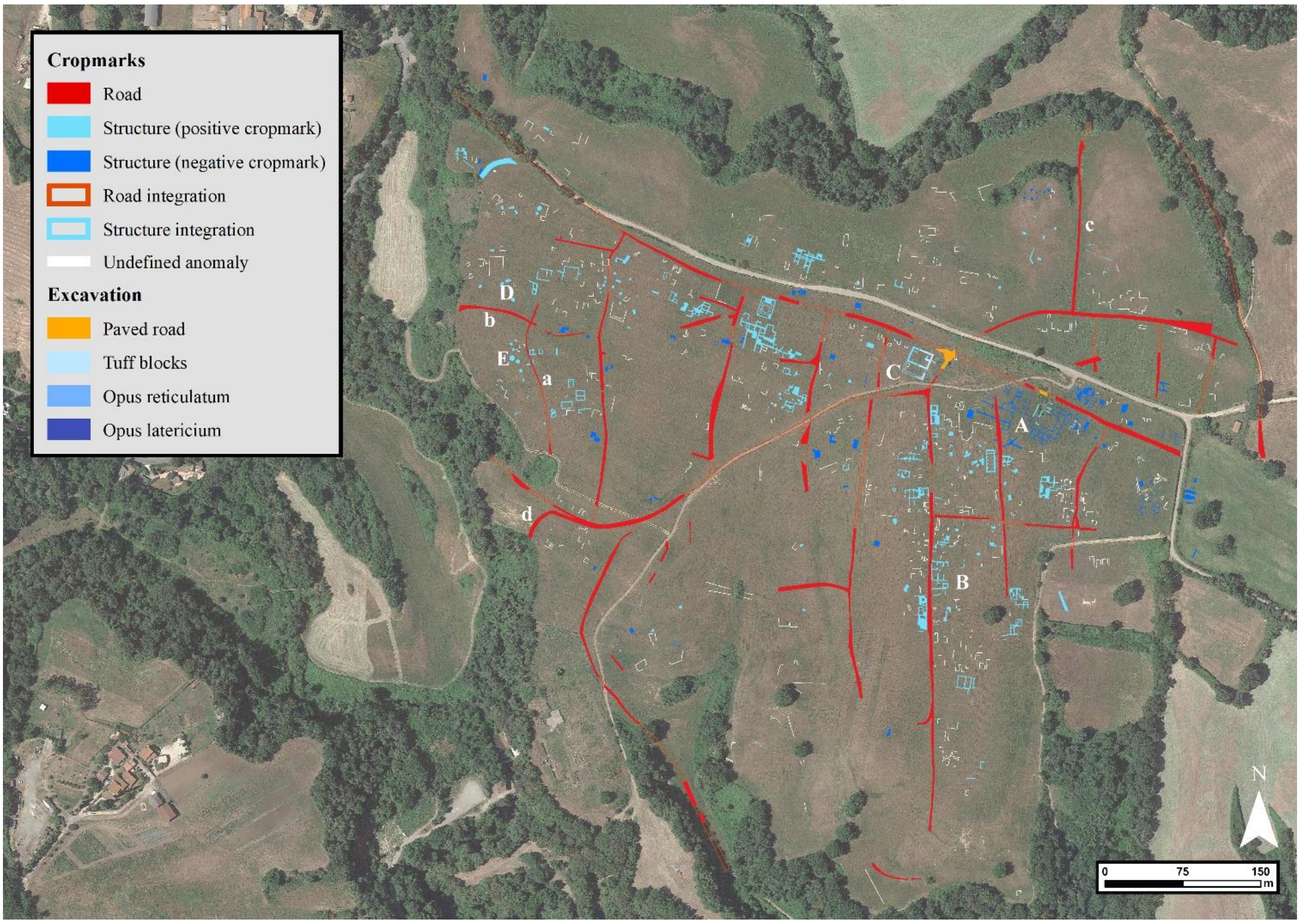

Fig. 4. Overall plan of evidence identified over the three years integrated with past excavations.

As a result, the succession of the various phases of settlement, from the formation of the urban centre to the still little-studied situation in the Middle Ages, identified by a particularly multifaceted vertical stratigraphy, also corresponds horizontally to an oscillation in the extent and organization of the site that we know only partially and that complicates the interpretation of the anomalies.

In order to overcome an approach to low-altitude remote sensing that is exclusively or almost wholly methodological and largely disconnected from the historical and archaeological context, it was decided to adopt an interdisciplinary approach, which aims to deepen the archaeological investigation of the site. Indeed, an attempt has been made to broaden the horizon of research in the area through an investigation that is extensive, but at the same time detailed, especially in the areas for which we have no excavation data. This means that these

[67] GOJDA, HEJCMAN 2012.

sectors can finally be studied and contribute to an overall view that is considered necessary in archaeological research and even more so in the context of *Veii* given that it is so heavily characterised by open spaces.

In order to correlate the drone data with the documentation of published and unpublished archaeological activities, systematic research is being carried out to identify any information that can be georeferenced and included in the GIS. At the same time, this work is also proving crucial in bringing new excavation-verified data into the investigation of the significance of the identified anomalies, or rather, for the purpose of their classification in relation to the buried archaeological remains.

The cataloguing and digitisation of the unpublished material are being carried out mainly at the *Archivio di Stato di Roma*, the *Archivio Centrale dello Stato*, the archives of the Museum of Villa Giulia, the *Biblioteca Apostolica Vaticana*, the *Istituto Nazionale di Archeologia e Storia dell'Arte*, and the archives of the British School at Rome[68], where documents of the large number of investigations that have been carried out at *Veii* since 1370, with the first known looting of stone materials[69], and more intensively from the great excavation campaigns of the early 19th century to the present are preserved[70]. In this paper only a small amount of mostly published data, significant for the archaeological and methodological discussion, will be cited in order to supplement and provide a comparison with the remote sensing results and demonstrate the effectiveness of this approach. Reference will be made in particular to the two trenches undertaken by the Laboratory of Topography at Sapienza Università di Roma[71], those carried out from 2003 to 2015 between the North-West Gate and *Caere* Gate[72], the investigations of the sanctuaries of Campetti *Caere* Gate[73] and Campetti North[74], as well as the cadastral maps preserved at the *Archivio di Stato di Roma*[75].

[F. M.]

[68] We would like to thank the Directors of the Institutes for authorising the consultation of the documents stored in their archives as well as the staff for their support and availability.
[69] DELPINO 1985: 17.
[70] *Ivi*: 31; DELPINO 1999; LIVERANI 1987: 15-24.
[71] JAIA, CELLA 2015.
[72] BIAGI *et al.* 2020.
[73] TORELLI, POHL 1973.
[74] PALLOTTINO 1938; CAROSI 2002.
[75] Archivio di Stato di Roma, *Fondo Presidenza generale del Censo,* Catasto Gregoriano, Mappe, n. 134, Agro Romano; Catasto Alessandrino, Tavola 433/13.

VEGETATION INDEX	FORMULA
DVI (Difference Vegetation Index)	$NIR - RED$
GDVI (Greeness Difference Vegetation Index)	$NIR - GREEN$
SR (Simple Ratio)	$\frac{NIR}{RED}$
GRVI (Green Reflectance Vegetation Index)	$\frac{NIR}{GREEN}$
SRre (Simple Ratio rededge)	$\frac{NIR}{REDEDGE}$
NDVI (Normalised Difference Vegetation Index)	$\frac{NIR - RED}{NIR + RED}$
GNDVI (Green Normalised Difference Vegetation Index)	$\frac{NIR - GREEN}{NIR + GREEN}$
BNDVI (Blue Normalised Difference Vegetation Index)	$\frac{NIR - BLUE}{NIR + BLUE}$
NLI (Nonlinear vegetation Index)	$\frac{NIR^2 - RED}{NIR^2 + RED}$
MNLI (Modified Nonlinear vegetation Index)	$\frac{(NIR^2 - RED)\,(1 + 0.5)}{NIR^2 + RED + 0.5}$
RDVI (Renormalised Difference Vegetation Index)	$\frac{NIR - RED}{(NIR + RED)^{0.5}}$
MSR (Modified Simple Ratio)	$\frac{\frac{NIR}{RED} - 1}{\sqrt{\frac{NIR}{RED} + 1}}$
SAVI (Soil Adjusted Vegetation Index)	$\frac{NIR - RED}{NIR + RED + 0.5}\,(1 + 0.5)$
GSAVI (Green Soil Adjusted Vegetation Index)	$\frac{NIR - GREEN}{NIR + GREEN + 0.5}\,(1 + 0.5)$
MSAVI2 (Modified Soil Adjusted Vegetation Index 2)	$\frac{2\,NIR + 1 - \sqrt{(2\,NIR + 1)^2 - 8\,(NIR - RED)}}{2}$
OSAVI (Optimised Soil Adjusted Vegetation Index)	$\frac{NIR - RED}{NIR + RED + 0.16}\,(1 + 0.16)$
GOSAVI (Green Optimised Soil Adjusted Vegetation Index)	$\frac{NIR - GREEN}{NIR + GREEN + 0.16}\,(1 + 0.16)$
TDVI (Transformed Difference Vegetation Index)	$1.5\,\frac{NIR - RED}{\sqrt{(NIR^2 + RED + 0.5)}}$
GEMI (Global Environment Monitoring Index)	$n\,(1 - 0.25\,n) - \frac{RED - 0.125}{1 - RED}$ $n = \frac{2\,(NIR^2 - RED^2) + 1.5\,NIR + 0.5\,RED}{NIR + RED + 0.5}$
ARVI (Atmospherically Resistant Vegetation Index)	$\frac{NIR - RED - 1\,(RED - BLUE)}{NIR + RED - 1\,(RED - BLUE)}$
TVI (Triangular Vegetation Index)	$\frac{120\,(NIR - GREEN) - 200\,(RED - GREEN)}{2}$
MTVI1 (Modified Triangular Vegetation Index)	$1.2\,[1.2\,(NIR - GREEN) - 2.5\,(RED - GREEN)]$
MCARI2 (Modified Chlorophyll Absorption in Reflectance Index 2)	$1.5\,\frac{2.5\,(NIR - RED) - 1.3\,(RED - GREEN)}{\sqrt{(2\,NIR + 1)^2} - (6\,NIR - 5\sqrt{RED}) - 0.5}$
Clg (Chlorophyll Index Green)	$\frac{NIR}{GREEN} - 1$
Clre (Chlorophyll Index Rededge)	$\frac{NIR}{REDEDGE} - 1$
NDRE (Normalised Difference Red Edge)	$\frac{NIR - REDEDGE}{NIR + REDEDGE}$
MCARI (Modified Chlorophyll Absorption in Reflectance Index)	$(REDEDGE - RED) - 0.2\,(REDEDGE - GREEN)\,(\frac{REDEDGE}{RED})$
MCARI/OSAVI (Modified Chlorophyll Absorption Ratio Index / Optimized Soil Adjusted Vegetation Index)	$\frac{(REDEDGE - RED) - 0.2\,(REDEDGE - GREEN)\,(\frac{REDEDGE}{RED})}{\frac{NIR - RED}{NIR + RED + 0.16}\,(1 + 0.16)}$
TCARI (Transformed Chlorophyll Absorption Ratio Index)	$3\,(REDEDGE - RED) - 0.2\,(REDEDGE - GREEN)\,(\frac{REDEDGE}{RED})$
NPCI (Normalised Pigment Chlorophyll Index)	$\frac{REDEDGE - BLUE}{REDEDGE + BLUE}$
ARI1 (Anthocyanin Reflectance Index)	$\frac{1}{GREEN} - \frac{1}{REDEDGE}$
ARI1B (Anthocyanin Reflectance Index B)	$\frac{1}{GREEN} - \frac{1}{RED}$
ARI2 (Anthocyanin Reflectance Index 2)	$(\frac{1}{GREEN} - \frac{1}{REDEDGE})\,NIR$
SIPI (Structure Intensive Pigment Index)	$\frac{NIR - BLUE}{NIR - RED}$
PSRI (Plant Senescence Reflectance Index)	$\frac{RED - BLUE}{NIR}$
PSRIm (modified Plant Senescence Reflectance Index)	$\frac{RED - GREEN}{NIR}$
NDRER (Normalised Difference Red Edge-Red)	$\frac{REDEDGE - RED}{REDEDGE + RED}$
RGR (Red-Green Ratio)	$\frac{RED}{GREEN}$

Tab. 1. The 38 vegetation indices tested in the study.

Agronomic analysis

In order to provide an agronomic characterisation of the site, the Campetti area can be divided into three zones. The road that crosses the area from west to east provides the main boundary and divides the site into two, although the southern sector is considerably larger. A second subdivision, which compared to the previous one does not determine a change in cultivation, is provided by the secondary road that divides the south portion in a diagonal fashion from north-east to south-west and continues off the plateau. According to these limits, the site can be divided into Campetti north and Campetti south, which in turn is divided into an eastern and western zone (fig. 5).

