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Integrated Approaches to Understanding Complex Long-Term Reclamation Processes in the Hinterland of Ravenna (Italy)

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Integrated Approaches to Understanding Complex Long-Term Reclamation Processes in the Hinterland of Ravenna (Italy)

Michele Abballe, Marco Cavalazzi and Celeste Fiorotto

ABSTRACT
In this paper, we aim to present the results of interdisciplinary research focusing on the surroundings of Lugo, a town in the hinterland of Ravenna. The area is known for the extraordinary preservation of the centuriated field system, although its 'Roman' origin has been rightly questioned in the last three decades. Our data show how this seemingly homogenous area has a complex history due to intense alluvial events. If artefact surveys have been helpful in studying the main trends in the evolution of settlement patterns, only a systematic geoarchaeological investigation has allowed us to better understand the physical transformations occurring in the landscape, their potential effect on the settlement suitability of the area, and the mechanisms that led to the complete reclamation of a former wetland known as Orizzonte Veggiani. About the latter, archaeobotanical analysis of seeds, fruits, and charcoal starts to help us understand its land use/land cover.

KEYWORDS
Landscape archaeology; geoarchaeology; archaeobotany; remote sensing; wetland; centuriation; reclamation; Middle Ages

Introduction

The landscape archaeological analysis of alluvial floodplains presents several limits, especially because of geomorphological biases connected to subsidence and alluvial phenomena. The interest in bias effects started in the 1960s (e.g. Phillips, Ford, and Griffin 2003; Vascelius 1960; Binford 1964) and reached its acme in the middle of the 1980s when the post-processual critique started (Banning 2021). After this period, American landscape archaeology chose a different path from the European one, with the former preferring a full-coverage approach with a low level of intensity, while the latter continued adopting a high level of intensity in small areas (Opitz et al. 2015; Alcock and Cherry 2016). Anyway, archaeologists preferred to adopt statistical corrections to biases, while interdisciplinary approaches are still rare, particularly in 'difficult landscapes', such as the clay ones (Mills 2007, 132–134; Banning 2021, 5).

The impact of the geomorphological biases on archaeological research/knowledge reaches its acme in alluvial floodplains with a high rate of vertical growth due to river

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deposition (Brown 1997, 1–5). In these contexts, only an integrated approach that includes several disciplines and methodologies, such as geoarchaeology, artefacts survey, geophysics, archaeobotany, remote sensing and so on, can limit the impact of this kind of bias (Denham and Grono 2017).

This paper aims to present the results of interdisciplinary research focusing on the surrounding area of the town of Lugo, in the hinterland of Ravenna, northern Italy. From the historical point of view, the main goal of this investigation was to better define the interaction of the anthropogenic and environmental factors in a lowland/wetland after the crisis of the Roman Age (3rd-4th centuries CE) until the beginning of the medieval land reclamation process (13th-14th centuries CE). In addition, from the methodological point of view, we wanted to test an integrated approach combining archaeology, geoarchaeology, and archaeobotany to investigate such a complex geomorphological context. Indeed, while applying geoarchaeological and archaeobotanical approaches together is more and more frequent (e.g. limiting to the nearest cases to the area investigated: Guarnieri 2019; Rucco et al. 2019), more complex investigations, which also include artefact surveys or extensive off-site geophysics are still rare. Despite the difficulties of carrying out an artefact survey in a deeply buried alluvial context, this research method can effectively complete the geoarchaeological and archaeobotanical data, and vice versa.

To reach these objectives, we started a systematic artefact survey in 2009, analysing the lowland of the Ravenna hinterland (northern Italy), one of the main urban centres of the Roman and Byzantine Empire. Previous research, based on the analysis of written sources, already showed how this area was characterised by a medieval land reclamation process, but systematic archaeological investigations were still missing. The impact of the alluvial activities of the Apennine rivers is very relevant here because of their torrential regime, which caused sudden and impactful floods. The Roman sites are sometimes buried up to 10 metres deep (Franceschelli and Marabini 2007, 76–93), but we have been able to detect areas where Late Antique and Medieval sites were outcropping on the surface. To deepen our knowledge, we started several ancillary research activities in 2018, includ- ing geoarchaeological and archaeobotanical analyses.

