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RESEARCH ARTICLE

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"There's more than meets the eye": Developing an integrated archaeological approach to reconstruct human–environment dynamics in the Pontine marshes (Lazio, Central Italy)

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Abstract

In this article, we present the results of a pilot study that adopts an interdisciplinary off-site approach combining detailed surface survey, remote sensing analyses, geophysical prospections, geoarchaeological investigations and palaeoenvironmental analyses to investigate long-term human-environment interactions in the Pontine plain (Lazio, Central Italy). Focusing on a small study area just north of the ancient Roman way station of *Ad Medias*, in the middle of this former wetland, the developed integrated approach turned out to be very much successful, providing additional information on (a) the interpretation of the surface record in light of landscape and environmental dynamics, (b) the exposure of "hidden landscapes" that date from before the Roman phase of exploitation that is well-attested in the surface archaeological record, and (c) the texture of this Roman landscape, allowing for a more accurate interpretation of both mapped surface materials and the wider context in which these surface sites were set.

KEYWORDS

centuriation, Early Bronze Age, human–environment interaction, landscape archaeology, Longue durée, Pontine plain, Roman period, wetland

1 | INTRODUCTION

The advent—and subsequent fast development—of an intensive archaeological surface survey as a major investigative technique from the 1950s onwards, placed due attention on the abundance of tangible archaeological evidence preserved in modern agricultural landscapes across the Mediterranean.[1] The tens of thousands of surface scatters identified over the past decades have informed—and transformed—our understanding of regional occupation histories between prehistory and the Middle Ages. At the same time, the data derived from regional surveys are reaching the quality and quantity needed for comparative analysis, allowing Potter (1979) supraregional syntheses of long-term economic and demographic developments (for the potential of such analyses see Alcock & Cherry, 2004; P. A. J. Attema, 2017).

However, as the field of surface survey matured, it has become clear that there are limitations in the extent to which this investigative technique can detect the full range of past human activities in rural landscapes. One reason for this is that most field surveys adopt site-oriented approaches, which are generally biased towards locations and periods characterised by durable architecture and high rates of pottery consumption. This is problematic, because for much of history the prolonged living in fixed locations might not have been the norm (most notably in prehistoric mobile hunter–gatherer societies). Also, the use of durable construction materials and access to

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[1] An important source on Italy's rural landscapes is the *Forma Italiae* series that comprises almost 50 volumes to date. The Tiber Valley Project, led by John Ward Perkins, the then director of the British School at Rome, is generally considered to mark the beginning of intensive surface surveys in Italy (see mainly Potter, 1979).

pottery varied considerably between periods and between segments of society, rendering the identification of some periods and segments problematic with traditional survey methods that depend on "sites" (Millett, 1991). To some extent, these issues have been addressed by intensive off-site approaches, which have been quite successful at capturing both smaller sites and marginal social groups, and other types of activities (manuring, rubbish disposal and other vestigial activities).[2] However, these approaches again still only identify human activities that resulted in the deposition of durable material remains visible on the surface.

A second limitation of field survey data, therefore, is that it cannot capture the many activities and features of rural landscapes that did not involve tangible material culture. We may especially think of ephemeral features in the landscape, such as ditches, pits, fields and field divisions, and canals. Even if such features might occasionally involve the deposition of artefacts, these would be quantitatively very sparse and hence difficult to track on the surface; moreover, the original bottom of such features may often be deeply buried, and any artefacts, therefore, remain beyond the reach of the plough.

In practice this means that surface survey has predominantly been successful in the detection of artefact-rich phases of history (i.e., Greco-Roman period sites) and contexts (domestic and to a lesser extent ritual sites, burial grounds; Campana, 2017, p. 1224); archaeologically more ephemeral periods and activities remain much more obscure. Though complementary methods such as remote sensing (analysis of aerial photographs, satellite imagery, cartographic sources and, more recently, LiDAR data) may significantly complement artefact survey data, they are only rarely integrated with systematic survey approaches. Other complementary methods, including geophysical prospection and test trenching, have for long been contingent on the results of the surface survey as such further strengthening the focus on archaeological sites identified through field survey, neglecting most of the continuous past cultural landscape.

We, therefore, argue that new approaches are needed to come to more nuanced and integral reconstructions of the use history of rural areas in the Mediterranean. In this article, we present the results of a pilot study that employs an interdisciplinary off-site approach to study past human engagements with the environment in the Pontine plain, central Italy. It ties in with other recent (experimental) work that highlights the importance of such an approach to reconstruct the full range of activities and interventions associated with rural settlement and land use (Campana, 2017; de Neef, Armstrong, & van Leusen, 2017). Our study complements such work by expanding the range of approaches, combining detailed surface survey, remote-sensing analyses, geophysical prospections, geoarchaeological investigations and palaeoenvironmental analyses.

After a brief discussion of the geographic and research context in which the research took place (Section 2), we first describe the adopted methodology and provide a brief overview of acquired data (Section 3). In Section 4, we will draw the results for each individual method together and illustrate the effectiveness of the adopted integrated field approach along three thematic lines: highlighting links between human settlement, the ancient landscape and environment (Section 4.1); unveiling the presence of "hidden" periods of past human occupation (Section 4.2) and providing insight into the texture of past cultural landscapes (Section 4.3). In the concluding section we reflect on the broader implications of this promising pilot study, both for future research in the Pontine plain and for scholarship on rural Mediterranean landscapes in general.

2 | THE STUDY AREA: RESEARCH CONTEXT, GEOGRAPHY AND HISTORY

The discussed work is part of the Pontine Region Project (PRP), a landscape archaeological project that studies the *longue durée* of settlement and land-use in the Pontine Region (P. Attema, 1993; P. Attema, Burgers & van Leusen, 2010; P. Attema, de Haas, & Tol, 2011; de Haas, 2011; Tol, 2012). This region is situated some 50 km south of Rome and consists of a coastal plain bounded to the west by the Tyrrhenian Sea, and to the north and east by the pre-Apennine limestone range of the Lepine Mountains and the tuff slopes of the Alban Hills (Figure 1). The Pontine plain itself consists of a higher system of marine terraces along the coast and, further inland, a low-lying area that is generally known as the Pontine marshes. Extensive information on the geology and soils of the plain and adjacent mountains has been published by Sevink, Duivenvoorden, and Kamermans (1992), Sevink, Remmelzwaal, and Spaargaren (1984) and Sevink, Vos, Westerhoff, Stierman, and Kamermans (1982). This included soil maps of the Pontine plain, which record the occurrence and characteristics of the various marine complexes, as well as of Late-Holocene fluvio-colluvial deposits that are of anthropogenic origin and are linked to massive soil erosion, that is, the result of intensive land use in the adjacent mountains. The soil maps and associated data formed important background information for all later archaeological surveys and studies.

Although archaeological research within the PRP was already done here in the 1980s and 1990s (P. Attema, 1993), over the last 15 years the Pontine marshes have become the focus of a wide range of archaeological studies (Cassieri, van Leusen, Feiken, Anastasia, & Tol, 2011; de Haas, 2011, 2017; Feiken, Tol, & van Leusen, 2012; Tol, de Haas, Armstrong, & Attema, 2014), often also paying attention to environmental aspects, and it is here that the discussed pilot project was carried out. In parallel, studies on the Late Quaternary geology of the marshes were boosted by the discovery of tephra from the Somma–Vesuvius Avellino pumice eruption that occurred during the Early Bronze Age (Sevink et al. 2011). They led to a deep insight into the genesis of this landscape (Bakels, Sevink, Kuijper, & Kamermans, 2015; Sevink, 2020; Sevink et al. 2018; Sevink, van der Plicht,

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[2] On off-site and manuring: Bintliff & Snodgrass (1988), Wilkinson (1989) and Alcock, Cherry, and Davis (1994) with critical remarks, countered by Snodgrass (1994) in the same volume. For more recent discussions: Caraher, Nakassis, and Pettegrew (2006) and de Haas (2012).

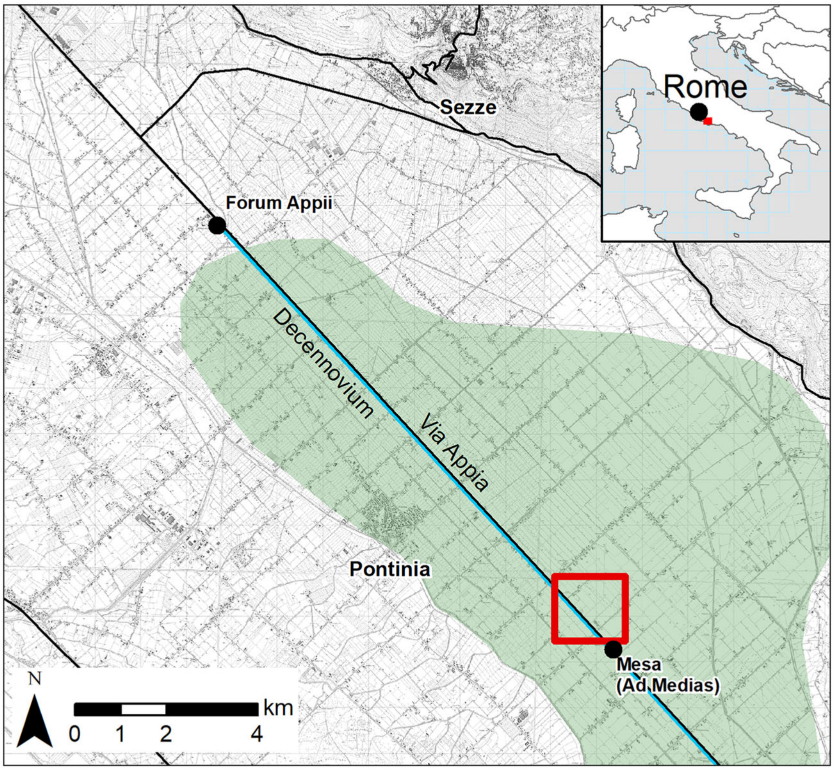


FIGURE 1 Location of the pilot study area (marked by red rectangle) in the Pontine plan (shaded area: Extent of centuriation). Inset: Location of the Pontine region in Italy [Color figure can be viewed at wileyonlinelibrary.com]

Feiken, van Leusen, & Bakels, 2013; Sevink, van Gorp, di Vito, & Arienzo, 2020; van Gorp & Sevink, 2019; van Gorp, Sevink, & van Leusen, 2020).

For much of history, the lower Pontine plain consisted of an extensive wetland that without sustained maintenance efforts was unsuited for large-scale occupation. This was the case both in ancient and in more recent times, until reclamation efforts under Mussolini in the 1930s resulted in the more durable reclamation and settlement of the area. At the same time, such wetland environments constitute incredibly versatile and rich landscapes offering plentiful resources (Horden & Purcell, 2000, p. 187). For the Pontine wetland this finds ample confirmation in the ethnographic and historical sources that attest to a wide variety of small-scale activities, including seasonal habitation related to transhumant pastoralism, small-scale agriculture and fishing (see also Walsh, 2014, ch. 4; Walsh, Attema, & de Haas, 2014).

Furthermore, ancient sources recount how the area played a pivotal role in Rome's earliest expansion. As part of Rome's interventions in the late 4th century BC, a large consular road (the *Via Appia*) was constructed straight through the wetland, and regularly spaced road stations were installed along its course. At the same time a canal (the *Decennovium*) was dug, starting at the road station of *Forum Appii* and running parallel to the *Appia* for 19 miles before discharging into the Tyrrhenian Sea. Moreover, written sources mention various attempts to reclaim the Pontine marshes. The first such attempt would relate to Rome's initial conquest of the area, in relation to which the foundation of the *tribus Pomptina* in 358 BC and the *tribus Oufentina* in 318 BC are mentioned. Written sources point at repeated attempts to drain the area in the early 2nd century BC, followed by numerous renewed initiatives in both Roman and post-Roman times (Hofmann, 1956; Linoli, 2005).

Archaeological evidence for the waxing and waning of human exploitation of the Pontine marshes comes from prior PRP field surveys carried out between 2007 and 2016 (de Haas 2011; Tol et al., 2014; Tol & de Haas 2016). These surveys mapped small-scale activities related to the exploitation of the wetland's natural resources by mobile hunter-gatherer groups in prehistoric times (La Rosa, de Haas, & Tol, 2016), very limited evidence for exploitation of the wetland in protohistoric and Archaic periods (but perhaps from more sustainably occupied settlements; see Feiken et al., 2012) and, by contrast, a Roman Republican landscape with two road stations (*Forum Appii*, *Ad Medias*), and numerous small habitation sites scattered over the area. These habitation sites exhibit highly standardized ceramic assemblages pointing at a foundation date in the late 4th or early 3rd century BC. Many of the recorded sites were abandoned within one or two centuries and continuity into the first century AD is restricted to only a handful of sites. Dispersed finds of glazed ceramics reflect renewed human engagement with the wetland environment in Late- and Post-Medieval times.

The direct impetus for the pilot study discussed here was provided by geophysical prospections carried out in 2014 at *Ad Medias*. These prospections allowed us to connect several subsurface features to the archaeological remains recorded on the surface during our field surveys but also revealed many anomalies that did not have such a material correlate. These include an enigmatic feature consisting of at least 10 concentric circles surrounded by a sequence of straight lines, as well as several large north–south- and east–west-oriented linear anomalies

(Figure 2). The largest of these linear anomalies are some 6.5-m wide and part of a much larger system of ditches, roads and canals. Together, these form a land division system (or centuriation) that was already identified in the 1980s and tentatively associated with the establishment of the *tribus oufentina* in the late 4th century BC (Cancellieri, 1985, 1990; Coarelli, 2005, pp. 188–189; de Haas, 2011, pp. 210–213; cf. Figure 1).