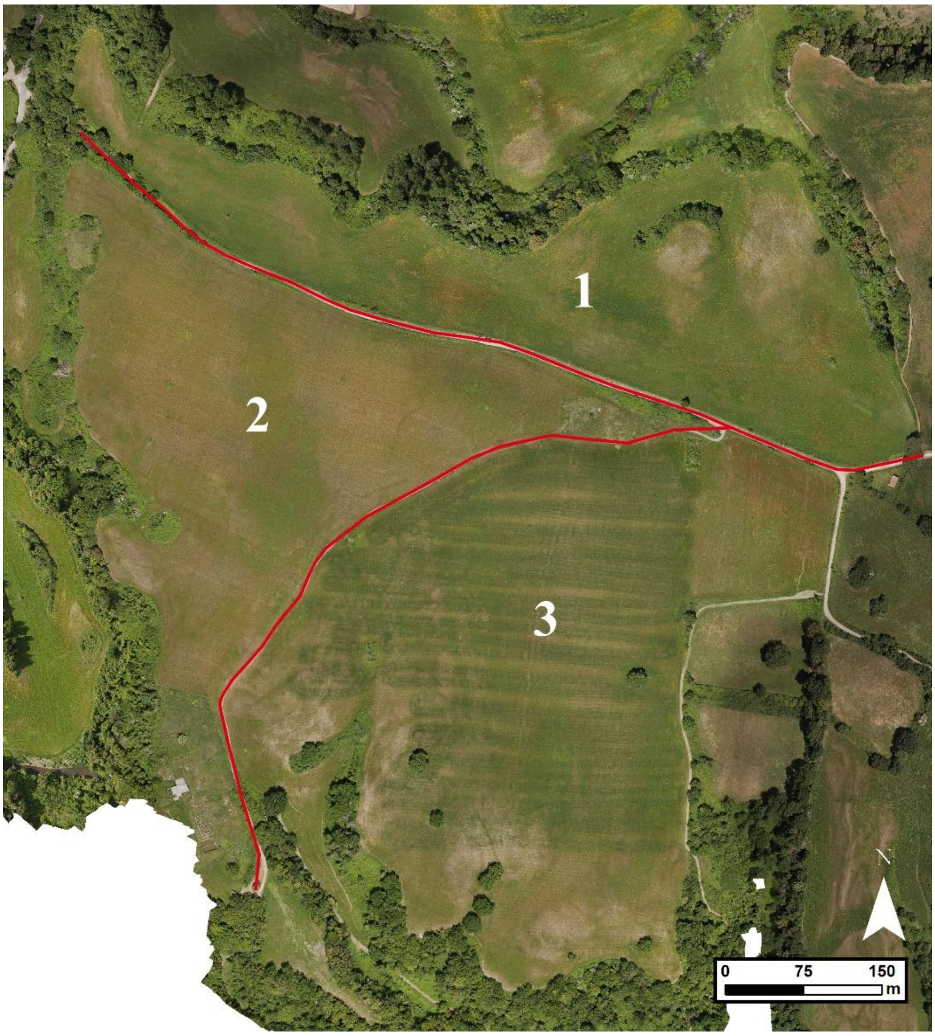

Fig. 5. Division of the three areas of Campetti mentioned in the study. 1: north; 2: south-west; 3: south-east (Orthophoto 2021).

In both 2020 and 2021 there was a pasture crop in Campetti north characterised by a multitude of plant species aimed at providing fodder. In the south, wheat (*Triticum durum* Desf.) was being grown in 2020 and ryegrass (*Lolium multiflorum* Lam.) in 2021.

Both wheat (winter wheat: *Triticum aestivum* L.; durum wheat: *Triticum Durum* Desf.) and ryegrass (*Lolium multiflorum* Lam.) are herbaceous crops belonging to the *Poaceae* family. They are characterized by a fibrous root system, composed of several roots with a low level of branching[76]. Their different inflorescence determines one of the main differences between wheat and ryegrass: for wheat, anthesis occurs with closed glumes (cleistogamy), favouring self-pollination and autogamy[77], while for ryegrass, on the other hand, it occurs with open glumes, favouring cross-fertilization and allogamy[78].

In fact, wheat is genetically classified as a crop with strong autogamy (99%)[79], i.e., reproduction occurs from the union of gametes from the same individual. Therefore, the commercial varieties are pure lines, i.e., made up of individuals that are genetically identical to each other. The phenotypic variations within an autogamous population will, therefore, be attributed only to the environmental component. On the contrary, Italian (*Lolium multiflorum* Lam.) and perennial (*Lolium perenne* L.) ryegrass are substantially allogamous plants with a low percentage of autogamy, due to the presence of self-incompatibility systems[80]; in this case the individuals of a population will be genetically different from each other, thus introducing a further element of variability, which will be determined by both environmental and genetic factors

In the field context this characteristic determines different behaviours in the crops: the genetic uniformity of the wheat determines a homogeneous development of the crop, with each individual equal or similar to the other in terms of height, biomass and phenological stage. Any differences highlighted in terms of vigour within the crop will, therefore, be due to the environment and the soil, and consequently the crop vigour gradient will be linked to the soil or environmental gradient.

With regard to ryegrass, its genetic heterogeneity results in a crop with very different individuals in terms of height, biomass and phenological stage. Therefore, in addition to the effects caused by the environment, the genetic elements will create a salt-pepper effect that is linked to the difference between individuals that may even be immediately adjacent.

Consequently, the fact that the wheat vigour gradient is influenced for the most part by the environment and the soil means that it could be a good indicator of the soil heterogeneities linked to the buried features. On the other hand, the noisy salt-pepper effect caused by the genetics of the ryegrass, could cover the environmental effects and make it more difficult to read the soil gradient.

The fibrous root system consists of adventitious roots that can extend horizontally for 30 to 35 cm just below the surface and grow diagonally downward within the top 30 cm of soil depth. Below 30 cm, however fewer and less branched roots extend vertically to 150 cm or deeper[81]. That being said, 70% of the total root length is usually found in the top 30 cm of the soil layer, where nutrients are concentrated[82]. In any case, root development is highly influenced by genetics[83].

The phenological stages of cereals are generally classified with an internationally accepted scale, such as Zadoks' growth stages[84] (fig. 6). This scale is suitable for both wheat and ryegrass[85]. The growth stages (GS) are graded in order of their ontogenetic appearance, according to 10 principal growth stages identified by a number from 0 to 9. Each principal growth stage can be divided into 10 secondary growth stages numbered from 0 to 9, meaning that secondary growth stages are indicated by a two-digit code.

Stem elongation (Zadoks GS 3) is the vertical development GS of the crop in which the distension of the internodes occurs. The water and nutrient requirements of the crop is at its highest during this phase; indeed, any deficiency of these elements during this phase has an accentuated effect on development and causes delays

[76] LERSTEN 1987.
[77] FRIEDRICH *et al.* 2012.
[78] ARCIONI, MARIOTTI 1983.
[79] FRIEDRICH *et al.* 2012.
[80] ARCIONI, MARIOTTI 1983.
[81] GREGORY *et al.* 1978; GOJDA, HEJCMAN 2012: 1661.
[82] MANSKE, VLEK 2002.
[83] MIAN *et al*. 1993; ZOBEL 2005; EHDAIE, WAINES 2006.
[84] ZADOKS *et al.* 1974.
[85] CHYNOWETH *et al.* 2014.

in growth. For this reason, this is one of the phases during which intra-field variability is highlighted[86]. The other phase characterized by evident viability is maturation, in particular the phases of milk and dough deve-lopment (Zadoks GS 7, 8 and 9). These are the phases in which the water content of the caryopsis (grain) gradually decreases (from 75% of the water content during the milk phase to <35% at physiological maturation) and the plant undergoes senescence and yellowing. Water or nutritional deficiencies cause these phases to occur earlier than usual, whereas good water and nutrient availability, on the contrary, delay senescence and yellowing[87]. These phases are very interesting for the study of sub-soil archaeological features because the visibility of the intra-field variability from remote sensing is at its maximum[88]. The correlation between remote sensing spectral parameters and wheat biomass is very high during Zadoks GS 3 (R2: 0.84), while it decreases during the subsequent phases (Zadoks GS 6 – R2: 0.29) before increasing once again in Zadoks GS 9 (R2: 0.48)[89].

The seasonal climatic trend has an influence on the timing of the phenological phases. For all of the 2020 and 2021 flights, both wheat and ryegrass growth stages were around the maturation phase (Zadoks GS 7-9: milk development, starch development, ripening)[90] and therefore considered optimal for analysis. In terms of the ryegrass, the aforementioned genetic variability determines a greater phenological gradient within the field, with the co-existence of several growth stages at any given moment. Finally, it was not possible to identify the phenological phase of the fodder crop due to the many vegetable species that composed it.

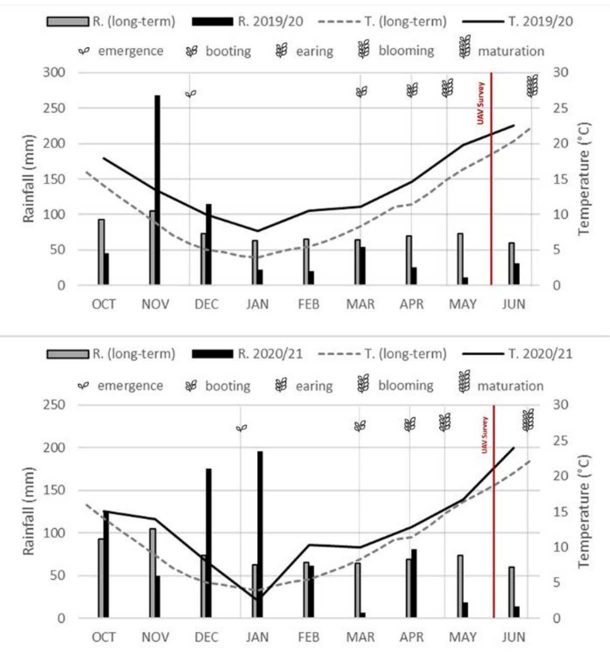

Fig. 6. Winter wheat growth stages in Zadoks' scale (Alley et al. 2019) in smaller plant size.

The aspects detailed below only concern studies carried out on wheat but given the similarity for most of the morpho-physiological aspects between wheat and ryegrass and given the fact that the literature relating to the latter is scarce for the aspects listed below, it is assumed for this analysis that the phenomena that determine an effect for the wheat also produce a comparable effect in the ryegrass.

Buried features such as roads and walls can act as an obstacle barrier for the percolation of rainwater, causing favourable (higher water retention) or unfavourable conditions (waterlogging) according to the depth of the sub-soil archaeological features as well as the meteorological regime of the specific area or season. On the other hand, depending on their nature and structure, features might also favour the percolation of water, causing positive phenomena such as better soil aeration (as in the case of clay soils or rainy years), or negative ones, such as water stress (e.g., in sandy soils or in drought seasons).

It has been shown that waterlogging has an effect on biomass and yield reduction for a large number of cultivated species[91]. In addition to reducing yield and biomass, waterlogging also has an effect on root development: by reducing oxygen availability, waterlogging causes a reduction in root respiration, which can cause the death of root cells, decrease cell permeability, or the complete death of roots as a result of long-lasting poor aeration[92]. Moreover, root growth limitation due to waterlogging, renders the plant fragile and reduces its capacity to cope with summer droughts because the volume of the explored soil and the available soil water are smaller[93].

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[86] EHDAIE *et al*. 2010; VIZZARI *et al*. 2019; SANTAGA *et al*. 2021.
[87] ZHANG, OWEIS 1999.
[88] HEJCMAN, SMRZ 2010; GOJDA, HEJCMAN 2012; XING *et al*. 2021.
[89] BAO *et al.* 2009.
[90] SANTAGA *et al*. 2021.
[91] BELFORD 1981; CAVAZZA, ROSSI PISA 1988; MEYER, BARRS 1988; MUSGRAVE 1994.
[92] PATWARDHAN *et al.* 1988.
[93] KALITA, KANWAR 1992.

Water stress also has an influence on the development of biomass and roots. Water deficit significantly decreases plant growth, which results in reduced shoot biomass including grain yield [94] and root biomass[95]. The decrease in growth rate is caused by a reduction in radiation use efficiency[96] and a reduction in LAI (leaf area index) in the limited water availability was measured[97].

Finally, buried features may also have an influence on the nutritional status of the soil and the consequent root development: it has been shown that the application of a low level of nutrients has led to a greater reduction in the production of superficial roots compared to deeper ones; consequently, plants recovered a smaller fraction of applied nutrients, which resulted Lowering the optimum rate of nutrients by 40% reduced root biomass by 27%, plant biomass by 25%, and grain yield by 19%. Root development has an influence on the absorption of nutrients and is related to the development of biomass. The correlation coefficient between plant nitrogen content and root biomass and between grain yield and root biomass was both positive and significant. A significant positive correlation between root biomass and P and K uptake has also been demonstrated[98].

The average temperature and monthly cumulative rainfall collected for the 2019/20 and 2020/21 seasons near the study area[99], were accompanied by long-term data of rainfall and temperature (rainfall: 1921-2018; temperature: 1951-2018)[100] obtained from the meteorological station of Papiano (PG), which is owned by the Università di Perugia (fig. 7).

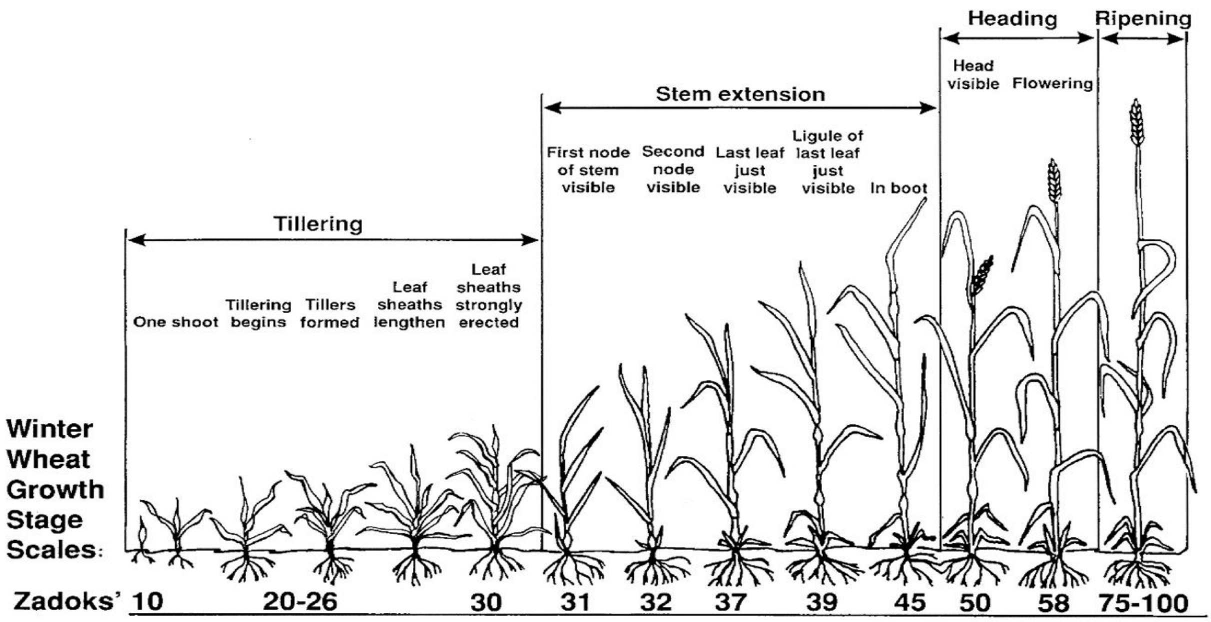

Fig. 7. Weather data of both 2019/20 and 2020/21 seasons, weather data, phenological phases of the wheat / ryegrass and the date of acquisition of the UAV images.