In this paper, after introducing the study context from the geomorphological and archaeological point of view, we will present the research methods and the main results they led to. These data will allow us to discuss several related themes, ranging from the physical transformations of this alluvial landscape and how these influenced our archaeological knowledge, how the landscape looked in the past, especially the wetland contexts, and how and when the processes that led to the reclamation of these depressed areas took place. This new knowledge confirms that only integrated approaches can help us shed light on such changing and complex landscapes.

Background

Geomorphological Context

The plain south of Lugo is located around 20 km western of Ravenna and bordered by the Santerno and Senio rivers, lying at an altitude between 25 and 10 m asl (Figure 1). Like other parts of the Po Valley, this plain experienced intense geomorphological transformations also in historical times, due to a combination of river sedimentation, subsidence, and anthropogenic interference. In fact, the local geological maps classify the whole study area within the Modena Unit (AES8a), which developed after the 6th century CE (Severi and Cremonini 2009; Cibin 2014). This classification suggests that the Roman palaeosurface is buried everywhere, but new data can undoubtedly shed light on differences existing on a more local scale. At the same time, the effects of the anthropogenic impact on the landscape can be recognised in the hundreds of square km of wetlands reclaimed and hundreds of km of river beds rectified across the Romagna plain. Historical cartography and written sources allow us to follow these changes quite well from the Modern Age onwards, as first studied by Lucio Gambi (1949). However, this is hugely more difficult for previous periods, with many open ques- tions (Abballe 2021a). For instance, petrographic studies opened the possibility that the Lamone river was flowing in the area of Lugo during the Neolithic (Cremonini and Bassetti 2019), contrary to what happens now. Still according to petrographic studies, the river Santerno may have joined the Senio already in Roman times (Marconi et al. 2008), while the written sources attest to this only around the 11th-12th centuries CE (Fran- ceschelli and Marabini 2007).

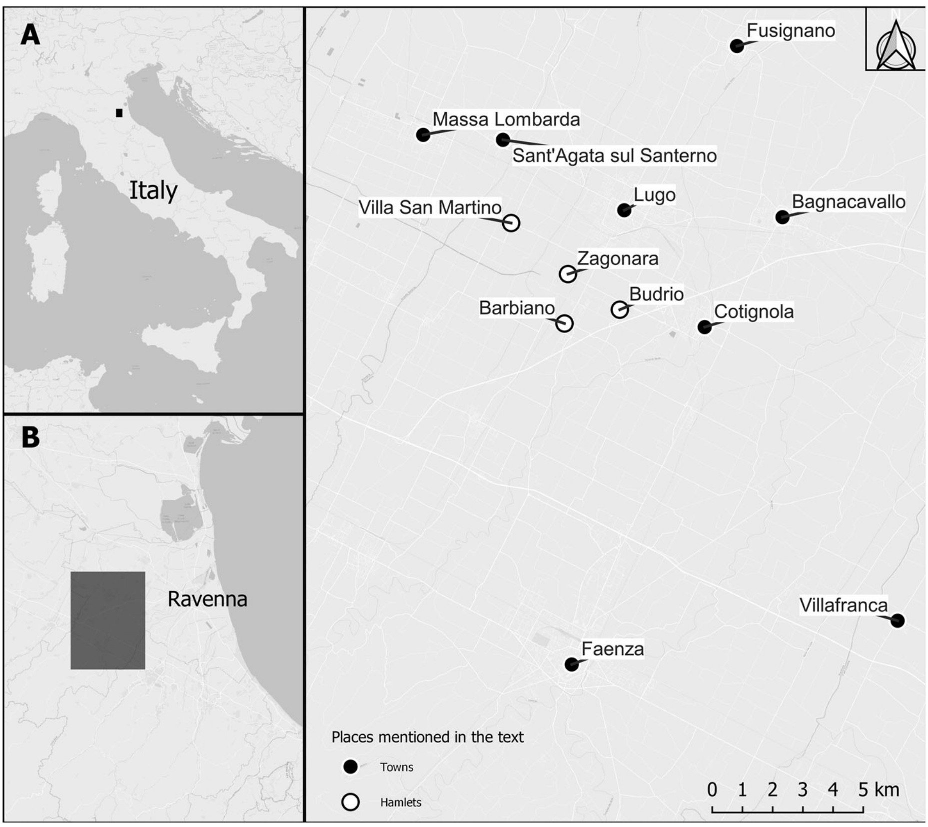

Figure 1. Map of the study area with locations mentioned in the text and positioning within Ravenna hinterland (B) and the Italian Peninsula (A) in Southern Europe (Esri basemap, Copyright © Esri).