As a follow-up, we conducted a small series of corings on these features, confirming their identification as ancient canals and ditches. Moreover, the fills of these ditches and canals proved to contain palaeoecological evidence suitable to reconstruct past land use and environmental conditions (de Haas, 2017). The identification and investigation of such subsurface elements is, therefore, clearly essential for a better understanding of the history of this rural landscape, but as they do not have a material correlate on the surface they would have been completely missed if our research relied purely on information from field surveys. A new field strategy, entailing a more systematic exploration of both surface and subsurface features, is, therefore, crucial for advancing the study of rural landscapes such as that of the Pontine marshes.

3 | METHODS, MATERIALS, AND SUMMARY OF RESULTS

To fully explore the range of surface and subsurface traces of past rural landscapes, we selected a test area of c. 400 × 1,000 m situated north of the site of *Ad Medias* (Figures 1 and 3). This area was selected, first, based on its proximity to the area previously investigated with good results at *Ad Medias*, second, because traces thought to represent human exploitation could be discerned on historical aerial photographs and maps (Figure 2), third, as this area had been almost completely investigated through archaeological field survey during our previous research, hence limiting the investments needed, and fourth, because we had developed good relations with the landowners, which was crucial for obtaining permission for the various types of fieldwork planned.

Our approach combines desktop studies (analysis of maps; aerial photographs and LiDAR data) with a suite of field techniques (fieldwalking, geophysical prospection and coring) and, finally, ecological sample analysis (Figure 3). Below we describe each of the different field techniques, and the data gathered, in more detail. The data themselves are presented fully in Appendices 1–5.

The area of study is located in the southern border zone of the Early Bronze Age lake that formed by damming of the outlet of the central basin near la Cotarda, in connection with the development of an alluvial fan by the Amaseno river as a result of the Holocene sea-level rise (van Gorp & Sevink, 2019). This took place shortly before the Early Bronze Age and before the tephra-fall that led to the widespread occurrence of the AV-layer. In this border zone, the pre-Holocene heavy lagoonal clays that are part of the Eemian Borgo Ermada marine complex form a slightly undulating surface, with some deep fluvial incisions and gradually descending to the northeast.

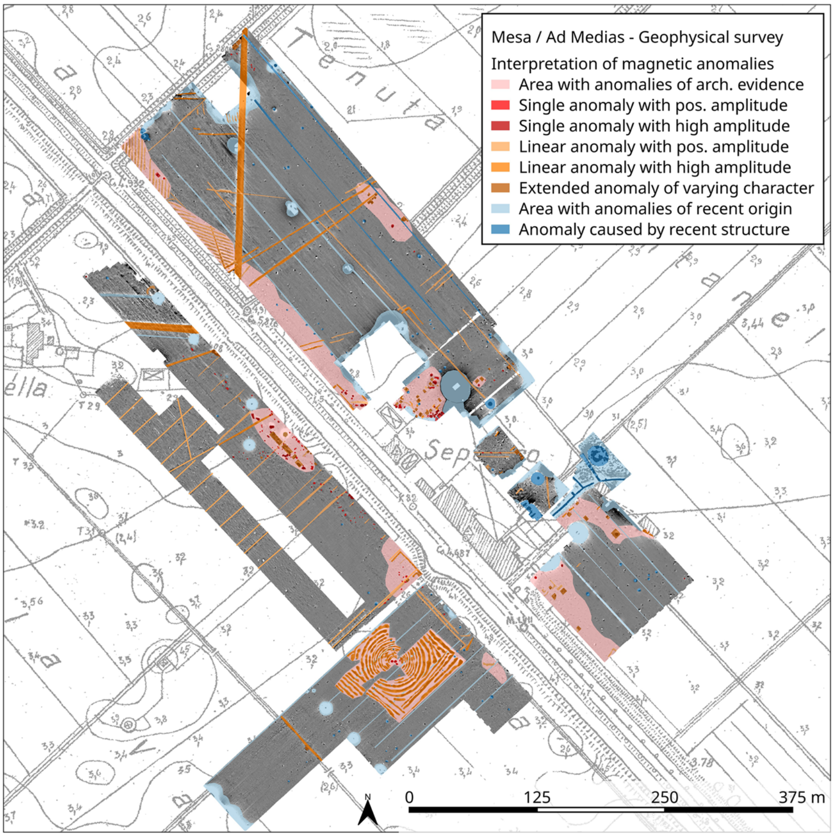
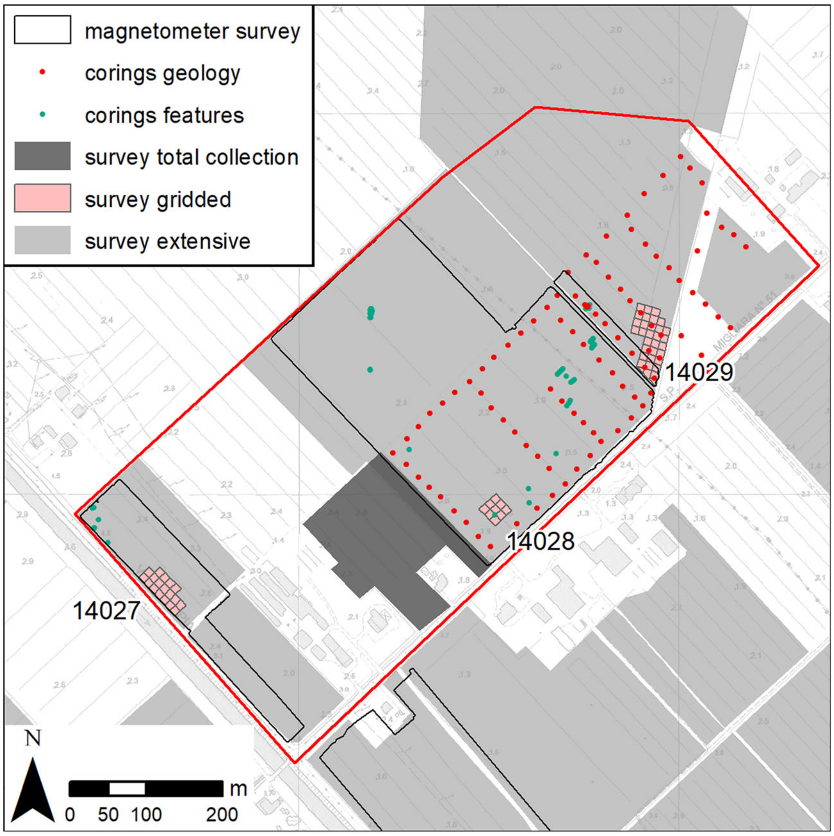


FIGURE 2 Interpretation of magnetometry data at *Ad Medias* [Color figure can be viewed at wileyonlinelibrary.com]

FIGURE 3 The study area: Areas covered by different field methodologies [Color figure can be viewed at wileyonlinelibrary.com]



The fluvial incisions were formed during the last glacial period when sea level was very low, but upon Holocene sea-level rise were largely filled in with sediment before the inland lake formed. Whereas, in the south, the Borgo Ermada clays are found at the surface, further north, they are thinly covered by Holocene often pyritic peaty clays, deposited in the border zone of the inland lake and over large areas holding the AV-layer at shallow depth (Bakels et al., 2015; Sevink, van Gorp, et al., 2020; van Gorp et al., 2020). Characteristic for these black clays is the occurrence of so-called terra bruciata material, often ascribed to ignicoltura (slash-and-burn)[3] but, in reality, resulting from drainage and concurrent oxidation of highly pyritic peaty clays with ensuing residual accumulation of reddish hard material, largely composed of iron hydroxides (Sevink, 2020).

Because of the major difference in age—Eemian versus Late Holocene—the lagoonal clays of the Borgo Ermada complex and the Late Holocene clays exhibit major differences in properties, allowing for easy identification of sediments encountered in the corings. Differences are in colour (mottled greyish blue vs. dark grey), organic matter content (nil vs. moderate to high), consistence (hard and dense vs. soft and plastic) and presence of calcium carbonate concretions (often abundant vs. absent).

3.1 | Archaeological field survey and artefact processing

The main aim of the field survey was to record any surface artefacts that are indicative of past settlement and/or land use. With this aim, most of the pilot area had already been investigated in 2013. At the time, walkers traversed fields spaced at 5-m distance, reporting on any ancient artefacts they observed. Conspicuous artefacts ("diagnostics") were collected individually, whereas concentrations of artefacts ("sites") were marked and subsequently resurveyed in a second stage.[4] In this second stage, grids of 10 × 10-m squares were laid out, which were then either traversed by two walkers collecting all artefacts from a 2-m-wide swathe (hence, collecting 40% of the surface artefacts; on sites 14027 and 14029) or, if artefact densities were relatively low, collecting all surface artefacts (on site 14028).

The collected artefacts were subsequently studied in two stages. After washing, they were subjected to a basic classification, comprising the counting and weighing of artefacts according to ware or functional class. Subsequently, a more detailed study, including full morphological description and drawing, was done for so-called "diagnostic artefacts" (for pottery: generally, rims, bases, handles and

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[3] In Italy, prehistoric slash-and-burn agriculture employing regular burning to combat weeds and plagues, and to prepare fields for sowing, is described as ignicoltura (see Forni, 1981).

[4] Rather than applying fixed (arbitrary) artefact density thresholds, we adopted an intuitive approach to site definition. Such an approach was deemed valid, considering the extremely low densities of off-site materials noted in the lower part of the Pontine plain during earlier gridded surveys, making concentration of material clearly stand out (de Haas, 2011).

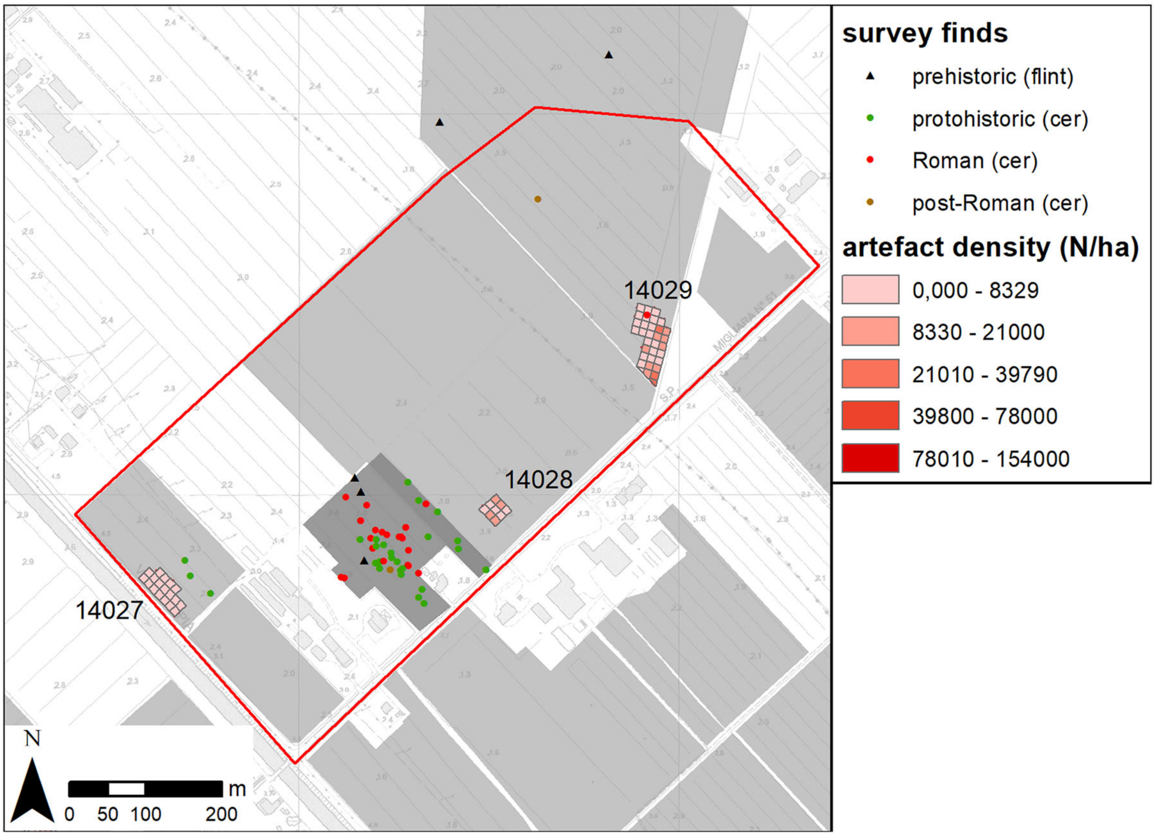

FIGURE 4 Distribution of sites and artefacts as observed during the field surveys [Color figure can be viewed at wileyonlinelibrary.com]

decorated body fragments) for more accurate dating and/or functional interpretation of mapped sites.

During the pilot in 2017, one additional area was surveyed with a more intensive off-site approach (Figure 3). Walkers were spaced shoulder to shoulder and the location of all artefacts was recorded individually. All artefacts were classified according to the same classification as used during the previous survey, but in contrast to the earlier survey, only ceramics that could not be readily identified or those deemed "diagnostic" were taken from the field.