With the exception of anomalous rain levels in November, the 2019/2020 season was characterized by an average monthly rainfall that was consistently lower than the long-term trends, as well as systematically higher temperature averages. This led to chronic water stress for the crops, with the consequence of emphasizing intra-field differences: where the soil was able to retain more water, the effect on the vigour of the crop in that area was appreciable, due to the fact that water was the main limiting factor of the season.

[94] GALLAGHER *et al*. 1975a;EHDAIE *et al*. 2008.
[95] EHDAIE *et al*. 1991.
[96] ASHRAF 1998.
[97] CHATTARAJ *et al*. 2013.
[98] EHDAIE *et al*. 2010.
[99] See *supra*.
[100] SANTAGA *et al.* 2021.

The differences in the physiological conditions of the vegetation present in the two years and the intra-field variability are therefore present and clearly evident from the observation of the orthophotos produced. In Campetti north portion, the herbage crop shows a tendency in both years to remain greener in the flat areas, although in 2021 it is more homogeneous than in 2020. At Campetti south, the wheat was quite advanced in maturity in 2020, tending to yellow in a marked and rather homogeneous way, with nuanced intra-field differences. In 2021, on the other hand, the situation was much more varied and clearly distinguishable in the western and eastern portions, perhaps due to errors in cultivation practices. In the west, there are clear differences and abrupt transitions between very advanced strips of ripening and areas that were still very green. It is also noticeable that this trend is not only very accentuated compared to 2020, but also that the effects were contrary to that year, with an inversion between more and less advanced zones of ripening. In the eastern zone, however, there is a uniform delayed ripening and there are damaged strips created by crop management failures, except for in the extreme eastern portion, which is clearly separated, and where the ryegrass had problems growing, giving way to a large number of weeds.

[F.S.S. - F. M.]

Results

Looking at the Campetti area, the 2020 and 2021 remote sensing campaigns produced very different results (fig. 8). The use of the same equipment and image processing techniques implies that the differences can be traced back to the environmental characteristics of the context during the campaign period.

With regard to the VIs tested, it is possible to note a certain variability in efficacy, which is largely attributable to the specific characteristics of the VI in relation to the plant species present and its stage of growth. This is evident when comparing Campetti north and south, where in both years there are different crops with different aptitudes (also genetic) to be influenced to a greater or lesser extent by buried archaeological features[101].

It should also be noted that even in the case of monocultures there can be considerable intra-field differences, consequently producing results that are also highly variable, especially if they extend over considerable areas such as in this case. These are caused by the chemical properties of the soil, its conformation and microclimatic variations that can lead to changes in soil moisture and organic matter.

Taking all of the above into account, it is only possible to rank the most effective VIs and to draw general conclusions locally. Indeed, in order to identify the greatest number of anomalies, different VIs were used depending on the area being observed (tab. 1).

In general, in 2020 SR[102] was the best VI for wheat, accompanied by the VIs closely related to it - that use only red and nir -, while in the herbage crop of the northern area, PSRIm[103] and MCARI[104] stood out depending on the zone. In 2021, DVI[105] and GEMI[106] were unexpectedly the best both in the southern area, where ryegrass was sown and in the northern area where herbage was present, while SR was one of the worst performing VIs. Similarly, most of the other VIs tested had similar results for both the southern and northern areas.

This is partly explained by the fact that the range of reflectance values in 2021 is more uniform between north and south than in 2020, where there was significantly more yellowing in the south than in the north. On the other hand, the effectiveness of SR is well known[107] and is even more explainable at the end of the plant life cycle, where the ratio between the NIR and red bands, that are involved in this VI, is what best highlights the cropmarks.

Regardless of the VIs used, considerable differences in the number and type of anomalies were found in the two years of data acquisition. Indeed, it is immediately evident that a much larger number of cropmarks were

[101] AGAPIOU *et al.* 2012.
[102] BIRTH, MCVEY 1968.
[103] VI modified from the PSRI formula (MERZLYAK *et al.* 1999) by replacing blue with green.
[104] DAUGHTRY *et al*. 2000.
[105] TUCKER 1979.
[106] PINTY, VERSTRAETE 1992.
[107] Cf. JAMES *et al.* 2020: 2.

detected in 2020 (fig. 8). On closer inspection, despite this numerical discrepancy, it can be seen that in 2021 new anomalies can be identified and that these are exclusively negative anomalies and predominantly located at the eastern edge of Campetti south portion (fig. 9). This can be explained by the conditions created in evidently favoured the appearance of negative cropmarks.

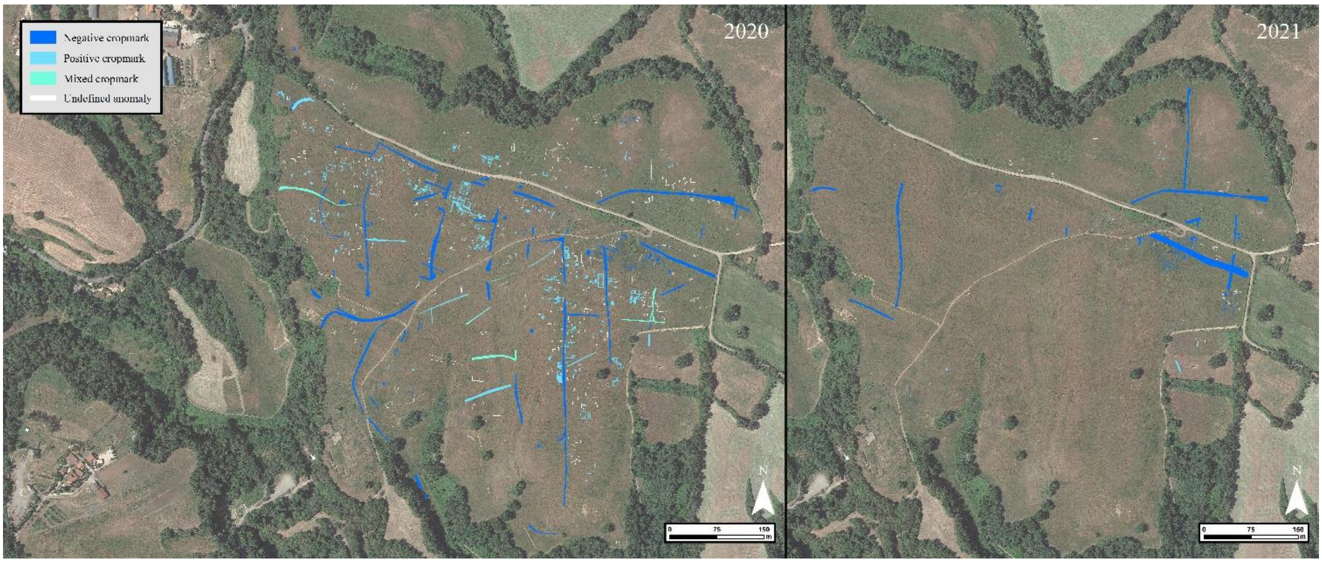

Fig. 8. Comparison of identified cropmarks in 2020 and 2021.

Furthermore, in the remaining parts of Campetti, it is again as a result of the vegetation conditions that most of the anomalies identified in 2020 were not found, which undoubtedly corresponded with a better period for the detection of positive cropmarks, characterised as it was by a general situation of strong water stress combined with low rainfall over the long term, as shown in the pluviometry graphs (fig. 7).

Once again in 2021, the fodder crops to the north, as well as to the east of the southern zone, with the exception of its extreme edge, show no anomalies due to the crop situation[108]. Moreover, the case of the western portion of the ryegrass is unique and is most likely caused by the abrupt variations in the phenological phase of the vegetation, which result in an alternation between uniformly green areas and others that are completely yellow, both of which are not suitable for the manifestation of anomalies.

The 2020 and 2021 remote sensing campaigns allowed for the detection of a large number of cropmarks in addition to those already observed in 2017[109] (fig. 4). By repeating the acquisition of data in the same context under different environmental conditions it has been possible to improve our understanding of what had, since 2017, seemed to be a particularly intricate situation. Indeed, the repeated identification of archaeological features was crucial for both confirming their presence and gaining a better understanding of them, while also allowing for more accurate digitisation[110].

In some instances, it was noted that the outlines of an anomaly can vary from one year to the next and that often, a cropmark that seemed rounded in one year might instead appear square and more clearly defined in another year. This is the case with a circular anomaly observed in 2017 that had been assumed to be a cistern[111]. The 2020 survey showed that it was a rectangular building with internal divisions, demonstrating the

[108] See *supra*.
[109] Materazzi, Pacifici 2022.
[110] Cf. Materazzi, Pacifici 2022: 6, fig. 5.
[111] Materazzi, Pacifici 2020: 105, fig. 6, n. 31.

Fig. 9. Detail of the 2021DVI map showing main negative cropmarks.

hypothetical nature of some observations if they are not repeated over time or supported by the other data[112] (fig. 10).

The repetition of flights under different conditions also makes it possible to identify false archaeological features. For this task, a thorough knowledge of the flight area and the changes that have occurred over time is essential. Here we have chosen to mainly present the initial results of the task of systemising and comparing data acquired with different methodologies, such as multispectral remote sensing, aerial and satellite images, historical photographs, maps, excavations and surveys.

As has already partly been mentioned, this approach, allows for the detailed but localised information of the various excavations carried out in the past to be linked to data from wide-ranging research such as remote sensing and beyond, making it possible to fill in the empty spaces between excavations. At the same time, the excavation data can help to divide anomalies into groups based on their characteristics and often to understand their significance.

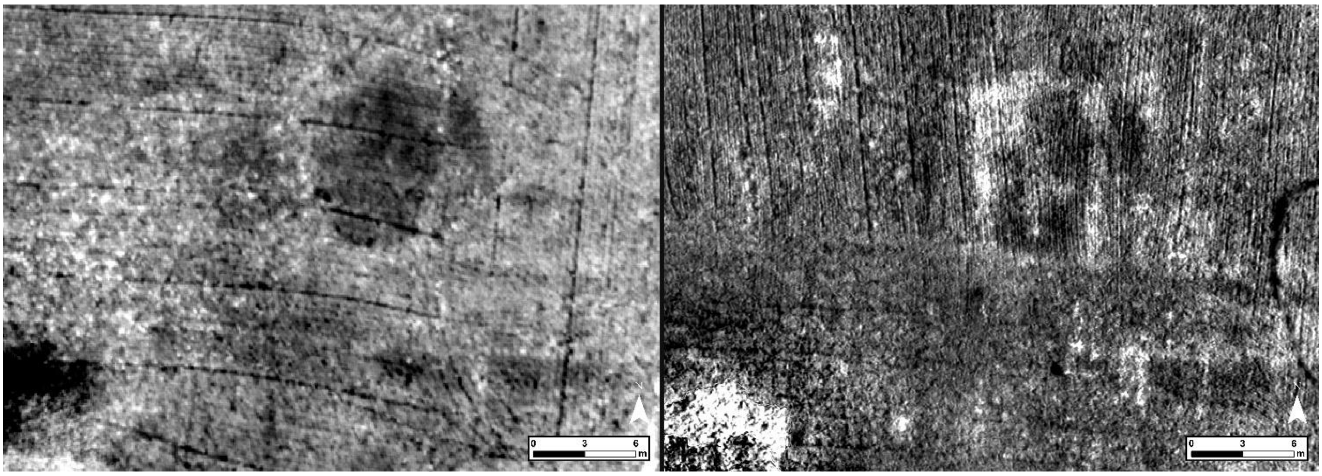

Fig. 10. The same cropmark as it appeared in 2017 and 2020 VI maps.

The study of maps and historical photographs has allowed us to resolve a number of questions, especially in relation to the ancient road system of the site. In particular, the map of the Isola Farnese territory from the 1819 *Gregoriano Cadastre* and the 1660 *Alessandrino Cadastre*, as well as the 1894 IGM map, show substantial differences compared to the contemporary property boundaries and road routes, which only correspond to the current situation to a small extent. The study of these and other documents is still ongoing, but it has already made it possible to understand some recurring anomalies of dubious categorisation. The numerous oblique linear cropmarks that have been noted on several occasions and that sometimes intersect with ancient streets would

[112] It should be emphasized that, upon re-examining the anomalies identified in the 2020 remote sensing in comparison with the new data, the significantly greater complexity of the anomalies associated with a structure near the main road axis becomes evident. This structure is situated approximately in the western part of the Campetti area (MATERAZZI, PACIFICI 2020: 105, fig. 6, n. 26). The proposed comparisons for this structure are now less convincing.

seem to largely be related to post-antique field boundaries and old beaten earth paths, reducing the number of axes that perpendicularly intersected the dense network of the north-south roads present. One route in particular, known as the Via delle Vignacce[113], which was already present in the first half of the 19th century, crossed Campetti south area and rejoined the present north-east – south-west route near the southern edge of the area. This road system and the boundaries that delimited the properties, which most likely sometimes consisting of ditches for field irrigation, seem to have changed as the 19th century progressed and again during the 20th century, and were partly abandoned as the years went on[114], however, they still affect the growth of vegetation, constituting a typical example of a false archaeological mark (fig. 11).

Among the numerous past investigations carried out in Campetti, the excavations conducted by the Laboratory of Ancient Topography of La Sapienza Università di Roma – still visible today – proved to be of great use as a comparison to the remote sensing data[115] (fig. 12), as they are located in a central area, which is rich in cropmarks of various types, although the ability to read the remains has deteriorated considerably due to their state of conservation. Trench no. 1, to refer to its original numbering, is positioned furthest to the east, in an area characterised by a high presence of negative cropmarks. In the upper layers, the trench revealed a section of the ancient road whose paving stones were removed in antiquity and that ran parallel to the current one with a two-storey building in *opus reticulatum* and *latericium* to the south of it[116].