Despite these uncertainties, geomorphological studies have successfully identified several palaeo fluvial ridges, surrounded by post-Roman floodplain deposits (Figure 2). The presence of these ridges provides evidence for possible changes in the hydrological network in the past (Cremonini 1994; Franceschelli and Marabini 2007; Abballe and Cavalazzi 2021). These ridges were, and sometimes still are, characterised by a slightly higher altitude (around 2 metres), while their surroundings can become naturally prone to water stagnation due to their lower position. These natural mechanisms, and the lack of hydraulic control over the territory, should have been the basis for the formation of the so-called Orizzonte Veggiani (OV). These geological deposits were discovered in the area of Lugo already in the second half of the twentieth century, above deeply buried Roman villas, and according to known radiocarbon dates, should have developed between the 6th (Franceschelli and Marabini 2007, 103) and the 11th-12th centuries CE (Marabini and Vai 2020, 71). This layer seems to have formed in water-saturated conditions, as it may happen in a poorly drained floodplain or marshland, likely covered by woodlands, as the medieval sources suggest (Pasquali 1993; Cavalazzi 2017; Fiorotto 2018, 2021).

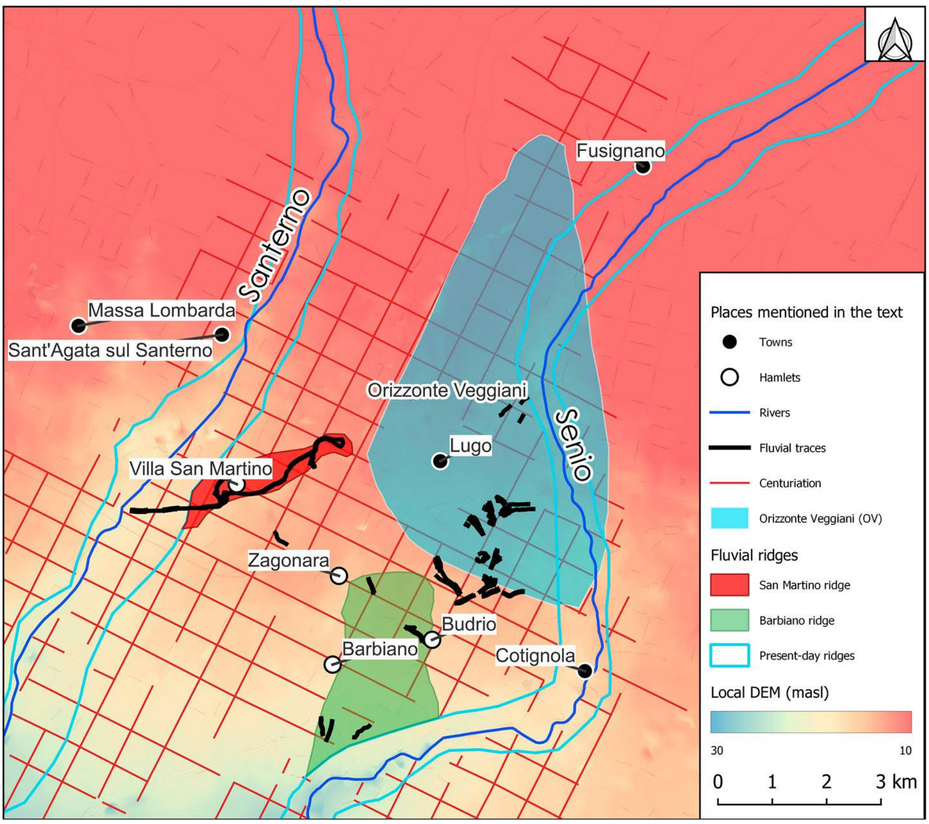

Figure 2. Study area with main rivers, remains of the 'centuriation', main geomorphological elements, including the extension of the Orizzonte Veggiani as reconstructed by Franceschelli and Marabini 2007 and main ridges reassessed through morphometric algorithms according to Abballe and Cavalazzi 2021, and fluvial traces mapped by remote sensing (sources used are listed in Table 2). Local DEM shown as basemap was produced by the author interpolating manually recorded elevation points (for methodology see Abballe and Cavalazzi 2021).