Figure 4 summarises the main data resulting from the field survey. The initial 2013 field surveys covered almost the entire study area under favourable conditions (all fields were freshly ploughed). The fields contained very low numbers of off-site finds, amongst which one glazed post-Roman fragment and, to the southwest along the *Appia*, several protohistoric handmade *impasto* fragments, including a handle that can be dated generically to the Bronze Age (Figures 4 and 5a). Additionally, three discrete scatters were observed that were subsequently investigated through a gridded survey (see Table 1). The first, located on the southwest edge of the area along the *Via Appia* (site 14027), measured ca. 0.24 ha and consisted of two smaller cores with relatively high artefact densities. Its artefact assemblage contains mainly cooking wares, architectural remains

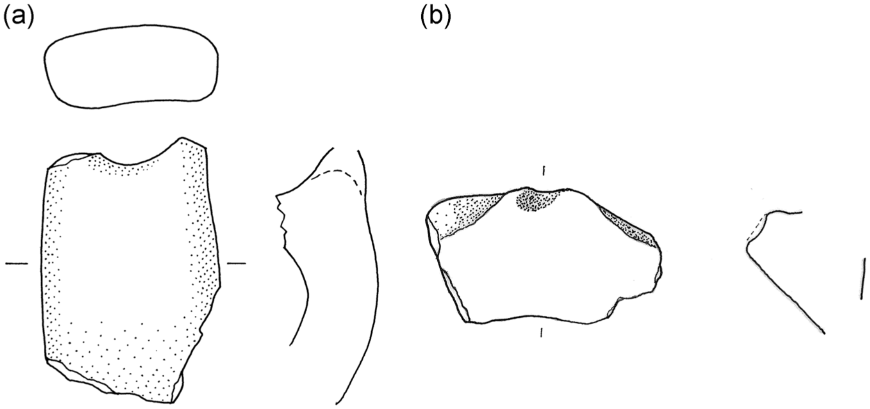

FIGURE 5 Protohistoric pottery collected during the initial surface survey (a, left) and during the complementary survey in February 2017 (b, right)

TABLE 1 Functional assemblage of sites mapped in the research area

	14027		14028		14029	
Function	*N*	%	*N*	%	*N*	%
Architecture	87	14.3	37	13.3	736	75.1
Kitchenware	146	23.9	142	51.1	169	17.2
Storage	8	1.3	4	1.4	9	0.9
Transport	79	13.0	3	1.1	12	1.2
Table ware	28	4.6	25	9.0	24	2.4
Household production	1	0.2	0	0	0	0
Indet	261	42.8	67	24.1	30	3.1
Total	610		278		980	

(tile, stone) and transport amphorae, and smaller proportions of storage and table wares, a loom weight and a Roman coin. Within this site sparse fragments of post-Medieval pottery were noted as well. The second artefact concentration (site 14028), situated in the central-southern part of the area, was much smaller, extending over an area of c. 0.08 ha. It contained—besides some sparse Palaeolithic artefacts—a similar range of ceramics, with mainly kitchen wares and, to a lesser extent, architectural remains and table wares. The third artefact concentration (site 14029) is the largest of the three at c. 0.27 ha and contains two main concentrations. It had conspicuously high proportions of architectural remains (75%) and kitchen wares (17%), and only small amounts of table wares, storage wares and transport amphorae besides, again, one loom weight and several Palaeolithic artefacts. Compared to many other sites in the wider area, the fragments collected here were considerably larger and showed a much more limited degree of weathering, suggesting that they have only recently been touched by the plough. This might be an explanation for the relatively high percentage of architectural fragments within the collected sample, as the roof collapse is likely to initially overlie occupation layers.

On the basis of their varied assemblages, all three sites were initially interpreted as rural farms (of different size); two of them appear rather short-lived (14028 and 14029), being founded in the late 4th or early 3rd century and abandoned already during the 3rd century BC. The third site (14027), was founded in the same period, but continued to be occupied until the advanced 2nd century AD (Appendix 1).

The complementary survey in February 2017 was carried out under comparably favourable circumstances. Interestingly, the more intensive fieldwalking approach used here complements our understanding of the surface archaeology very well (Figure 4): Whereas no artefact concentrations like the three discussed above were observed, a thin spread of Roman Republican period finds (mainly tiles, and the rim of a late 4th/early 3rd century BC black gloss plate) probably constitutes part of a general spread of off-site materials related to the Republican sites previously recorded (cf. de Haas, 2012). At the same time, the finds represent a much longer chronology of human frequentation, stretching far back beyond Roman times. First, several Palaeolithic flint artefacts were collected, which along with those observed during the less intensive initial survey of the area and subsequent gridded site-surveys indicate human frequentation in the Middle Palaeolithic, Upper Palaeolithic and the Neolithic (cf. La Rosa et al., 2016). Second, the survey also recorded a low-density spread (20 fragments) of protohistoric ceramic fragments, which may well represent the highly eroded remains of a Bronze- or Iron-Age site (Figures 4 and 5b).[5] A single piece of *maiolica rinascimentale* adds to the typical spread of isolated post-Medieval fragments that characterizes the wider area.

3.2 | Geophysical prospections

The geophysical prospections aimed to map any extant subsurface features. Building on previous experiences, we conducted a large-scale continuous magnetometer survey (on the principles and potential of this technique: Campana, 2009, 2017; Meyer, Kniess, & Goosens, 2012; de Neef et al., 2017; Powlesland, 2009; Ullrich et al., 2011). In the local conditions, this method is excellently suited to identify channels and ditches by the enhanced magnetization of their fills, as well as features with a high remanent magnetization caused by fire such as burnt bricks, kilns, fireplaces, and so forth.

The magnetic surveys were carried out by Eastern Atlas GmbH with an LEA MAX system, which consists of an array of 10 fluxgate gradiometer probes mounted on a light and flexible cart with individual wheel suspension. The probes register the vertical gradient of the Z-component of the Earth's magnetic field with an accuracy of 0.1 T (10^{-9} Tesla). The gradient is insensitive to the typical large fluctuations of the Earth's magnetic field and is determined mainly by the magnetisation of local anomalies in the shallow underground. The technical details of the magnetic survey system are specified in Table 2.

The data positioning for the magnetometer survey was realised with two dual-frequency Global Navigation Satellite System (GNSS) receivers. The rover of the system is attached to the magnetic array. A relative data accuracy of 0.02 m was achieved. To adjust the absolute data accuracy, the position on the basis of the global positioning system was referenced to the station LAT1 (Latina, Italy) by postprocessing.

The interpretation of the magnetic data follows a classification of single magnetic anomalies and areas with magnetic anomalies of similar type. The anomalies were classified according to their shape into single, linear or extended ones, and according to their amplitude into anomalies with either positive or dipole amplitudes with positive and negative parts of the signal. The possibly related features were then classified as archaeologically relevant, natural or modern (Table 3).[6]

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[5] For protohistoric occupation in the Pontine plain, see Alessandri (2013); Feiken (2014).

[6] The classification of magnetic anomalies can be ambiguous, as seen in “Related features” of Table 3. For example, elongated positive anomalies can be caused by refilled erosion gullies (natural), but also by refilled human-made ditches (archaeological relevant or recent).

TABLE 2 Technical specifications of the magnetometer survey system

Method	Magnetometer survey
System	LEA MAX
Sensors	Foerster Fluxgate Gradiometer FEREX CON650
Data logger	Eastern Atlas LEA D2 (10 channels)
ADC bandwidth	24 Bit
Measurement quantity	Vertical gradient $\Delta Z/z$ of Earth's magnetic field in nT
Measurement accuracy	±0.1 nT
Configuration	10 parallel sensors mounted on a cart
Resolution	0.5-m profile distance; 0.05-m in-line point distance
Topographical and distance measurement	RTK-GNSS with two Førsberg ReAct receivers, relative accuracy: 0.02 m + additional odometer (survey wheel) on the cart
Magnetic data processing	EALDEC: Data decoding (using global positioning system signals and odometer data) EALMAT: Statistical drift correction and normalisation GRIDDING: Kriging routine, search radius 0.7 m, resolution 0.25 × 0.25 m
Output data format	CSV (ASCII), GRD (grids), GEO-tif (tif and world-files)

TABLE 3 Classification scheme of magnetic anomalies

Class	Signature	Colour	Type of magnetic anomaly or area	Related features
(a) Magnetic anomalies of archaeological relevance				
0	🟥	Light Red	Area with magnetic anomalies of archaeological relevance	Settlement areas, areas with scattered finds
1	🟥	Red	Single magnetic anomaly with positive amplitudes	Pits, post holes
2	🟥	Dark Red	Single magnetic anomaly with high positive amplitudes or dipole characteristic based on higher magnetisation	Burnt loam, fire pits, burnt bricks, kilns (oven, lime kiln, ceramic kiln)
3	🟧	Light Orange	Linear magnetic anomaly with positive amplitudes	Ditches, pit alignments
4	🟧	Orange	Linear magnetic anomaly with high positive amplitudes or dipole characteristic based on high remnant magnetisation	Single walls, filled ditches, refilled hollow ways
5	🟫	Light Brown	Extensive magnetic anomaly with positive amplitudes, dipoles or mixed character	Foundations, houses, floors, Extraction pits
(b) Magnetic anomalies caused by natural features				
6	🟩	Light Green	Area with anomalies caused by natural structures and objects	Geological formation (bedrock, faults), Soil formation (erosion gullies)
7	🟩	Dark Green	Anomalies caused by natural objects	Solid rock, Lightning-induced remanent magnetisation
(c) Magnetic anomalies caused by recent features				
8	🟦	Light Blue	Area affected by anomalies caused by recent structures and objects	Enlarged anomalies on pipes, metal fences, buildings and ramparts
9	🟦	Dark Blue	Anomalies caused by recent objects	Foundations of modern buildings, pipes, pipe ditches, drainage ditches, scrap metal at the surface

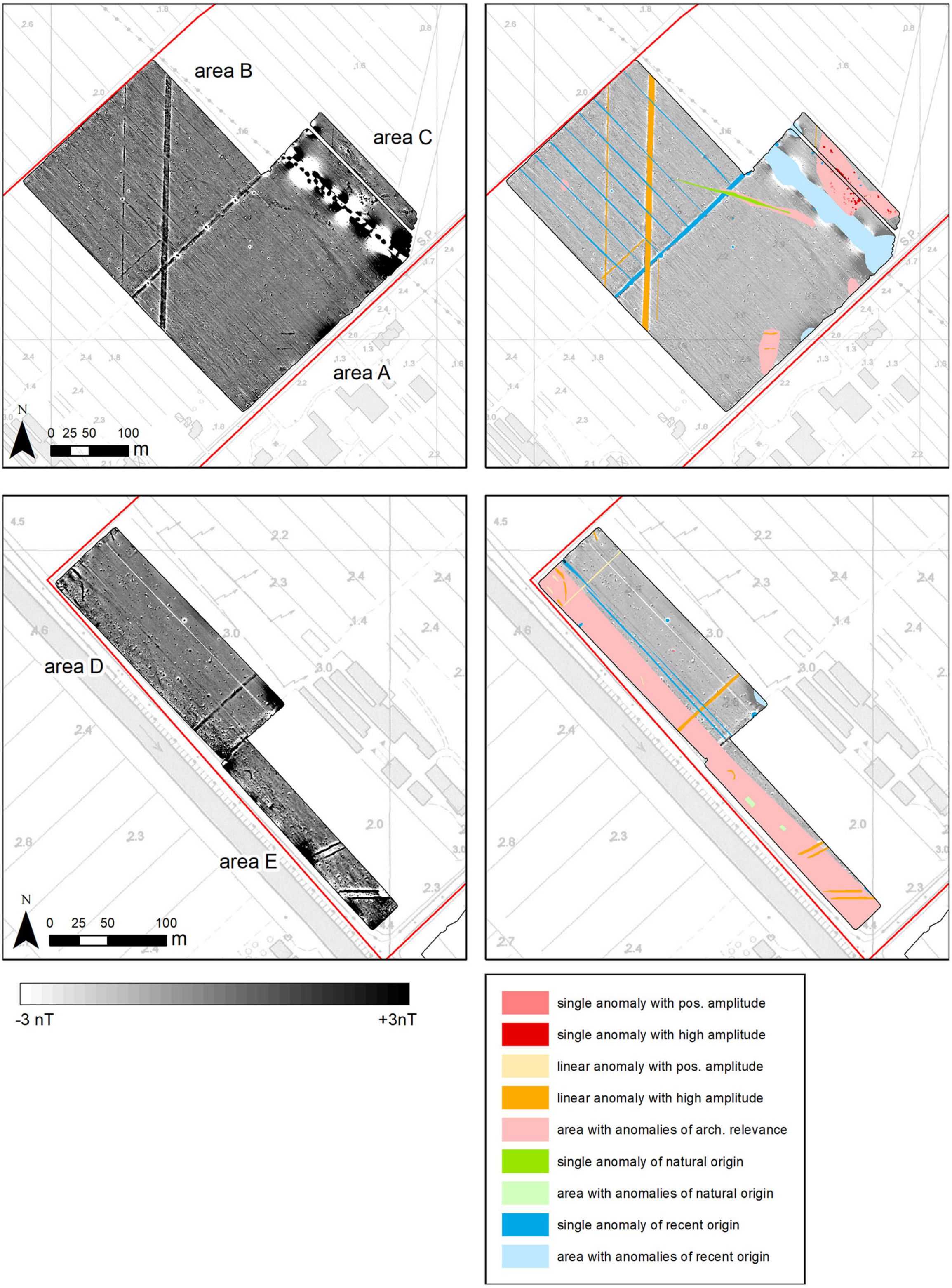

FIGURE 6 Magnetic data and interpretations from areas 1 (above) and 2 (below) [Color figure can be viewed at wileyonlinelibrary.com]

The magnetometer surveys were carried out over a period of 3 days, covering 11.8 ha in the north-eastern part of the area (Figure 6, areas A–C), and an additional 2.1 ha to the south (Figure 6, areas D and E). The data show a wide range of anomalies, including many of archaeological relevance but of difficult interpretation, as well as anomalies that represent significant natural and modern disturbances (mainly related to the Migliara 51 road and the *Via Appia* that both border the surveyed area, as well as metal pipes and other dispersed metal objects), and overlapping anomalies of different origin.