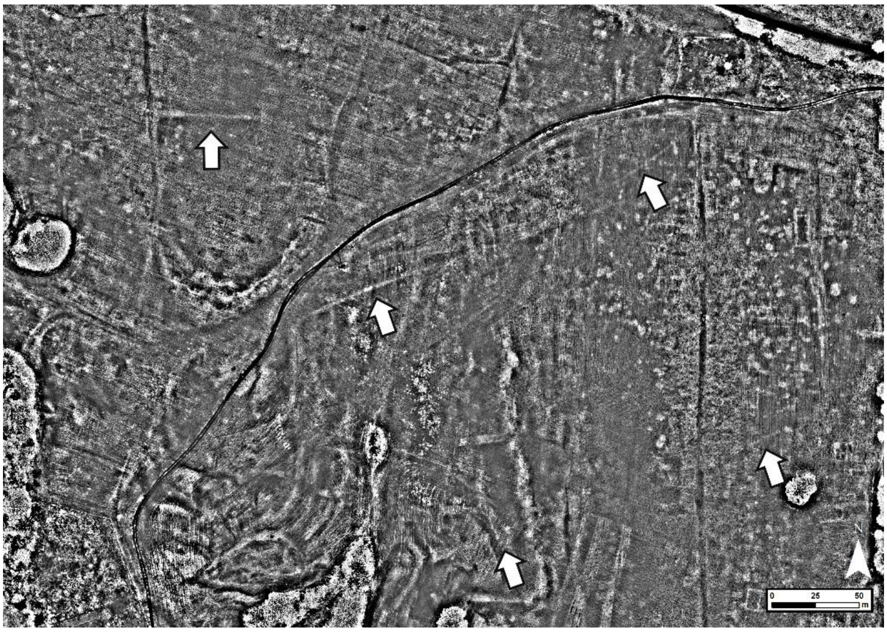

Fig. 11. Detail of the 2020 SR map showing false marks.

Thanks to the multispectral remote sensing it was possible to observe the continuation of these features; the three walls and the remaining parts of the building appear very clear, especially if the information obtained in the three years of remote sensing is combined (fig. 12b). The walls, characterised by well-defined negative cropmarks, trace a large rectangular building measuring about 29 x 29 m with an interior space of about 18 x 15.8 m (fig. 13b). It also has a double row of rooms attached to the south side and continues both to the east and west with other structures to form a large unitary complex. On the other hand, the road is partially visible thanks to the margins identified by positive cropmarks.

Trench no. 2 brought to light a particularly complex situation in what can be considered the centre of Campetti, characterised by the intersection of the two main road axes of the city[117]. The first is the same route identified in trench no. 1, which also in this case has been spoliated, as it continues its route across the entire plateau of *Veii*. The second is the road that, starting from south-west and largely tracing the modern diagonal road of Campetti south, continued after the abovementioned crossroads eastwards parallel to the previous one[118]. This is still largely preserved. Negative cropmarks bordered by positive bands are characteristic of its continuation and also of many other identified roads.

[113] WARD PERKINS 1961: 66.
[114] *Ivi*: 8.
[115] JAIA, CELLA 2015.
[116]*Ivi* 2015: 35-36; GUAITOLI 2016: 187, fig. 9
[117] JAIA, CELLA 2015: 37-40.
[118] GUAITOLI 2016: 183-184.

In addition to the other numerous elements identified in trench no. 2, which undoubtedly testify to the stratigraphic complexity of this focal point[119], a large tuff building was found for which little information is available and we refer to it based on what is known and on field observations (fig. 12a). Part of the imposing foundation walls remain, which are at least 1.6 m wide and formed by several rows of large, squared tuff blocks. The best-preserved section is 16 m long and oriented north-northeast – south-southwest (fig. 13a). Only a few blocks of the other walls and in some places only the spoliation trench remain. To the east, part of the terracing that served to even out the terrain is still visible[120]. Here it was possible to identify the buried part of the building that had never been excavated, particularly in the 2020 flight, but also to some extent in 2017. Both the wall opposite the previously mentioned one, which is also 16 m long and probably a part of the spoliation trench, can be identified by positive cropmarks, albeit faintly. This allows us – even if partially and provisionally in the absence of an excavation map – to reconstruct the plan of the building, which measured approximately 27 x 22 m. No other cropmarks connected to it to the west and south are visible at present.

A very interesting aspect that can be noted is the meaning of the difference between positive and negative crop-marks. Looking at the results, it is clear that the cropmarks that correspond clearly to masonry structures can be of both types (fig. 12). As has just been demonstrated with the case of the two trenches, it must be noted that in this context buried walls do not always create – as one would expect – a negative cropmark by preventing the proper growth of vegetation. On the contrary, in the majority of cases the exact opposite occurs and most of the buildings are defined by positive anomalies.

In this regard, it is useful to consider how the cropmarks are formed and what significance one or other type may have depending on possible buried archaeological evidence. Trench no. 1 shows that the constructional characteristics of the concrete walls and their shallow burial depth, between approximately 50 cm and 80 cm, would seem to prevent the development of the plant root system and produce negative cropmarks. Consequently, all of the remaining structures identified by positive anomalies must necessarily have different peculiarities, such as construction technique and relative attribute characteristics of the materials connected to the hydrogeological properties of the soil. The foundation in trench no. 2 makes it possible to understand the nature of a building defined by a positive cropmark. In fact, buried structures made of tuff, a very porous and friable material, like that buried at about 50 cm in depth, seem to retain water and allow cereals to delay ripening and stay green longer. Finally, the type of road identified in the trench explains the typical conformation of cropmarks connected to roads formed due to the dense paving that would prevent the roots from fully developing.

The edges of roads, on the other hand, still retain the water and cause the plants to be greener and higher, most likely because of the lateral rainwater channelling systems or because of the tuff block walls that sometimes delimitate them, e.g. the roads found at Piano di Comunità and Vignacce areas[121].

From these comparisons, it is possible provide a preliminary definition of certain issues. The clear majority of structures defined by positive cropmarks suggests that a large proportion of these are built of tuff. This is confirmed by the excavations carried out across the entire plateau, where, as we have seen, the Etruscan ma-sonry buildings from the Middle Orientalising period onwards are built of tuff[122]. However, it should be noted that the Roman structures are also partly built of tuff[123]. Vice versa, it is possible that the negative cropmarks of structures may refer to construction techniques of the Roman period, which involved the use of concrete, such as the *opus reticulatum* and *latericium* attested to here.

More certainty comes in the identification of Roman paved roads, often laid on top of the oldest routes[124], which can sometimes be easily distinguished by the characteristic conformation of the anomaly described above and which measure on average 2 to 4 m in width. In contrast to these, *glareata* or dirt roads would produce a simple, usually narrower, negative cropmark, as might be the case with road a (fig. 4).

119 COLONNA 2014: 71.
120 JAIA, CELLA 2015: 36-37.
121 D'ALESSIO 2015: 31, fig. 1.3.1.5; MICHETTI *et al*. 2020: 67-68.
122 See *supra*.
123 e.g. TORELLI, POHL 1973: 54-55; D'ALESSIO 2015: 32; MICHETTI *et al.* 2020: 66.
124 GUAITOLI 2016: 196.

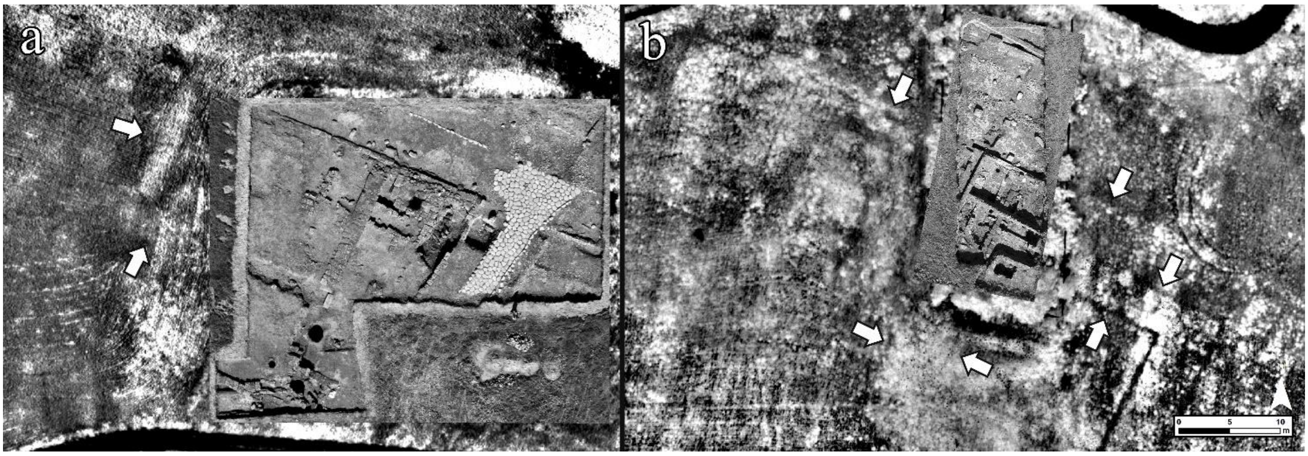

Fig. 12. Aerial photos of trenches carried out by the Laboratory of Topography at Sapienza University overlaid on VI maps showing crop-marks relating to the continuation of excavated structures (Jaia, Cella 2015). a: trench no. 2 on SR map 2020; b: trench no. 1 on DVI map 2021.

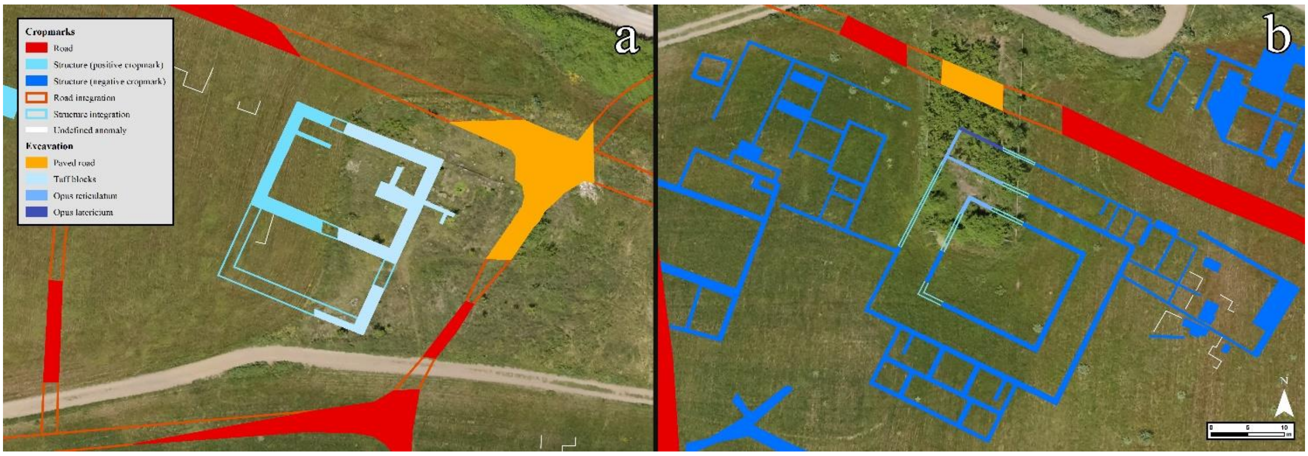

Fig. 13. Overall plan of the buried evidence integrated with the structures unearthed in the trenches of the Laboratory of Topography at Sapienza University. a: trench no. 2; b: trench no. 1.

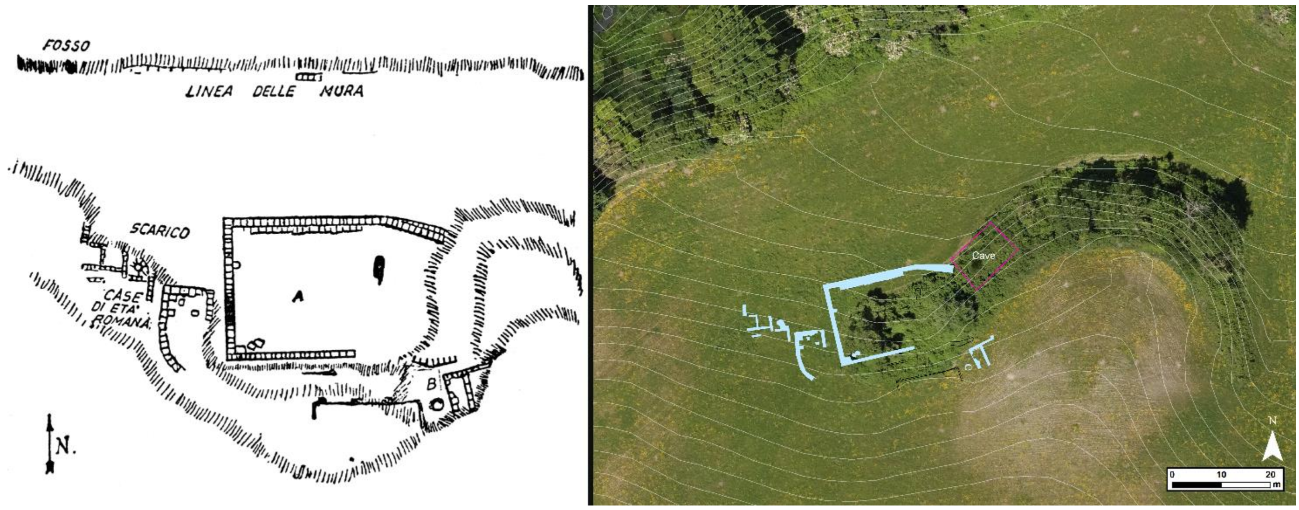

Fig. 14. Positioning of the Campetti North sanctuary. Left: plan of the structures identified in the 1937-1938 Pallottino's excavations (Pallottino 1938). The walls drawn at the top of the picture would not be to scale. Right: possible positioning in 2021 orthophoto.

Although caution is required in the strict application of these considerations, for which we still have too few case histories – even though from the latest investigations they would seem to also be valid in other areas of the city – this is an important step in the attempt to obtain more information from this methodology, which in the context of *Veii* seems to point, even if only partially, towards the possibility of separating Roman features from Etruscan ones.

The information obtained from the comparison with the archaeological excavation discussed so far has served to guide the identification and understanding of the other anomalies present. Other relationships between the identified cropmarks and past findings have been observed in the study area, following the georeferencing of the excavation plans that began in 2021 and that is still ongoing.

The road system of *Veii* and the connection with the accesses to the plateau is undoubtedly one of the issues most frequently addressed in relation to the site[125]. Despite this, remote sensing campaigns are also producing interesting new information on this issue.

The roads identified in the western end of Campetti would seem to be connected with the investigations at the sanctuary beside the *Caere* Gate and with the gate to the north of it identified in 2003[126]. Road a (fig. 4) seems to continue southwards, passing by the eastern edge of the *Caere* Gate sanctuary and would seem to coincide with the identification in that area of the excavation of a series of overlapping roadbeds datable to the second quarter of the 5th century BCE at the latest[127]. This is further confirmed by the information in the notebooks of Ingrid Pohl preserved at the Villa Giulia Archives as well as in the 'Archaeological Map of the Ancient City of Veio' of 1981[128], where a road flanked by a wall appears, curving from the north in a south-west direction, bordering the sanctuary. This correlation, in addition to providing us with a possible date, would also confirm the hypothesis presented in the past regarding the lack of 'redevelopment' of some roads in the Augustan period compared to the other north-south routes that were regularised in the Archaic period and subsequently paved[129].