Historical and Archaeological Context

Archaeologists neglected the northwestern portion of the Ravenna hinterland until recently. Only towards the end of the twentieth century, some local scholars started to catalogue the many casual discoveries of the previous decades (Cani 1980; Tamburini and Cani 1991). After this, more rigorous archaeological research was promoted in Lugo, like the excavations in the medieval urban fortress, the Rocca Estense (Gelichi 1991), and in the neolithic village at Fornace Gattelli (Staffè and Degasperi 2019). However, only from the 2000s, archaeological research was carried out on larger scales (Franceschelli and Marabini 2007; Augenti, Ficara, and Ravaioli 2012). Although without a diachronic approach, these investigations systematised part of the known data. For example, Franceschelli and Marabini (2007) gave the first complete reconstruc- tion of the geomorphological evolution of the area from the Roman period to the Middle Ages, focusing in particular on the Roman settlement pattern in the area, which seems to have been mainly dispersed and devoted to the agricultural exploitation of the countryside.

Still, due to archaeological data's scarcity and their fragmentary nature, many questions remained unanswered, like which kind of local processes produced the centuration we see today on the surface, that in most parts of the investigated area is not strictly 'Roman' (Franceschelli and Marabini 2007). So, it is still not clear which sectors of the centuriation are the result of a continuous process of vertical transmission since the Roman period and where and when it was simply traced again, through a process of lateral and horizontal transmission (Chouquer 2015).

Another unclear topic is the settlement's evolution after the end of the Roman period (Augenti et al. 2005; Franceschelli and Marabini 2007). That is, if a sparse settlement pattern, composed of rural villas and farms, continued into the Modern Age (Andreolli and Montanari 1983; Castagnetti 1982) or if mixed patterns emerged, with both sparse and nucleated settlements like in Cesena (Negrelli 2008) or south of Ravenna (Mancassola 2008).

In particular, it was hard to conciliate the idea that the sparse settlement pattern could have continued thanks to political stability assured by the role of Ravenna in Late Antiquity, while archaeology showed that most of the Roman villas were abandoned. Specifically, this may have happened in different moments, but especially during the 3rd or 7th centuries CE (Franceschelli and Marabini 2007). Furthermore, it was also difficult to reconcile this hypothesis with the numerous attestations of nucleated sites (fortified and unfortified villages) appearing in the written sources from the eleventh century onwards (Augenti, Ficara, and Ravaioli 2012).

Methods, Materials and Summary of Results

Archaeological Field Survey

The first results that we are going to discuss have been collected by surface artefact surveys, promoted by the 'Bassa Romandiola' project. This landscape archaeology project was started in 2009 by the University of Bologna with the aim of understanding the medieval landscape and how local communities interact with it. The artefact survey was systematic and any find was collected and its position recorded with a handheld

GPS. In this phase, the intensity of the research was defined through the distance between the archaeologists, equal to 10 metres. In the case of artefacts concentrations, the intensity arose to 1 m, and any find of the potential site was collected.

The sampling strategy was defined according to the preliminary review of the previously known data and applying what we can define as a systematic disproportional stratified strategy (Orton 2000, 30; Banning 2020). We defined several strata in the analysed area according to their historical, geomorphological, and archaeological characteristics, and then we applied a different sampling fraction to each stratum (Cavalazzi 2021a). This adapted strategy was essential to combine the resources at disposal with the aims of the research and, at the same time, to overcome the relevant geomorphological variability of this area. For example, we excluded from the sample all the areas that, according to known data, were marshes until the Modern period.

In five campaigns, approximately 15% of the Bassa Romagna territory has been surveyed (around 78 sq km), detecting 73 artefact concentrations (Table 1), dating from the 5th to the 18th centuries CE (Cavalazzi et al. 2018; Cavalazzi and Mancassola 2021; Cavalazzi 2022). Despite the often thick alluvial cover, we have been able to detect several medieval sites (Figure 3) since they were located within 'geomorphological windows', portions of fluvial ridges not buried by later alluvial events but whose higher elevation may no longer be recognisable due to the alluvial sediments deposited around them (Cavalazzi 2021a).