Most prominently, additional data were obtained for the earlier mentioned centuriation system. An NS–EW-oriented strong linear positive anomaly measuring ca. 7 m in width can be interpreted as one of the main arteries of the system and constitutes the continuation of the canal mapped earlier during geophysical surveys around *Ad Medias* (see above; also, Tol et al., 2014, pp. 124–126; de Haas, 2017). Throughout the mapped areas there are additional linear features (areas A and B; southern margin of subarea E), all of the much smaller dimensions (most measuring between 1 and 1.3 m in width) that run either parallel (cf. Figure 9, no. 1) or perfectly perpendicular (Figure 9, nos. 3 and 4) to this main canal, and they might represent secondary canals or ditches. Another series of interesting features was detected in the northeastern edge of the survey area. In terms of location, they partly overlap with one of the Republican sites (14029) mapped during the surface survey in 2013 but extend towards the west for a significant distance. The full extent of this feature towards the north (beyond the investigated area) and the south (where the magnetic signal is heavily disturbed by a modern metal pipe) cannot be established. The mapped anomalies here comprise several concentrations of small oval or triangular shaped features. They demonstrate very high positive amplitudes, suggesting the presence of burnt material in them. In area 1, magnetometry revealed a broad band of scattered anomalies up to 35–40 m from the *Via Appia* without any specific clear, larger anomalies standing out. Two anomalies with high positive amplitudes in the southern part of area E possibly include field boundaries and/or canals belonging to the centuriation system; the dispersed linear and curvilinear features in the north corner of area D are also caused by ditches or fills, but currently lack a clear interpretation.

3.3 | Coring

Coring was carried out with two aims. First, to map in detail the surface geology of the area and potentially relevant processes of landscape change that may affect the interpretation of the archaeological remains (e.g., subsidence, anthropogenic interferences); and second, to understand the stratigraphic properties of any archaeologically relevant features identified during the archaeological field surveys and geophysical prospections.

3.4 | Cross-sections of the stratigraphy

To meet the first aim, corings were conducted along 11 transects at 20-m intervals. All corings were conducted by hand, using an Edelman core and usually extended to a depth of c. 1 m or less, where the sediments of the Borgo Ermada complex were reached. Only in specific areas were these encountered at greater depth and hence our corings extended further, up to a maximum depth of c. 2 m. The stratigraphy was described in terms of the composition of strata and their genesis.[7]

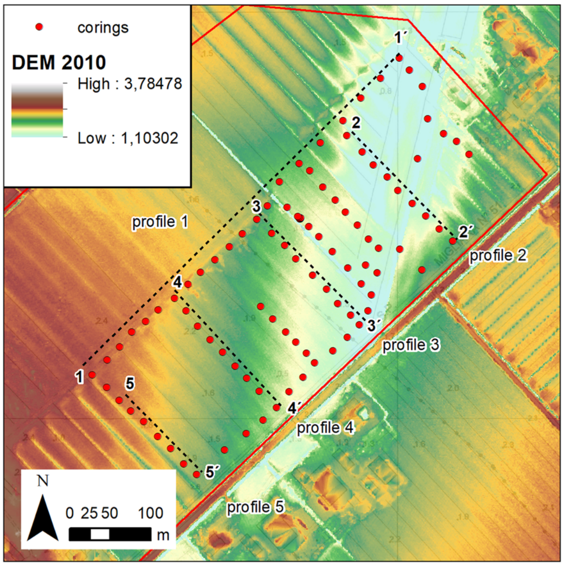

FIGURE 7 The coring profiles [Color figure can be viewed at wileyonlinelibrary.com]

The focus was on the central-northern part of the study area, where c. 100 corings were made along two southwest/northeast oriented and eight northwest/southeast-oriented transects (Figure 7). We, here, present cross-sections for five such transects (Figure 8).

The sequence of Holocene dark lacustrine clays over heavy lagoonal clays of the Borgo Ermada complex is clearly visible in the corings of Profiles 1, 4 and 5. Especially in the slightly higher areas to the south, the Pleistocene Borgo Ermada deposits are found very close to the surface. The northern part of the area, however, shows a clear north–south-running depression, which may be interpreted as an old river valley cut in the Pleistocene subsurface and draining in a northern direction.

Cross-sections 2 and 3 cut across this lower-lying part of the study area and reveal the stratigraphy and chronology of this Holocene valley fill. It is clearly represented in Profile 2 by a grey plastic (in some cores sandy) clay, which occurs up to a depth of more than 180 cm (in some corings we did not reach the Borgo Ermada complex). Because, in Profile 2, the thickness of this layer varies substantially, and in the central part of this profile, the Pleistocene subsurface lies considerably higher, the valley may, in fact, consist of several narrower channels. On top of this fill and to its south (especially in Profile 3), we encountered a second layer of dark clay with typical terra bruciata fragments and charcoal. In some corings in the southern part of Profiles 1–3, we encountered a distinct thin tephra layer in the lower part of this clay stratum, which was identified as the Avellino pumice layer and provides

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[7] The parameters registered were texture, the thickness of the layer, organic matter content, colour, carbonates, consistency, sedimentary facies, geological unit and the presence/absence of anthropogenic material (see Sevink et al., 1984). Quantification was based on Jahn, Blume, Asio, Spaargaren, and Schad (2006).

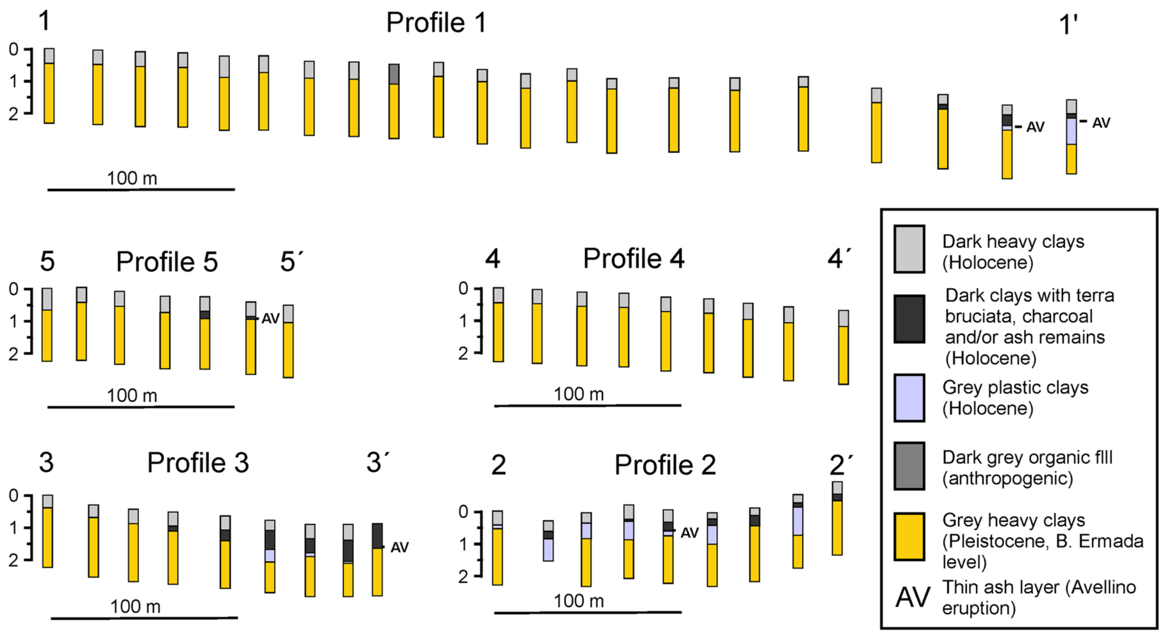

FIGURE 8 Stratigraphy observed in the coring transects [Color figure can be viewed at wileyonlinelibrary.com]

a clear chronological marker.[8] It demonstrates that the fill of the incised valley largely dates from before the Early Bronze Age.

3.5 | Coring in artefact scatters and anomalies

To reach the second aim, corings were made in artefact scatters encountered during the field surveys and in any relevant anomaly observed in the geophysical prospections. To ensure the accurate linking of geophysical anomalies and coring locations, the GNSS rover was used to mark the positions of magnetic anomalies directly in the field. This allowed us to locate corings both inside and outside anomalies, even if these were small. Depending on the observed stratigraphy and the nature of the features under investigation, either individual corings were conducted or multiple corings were made along transects, in some cases with corings at very short intervals (30 cm at minimum). The same core and description standards were used as for the landscape reconstruction cores, but from selected cores, we also stratigraphically collected soil samples for sieving (see Appendix 2).

Following on the geophysical prospections, 10 (clusters of) anomalies were selected for further exploration through coring (Figure 9). Crudely, these represent four types of magnetic anomalies: first, a series of linear magnetic anomalies with an NS or EW orientation, thought to represent ditches/canals pertaining to the Roman centuriation (nos. 1, 3, 4 and 9; cf. de Haas, 2017); second, an irregular magnetic anomaly perhaps to be interpreted as a pit, that corresponds to ceramic scatter 14028; third, two elongated anomalies representing zones with possibly archaeological relevant features (nos. 5 and 6); and fourth, various irregular anomalies that may also represent pits (nos. 7 and 8). The descriptions of the individual coring profiles can be found in Appendix 2; in the following, we focus on the observations that are most relevant in the context of this article.

In four different locations (anomalies 1, 3, 4 and 9) corings were intended to further investigate the linear anomalies thought to be part of the Roman centuriation. Anomaly 9, particularly, was thought to represent a centuriation canal also visible in the 1920s map (cf. Figure 9), suggesting that this ditch was still open until recently. Below the two uppermost strata, which are of recent date, we found three additional fill layers up to a depth of 140 cm that are very similar in texture and composition to the anthropogenic fills with charcoal and terra bruciata observed in corings for similar features (de Haas, 2017). Anomalies 3 and 4 (comprising corings 104–106) demonstrate a similar stratigraphic sequence. From these fills several samples were taken for botanical analysis and radiocarbon dating (see Sections 3.4 and 3.5; Appendices 3 and 4). At anomaly 1 we clearly established its stratigraphy, consisting of peaty–clayey ditch fills, which are covered by a layer of terra bruciata. An important chronological marker is the well-preserved AV-tephra layer in the top part of the sequence (underneath the terra bruciata), which provides a *terminus ante quem* for the ditch—pre-dating the Early Bronze Age eruption of the Vesuvius.

Two clusters of corings were placed at the concentration of anomalies (numbers 7 and 8) with high positive amplitudes in the northeastern corner of the study area. They showed a similar

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[8] The Avellino tephra layer was identified in the field as a 2- to 3-cm-thick intercalated sandy grey-creamy coloured tephra layer. This layer holds very conspicuous idiomorphic “golden” mica and sanidine crystals, of which the mica reaches sizes up to c. 4 mm. It has been found in hundreds of corings in the Holocene deposits of the Agro Pontino and Fondi basin, and its characteristics, origin and age (c. 1900 BC) are well established (Bakels et al., 2015; Feiken, 2014; Sevink, Bakels, et al., 2020; Sevink et al., 2011, 2013; Sevink, van Gorp, et al., 2020; van Gorp & Sevink, 2019).