Regarding the gate found about 150 m north-west of the sanctuary, it is possible to identify a road in its vicinity (fig. 4, b). With a west-east orientation and measuring about 2.5-3 m wide, this road is actually about 15 m further north than the gate. From the VI maps, only a very slight deviation to the south can be discerned, however, the cropmark is unfortunately interrupted as it approaches the limits of the field, where it is usually more difficult to recognise anomalies due to the lack of homogeneity in vegetation and the tracks made by agricultural vehicles. It should be noted that the gate referred to was closed during its final building phase (470-460 BCE) and converted into a defensive tower, with the consequent interruption of the road[130]. Despite the probable curvature towards the south, the misalignment is still present and the different orientation could suggest a more complex organisation of the space.

Another probable relationship between roads and access, more direct than the previous, was observed during the 2021 flight at Campetti north. It was indeed possible to clarify the route of road c (fig. 4), which had already been only partially identified in the past[131] and its direction towards the edge of the plateau[132]. Despite the difficulty in reading the remains hidden by the vegetation, a survey on site made it possible to identify the passage of the route towards the outside of the plateau, which is still partly visible and is also characterised by what at first glance would appear to be a defensive system connected to the walls[133]. Nearby, to the west of this access to the plateau, was the sanctuary of Campetti North [134], no longer visible but that is known to be located opposite the votive cave that still exists today, as described by Mario Torelli[135]. It is precisely in this area that square cropmarks measuring approximately the same as the dimensions reported by Massimo Pallottino[136] were

[125] Ward Perkins 1961: 3-20; Guaitoli 2016: 180-203; Campana 2018: 109-111.
[126] Biagi *et al.* 2020.
[127] Torelli, Pohl 1973: 56-57; Di Sarcina 2017: 133.
[128] Di Sarcina 2017: 130-133.
[129] Guaitoli 2016: 185-186, 195-198.
[130] Biagi *et al.* 2020: 444.
[131] Guaitoli 2016: 179, fig. 1.
[132] Materazzi Pacifici 2022: 204.
[133] The field observation was carried out on 3 March 2022.
[134] For more on the location of the Campetti North shrine: Carosi 2002.
[135] Torelli 1980: 19; after Carosi 2002: 357.
[136] Pallottino 1938: 402.

revealed, suggesting that they likely coincide with the buried remains of the sanctuary (fig. 14). Furthermore, some aerial photographs taken by the Aeronautica Militare in 1942 and by the RAF in 1943 seem to show the structures a few years after Pallottino's excavation concluded in 1938. Here it has been decided to reposition the plan of the structures discovered in the 1937-1938 excavations according to these suppositions, in a hypothetical and preliminary manner, although we reserve the right to adjust their position in the future in light of an overall reconsideration.

Similarly to the previous case, the very clear identification of a road to the south of *Caere* Gate, which makes a sharp bend to reach the edge of the plateau[137], probably allows for the identification of another access point (fig. 4, d). In this case, the difference in height of more than a dozen metres would suggest a minor route that may have passed along the slope to reach the burial area below[138].

[F. M.]

Discussion

The road system

The analysis of the anomalies identified as part of the flights carried out in 2020 and 2021 has made it possible to better define the layout of the road system in Campetti – partly already known from other investigation methods[139] – which permitted internal mobility, connection with the road system outside the plateau and probably contributed to defining the inner space of the settlement (fig. 15).

The type of anomalies detected, presented above[140], provide information relating to the probable structural characteristics of the road, which were undoubtedly built using techniques and materials – such as stones, paving stones or dirt – that ensured their resistance to atmospheric agents, primarily rainwater, as well as to the wear and tear caused by use. This hypothesis is confirmed by what has emerged from the investigations in the central portion of Campetti[141], where a section of the summit road that crossed the entire plateau (fig. 15, 1) and part of a second road axis that led southwards (fig. 15, 2) from it were identified. At least two rebuilding phases of the road surface were identified, characterised by a *glareata* probably created between the 6th and 5th centuries BCE and a restoration with lithic paving in the Augustan period[142].

The negative cropmarks relating to roads may testify to the reconstruction of at least part of the road system with a paved surface during the establishment of the *municipium*, an operation that must have affected the main part of the plateau, despite the fact that the new urban area itself was limited to the central portion of the plateau[143]. However, it cannot be excluded that some roads may be linked to older versions of paving (e.g., *via glareata*) related to the Etruscan period. It must be said, however, that it is difficult to propose any safe considerations in the absence of test trenches aimed at systematically correlating the type of anomalies identified with the exact construction techniques[144].

The results of remote sensing also confirm the presence, at least during the Roman period[145], of a road-related water management system[146] hypothetically consisting of drainage systems for rainwater or a possible water supply or disposal system active on the plateau.

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[137] MATERAZZI PACIFICI 2022: 203.
[138] See *infra*.
[139] GUAITOLI 2016: 183-194; CAMPANA 2018: 109-111; CAMPANA 2019: 30-31.
[140] See *Results*.
[141] JAIA, CELLA 2015.
[142] *Ivi*: 37-39.
[143] *Ivi*: 39-40.
[144] Probable evidence is the north-south oriented road identified in the excavations in the 1960s that led to the identification of the so-called sanctuary of *Caere* Gate and that corresponds with one of the routes identified by multispectral remote sensing (TORELLI, POHL 1973: 56-57 DI SARCINA 2017: 133).
[145] JAIA, CELLA 2015: 36, 39. The edition of the excavation will make it possible to better define the set of services connected to the roads and to put forward hypotheses on the relationship with the type of anomalies identified.
[146] See *Results.*

The analysis of the data has made it possible to define with considerable precision and detail the layout of the two main roads that crossed the Campetti area and, continuing onwards, connected the entire plateau[147]. The first, not far from the modern Vicolo Formellese, crosses the entire top of the central ridge from north-west to south-east, while the second, with an irregular course, rises from the south-western offshoots of the Campetti area and runs roughly parallel to the slope, exploiting its points of lower inclination, crosses the other main axis, and continues further in the northern portion of Campetti, passing close to the access point called *Formello* Gate and then continuing through the Macchiagrande area in the north-eastern portion of the plateau.

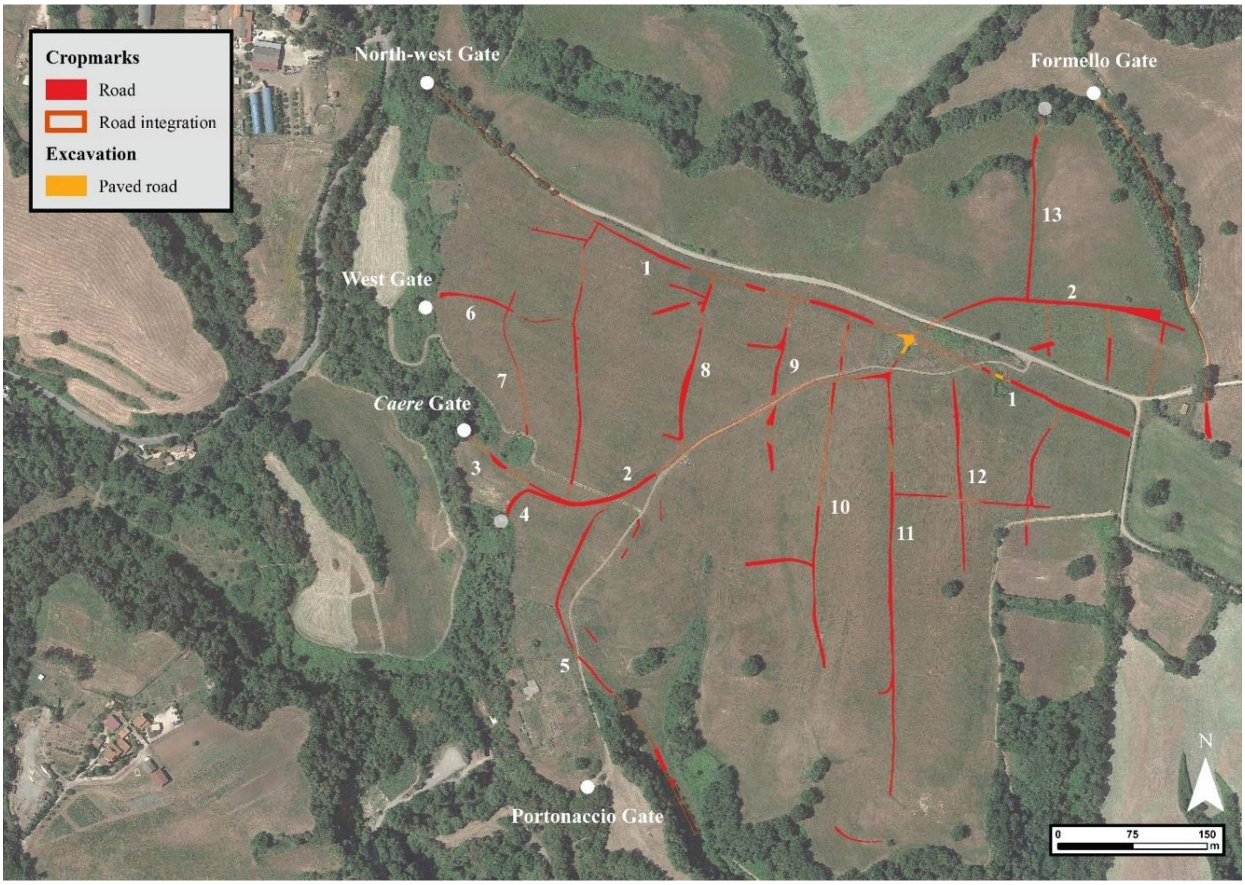

Fig. 15. Overall plan of roads identified over the three years integrated with past excavations and the accesses to the plateau.

It has been possible to identify three offshoots of its south-western end: one (fig. 15, 3) that, bending north-westwards, certainly went through the *Caere* Gate, passing immediately south of the homonymous sanctuary[148]; a second (fig. 15, 4) that, detaching itself from the first one, reached the south-western slopes with a short curvilinear section to the south – at a point for which, at the present state of knowledge, no access to the plateau is known –; a third (fig. 15, 5), which, by means of a wide curve to the south-east passing nearby the so-called Campetti South sanctuary, most likely entered the narrow valley known as the Valloncello dei Campetti, that descends from the plateau into the gorge of the Piordo stream. According to the hypothesis proposed by Ward-Perkins, this last offshoot would have been related to the Roman route of the road that led to the area of the sanctuary of Portonaccio, curving north-west once it left the saddle and then passing by the sanctuary and continuing with a curvilinear route to the west. The Etruscan road route, on the other hand, must have passed more

[147] The centrality of these two roads for the mobility of the entire plateau has long been identified (GUAITOLI 2016: 183-184; CAMPANA 2018: 109).
[148] TORELLI, POHL 1973.

directly through a smaller rock-cut to the north-west of the sanctuary continuing south-westwards[149], a situation confirmed by the identification of some wall structures related to the Portonaccio *Gate* from the Etruscan period[150].

The intersection between the two main axes in the summit portion of Campetti makes it possible to confirm the 'broken' path of the second main west-east axis, which grafts onto the other thanks to a short section with a regular course (corresponding to the '*diverticulum*' identified by the Sapienza excavations). This orthogonal crossing forms a nodal point of the Campetti area and almost certainly of circulation for the entire plateau.

The set of roads that exclusively make up the internal road system of the Campetti area can instead be divided into two groups. The first is characterised by irregular routes, mostly curvilinear and clearly conditioned by the natural orography of the slope (fig. 15, 6-7), while the second one is predominated by straight road axes with approximately north-south orientation, perpendicular to the slope and placed at almost regular intervals, in particular in the SE area. It is possible to give an indicative distance between them of around 55-80 m (fig. 15, 8-12).

The irregularity of part of the identified road system would seem to be the product of a development influenced by the natural orography of the occupied area, with routes that take advantage of the less accentuated slopes and that probably originated in a spontaneous manner, perhaps linked to habitual use. The regularly aligned routes, on the other hand, seem to impose themselves on the landscape by crossing it orthogonally to the direction of the slope and dividing it into roughly regular spaces, testifying to the intentional organisation of the settlement area and the ability and willingness to make a greater planning effort than the irregular routes[151].

As is evident, it is particularly difficult to precisely define the chronological development of the elements of the road system attested at Campetti, due also to the very limited amount of data from other investigation methodologies available to us.

However, what we know so far, and the characteristics of the road layouts would seem to provide useful information to advance some preliminary hypotheses and confirm for the Campetti area what has already been proposed regarding the chronological development of the roads on the entire plateau by Marcello Guaitoli[152].

First of all, it is necessary to emphasise the particular antiquity of the main routes across the plateau, which have been used for these purposes since the 8th century BCE[153]. The curvilinear and irregular layout of part of the roads would seem to be compatible with the earliest organisation of mobility on the plateau, which, as already noted, must have originated spontaneously at the same time as the first phase of occupation of the plateau. It was only at a later stage, however, that an intentional and planned intervention must have taken place, involving the construction of regular road axes, both in terms of layout and length, with the aim of regularising the internal space of the plateau.

As has already been proposed[154], this operation may have taken place during the Archaic Period, the moment when the occupation of the plateau was at its maximum, as demonstrated by both surveys and excavations, a circumstance that must have required a reorganisation of the settlement to meet its new requirements. This circumstance also seems to be confirmed by the results of the Sapienza excavations, which have dated the construction of the *glarea* surface of the main summit axis to between the 6th and 5th centuries BCE[155].

The realignment of the road layout of this portion of the plateau could also include the regularisation of the second main road axis of the plateau, in particular at the point where it intersects with the other main road, through the construction of the short connecting section that creates a diagonal junction.

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[149] WARD-PERKINS 1961: 8-13.
[150] See *Discussion. The access system*.
[151] These axes can be compared with the one identified by the Piano di Comunità excavation. This one, which is straight and regular in size, crosses the area to the north-east of this portion of the plateau against the slope, and in all probability must have fitted roughly orthogonally on the continuation of the main summit axis.
[152] GUAITOLI 2016.
[153] *Ivi*: 184. The main summit route must have replaced the ditch paleoalveum that previously occupied the same position at this stage. JAIA, CELLA 2015: 37.
[154] GUAITOLI 2016: 195-196.
[155] JAIA, CELLA 2015: 37.