We can highlight some main characteristics of the dataset collected:

i) The oldest human presence seems to date to the 5th CE, likely reoccupying, through sparse houses and farms, areas where alluvial events may have covered the Roman palaeolandscape (Cavalazzi et al. 2018; Abballe and Cavalazzi 2022).
ii) The number of the sites grew between the 8th-10th centuries CE (Figure 4), namely the Carolingian and Ottonian periods, sometimes in continuity with preexisting sites (Cavalazzi et al. 2018). This growth occurred according to two main trends: a dispersed site pattern, as recorded in the area of Zagonara (Figure 4.A), and a nucleated pattern, as recorded in the area of Bagnacavallo (Figure 4.B).
iii) All rural sites, both sparse and clustered, were abandoned by the thirteenth century CE, likely due to a general reorganisation of the settlement patterns. This transformation was promoted by the territorial policies of the urban communes such as

Table 1. Archaeological sites detected during the field survey project 'Bassa Romandiola' between 2009–2018 (Cavalazzi et al. 2018; Abballe and Cavalazzi 2022).

Site typology	General Chronology	Total Number
Castle	11th/13th-15th CE	5
Church	11th-15th CE	4
Early medieval-High Medieval house	8th-12th CE	22
Late Antique-High Medieval house	5th-12th CE	7
Late Antique house	5th-7th CE	1
Late Medieval-Modern Age farmhouse	14th-18th CE	8
Late Medieval-Modern Age productive site	14th-18th CE	6
Medieval harbour	11th-15th CE	1
Medieval not-fortified village	11th/12th-14th/15th CE	4
Concentrations not clearly defined	5th-15th CE	15
Total		73

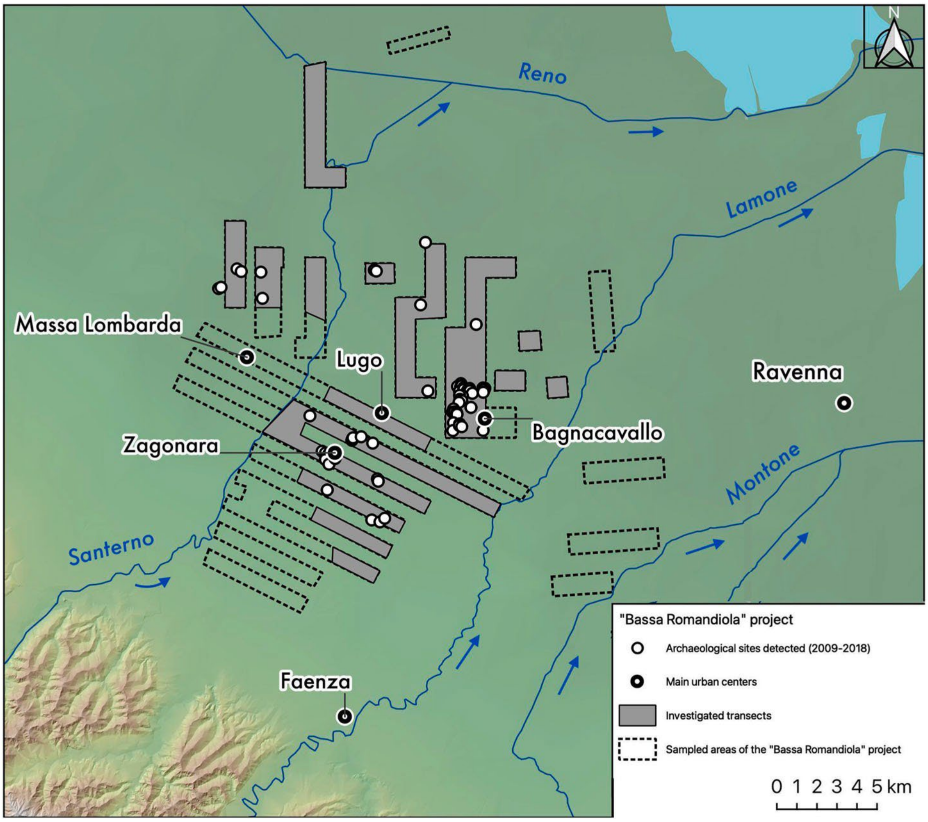

Figure 3. 'Bassa Romandiola' project (2009-2021): area investigated, archaeological sites detected, and main rivers in blue (TINITALY DEM with hillshade basemap)

Faenza, Imola or Ravenna itself (Figure 4), rural lords and bishops. Throughout this process, the rural population was concentrated in the main rural fortified villages, while sparse settlements almost disappeared (Cavalazzi et al. 2018; Cavalazzi 2021b).