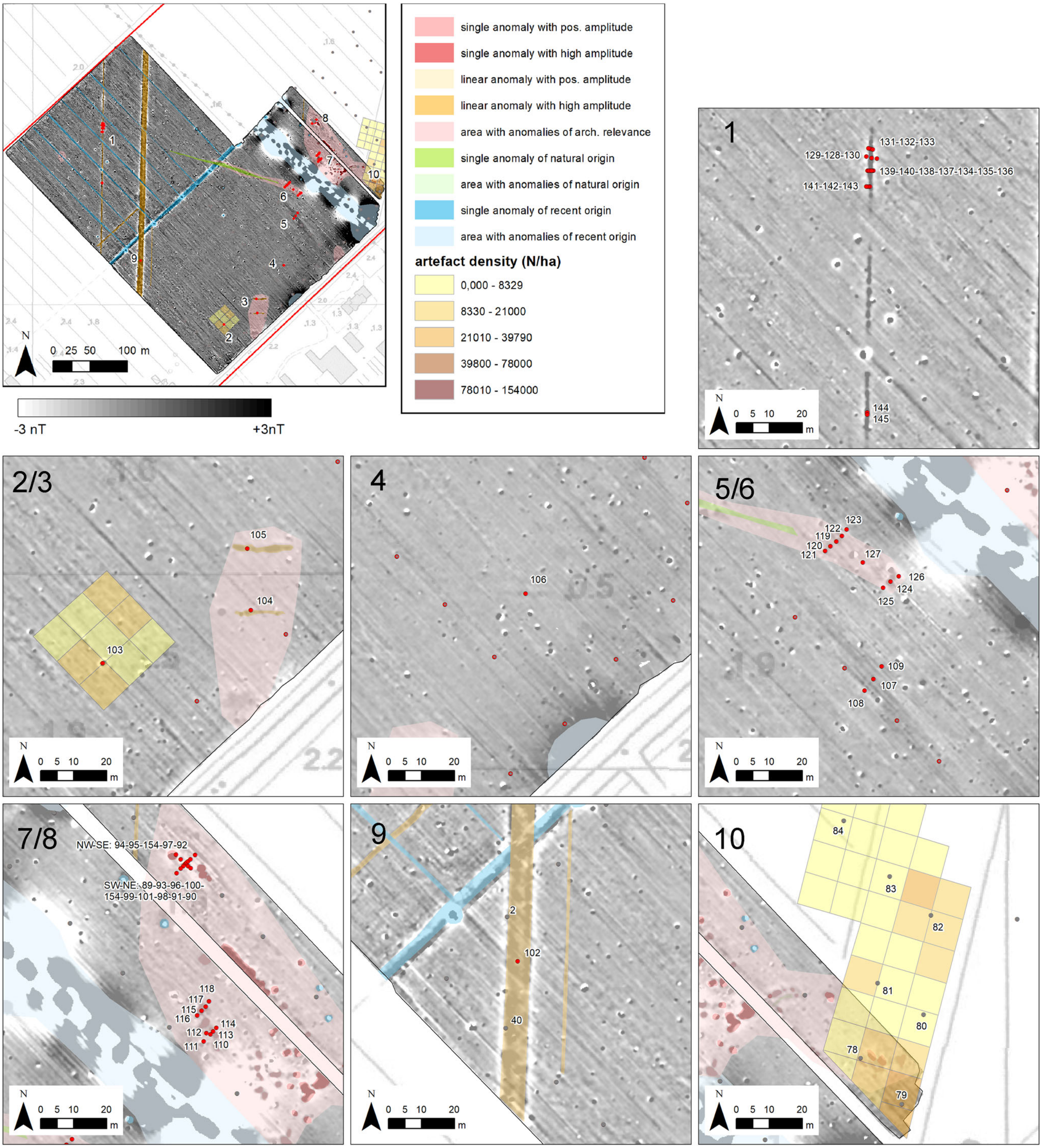

FIGURE 9 The corings in geophysical anomalies and ceramic scatters [Color figure can be viewed at wileyonlinelibrary.com]

stratigraphy with below the dark peaty clay topsoil a thin layer of peaty clay with terra bruciata and some tephra, and the earlier Holocene clay fill. However, cores 102 and 103 showed a clear stratum of pure terra bruciata with below it, an intact 2-cm-thick tephra layer and, below that, a 1-cm-thick layer of peat, which in turn rests on top of the grey plastic homogeneous clay interpreted as a gully fill. It seems we are dealing here with small and irregular pits dug into the Pleistocene clays, filled with peat and terra bruciata layers. The intact tephra layer in several cores provides evidence that these presumably human-made features pre-date the Avellino event. From one core the peat layer that sits below the tephra was sampled for radiocarbon analysis (see Section 3.4).

At two different locations, we investigated anomalies (numbers 2 and 10) situated at a location where the field survey had previously identified a small ceramic surface scatter. Coring 103 at anomaly 2 (corresponding to the location of site 14028) concerned a small round feature with negative amplitudes and showed an anthropogenic fill, from which the ceramics derive that had been observed on the surface (it has clearly been touched by the plough). At anomaly 10, corresponding to the location of site 14029, a cluster of corings was placed (cores 78–84). Several of the cores (78, 80–82) contain intact layers of terra bruciata, AV-tephra and/or peat as also seen at anomalies 7 and 8. These strata overlie the plastic grey natural fill of the valley; conspicuously, in the core of the ceramic scatter, this Pleistocene Borgo Ermada deposit was relatively close to the surface, at only 60-cm depth. This suggests that the Roman site was situated on a slight elevation, just besides the depression itself, which had already been largely filled with grey clays before the Early Bronze Age. In this valley, at a late stage, peat and tephra were deposited and, on top of these deposits, dark heavy clays. These form the extension of the pyritic black peaty clays that characterize the southern part of the "protohistoric" lake (see van Gorp et al., 2020; van Gorp & Sevink, 2019). The terra bruciata we find in this upper clay layer points to a pre-Roman phase in which the area was relatively well-drained, leading to oxidation of the pyritic clays and concurrent residual accumulation of the iron hydroxide concretions (see Sevink, 2020). During the Roman occupation, the filled-up channel, most probably, formed a minor depression.

3.6 | Sample analyses

Sediment samples were collected from the corings and, therefore, represent only small volumes of approximately 0.2 L. This is in line with the purpose of these samples, which was to explore their potential for botanical research, and they, therefore, allow qualitative observations but not quantitative analyses. The soil samples were collected and analysed to obtain material for dating deposits and explore the potential for reconstructing local vegetation and land use (28 samples in total; see Appendix 3). Although the Edelman core is not particularly well-suited for sampling due to the relatively high potential for cross-contamination, the samples consist of heavy compact clay-rich soil which could be collected as a solid sample, whereby most contamination would take place by soil adhering to the outside of the sample when lifting the core from the borehole. Pollen samples of 3 cl were taken from the inside of the solid samples in the lab, thus minimizing this effect. After small subsamples for possible pollen analysis were extracted, the samples were washed over a 0.2-mm sieve, which allows even very small plant remains to be detected. The residues were studied for the presence of charcoal fragments, bone fragments, charred seeds, and nongenerative plant parts (Appendix 4). All these were picked out and air-dried, except for one waterlogged seed found in sample 140-1. All macro remains were identified to the lowest possible taxonomic level using various standard identification guides (Cappers, Bekker, & Jans, 2006; Jacomet, 2006; Neef, Cappers, & Bekker, 2012) and the reference collection of the Groningen Institute of Archaeology. Selected charcoal fragments were sent out to the Angstrom Laboratory (Uppsala University, Sweden) for radiocarbon dating. Where possible, the charcoal fragments selected represent short-lived material, such as twiglet fragments. However, this was not possible for all samples and the relatively small charcoal fragments were too small to identify. Nonetheless, the consistency of the radiocarbon dates supports the validity of the radiocarbon results (see below). On the basis of the dating results, we proceeded to prepare six pollen samples for a selection of the contexts. The samples were prepared according to Faegri and Iversen (1989). The material was embedded in glycerol gelatine and sealed in with paraffin wax. Microfossils were counted at a magnification of 400, or 1,000, if necessary. Pollen was identified with the keys and illustrations of Beug (2004) and the reference collection of the Groningen Institute of Archaeology. Eventually, only one of the samples was analysed palynologically, based on a good pollen preservation and the presence of cereal pollen (see below; Appendix 5).

3.7 | Results: Radiocarbon dates

In total, five samples were sent out for radiocarbon dating (Table 4).[9] Four of these concerned charcoal samples from the anthropogenic fills from three linear (east–west-oriented) anomalies related to the Roman centuriation; the fifth concerns a peat sample from the bottom of one of the irregular shallow anomalies in Cluster 7, with ash deposits on top of it.

The dates from the linear anomalies related to the centuriation give dates ranging from the 10th/9th century BC to the 2nd century AD. Sample 104-1 gives a date of 1000-800 BCE. If this material is not secondarily deposited in the ditch, this suggests a pre-Roman date for this ditch feature. The dates from cores 105 and 106 are compatible with a Roman date, although sample 106-2 provides a probable date in the early 4th century BC, which is slightly earlier than the date often assigned to the centuriation on historical grounds. The two samples from core 105 provided calibrated dates of c. AD 100 and 200 for the upper sample and 200–50 BC for the lower sample. This would suggest that this presumed ditch feature was indeed excavated before 200–50 BC and had started to fill up by this time—and perhaps earlier, because there is another 15 cm of fill below the dated fill. The second/upper fill layer would then date considerably later, but still in the Roman period. While, thus in general, in line with an ancient date for the centuriation, the dates may suggest we are dealing with a system that may have a much longer history.

3.8 | Macro-botanical samples

The total volume available per sample (<0.2 L) is way below the amount commonly used for macro-botanical analyses, which is a

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[9] A sixth sample (bone) was sent in to date the lower fill of core 102 (the larger centuriation canal), but this sample proved too small to be dated. Radiocarbon dating is based on AMS measurements of samples following pretreatment by ABA-method, the radiocarbon age being corrected using the standard procedure for such calibration (see Dee et al., 2020). Values obtained were age-calibrated using the OxCal4.3 software package (Bronk Ramsey, 2017) and the IntCal13 calibration curve.

TABLE 4 Radiocarbon dates

Sample	Context	Material	Date code	Date BP	Date cal BC (95.4% probability)	δ13C‰ V-PDB
PP104-1	Anthropogenic fill in linear anomaly (Centuriation?)	Charcoal	Ua-56663	2787 ± 27	1010–840 BC	−25.8
PP105-1	Upper anthropogenic fill in linear anomaly (Centuriation?)	Charcoal	Ua-56664	1888 ± 26	AD 60–220	−28.2
PP105-3	Lower anthropogenic fill in linear anomaly (Centuriation?)	Charcoal	Ua-56665	2109 ± 26	200–50 BC	−26.2
PP106-2	Anthropogenic fill in linear anomaly (Centuriation?)	Charcoal	Ua-56666	2315 ± 26	410–350 BC [280–260 BC]	−25 (estimated value)
PP117-1	Thin peat layer below tephra layer	Peat	Ua-56667	3472 ± 28	1890–1730 BC [1720–1690 BC]	−26.8

direct consequence of the adopted field methods. Although the ideal sample volumes for this type of analysis heavily depends on the (presumed) concentration of plant remains, a volume of around 3 L would be normal in a test trench situation. Nonetheless, it turned out to be sufficient to provide what was needed in this exploratory phase of the fieldwork. Most importantly at this stage, several of the samples contained tiny fragments of charred fragments suited for radiocarbon dating.

Small fragments of charred seeds and other plant parts were present in several samples, but seeds identified with certainty could only be obtained from two. Both these samples were recovered from core 105, a linear anomaly convincingly dated to the Roman period (see previous section). Despite the low number of plant remains identified to the species level, the information provided is rather promising. Charred seeds of henbane and sun spurge tentatively point to arable weed vegetation associated with clay soils, but considerably more convincing is a glume base of Emmer wheat. These overall results are reason enough to suggest that the features are worth examining for plant macro remains, although a higher sample volume would be necessary for a more detailed interpretation of the palaeoenvironment.

3.9 | Results: Pollen samples

Most of the pollen was poorly or even badly preserved, but a clear exception was the pollen in sample 105-3, the lowest sample available from one of the linear anomalies (see Appendix 5). Not only was the pollen in this sample well preserved, but it also tells a rather clear story. Two ecological categories are well represented. The first of these are taxa associated with moist to wet conditions, such as monolete psilate fern spores, and cattail pollen. Though it is hard to say to what extent these represent reworked material that was already present in the clay matrix before the ditch system was laid out, the physical state of these remains is fully comparable to the rest of the botanical material recovered from the same sample. This means they likely date back to roughly the same period, and partly represent the vegetation in and along the ditch proper.

Another clearly represented group is made up of taxa associated with an open, agricultural landscape. Most prominent in this respect are the cereals, but also some of the other taxa identified to a higher level—such as Caryophyllaceae and Chenopodiaceae—at least partly represent plants associated with arable or ruderal environments (see also the discussion of the macro remains above).

The overall spectrum clearly points to a moist open landscape. Some of the tree species encountered, most notably alder (*Alnus*) and willow (*Salix*) probably represent trees that grew in the plain itself. The palynological samples that were not fully analysed here because of less-favourable preservation conditions, confirm the image of an open landscape, with nonarboreal pollen values higher than 75%.