The development of a regular road system during the Archaic Period thus seems to respect and integrate the two main roads, which certainly occupy obligatory routes for their characteristics and purposes, as well as the curvilinear routes, which were probably still in use[156].

All of these elements would seem to support the hypothesis, already partly put forward by scholars[157], of a *longue durée* mobility system on the plateau that integrates the oldest elements and adapts them to the new quantitative and qualitative requirements linked to the development of the settlement on the plateau.

[M. P.]

The plateau access system

Although the data obtained do not provide direct information regarding the number of possible access points to the plateau nor as to how they were laid out, it is possible to propose some observations and hypotheses on the issue (fig. 15).

At present four entranceways are known for the Campetti area, described by Ward-Perkins in his study on the topographical development of the city and identified almost exclusively on the observation of the orography of the plateau slopes, as well as in relation to the considerations made regarding the roads that through these accesses must have connected the internal and external thoroughfares of the settlement[158].

The scholar identified a north-facing entranceway, called Formello Gate[159], which occupied a deep and long rock-cut depression that still clearly separates Campetti at Macchiagrande[160] and led outside the settlement into the valley of the Valchetta stream. A further entranceway, called the North-West Gate was identified near the north-west limit of the plateau and corresponds with the cutting that still allows access from the modern metalled road. The *Caere* Gate was most likely located near the western slopes, to the south of the latter and inside a deep depression, once again exploiting a deep rock-cut depression on the edge of the plateau, allowing passage to and from the west. Finally, near the southern edge of Campetti in the narrow rock-cut area immediately south of the sanctuary, another entranceway was found that, in addition to allowing transit, also permitted communication with the sacred area of Portonaccio, hence its name, the Portonaccio Gate.

To the abovementioned, it is also possible to add a fifth entranceway, the only one explored through excavation by La Sapienza Università di Roma in collaboration with the local Superintendency and still undergoing publication, which was identified along the western edge of the plateau approximately halfway between the North-West Gate and the *Caere* Gate. This research has demonstrated the probable presence of minor entranceways that are currently unknown and difficult to locate, slopes and which must have flanked the main gate system.

As has already been noted, Ward-Perkins did not locate the remains of the gates in the field – apart from some slight remains of the Portonaccio Gate[161] – but persuasive considerations regarding the development of the plateau limits and the increasing understanding of the internal road system of the ancient city allow us to observe the validity of the considerations put forward by the English scholar.

The evidence concerning the road system within the plateau, which has clearly become apparent thanks to the use of multispectral remote sensing[162], substantially corresponds to what has been hypothesised regarding the main entranceways. While the Formello Gate corresponds with a road axis that is only marginally examined in the present work, but which certainly must have crossed the deep gorge that characterises the edge of the plateau at this point, two of the offshoots that form the south-west end of the second main road axis clearly merge into the saddle of the *Caere* Gate in one case (fig. 15, 3), running into the small valley that descends from the plateau to south-east into Piordo stream gorge in the other case (fig. 15, 5). As already noted, this latter is

[156] The negative type of anomalies would suggest their repaving not dissimilar to that of the others, perhaps by virtue of the impossibility of integrally modifying a particularly deep-rooted and ancient development pattern in the area.
[157] CAMPANA 2018: 111.
[158] WARD-PERKINS 1961.
[159] Named after the modern village of Formello towards which the access is directed.
[160] This is the modern toponym referring to the northern portion of the plateau, located north of the central summit road axis and crossed by the continuation of the second, more irregular one.
[161] Remains of the structure of this gate were still visible at the time of the field survey in the 1950s. WARD-PERKINS 1961: 10-11.
[162] See *infra*.

probably the Roman route[163], that does not respect the pre-existing Etruscan route that passed through Portonaccio Gate. It is difficult at the present state of knowledge to make more detailed hypotheses regarding the chronology of these two southern access points to Campetti.

The situation concerning the North-West Gate is more complex, through which, as mentioned above, the modern route leads to the modern provincial road through a deep cut. The stratigraphical analysis of the walls of the cut[164] revealed numerous *basoli* out of their original position in the cross-section of both walls, however, in the north-east one it was possible to identify an alignment of approximately 1.5 m in length made up of four stones and with traces of preparation with lithic and sandy layers underneath. An in-depth analysis of the evidence was hindered by its challenging location high up on the escarpment. However, it likely indicates that the Roman road originally occupied a higher position, and the cut was subsequently deepened in a more recent era[165]. Another potential explanation is that these remains represent the paving of a secondary road that extended northward.

The depth of these remains, detected by the analysis of the cutting section, would also appear to be compatible with the limited number of cropmarks identified in this portion of Campetti, and only more data collected through multidisciplinary investigations or excavations will make it possible to better clarify the various aspects related to this entranceway.

The analysis of the identified routeways might also point to the presence of two further hitherto unattested accesses to the plateau. One of these (fig. 15, 4) would be an access along the western edge identified at the end of the 'central' offshoot of the second main axis, which, with a short stretch, reaches the limits of the plateau just south of the *Caere* Gate. This access perhaps provided a connection with the small valley in which there was a substantial burial area that has never been investigated through excavations, but which is known through analysis of aerial images[166]. In the second case (fig. 15, 13), the short rectilinear axis that perpendicularly faces the slope of the northern portion of Campetti reaching the northern slopes, would suggest that there was also a further entranceway at this point. It is located just to the west of the Formello Gate, perhaps in an auxiliary function position with respect to the main entrance, which is among one of the most notable of the entire urban system.

In view of the size of the gate known from recent excavations and the one noted not far from the Formello Gate[167], it is possible to hypothesise a system of smaller entrances to the urban centre that exploited orographic irregularities and that are less evident today than those of the so-called main entrances, e.g. the *Caere* Gate or the deep gully of the Formello Gate. These must have had structures that were smaller in size and less complex, perhaps allowing for auxiliary management of movement in and out of the city.

Furthermore, the persistence at Campetti of the relationship between the entrances to the plateau and the sanctuary areas has not been overlooked[168]. It is confirmed, in addition to what is already known, by the proximity of the possible northern minor entrance with the sacred area of Campetti North (fig. 15, 13), or of that indicated by the offshoot of the second central axis with the sanctuary related to the nearby *Caere* Gate (fig. 15, 3-4).

[M. P.]

Characteristics of the settlement pattern

The considerable amount of data obtained also suggests some interesting points for reflection regarding settlement patterns in the Campetti area. Among the many structures scattered throughout the area, most of which were probably constructed from tuff blocks, some large concentrations of masonry buildings stand out, while towards the south the evidence is sporadic. These are located in the flatter areas, especially the most elevated ones, while noticeably absent in the steeper parts of the plateau. This is most noticeable at Campetti

[163] See *Discussion. The road system*.
[164] It is a trapezoidal section cut into the earth layers and extends approximately 150 m in length and 5 m in width at street level.
[165] WARD-PERKINS 1959: 42, 78; WARD-PERKINS 1961: 6. Stefano Campana and Marcello Guaitoli, on the other hand, argue that the cut is entirely subsequent, and the ancient gate should be placed just north of the cut (Campana, Guaitoli 2023: 293). This seems to be in disagreement with the observations made by Gell, who recalls the Roman pavement still present in his time (Gell 1832: 19, 24). It is evident that further investigations will be necessary to clarify the matter.
[166] GUAITOLI 2016: 213, fig. 38.
[167] See *Results*.
[168] On the subject CAMPOREALE 2012.

north, although there is still no clear view of the buried remains, and at Campetti south, with the exception of the flatter south-eastern area.

A long sequence of large Roman structures – deduced from the negative cropmarks that would demonstrate the use of Roman building techniques[169] – starts from the east, in the direction of the Roman *municipium*, and are placed along the main axis, especially to the south of it, continuing westwards until the intersection of the two main axes (fig. 4, A).

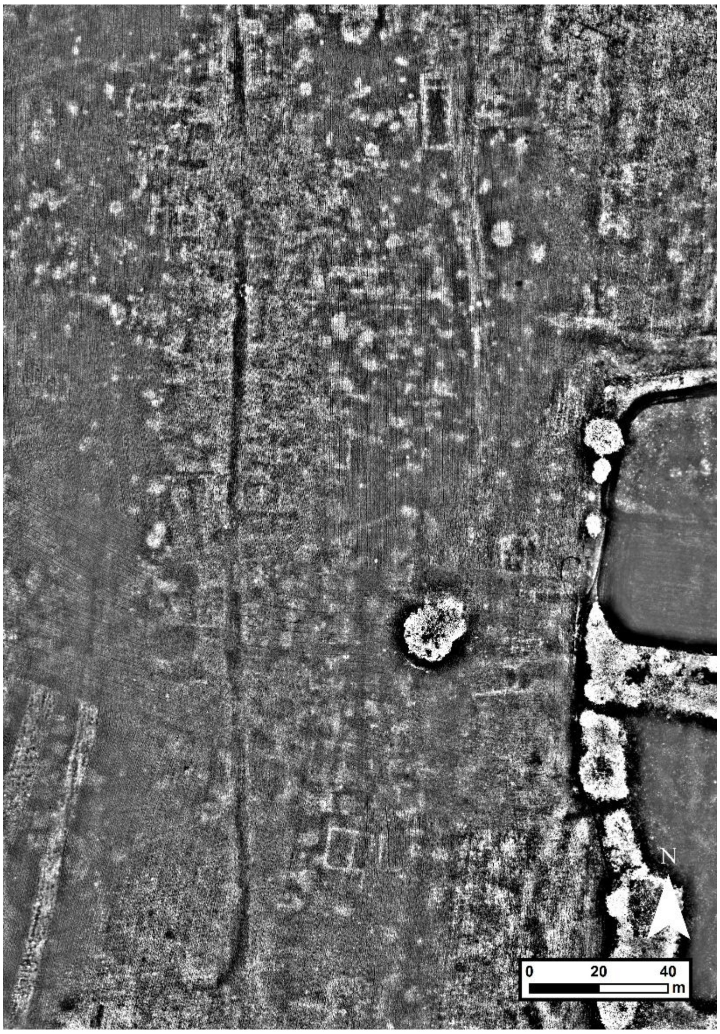

Fig. 16. 2020 SR map showing a huge concentration of tuff structures along two parallel north-south roads.

The considerable amount of data obtained also suggests some interesting points for reflection regarding settlement patterns in the Campetti area. Among the many structures scattered throughout the area, most of which were probably constructed from tuff blocks, some large concentrations of masonry buildings stand out,

A second concentration of features, entirely made up of tuff structures (i.e., positive cropmarks) is positioned running along almost the entire length of the road that runs south from the intersection of the two main axes and along the parallel (figg. 4, B; 16). These buildings are oriented in reference to the roads and are so numerous as to often render their layout unclear, something that is also most likely exacerbated by their state of preservation, as is evident on the hilltops, where they have been eroded and at least partially dispersed by ploughing.

On the contrary, far from the roads, the number of anomalies identified decreases significantly (fig. 4). While bearing in mind the possibility that cropmarks occur in smaller quantities in these areas due to circumstances that cannot be fully assessed at the moment – e.g. their archaeological nature, or the fact that the remains are located at greater depths – this could suggest that the area was used for something other than building or perhaps that structures present in this sector were constructed with perishable materials that are difficult to identify.

If the first phase of occupation of the settlement must have been characterised by groups of huts and family plots spread all along the area, as well as the entire plateau[170], the reorganisation and regularisation of the road system must have involved intentional planning of the exploitation of the settlement space. This operation certainly occurred on more than one occasion, as evidenced at least by the two macro-interventions that have been identified so far, to be placed in the first case in the Archaic period[171] and in the second at the time of the Roman reoccupation of the plateau[172].

The particular concentration of structures most likely dating to the Roman period along the main summit axis (fig. 4, blue lines) seems to confirm the precise reorganisation of the central summit portion of the Campetti area during the Augustan period for settlement purposes, in terms of both roads and buildings, which is in line

[169] See *Results.*
[170] Bartoloni 2009, p. 100.
[171] Guaitoli 2016: 195-196.
[172] Jaia, Cella 2015: 39-40.

with what has emerged from La Sapienza excavations[173]. On the other hand, the large concentration of tuff block structures probably datable to the Etruscan phase is evident in numerous points of the area (fig. 4, light blue lines), which – although very difficult to read from a qualitative point of view – makes it possible to perceive the intensity and density of the pre-Roman occupation of the surface of the plateau.

The intersection of the two main axes connecting the entire urban area acts as the central hub of not only the Campetti area, but also certainly for the entire plateau. This is a central junction for the road system of both the Etruscan city and the Roman *municipium*, as demonstrated by the care taken in the renovation of this cross-roads in the Augustan period.

Proof of the importance and centrality of this main intersection for the whole of Etruscan *Veii* is the presence, between the 6th and 5th centuries BCE, of the large tuff block building located in one of the highest points of the plateau, which has only partially been excavated and was interpreted as a temple based on the findings relating to its decommissioning[174] (fig. 4, C). Thanks to multispectral imaging it has been possible to reconstruct a reliable reconstruction of its plan, which testifies to its grandeur and the great effort that went into its construction (fig. 13a). Measuring at least 27 x 22 m, it would appear to be not only the largest temple building at *Veii*, when compared to the well-known temple of Portonaccio[175], which measures approximately 18 x 18 m, but also at present the only one that was certainly located within the city walls.

Moreover, as already noted, the overall picture of the sacred areas attested in Campetti, which are mostly located at central hubs of the road system such as road junctions or access points, once again emphasises their centrality within the urban fabric and the close link between the aspects of worship and urban organisation.

A final suggestion is linked to the high number of seemingly rounded positive cropmarks that can be observed, especially where the soil layer would appear to be shallower (Figg. 4, D-E; 17). Although most of these certainly testify to the long and intense history of anthropic use of the plateau, it is nevertheless possible to put forward the hypothesis that some of them may be related to hut structures, pits, or more generally, to features linked to the most ancient phases of occupation that especially characterise Campetti, beginning from an advanced stage of the Final Bronze Age onwards, as demonstrated by the archaeological evidence from this area that can be placed within this chronological horizon[176]. Only a careful dimensional and planimetric analysis of this evidence carried out on a quantitatively significant number of anomalies and combined with the necessary verification through excavation will allow for the possibility of identifying objective parameters to interpret their nature with any certainty.