Despite these good results, we should also emphasize the fact that not all pollen samples were equally well preserved. Not surprisingly, deeper deposits were better preserved due to the simple

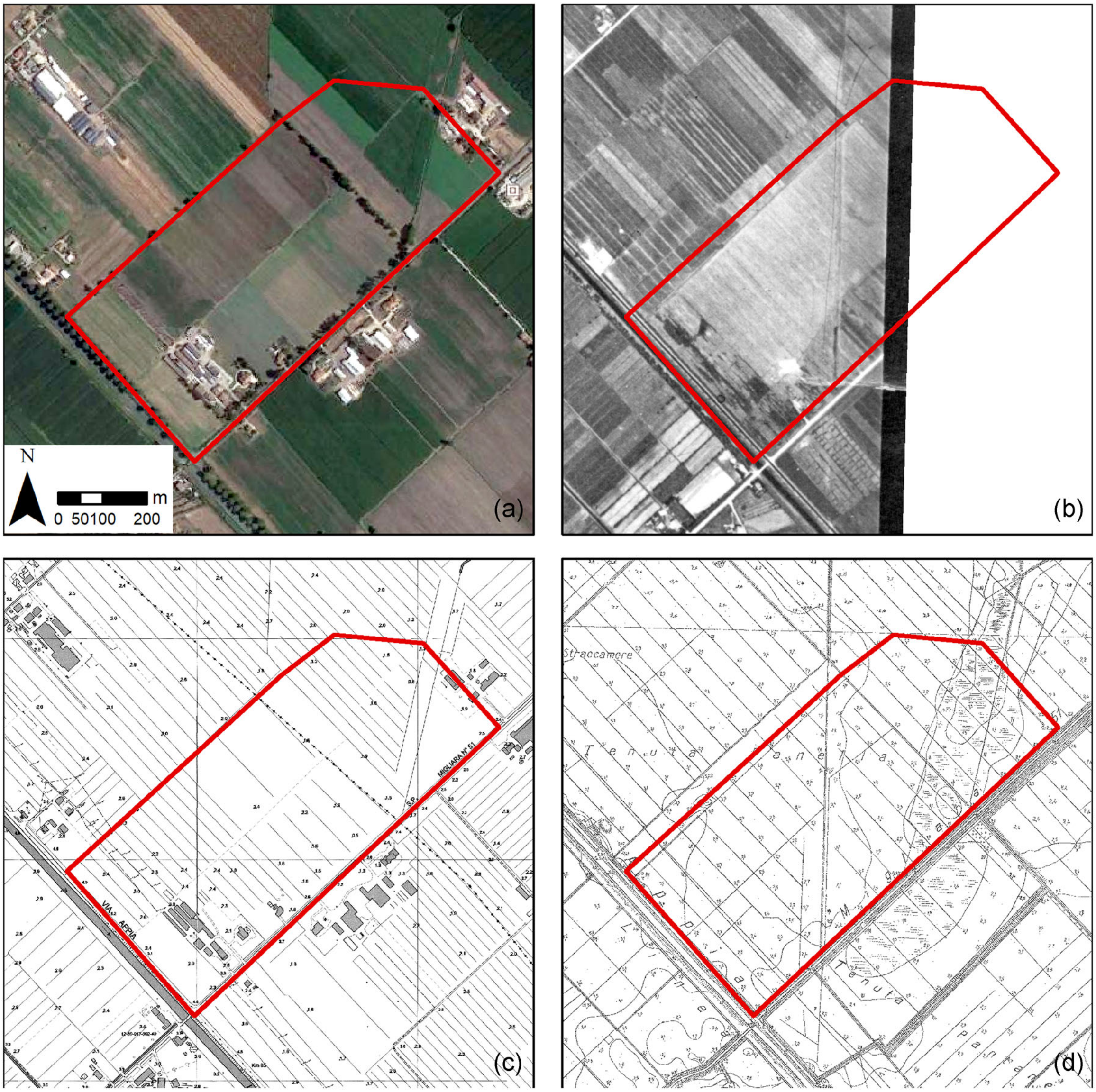

FIGURE 10 The research area in aerial photos from 1990 (a) and 1955 (b) and topographic maps from 2002 (c) and 1928 (d) [Color figure can be viewed at wileyonlinelibrary.com]

fact that these have remained more permanently moist than those closer to the surface.

3.10 | Geographic information system (GIS) studies

GIS-based data management and spatial analyses were crucial to our pilot study.[10] First, the GIS environment was used to upload and clean spatial data (area boundaries, coring locations, survey grids and locations of diagnostic artefacts) gathered in the field using ArcPad 7.0 software on a Mio 168 Pocket PC. These data could subsequently be visualised and analysed in superposition with the geophysical prospection data and cartographic sources. We used the following sources for such visual comparisons and the identification of crop marks (Figure 10): The *Carta Tecnica Regionale* (topographic maps at 1:5,000 and 1:10,000 from 2002 and 1990 respectively; various sets of aerial photographs from Google Earth (2002–2017) as well as historical maps provided by the *Istituto Geografico Militare* (1936 and 1955). Additionally, we used the detailed maps from 1927 (1:5,000), which provide important information regarding the landscape and associated morphological structures before the large-scale reclamations of the 1930s and can, therefore, be used to identify and date more recent historical landscape features. Moreover, these maps provide high-resolution elevation data (hundreds of elevation points and isolines at 5-cm intervals) and, therefore, also allow us to assess recent landscape changes by comparison with recent elevation data (see below).

A final, crucial source of information is a 2010 digital elevation model (DEM) based on LiDAR data kindly provided by the *Ministero*

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[10] We used ESRI's ArcGIS 10.5.1 and various analysis tools therein. All data are georeferenced to the European Datum 1950 UTM zone 33 North projected system.

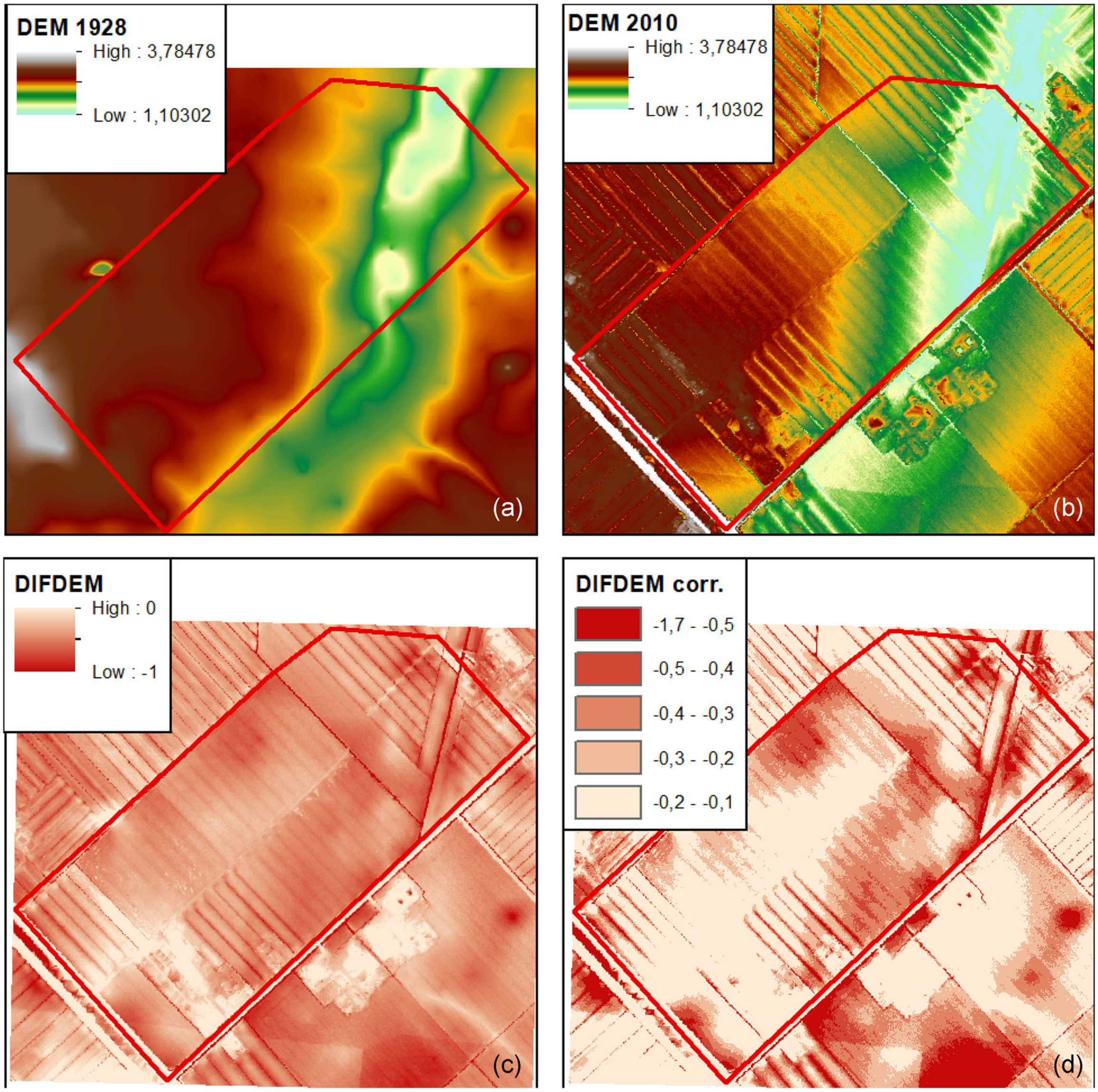

FIGURE 11 Reconstructing local relief change: Digital elevation models based on recent LiDAR data (a) and the 1928 map (b), and the uncalibrated (c) and calibrated (d) differences between these elevation models (in meters) [Color figure can be viewed at wileyonlinelibrary.com]

dell'Ambiente (1 × 1 m resolution). This DEM was used to reconstruct changes in microrelief in relation to the geological profiles obtained through coring. These changes were analysed by comparing this DEM with an elevation model interpolated from the elevation data of the aforementioned 1:5,000 1920s maps (Figure 11 top left and right).[11]

An initial comparison suggests quite substantial changes in elevation between 1928 and 2010, of between 0.5 and 1 m throughout the area. These differences can in part be explained by the interpolation method used to create the 1928 DEM (which may result in local deviations); it is also highly unlikely that the 1920s cartographers used the same vertical 0-point as was used in 2010, and hence the two DEMs need vertical calibration.

To this end, we compared the altitude of 100 random points in areas where subsidence is the least likely to have caused differences in altitude and where the values should, therefore, "match". As the Pleistocene Borgo Ermada deposits are not prone to subsidence (they are extremely dense clays, with low moisture content), locations where these lie at or very close to the current surface and where the terrain is level (thus excluding potential distortions caused by slope erosion) can be used to calibrate the two DEMs. After filtering out outliers in the points data set (points with a large difference probably caused by erosion or anthropogenic interference), there appears a clear linear relation with a high correlation ($R = 0.83$), which suggests there is a systematic difference in c. 20 cm between the points in the two DEMs. This may roughly be taken as the

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[11] This "historical" DEM was created by digitizing all 5-cm elevation contour lines and elevation points from the map and applying the topo-to-raster interpolation tool in ESRI ArcGIS.

systematic difference between the two elevation models caused by issues with the elevation data.

The lower right of Figure 10 shows a classified DIFDEM corrected for this systematic error. This DEM shows that the lower-lying northern part of the area is more affected by subsidence than the southern part. Particularly in those areas where peaty clayey deposits were encountered (e.g., around Profiles 2 and, especially, 3), differences in elevation range between c. 20 and 50 cm, whereas in most of the southern area (with Pleistocene clays close to or at the surface) the difference is in the order of only 10–20 cm. Thus, the comparison of DEMs seems to confirm that subsidence was much more influential in the northern "depression". What's more, it suggests that in Roman times, this depression must have been much less pronounced.

4 | THE INTEGRATED METHODOLOGY: SELECTED RESULTS

Having summarised briefly the outcomes of each approach used during the pilot study, in the following, we want to highlight the added value of integrating these different approaches in reconstructing rural landscapes. To this end, we focus on three topics that have general relevance for landscape archaeological field research: first, the interpretation of the surface record in light of landscape and environmental dynamics (Section 4.4.1); second, the reconstruction of what Bintliff, Howard, and Snodgrass (1999; Section 4.2) have called "Hidden Landscapes" and third, the reconstruction of what we may call the "texture" of the Roman landscape (Section 4.3). For each of these themes, we argue, our integrated approach holds great potential.

4.1 | Methodological implications: Archaeology and landscape

One area where our integrated methodology provides new insights concerns the relations between landscape and the archaeological record. As is well-known, the present-day landscape may provide a biased if not misleading context to understand past settlement and land use, most prominently because of processes of erosion and deposition. However, also in relatively stable landscapes such as that of the Pontine plain, changes may have profoundly affected relief, even at a highly localized scale. This, in turn, can affect the interpretation of the archaeological surface record.

This point is clearly illustrated by the results of our field surveys and coring in the northern part of the research area as well as the GIS modelling. In this area, site 14029 occupies a location that at first sight seems rather difficult to explain: it is situated in a depression, which in the 1930s, was still quite marshy. Such a location seems rather odd as a preferred site for human settlement. Our corings demonstrate that, whereas the site indeed lies on peaty and clayey sediments, such sediments are much more prone to subsidence than the surrounding Borgo Ermada level clays, as is confirmed by the comparison of elevation models discussed. This suggests that in Roman times, the depression in which site 14029 lies was surely less pronounced. Rather than in a depression, the site would have been situated on the edge of relatively well-drained soils—a rather favourable location within the local landscape.

4.2 | Survey intensity and hidden landscapes

Fieldwalking survey is excellently suited to map activity areas for periods with high levels of ceramic consumption and the use of durable construction materials, such as the Roman period. However, scholars have questioned the effectiveness of the method in mapping the more ephemeral traces of pre- and post-Roman activity (cf. Bintliff et al., 1999; Bintliff, Farinetti, Slapšak & Snodgrass, 2017; de Neef et al., 2017; van Leusen, Pizziolo, & Sarti, 2011), and this scepticism is further corroborated by the pilot study. During our regular and already quite intensive field surveys, protohistoric ceramics were only found in very small quantities, and their scattered distribution is quite difficult to interpret. Only during the extremely intensive (100% coverage) survey conducted as part of this pilot study did we manage to identify a (still very) slight but spatially more coherent scatter of such materials, which may indeed represent the vestiges of a Bronze Age site.

However, it is especially thanks to the combination of geophysical prospections, systematic coring and radiocarbon dating that we obtain a fuller view of the nature and scale of pre-Roman interferences in the landscape. Several of the small irregular anomalies mapped in the magnetometry (most notably cores 112–113, 115 and 117) reveal a stratigraphy with a stratum of pure *terra bruciata*, an intact ash-layer (again belonging to the Early Bronze Age Avellino eruption) and, below that, a thin layer of peat. A peat fragment from this lower stratum (from core 117) provides a radiocarbon date in the Early Bronze Age (between 1900 and 1700 BC; Table 4), which fits well with the identification of the ash that sits directly on top of it as belonging to the Early Bronze Age Avellino eruption. Even though the exact relation between the different deposits and the magnetic signals in the geophysical data remains uncertain, it seems likely that the *terra bruciata* causes strong positive magnetic signals. As such, the anomalies do appear to relate to anthropogenic features, possibly irregular-shaped pits dug into the Holocene grey clay fill of the depression (see Section 3.1) that apparently had begun to fill up by the Early Bronze Age (with the ash layer found providing a *terminus ante quem* for the digging of the pits).

Additional data for pre-Roman landscape modifications may, surprisingly, come from the system of ditches and canals commonly attributed to the early Roman period. Coring in Cluster 1, in one of the associated north–south-oriented linear anomalies, showed that AV-tephra was deposited in this ditch, thus providing an Early Bronze Age date for the ditch itself. Also, the radiocarbon date from charcoal in the fill of one of the minor ditches (core 104) provides a date of 1000–800 BCE. If this material is not secondary, it suggests a much more complicated picture for the development of the land division scheme than previously suggested. Though the entire scheme has been interpreted as a single project—with discussion focussing on the date of its establishment, either just before (related to the establishment of the *tribus Oefentina* in 318 BCE) or coeval with (or immediately after) the construction of the *Via Appia* (dated to 312 BCE)—it might have been a much more piecemeal project, that partly depended on the restructuring/connecting of water outlets (possibly connected to agricultural exploitation) of much more ancient origin, possibly going as far back as the Early Bronze Age. If this hypothesis proves correct (we plan additional coring and, possibly, test-trenching on these features), these traces constitute the earliest indications for anthropogenic landscape modification attested in the Pontine plain. They would have remained completely unknown if we had relied on surface evidence only.

4.3 | Beyond dots on the map—Mapping the texture of the landscape

As already alluded to, the surface survey has been relatively successful in reconstructing periods of relatively high ceramic consumption, and Roman landscapes: settlements of this period are not only well visible on the surface, but also particularly abundant. In fact, the Roman period is one of the few for which we can actually use the surface record to move "beyond dots on the map" and look more closely into the texture of landscape; or, in other words, to explore the interpretation of small sites and off-site distributions as reflections of past land-use practices (Bintliff & Snodgrass, 1988; de Haas, 2012; Witcher, 2006).

The highly intensive field survey methodology and collection strategy employed in the pilot study area (and in the wider Pontine plain—see de Haas & Tol (forthcoming); Tol, de Haas, & Attema, (forthcoming))—using 10 × 10-m grids with 40% coverage, generally supplemented by diagnostic sampling—allow for much more refined interpretations of small and simple scatters. All three documented sites can be securely dated to the Mid-Republican period, with only one of them—site 14027, situated on the *Via Appia*—continuing into the Late Republic and Early Imperial period. All three sites yielded domestic assemblages (consisting of tiles, cooking wares, transport amphorae, tablewares and—in the case of 14029—a loomweight) that invite interpretation as farmsteads. When relating surface and subsurface data for the pilot area, the situation becomes more complicated. At site 14029, only its southern margin was covered during the magnetometer survey, revealing scant structural evidence. The same is true for site 14027. At the location of site 14028, only a small round anomaly with negative amplitudes (core 103) was identified, which is very likely an anthropogenic fill. It seems reasonable to assume that the ceramics observed on the surface either derive from this fill or, alternatively, we might be dealing with the vestigial remains of a once larger archaeological site that has largely been obliterated by repeated ploughing with all related materials ending up in the plough layer. It thus seems that in this part of the Pontine plain deep ploughing has destroyed most of the structural remains originally associated with the sites mapped at the surface, and the archaeological materials associated with them ended up in the plough layer. Surviving traces predominantly seem to reflect features that were excavated deeper, such as (refuse) pits. Alternatively, it is entirely possible that we are not dealing with three individual farmsteads, but rather with only one or two, whereby the other concentrations of surface material simply relate to isolated points of refuse collection.

At the same time the systematic collection of off-site materials during the pilot study (and in fact in all our surveys in the wider Pontine plain) provides valuable information on Roman land-use strategies. In line with observations elsewhere the recorded sites have limited off-site scatters, suggestive of the absence of intensive market-oriented production.

The integration with data from the geophysical survey and the coring provides a much fuller view of the wider context into which these surface materials must be placed. A good example is the centuriation: magnetometry managed to pick up the remnants of one of its main canals, as well as a series of smaller side-channels that run perpendicular to it. These canals are invisible on the surface but must have constituted important elements in the lived landscape of the local inhabitants in delimitating space, improving agricultural land and providing access to water.

Furthermore, the samples collected during coring in the fills of these canals show great potential for the reconstruction of the landscape and vegetation setting and provide valuable clues on ancient agricultural practices.

5 | DISCUSSION AND FURTHER WORK

Having highlighted three issues, to which our integrated approach provides valuable new insights, we should also acknowledge the limitations of our pilot research: because it was conducted at one specific moment in time, not all methods could be applied over the entire area: it was not possible to survey unploughed areas because of insufficient visibility conditions; conversely, several deep-ploughed fields were ill-suited to geophysical prospection. Also, because of time and financial restraints we were not able to conduct corings in all archaeologically relevant features or to analyse all samples we collected. Additionally, even though a wide suite of methods has been applied during this pilot, yet others might complement our results (e.g., additional geophysical methods such as resistivity or GPR might disclose additional subsurface features). Also, in terms of scale, our pilot study is limited: because of the small size of the research area the outcomes have limited value for an overall understanding of developments in settlement and land use in the Pontine plain as a whole and will need future testing over additional (larger) areas.

Despite these limitations, as a methodological exercise, we consider the pilot study as highly successful. The results indeed illustrate the complementarity of the different methodologies, and hence, the added value of this integrated approach with respect to more traditional approaches prevalent in archaeological survey. At the same time, they expose several methodological issues in applying surface and subsurface investigations separately.

An important result is a further confirmation that differential retrieval rates of archaeological evidence between historical periods are very much real. The application of a standard partial spatial coverage and sampling procedure for the initial survey of this area in 2013, failed to map the extensive evidence for pre- and protohistoric, as well as post-Medieval activity in the area, which was only revealed by adopting full-coverage surface investigations. This means it is likely that the extensive field surveys carried out over the last decade by the Pontine Region Project in the lower Pontine plain surveys—that used commonly applied surface survey protocols—are likely to underrepresent pre- and post-Roman (Republican and Imperial) occupation. Apparently, commonly applied methods in the surface survey have considerable difficulty in charting evidence for other historical periods that had a smaller material footprint, constructed in less durable materials or adopted a less "localized" lifestyle.

At the same time, the large-scale geophysical prospections revealed the presence of abundant subsurface features in the study area that apparently did not produce a material surface correlate. Reasons for this might vary: for example, the mapped prehistoric pits did not produce a recognizable material footprint (if present on the surface small lumps of charcoal and *terra bruciata* would certainly have escaped our attention) or some of them might be too deeply buried, lying beyond the reach of the plough. In any case, the results of the magnetometry are a strong reminder that the anthropogenic footprint in this landscape (and probably in most ancient landscapes) stretches far beyond that what is visible on the surface, both in extent and in chronology. It also reminds us that the information that can be surmised based on surface investigations (including both surface survey and the study of ancient aerial photos), and the interpretation schemes that we adopt to classify them, are simplifications of reality. This is most clearly illustrated by the land division scheme mapped in the geophysical data. Coring confirmed that the anomalies tentatively related to the Roman land division system indeed represent canals containing relatively recent upper fills, but—based on stratigraphy and radiocarbon dates—preserving lower fills that might be of more ancient origin, suggesting that at least part of these drainage works have a deeper and much more complex history.

In sum, we have successfully integrated soil science, surface survey and geophysics to provide a fuller picture of past human activity than would have been possible based on any of these methods by itself, providing additional insight into the structure, dating and development of human engagements with the landscape. We have demonstrated that the human impact on the local landscape is much more profound, complex and dynamic than could be surmised based on surface observations alone—and can only be disentangled through an integrated approach such as the one adopted here.

When looking towards the future, several caveats are in order, mainly associated with the cost-benefit ratio of the work discussed. First, the applied combined methodology is rather costly and covering larger study areas completely will be beyond the means of many archaeological projects. We do feel, however, that a sampling approach of similar small-scale intensive research applied to the different landscape units and topographical locations (e.g., close to and away from main rivers and roads) that make up a larger region would complement the results of more extensive work by identifying possible biases in period distribution based on surface investigations alone, by exposing a fuller range of human-induced features in the landscape, and by procuring information on the landscape setting and agricultural strategies of past populations.

Second, despite the insights obtained still many questions remain for which additional similar work—and ultimately invasive approaches such as test-trenches—are needed (Verhagen, 2013). For example, further sampling of the possibly Early Bronze Age pits is needed to build up a robust set of dates; additional sampling on the centuriation is necessary to assess whether the few dates now available represent anomalies or are part of a consistent pattern, whereas additional corings (and test trenches) may provide a broader foundation for palaeoenvironmental reconstructions.

Notwithstanding these issues, the discussed pilot study has already resulted in substantial follow-up efforts.[12] The authors have extended their collaboration to:

1. Extend the pilot study towards other parts of the Pontine plain with different landscape characteristics and locational attributes to get a further grip on the historical relationship between man and environment in the Pontine plain;
2. Develop further work on the centuriation to establish its chronology and development, as well as its relationship with the surface archaeological record. To this end, we will adopt a combination of remote sensing (study of aerial photos and localized geophysical surveys) and small-scale excavation to retrieve both palaeobotanical evidence and samples for radiocarbon dating;
3. Work on a set of three-dimensional models (for different time periods) as an attempt to reconstruct and digitally preserve ancient rural landscapes. We plan to incorporate these into local initiatives to promote local archaeological heritage.

In conclusion, we feel that after years of (macro-scale) work in the Pontine plain, with the transition towards the selective adoption of microscale work such as that presented in this article, we have taken a significant step towards a better understanding of the dynamic history of man–environment relationships in the Pontine plain.

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[12] The findings for the prehistorical and protohistorical period have already been taken up by the Avellino Event Project, a research effort by the University of Groningen and the University of Leiden that aims to assess the geoarchaeological evidence for a northward migration brought about by the Early Bronze Age Avellino eruption.

cultivation in Northwestern Europe's coastal salt marshes, 600 BC to AD 800" (project number 275-61-005).

AUTHOR CONTRIBUTIONS

G. T and T. D. H. designed the research. Surveys were carried out by G. T. and T. D. H.; J. S. and T. D. H. carried out the coring; B. U. and W. D. N. executed the geophysical prospections and M. S. carried out botanical analyses, while T. D. H. conducted spatial analyses (cartography, subsidence modelling and coring profiles).

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REFERENCES

Alcock, S., & Cherry, J. (2004). Side by side survey, *Comparative regional studies in the Mediterranean world*. Oxford, UK: Oxbow Books.

Alcock, S. E., Cherry, J. F., & Davis, J. L. (1994). Intensive survey, agricultural practise and the classical landscape in Greece. In I.Morris (Ed.), *Classical Greece. Ancient histories and modern archaeologies* (pp. 137–170). Cambridge, UK: Cambridge University Press.

Alessandri, L. (2013). Latium Vetus in the Bronze Age and Early Iron Age *(BAR International Series 2565)*. Oxford, UK: Archeo Press.

Attema, P. (1993). *An archaeological survey in the Pontine Region. A contribution to the settlement history of south Lazio 900–100 BC* (PhD thesis), Rijksuniversiteit Groningen, Groningen, the Netherlands.

Attema, P. A. J. (2017). Landscape archaeology in Italy: Past questions, current state and future directions. In T.de Haas & G. Tol (Eds.), The economic integration of Roman Italy. Rural communities in a globalizing world *(Mnemosyne Supplements History and Archaeology of Classical Antiquity 404)* (pp. 426–435). Leiden/Boston: Brill.

Attema, P., Burgers, G.-J., & vanLeusen, M. (2010). *Regional pathways to complexity, settlement and land-use dynamics in early Italy from the Bronze Age to the Republican Period*. Amsterdam, the Netherlands: Amsterdam University Press.

Attema, P., deHaas, T., & Tol, G. (2011). *Between Satricum and Antium:* Settlement dynamics in a coastal landscape in Latium Vetus (*Babesch Supplements 18)*. Leuven, Belgium: Peeters.

Bakels, C., Sevink, J., Kuijper, W., & Kamermans, H. (2015). The Agro Pontino region, refuge after the Early Bronze Age Avellino eruption of Mount Vesuvius. *Italy? Analecta Preahistorica Leidensia*, *45*, 55–68.

Beug, H. J. (2004). *Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete*. München, Germany: Pfeil.

Bintliff, J., & Snodgrass, A. (1988). Off-site pottery distributions: A regional and interregional perspective. *Current Anthropology*, *29*(3), 506–513.