[F.M.- M. P.]

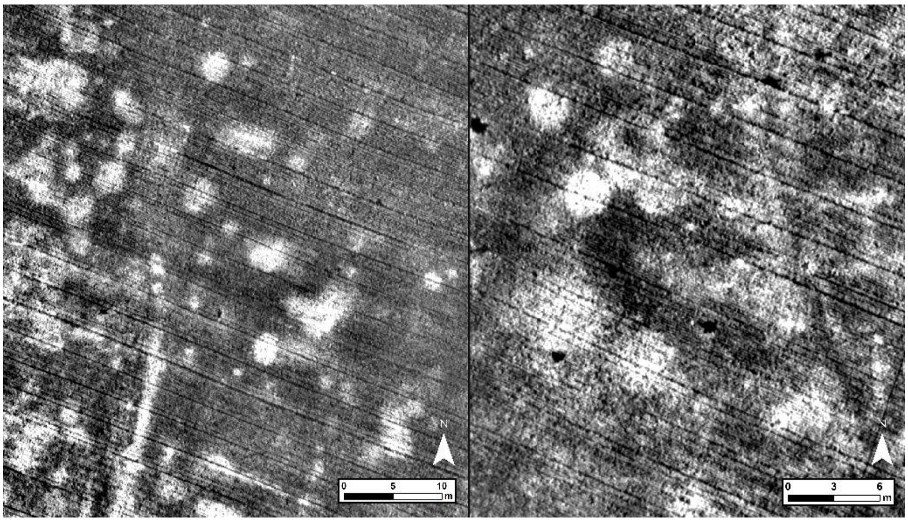

Fig. 17. 2020 SR map showing rounded shape positive cropmarks probably partly referable to the earliest phases of the settlement.

Conclusions and future perspectives

This paper presents the updates of the ongoing research dedicated to the Etruscan city of *Veii* with the aim of collecting new and consistent data to better investigate and define the chronological and topographical

[173] JAIA, CELLA 2015: 39.
[174] *Ivi*: 37.
[175] COLONNA *et al.* 2002:
[176] See *Study Area.*

development of the urban area and its vicinity and to contribute to the knowledge of the urban phenomenon in Etruria.

The data presented here refer to remote sensing conducted in 2020 and 2021 with an innovative form of drone equipped with a six-band multispectral camera and high-accuracy GNSS RTK. The cropmarks that were identified were compared with observations from previous remote sensing surveys carried out in 2017 in order to produce an overall plan that integrates all buried archaeological evidence.

The study started with an in-depth environmental and agronomic analysis; the weather conditions over the short and long term, provided by two weather stations near the site, were critically related to the plant species present with a twofold objective: to understand the dynamics of cropmarks formation and to attempt to obtain as much information about the buried remains as possible.

The results have highlighted the complexity and multifaceted nature of the relationship between plants and buried remains, emphasizing the impossibility of drawing universally applicable conclusions. A thorough examination of the environmental and archaeological context is therefore always necessary to consider all variables at play. Only through this approach is it possible to obtain significant results and achieve the necessary awareness for the identification and interpretation of cropmarks.

Each plant species may be more or less suited to exhibit a certain type of cropmark, contingent upon meteorological conditions from sowing onward. The manifestation of crop stress, primarily linked to water availability, plays a crucial role in this regard.

In general, it has been feasible to delineate two principal growth stages of the universally accepted Zadoks' scale in which plants are most affected by buried remains: stem elongation (Zadoks GS 3) and maturation, particularly during the phases of milk and dough development (Zadoks GS 7, 8, and 9). Furthermore, it has been demonstrated that autogamous species are better suited to manifesting cropmarks due to their more homogeneous development, as exemplified by wheat, which has proven to be the most suitable crop among those tested, especially for the visualization of positive cropmarks during the maturation stage.

As a result, we are now closer to a deeper understanding of the relationship between plants and buried remains in the various contexts presented, and it was possible to associate the type of cropmark identified with important information about the buried remains from which it originated, e.g. the construction materials used.

Subsequently, the data acquired were correlated with those from archaeological excavations and with historical mapping to try to add useful information to the understanding of the context investigated.

Thanks to this methodology, it was possible to provide new essential information, both from a technical point of view and more generally for the development of the method, while from a purely archaeological perspective it has helped to enrich the understanding of the city's urban layout during the Etruscan and Roman periods.

The evidence identified was presented and analysed, particularly in cases where it could be linked to the bibliographic and archival records. From an overall standpoint, some of the most important issues relating to the site were developed upon – albeit in a preliminary way – such as the road system and access system but also the settlement pattern, the complexity and articulation of which we can infer thanks to the exceptional possibility of observing for the first time consistent traces of habitation in what must have been one of the most populated areas of the city.

Indeed, Campetti is presented as a particularly lively sector of the city, with numerous roads and minor axes combining to produce quite an intricate urban layout, most likely from as early as the Etruscan period, which was partly redefined and regularized in the Augustan period, when buildings became more densely concentrated along the road axes and aligned with them, developing mainly along the main west-east axis and the long roads perpendicular to it heading south. The study thus presents an increasingly clear situation for this area, demonstrating the effectiveness of the interdisciplinary approach and methodology used.

The systematic remote sensing campaigns started in 2022 are tasked with focusing on other areas of the settlement and attempting to enhance the existing understanding. The repetition of flights at various times, under different field conditions, and the utilization of new technologies, including thermal sensors, are anticipated to contribute to this effort.

What has been presented here demonstrates how the application of multispectral imaging represents a decisive upgrade in the methodological development of archaeology for the study of the ancient landscapes and urban centres, especially those with a break in occupation. The quantity and, through appropriate analysis of the data, the quality of the information that can be obtained by this method of investigation make it possible to conduct analyses on a large scale, grasping aspects that could not otherwise be deduced through excavations of necessarily limited extension, demanding surveys or other geophysical surveys of more challenging application.

The correct application of this technique and its necessary integration with the entire palimpsest of data often available, will in the future allow for a better understanding of ancient urban phenomena, particularly for the pre-Roman period.

[F. M. - M. P.]

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REFERENCES

ADAMOPOULOS E., RINAUDO F., 2020, "UAS-Based Archaeological Remote Sensing: Review, Meta-Analysis and State-of-the-Art", in *Drones* 4.46. https://doi.org/10.3390/drones4030046.

AGAPIOU A., HADJIMITSIS D.G., ALEXAKIS D.D., 2012, "Evaluation of Broadband and Narrowband Vegetation Indices for the Identification of Archaeological Crop Marks", in *Remote Sensing* 4: 3892-3919.

AMBROSINI L., 2009, *Il santuario di Portonaccio a Veio. III - La cisterna arcaica con l'incluso deposito di età ellenistica (Scavi Santangelo 1945-1946 e Università di Roma "La Sapienza" 1996 e 2006),* Roma.

ALLEY M.M., PRIDGEN T.H., BRANN D.E., HAMMONS J.L., MULFORD R.L., 2019, "Nitrogen Fertilization of Winter Barley: Principles and Recommendations.", in *Virginia Tech*, https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/424/424-801/424-801.pdf.

ARCIONI S., MARIOTTI D., 1983, "Selfing and Interspecific Hybridization in Lolium Perenne L. and Lolium Multiflorum Lam. Evaluated by Phosphoglucoisomerase as Isozyme Marker", in *Euphytica* 32: 33-40.

ASHRAF M.Y., 1998, "Photosynthetic efficiency of wheat under water stress conditions", in *Pakistan Journal of Scientific and Industrial Research* 41.3: 156-163.

BAO Y., GAO W., GAO Z., 2009, "Estimation of winter wheat biomass based on remote sensing data at various spatial and spectral resolutions", in *Frontiers of Earth Science in China* 3: 118–128.

BARBARO B., 2010, *Insediamenti, aree funerarie ed entità territoriali in Etruria meridionale nel bronzo finale,* Firenze.

BARTOLONI G., 2009, "I primi abitanti di Roma e Veio", in G.M. DELLA FINA (a cura di), *Gli Etruschi e Roma: Fasi monarchica e alto-repubblicana* (Atti Orvieto 2009), in *Annali della fondazione per il Museo* «*Claudio Faina*» 16: 93-117.

BARTOLONI G., 2012, "I primi abitanti di Veio: l'insediamento di Isola Farnese", in I. VAN KAMPEN (a cura di), *Il nuovo museo dell'Agro veientano a Palazzo Chigi a Formello*, Roma: 47-49.

BARTOLONI G., 2017, 'In margine a "Dalla capanna al palazzo: edilizia abitativa nell'Italia preromana": le "rectangular timber buildings', in *Aristonothos. Scritti per il Mediterraneo antico* 13.1: 11-48.

BARTOLONI G., ACCONCIA V. (a cura di), 2012, *L'abitato etrusco di Veio: ricerche dell'Università di Roma "La Sapienza" II - Un edificio tardo-arcaico e la sequenza stratigrafica*, Roma.

BARTOLONI G., BERARDINETTI A., DRAGO L., DE SANTIS A., 1994, "Veio tra IX e VI sec. a.C.: primi risultati sull'analisi comparata delle necropoli veienti", in *Archeologia Classica* XLVI: 1-46.

BARTOLONI G., TABOLLI J., CERASUOLO O., 2019, "Introduction. Exploring *Veii*", in TABOLLI 2019: 1-5.

BASSO P., DOBREVA D., 2020, "Aquileia: first results from the market escalation and the late antiquity town walls (part one)", in *FOLD&R FastiOnLine documents & research* 482, http://www.fastionline.org/docs/FOLDER-it-2020-482.pdf.

BELFORD R.K., 1981, "Response of winter wheat to prolonged waterlogging under outdoor conditions", in *The Journal of Agricultural Science* 97: 557-568.

BIAGI F., NERI S., SAGRIPANTI L., SARTINI E., 2020, "Il cerchio si chiude: mercenari italici all'assedio di Veio (396 a.C.)?", in V. ACCONCIA (a cura di), *L'età delle trasformazioni: l'Italia medio-adriatica tra il V e il IV secolo a.C. Nuovi modelli di autorappresentazione delle comunità a confronti e temi di cultura materiale* (Atti Chieti 2016), Roma: 439-454.

BIRTH G.S., MCVEY G.R., 1968, "Measuring color of growing turf with a reflectance spectrophotometer", in *Agronomy Journal* 60: 640-649.

BOITANI F., 2008, "Nuove indagini sulle mura di Veio nei pressi di Porta nord-ovest. Con appendice di Sara Neri e Folco Biagi", in O. PAOLETTI (a cura di), *La città murata in Etruria* (Atti Chianciano Terme, Sarteano, Chiusi aprile 2005), Pisa-Roma: 135-154.

BOITANI F., BIAGI F., NERI S., 2016, "Le fortificazioni a Veio tra Porta Nord-Ovest e Porta Caere", in P. FONTAINE, S. HELAS (a cura di), *Le fortificazioni arcaiche del* Latium vetus *e dell'Etruria meridionale (IX-VI sec. a.C.). Stratigrafia, cronologia e urbanizzazione* (Atti Roma 2013), Bruxelles-Roma: 19-35.

CAMPANA S., 2018, *Mapping the Archaeological Continuum. Filling "Empty" Mediterranean Landscapes*, Cham.

CAMPANA S., 2019, "The Emptyscapes Project: Filling Gaps in Space and Time at Veii", in Tabolli 2019: 29-33.

CAMPANA S., GUAITOLI M., 2023, “Dall'abitato protostorico alla città imperiale. Entrando a Veio: risultati e prospettive dell'applicazione di prospezioni integrate”, in *Atlante tematico di topografia antica* 33: 285-300.

CAMPOREALE G., 2012, “Sulla sacralità delle porte urbiche in Etruria”, in G.M. DELLA FINA (a cura di), *Il* fanum voltumnae *e i santuari comunitari dell'Italia antica* (Atti Orvieto 2011), in *Annali della fondazione per il Museo «Claudio Faina»* 19: 327-348.

CAROSI S., 2002, “Nuovi dati sul santuario di Campetti a Veio”, in *Archeologia Classica* LIII: 355-377.

CASANA J., WIEWEL A., COOL A., HILL A.C., FISHER K.D., LAUGIER E.J., 2017, “Archaeological Aerial Thermography in Theory and Practice”, in *Advances in Archaeological Practice* 5.4: 310-327.

CASANA J., KANTNER J., WIEWEL A., COTHREN J., 2014, “Archaeological aerial thermography: a case study at the Chaco-era Blue J community, New Mexico”, in *Journal of Archaeological Science* 45: 207-219.

CASCINO R., DI GIUSEPPE H., PATTERSON H.L. (a cura di), 2012, *Veii. The Historical Topography of the Ancient City. A Restudy of John Ward-Perkins's Survey*, London.

CASCINO R., 2015, “Gli scavi Ward-Perkins a Porta Nord-Ovest”, in CASCINO *et al.,* 2015: 103-110.

CASCINO R., FUSCO U., SMITH C., (a cura di) 2015, *Novità della ricerca archeologica a Veio. Dagli scudi di John Ward-Perkins alle ultime scoperte*, (Atti Roma 2013), Roma.

CAVAZZA L., ROSSI PISA P., 1988, “Effect of water-table depth and waterlogging on crop yield” in *Agricultural Water Management* 14: 29-34.

CHATTARAJ S., CHAKRABORTY D., GARG R.N., SINGH G.P., GUPTA V.K., SINGH S., SINGH R., 2013, “Hyperspectral remote sensing for growth-stage-specific water use in wheat”, in *Field Crops Research* 144: 179-191.

CHYNOWETH R., ALLAN J., TRETHEWEY K., ROLSTON P., ZEALAND N., "2014, “Reduced stem length increases perennial ryegrass seed yield”, in *Agronomy New Zealand* 44: 61-70.

COLONNA G., (a cura di) 2002, *Il santuario di Portonaccio a Veio I. Gli scavi di Massimo Pallottino nella zona dell'altare (1939-1940)*, Roma.

COLONNA G., 2014, “Gli scavi Santangelo nell'area urbana di Veio (1945-1952)”, in *Archeologia Classica* LXV: 59-102.

COLONNA G., (a cura di) 2020, *Il santuario di Portonaccio a Veio II. Gli scavi di Maria Santangelo (1944-1952)*, Roma.

COMELLA A., STEFANI G., 1990, *I materiali votivi del santuario di Campetti a Veio. Scavi 1947 e 1969*, Roma.