Bintliff, J., Howard, P., & Snodgrass, A. (1999). The hidden landscape of prehistoric Greece. *Journal of Mediterranean Archaeology*, *12*(2), 139–168.

Bintliff, J., Farinetti, E., Slapšak, B., & Snodgrass, A. (2017). *Boeotia Project, Volume II: The city of Thespiai. Survey at a complex urban site*. McDonald Institute Monographs, University of Cambridge, Cambridge, UK.

Bronk Ramsey, C.2017. OxCal Program, Version 4.3.

Campana, S. (2009). Archaeological site detection and mapping: Some thoughts on differing scales of detail and archaeological 'non-visibility'. In S.Campana & S. Piro (Eds.), *Seeing the unseen. Geophysics and landscape archaeology* (pp. 5–26). Boca Raton/London/New York/Leiden: Taylor and Francis.

Campana, S. (2017). Emptyscapes: Filling an 'empty' Mediterranean landscape at *Rusellae*, Italy. *Antiquity*, *91*(359), 1223–1240.

Cancellieri, M. (1985). Pianura Pontina. In R.Bussi & V. Vandelli (Eds.), *Misurare la terra: centuriazione e coloni nel mondo romano. Città, agricoltura, commercio: materiali da Roma e dal suburbio* (pp. 44–48). Modena, Italy: Panini.

Cancellieri, M. (1990). Il territorio Pontino e la Via Appia. *Archeologia Laziale*, *X*, 61–72.

Cappers, R. T. J., Bekker, R. M., & Jans, J. E. A. (2006). *Digitale zadenatlas van Nederland*. Eelde/Groningen, the Netherlands: Barkhuis Publishing/University of Groningen.

Caraher, W. R., Nakassis, D., & Pettegrew, D. K. (2006). Siteless survey and intensive data collection in an artefact-rich environment: Case studies from the Eastern Corinthia, Greece. *Journal of Mediterranean Archaeology*, *19.1*, 7–43.

Cassieri, N., vanLeusen, M., Feiken, H., Anastasia, C., & Tol, G. (2011). Ricerche geoarcheologiche nell'area di Tratturo Caniò (Sezze, Latina). *Lazio e Sabina*, *9*, 393–398.

Coarelli, F. (2005). Un santuario medio-repubblicano a Posta di Mesa. In W. V.Harris & E. Lo Cascio (Eds.), *Noctes Campanae. Studi di storia antica ed archeologia dell'Italia preromana e romana in memoria di Martin W. Frederiksen* (pp. 181–190). Napoli, Italy: Luciano Editore.

Dee, M. W., Palstra, S. W. L., Aerts-Bijma, A. T., Bleeker, M. O., deBruijn, S., Ghebru, F., … P., & Meijer, H. A. J. (2020). Radiocarbon dating at Groningen: New and updated chemical pretreatment procedures. *Radiocarbon*, *62*(1), 63–74.

de Haas, T. (2011). *Fields, farms and colonists: intensive field survey and early Roman colonization in the Pontine region, central Italy*. Eelde/Groningen, the Netherlands: Barkhuis Publishing/University of Groningen.

de Haas, T. (2012). Beyond dots on the map: Intensive survey data and the interpretation of small sites and off-site distributions. In P. Attema & G. Schoerner (Eds.), *Comparative issues in the archaeology of the Roman rural landscape. Site classification between survey, excavation and historical categories*. Journal of Roman Archaeology supplementary series 88 (pp. 55–79). Portsmouth, RI: Journal of Roman Archaeology.

de Haas, T. (2017). Managing the marshes: An integrated study of the centuriated landscape of the Pontine plain. *Journal of Archaeological Science: Reports*, *15*, 470–481.

de Haas, T., & Tol, G. (forthcoming). The analytical potential of intensive field survey data: Developments in the collection, analysis and interpretation of surface ceramics within the Pontine Region project. In: M. Nazou, A. Meens & W. van de Put (Eds.), Fields, Sherds and Scholars. Recording and Interpreting Survey Ceramics.

de Neef, W., Armstrong, K., & van Leusen, M. (2017). Putting the spotlight on small protohistoric pottery scatters in Northern Calabria (Italy). *Journal of Field Archaeology*, *42.4*, 283–297.

Faegri, K., & Iversen, J. (1989). *Textbook of pollen analysis* (4th ed.). Chichester, UK: Wiley.

Feiken, H. (2014). *Dealing with biases: Three geo-archaeological approaches to the hidden landscapes of Italy*. Eelde/Groningen, the Netherlands: Barkhuis Publishing/University of Groningen.

Feiken, H., Tol, G. W., & vanLeusen, P. M. (2012). Reconstructing a Bronze Age hidden landscape: Geoarchaeological research at Tratturo Caniò (Italy, 2009). *Palaeohistoria*, *53/54*, 109–159.

Forni, B. (1981). Dalla ignicoltura cerealicola del prossimo oriente alla genesi dell'aratrocoltura in Italia: Suo significato, struttura, conseguenze culturali. *Rivista di storia dell'agricoltura*, *1*, 183–236.

Hofmann, M. (1956). Pomptinae Paludes, *Paulys Realencyclopädie der classischen Altertumswissenschaft Suppl. VIII* (pp. 1135–1183). Stuttgart, Germany: J.B. Metzlersche Buchhandlung.

Horden, P., & Purcell, N. (2000). *The corrupting sea: A study of Mediterranean history*. Malden, MA: Wiley–Blackwell.

Jacomet, S. (2006). *Identification of cereal remains from archaeological sites* (2nd ed.). Basel, Switzerland: IPAS.

Jahn, R., Blume, H. P., Asio, V. B., Spaargaren, O., & Schad, P. (2006). *Guidelines for soil description*. Rome, Italy: FAO.

La Rosa, M., deHaas, T. C. A., & Tol, G. W. (2016). Prehistoric occupation of the lower Pontine plain (Lazio, Central Italy): The evidence from recent field surveys. *Palaeohistoria*, *57/58*, 21–35.

Linoli, A. (2005). Twenty-six centuries of reclamation & agricultural improvement on the Pontine marshes. In C.Ohlig (Ed.), *Integrated land and water resources management in history* (pp. 27–55). Siegburg, Germany: BoD.

Meyer, C., Kniess, R., & Goosens, L. (2012). Magnetic prospection at Illa d'en Reixac: Working with buried remains at Ullastret (Catalonia), *Proceedings of the 1st MAC International Workshop of Archaeological Geophysics* (pp. 59–62). Ullastret, Spain: Museu d'Arqueologia de Catalunya.

Millett, M. (1991). Pottery: Population or supply patterns? The Ager Tarraconensis approach. In G.Barker & J. Lloyd (Eds.), *Roman Landscapes: Archaeological survey in the Mediterranean region* (pp. 18–26). Rome, Italy: British School at Rome.

Neef, R., Cappers, R. T. J., & Bekker, R. M. (2012). *Digital atlas of economic plants in archaeology*. Eelde/Groningen, the Netherlands: Barkhuis Publishing/University of Groningen.

Potter, T. W. (1979). *The changing landscape of South Etruria*. London, UK: Paul Elek.

Powlesland, D. (2009). Why bother? Large scale geomagnetic survey and the quest for "Real Archaeology". In S.Campana & S. Piro (Eds.), *Seeing the unseen. Geophysics and landscape archaeology* (pp. 167–182). Boca Raton/London/New York/Leiden: Taylor and Francis.

Sevink, J. (2020). Burnt clay or terra bruciata in coastal basins of Southern Lazio, Italy: Evidence for prehistoric ignicoltura or resulting from drainage of Holocene pyritic sediments?*Journal of Archaeological Science: Reports*.*32*, 1–11.

Sevink, J., Bakels, C. C., vanHall, R., & Dee, M. W. (2020). Radiocarbon dating distal tephra from the Early Bronze Age Avellino eruption (EU 5) in the coastal basins of southern Lazio (Italy): Uncertainties, results, and implications for dating distal tephra. *Quaternary Geochronology*.

Sevink, J., Bergen, M. J., van, Plicht, J., vander, Feiken, H., Anastasia, C., & Huizinga, A. (2011). Robust date for the Bronze Age Avellino eruption (Somma-Vesuvius): 3945 +/-10 calBP (1995 +/- 10 calBC). *Quaternary Science Reviews*, *30*(9–10), 1035–1046.

Sevink, J., di Vito, M. A., Piochi, M., Mormone, A., Bakels, C. C., & vanGorp, W. (2018). A rare Mid-Würmian lithoid tuff in the Agro Pontino graben (Southern Lazio, Italy) and its identification as an Albano 5–7 related distal tephra deposit (41–36 kaBP): Characteristics, provenance and paleogeographical implications. *Annals of Geophysics*, *61*(1), S109. https://doi.org/10.4401/ag-7574

Sevink, J., Duivenvoorden, J., & Kamermans, H. (1992). The soils of the Agro Pontino. In A.Voorrips, S. H. Loving & H. Kamermans (Eds.), The Agro Pontino Survey Project: Methods and preliminary results *(Studies in Prae- en Protohistorie 6)* (pp. 31–51). Amsterdam, the Netherlands: Universiteit van Amsterdam.

Sevink, J., Remmelzwaal, A., & Spaargaren, O. C. (1984). The soils of Southern Lazio and adjacent Campania. *Publication of the Fysisch Geografisch en Bodemkundig Laboratorium (Universiteit van Amsterdam)*, *38*, 140.

Sevink, J., van derPlicht, J., Feiken, H., van Leusen, P. M., & Bakels, C. C. (2013). The Holocene of the Agro Pontino graben: Recent advances in its palaeogeography, palaeoecology, and tephrostratigraphy. *Quaternary International*, *303*, 153–162.

Sevink, J., vanGorp, W., di Vito, M., & Arienzo, I. (2020). Distal tephra from Campanian eruptions in early Late Holocene fills of the Agro Pontino graben and Fondi Basin (Southern Lazio, Italy): Implications for tephrostratigraphic records from central Mediterranean sediment archives. *Journal of Volcanology and Geothermal Research*.

Sevink, J., Vos, P., Westerhoff, W. E., Stierman, A., & Kamermans, H. (1982). A sequence of marine terraces near Latina (Agro Pontino, Central Italy). *Catena*, *9*, 361–378.

Snodgrass, A. M. (1994). Response: The archaeological aspect. In I. Morris (Ed.), *Classical Greece: Ancient histories and modern archaeologies* (pp. 197–200). Cambridge, UK: Cambridge University Press.

Tol, G. (2012). *A fragmented history. A methodological and artefactual approach to the study of ancient settlement in the territories of Satricum and Antium*. Eelde/Groningen, the Netherlands: Barkhuis Publishing/University of Groningen.

Tol, G., & deHaas, T. (2016). The role of minor centres in regional economies: New insights from recent archaeological fieldwork in the lower Pontine plain. *The Amphora*, *44*, (2), 33–61.

Tol, G., deHaas, T., Armstrong, K., & Attema, P. (2014). Minor centres in the Pontine plain: The cases of Forum Appii and Ad Medias. *Papers of the British School at Rome*, *82*, 109–134.

Tol, G., deHaas, T., & Attema, P. (forthcoming). Between urban and rural: the role of minor centres in the economies of Roman Italy. Barkhuis Publishing/University of Groningen, Eelde/Groningen, the Netherlands.

Ullrich, B., Kaufmann, G., Kniess, R., Zoellner, H., Meyer, M., & Keller, L. (2011). Geophysical prospection in the Southern Harz Mountains, Germany: Settlement history and landscape archaeology along the interface of the Latène and Przeworsk cultures. *Archaeological Prospection*, *18.2*, 95–104.

van Gorp, W., & Sevink, J. (2019). Distal deposits of the Avellino eruption as a marker for the detailed reconstruction of the Early Bronze Age depositional environment in the Agro Pontino and Fondi Basin (Lazio, Italy). *Quaternary International*, *499*(B), 245–257.

van Gorp, W., Sevink, J., & van Leusen, M. (2020). The role of subsidence in Early Bronze Age lake and sea level reconstruction in the Agro Pontino (Lazio, Italy) over the last 4ka using the Avellino tephra marker bed. *Catena*.

van Leusen, M., Pizziolo, G. & Sarti, L. (Eds.), 2011). Hidden landscapes of Mediterranean Europe: Cultural and methodological biases in pre- and protohistoric landscape studies, *Proceedings of the international meeting, Siena, Italy*. BAR International Series 2320 Oxford, UK: Archeo Press.

Verhagen, P. (2013). Chapter 12: Site discovery and evaluation through minimal interventions: core sampling, test pits and trial trenches. In C. Corsi, B. Slapšak & F. Vermeulen (Eds.), *Good practice in archaeological diagnostics: Non-invasive survey of complex archaeological sites* (pp. 209–26). Cham, Switzerland: Springer.

Walsh, K. (2014). The archaeology of Mediterranean landscapes, *Human-Environment Interaction from the Neolithic to the Roman Period*. Cambridge, UK: Cambridge University Press.

Walsh, K., Attema, P., & deHaas, T. (2014). The Pontine marshes (Central Italy): A case study in wetland historical ecology. *BaBesch*, *89*, 27–46.

Wilkinson, T. J. (1989). Extensive sherd scatters and land-use intensity: Some recent results. *Journal of Field Archaeology*, *16.1*, 31–46.

Witcher, R. E. (2006). Broken pots and meaningless dots? Surveying the rural landscapes of Roman Italy. *Papers of the British School at Rome*, *74*, 39–72.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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