COWLEY D., VERHOEVEN G.J.J., TRAVIGLIA A., 2021, “Archaeological Remote Sensing in the 21st Century: (Re)Defining Practice and Theory”, in *Remote Sensing* 13: 1-4.

CZAJLIK Z., ÁRVAI M., MÉSZÁROS J., NAGY B., RUPNIK L., PÁSZTOR L., 2021, “Cropmarks in Aerial Archaeology: New Lessons from an Old Story”, in *Remote Sensing* 13: 189-205.

D'ALESSIO M.T., 2015, “Il paesaggio urbano tra l'età del ferro e la tarda età imperiale”, in CASCINO *et al.* 2015: 27-33.

DAUGHTRY C.S.T., WALTHALL C.L., KIM M.S., BROWN DE COLSTOUN E., MCMURTREY J.E., 2000, “Estimating Corn Leaf Chlorophyll Concentration from Leaf and Canopy Reflectance”, in *Remote Sensing of Environment* 74.2: 229-239.

DELPINO F., 1985, *Cronache Veientane. Storia delle ricerche archeologiche a Veio, I, dal XIV alla metà del XIX secolo*, Roma.

DELPINO F., 1999, “La “scoperta di Veio etrusca”, IN A. MANDOLESI, A. NASO (a cura di), *Ricerche archeologiche in Etruria Meridionale nel XIX secolo*, (Atti Tarquinia 1996), Firenze: 73-85.

DI GIUSEPPE H., 2018, *Lungo il Tevere scorreva lento il tempo dei paesaggi tra XV e I secolo a.C.*, Roma.

DI SARCINA R., 2017, “Indicatori di produzione di terrecotte architettoniche nel santuario di Porta *Caere* a Veio”, in *Scienze dell'Antichità* 23.2: 129-138.

DRAGO L. (a cura di), 1998, *Scavi e ricerche archeologiche dell'Università di Roma “La Sapienza”*, Roma.

EHDAIE B., HALL A.E., FARQUHAR G.D., NGUYEN H.T., WAINES J.G., 1991, “Water-use efficiency and carbon isotope discrimination in wheat”, in *Crop Science* 31:1282-1288.

EHDAIE B., WAINES J.G., 2006, “Determination of a chromosome segment influencing rooting ability in wheat-rye 1BS–1RS recombinant lines”, in *Journal of Genetics and Breeding* 60: 71-76.

EHDAIE B., ALLOUSH G.A., WAINES J.G., 2008, “Genotypic variation in linear rate of grain growth and contribution of stem reserves to grain yield in wheat”, in *Field Crops Research* 106: 34-43.

EHDAIE B., MERHAUT D.J., AHMADIAN S., HOOPS A.C., KHUONG T., LAYNE A.P., WAINES J.G., 2010, “Root System Size Influences Water-Nutrient Uptake and Nitrate Leaching Potential in Wheat”, in *Journal of Agronomy and Crop Science* 196: 455-466.

FIORINI L., MATERAZZI F., 2017, “Un *Iseion* a Gravisca? Fotogrammetria, telerilevamento multispettrale da APR e dati archeologici per una possibile identificazione”, in *FOLD&R FastiOnLine documents & research* 396, http://www.fastionline.org/docs/FOLDER-it-2017-396.pdf.

FRIEDRICH C., LONGIN H., MU J., 2012, “Hybrid breeding in autogamous cereals”, in *Theoretical and Applied Genetics* 125: 1087-1096.

FULDAIN GONZÁLEZ J.J., VARÓN HERNÁNDEZ F.R., 2019, “NDVI Identification and Survey of a Roman Road in the Northern Spanish Province of Alava”, in *Remote Sensing* 11. https://doi.org/10.3390/rs11060725.

FUSCO U., 2011, “Il culto di Eercole presso il complesso archeologico di Campetti, area S-O, a Veio: testimonianze dall’età etrusca a quella romana”, in *Archeologia Classica* LXII: 379-412.

FUSCO U., 2015, “I santuari presso Campetti, area SO”, in CASCINO *et al.* 2015: 40-48.

GELL W., 1832, “Gli avanzi di Veji”, in *Memorie dell’Instituto di Corrispondenza Archeologica* 1: 1-29.

GOJDA M., HEJCMAN M., 2012, “Cropmarks in main field crops enable the identification of a wide spectrum of buried features on archaeological sites in Central Europe” in *Journal of Archaeological Science* 39: 1655-1664.

GREGORY P., MCGOWAN M., BISCOE P., HUNTER B., 1978, “Water relations of winter wheat: 1. Growth of the root system”, in *The Journal of Agricultural Science* 91.1: 91-102.

GUAITOLI M., 2016, “Veio: osservazioni preliminari sulla topografia della città”, in S. QUILICI GIGLI, L. QUILICI (a cura di), *Roma e suburbio, strade e acquedotti, urbanistica*, Roma: 177-214.

HEJCMAN M., SMRŽ Z., 2010, “Cropmarks in stands of cereals, legumes and winter rape indicate sub-soil archaeological features in the agricultural landscape of Central Europe”, in *Agriculture, Ecosystems & Environment* 138: 348-354.

JAIA A.M., CELLA E., 2015, “*Paesaggi urbani a Veio. Saggi di scavo della Sezione Topografia Antica della Sapienza*”, in CASCINO *et al.* 2015: 34-40.

JAMES K., NICHOL C.J., WADE T., COWLEY D., GIBSON POOLE S., GRAY A., GILLESPIE J., 2020, “Thermal and Multispectral Remote Sensing for the Detection and Analysis of Archaeologically Induced Crop Stress at a UK Site”, in *Drones* 4.61. https://doi.org/10.3390/drones4040061.

KALITA P.K., KANWAR R.S., 1992, “Shallow water table effects on photosynthesis and corn yield”, in *Transaction of the American Society of Agricultural and Biological Engineers* 35: 97-104.

LEHMANN J.R.K., SMITHSON K.Z., PRINZ, T., 2015, “Making the invisible visible: using UAS-based high-resolution color-infrared imagery to identify buried medieval monastery walls”, in *Journal of Unmanned Vehicle Systems* 3: 58-67.

LERSTEN N.R., 1987, “Morphology and Anatomy of the Wheat Plant”, in E.G. HEYNE (a cura di), *Wheat and Wheat Improvement*, Madison: 33-75. https://doi.org/10.2134/agronmonogr13.2ed.c2.

LIVERANI P., 1984, “L’*ager Veientanus* in età repubblicana”, in *Papers of the British School at Rome* 52: 36-48.

LIVERANI P., 1987, *Municipium Augustum Veiens*, Roma.

LIVERANI P., 2015, “Gli scavi di Teresa Cristina di Borbone a Veio”, in CASCINO *et al.* 2015: 97-103.

MANSKE, G.G.B., VLEK P.L.G., 2002, “Root architecture - wheat as a model”, in Y. WAISEL, A. ESHEL (a cura di), *Plant Roots: The Hidden Half*, New York: 249-259.

MATERAZZI F., PACIFICI M., 2020, “Novità dall’area urbana di Veio. Rilevamento multispettrale da drone e indici di vegetazione: nuovi strumenti per l’identificazione dei crop-mark dall’area di Campetti”, in *Scienze dell’Antichità* 26.1: 95-117.

MATERAZZI F., PACIFICI M., 2022, “Archaeological crop marks detection through drone multispectral remote sensing and vegetation indices: A new approach tested on the Italian pre-Roman city of Veii”, in *Journal of Archaeological Science: Reports* 41, https://doi.org/10.1016/j.jasrep.2021.103235.

MATERAZZI F., PACIFICI M., 2022 c.s., "Multispectral Remote Sensing Using Drones. An Innovative Approach to Investigating the Urban Landscape of Veii", in A. CRISTILLI, G. DI LUCA, F. DE LUCA, A. GONFLONI (a cura di), *Experiencing the Landscape in Antiquity 2* (Atti Roma 2021), Oxford: 233-240.

MERZLYAK M.N., GITELSON A.A., CHIVKUNOVA O.B., RAKITIN V.Y., 1999, "Nondestructive optical detection of pigment changes during leaf senescence and fruit ripening", in *Physiologia Plantarum* 106: 135-141.

MEYER W.S., BARRS H.D., 1988, "Response of wheat to single short-term waterlogging during and after stem elongation", in *Australian Journal of Agricultural Research* 39: 11-20.

MIAN M.A.R., NAFZIGER E.D., KOLB F.L., TEYKER R.H., 1993, "Root growth of wheat genotypes in hydroponic culture and in greenhouse under different moisture regimes", in *Crop Science* 33: 283-286.

MICHETTI L.M., BIELLA M.C., BELELLI MARCHESINI B., TOPPETTI F., SARRACINO D., BISCHERI M., PACIFICI M., STOMEO L., BIANCHI L., 2020, "Novità dall'area urbana di Veio. Recenti indagini nel distretto meridionale", in *Scienze dell'Antichità* 26.1: 61-94.

MICHETTI L.M., 2021, "L'impatto della "romanizzazione" su Veio e il suo territorio: tracce di continuità e discontinuità in ambito sacro, abitativo e funerario", in *Scienze dell'Antichità* 27.2: 25-48.

MUSGRAVE M.E., 1994, "Waterlogging effects on yield and photosynthesis in eight winter wheat cultivars", in *Crop Science* 34: 1314-1318.

MURRAY-THREIPLAND L., 1963, "Excavations beside the North-West Gate at *Veii*, 1957-1958. Part II. The Pottery", in *Papers of the British School at Rome* 31: 33-73.

NOMI F., SPERDUTI A., BONDIOLI L., GUIDI A., 2020, "BABY ON BOARD! Le sepolture infantili della necropoli protovillanoviana di Veio-Pozzuolo", in P. BOCCUCCIA, E. RODRIGUEZ, T. TROCCHI (a cura di), *Le deposizioni infantili nelle età del bronzo e del ferro. Per una lettura integrata tra archeologia e bioarcheologia* (Atti Verucchio 2020), Firenze: 36-38.

PALLOTTINO M. 1938, "Scavo di un'area sacra a Veio", in *Le Arti* 1: 402-403.

PATTERSON H., WITCHER R., DI GIUSEPPE H., 2020, *The Changing Landscapes of Rome's Northern Hinterland. The British School at Rome's Tiber Valley Project*, Oxford.

PATWARDHAN A.S., NIEBER J.L., MOORE I.D., 1988, "Oxygen carbon di-oxide and water transfer in soils: mechanisms and crop response", in *Transaction of the American Society of Agricultural and Biological Engineers* 31: 1383-1395.

PINTY, B., VERSTRAETE M., 1992, "GEMI: a Non-Linear Index to Monitor Global Vegetation From Satellites", in *Vegetation* 101: 15-20.

PISZ M., TOMAS A., HEGYI A., 2020, "Non-destructive research in the surroundings of the Roman Fort Tibiscum (today Romania)", in *Archaeological Prospection* 27: 219-238.

POIRIER N., HAUTEFEUILLE F., CALASTRENC C., 2013, "Low Altitude Thermal Survey by Means of an Automated Unmanned Aerial Vehicle for the Detection of Archaeological Buried Structures", in *Archaeological Prospection* 20: 303-307.

SANTAGA F.S., BENINCASA P., TOSCANO P., ANTOGNELLI S., RANIERI E., VIZZARI M., 2021, "Simplified and Advanced Sentinel-2-Based Precision Nitrogen Management of Wheat", in *Agronomy* 11. https://doi.org/10.3390/agronomy11061156.

SCUDERO S., MARTORANA R., CAPIZZI P., PISCIOTTA A., D'ALESSANDRO A., BOTTARI C., DI STEFANO G., 2018, "Integrated Geophysical Investigations at the Greek Kamarina Site (Southern Sicily, Italy)", in *Surveys in Geophysics* 39: 1181-1200.

ŠEDINA J. HOUSAROVÁ E., MATOUŠKOVÁ E., 2016 "Documentation of Urn Graves of Knovíz Culture by RPAS", in *Geoinformatics Fce Ctu* 15.2: 71-82.

TABOLLI J. (a cura di), 2019, *Veii*, Austin.

TORELLI M., 1980, *Etruria*, Roma-Bari.

TORELLI M., POHL I., 1973, "Veio. Scoperta di un piccolo santuario etrusco in località Campetti", in *Notizie degli scavi di antichità* 27: 40-258.

TUCKER C., 1979, "Red and Photographic Infrared Linear Combinations for Monitoring Vegetation" in *Remote Sensing of Environment* 8: 127-150.

URIBE P., ANGÁS J., ROMEO F., PÉREZ-CABELLO F., SANTAMARÍA D., 2021, “Mapping Ancient Battlefields in a multi-scalar approach combining Drone Imagery and Geophysical Surveys: The Roman siege of the oppidum of Cabezo de Alcalá (Azaila, Spain)”, in *Journal of Cultural Heritage* 48: 11-23.

VAGNETTI L., 1971, *Il deposito votivo di Campetti a Veio*, Firenze.

VAN KAMPEN I. (a cura di), 2003, *Dalla capanna alla casa. I primi abitanti di Veio,* Catalogo della Mostra (Formello 2003-2004), Formello.

VIZZARI M., SANTAGA F.S., BENINCASA P., 2019, “Sentinel 2-based nitrogen VRT fertilization in wheat: Comparison between traditional and simple precision practices”, in *Agronomy* 9. https://doi.org/10.3390/agronomy9060278.

WARD-PERKINS J.B., 1959, “Excavation behind the North-West at Veii”, in *Papers of the British School at Rome* 27: 38-79.

WARD PERKINS J.B., 1961, “*Veii*. The Historical Topography of the Ancient City”, in *Papers of the British School at Rome* 29: 1-123.

XING N., HUANG W., YE H., DONG Y., KONG W., REN Y., XIE Q., 2021, “Remote sensing retrieval of winter wheat leaf area index and canopy chlorophyll density at different growth stages”, in *Big Earth Data.* https://doi.org/10.1080/20964471.2021.1918909.

ZADOKS J.C., CHANG T.T., KONZAK C.F., 1974, “A decimal code for the growth stages of cereals”, in *Weed research* 14: 415-421.

ZHANG H.P., OWEIS T., 1999, “Water-yield relation and optimal irrigation scheduling of wheat in Mediterranean regions”, in *Agriculture water management* 38: 195-211.

ZOBEL R.W., 2005, “Primary and secondary root systems”, in R.W. ZOBEL, S.F. WRIGHT (a cura di), *Roots and Soil Management: Interaction Between Roots and the Soil*, Madison: 3-14.