Archaeological Archival Research

In order to increase the archaeological data, the Soprintendenza archives in Bologna (SABAP-BO) and Ravenna (SABAP-RA) have been explored to collect any archival reports from rescue and preventive archaeology. Although the amount of unpublished data from the last 15 years is not very high, there are valuable discoveries to understand the landscape evolution better. A complete list of archaeological reports considered in this paper is given in the Supplementary Material. However, here we will only focus on those providing a lot of information on buried soils and/or wetland deposits.

A significant dataset was produced during a watching brief for a water pipeline construction around the hamlet of San Martino, which led to the discovery of four archaeological sites (Casadio 2015). Moreover, a palaeosol datable to the Roman period was recognised in tens of stratigraphic sections. These data have been recently used to test palaeolandscape modelling using palaeoDEMs, which led to hypothesising a buried (pre)-Roman fluvial ridge in the area near Barbiano (Abballe 2020).

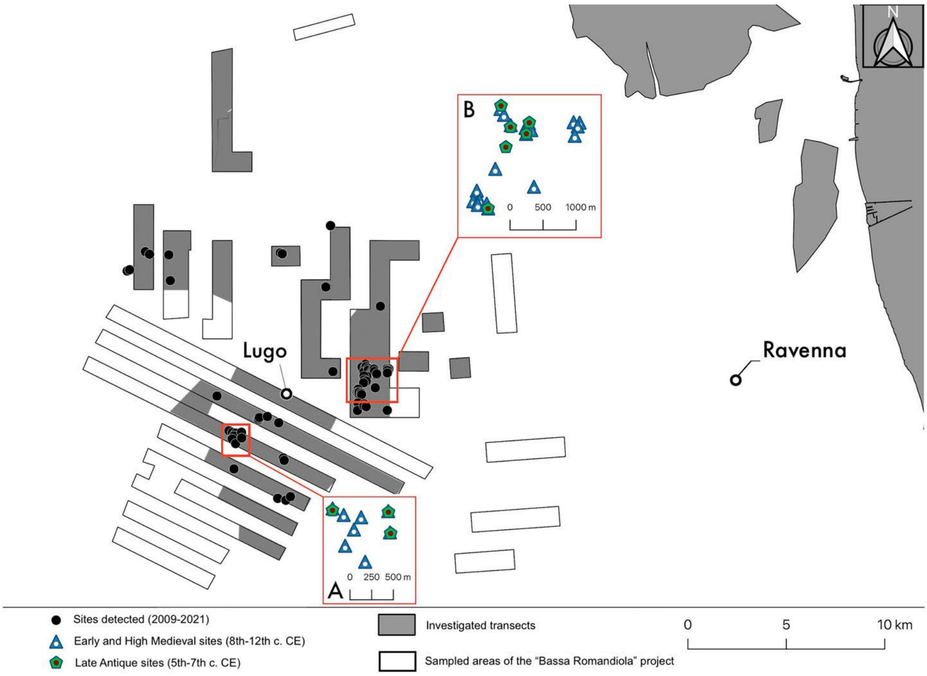

Figure 4. Late Antique and Medieval sites detected in the area of Zagonara (panel A, dispersed pattern) and Bagnacavallo (panel B, nucleated pattern). Basemap from European Environmental Agency.

In addition, exciting data have also been discovered in Piazza V. Emanuele II, within Cotignola city centre (Molinari 2013), where a complex and lengthy archaeological stratigraphy started on top of possible marshland deposits (Figure 7.A). Specifically, traces of reclamation efforts through possible wooden branches have come up at a depth of 1.95 m. A very similar situation has also been identified in 2009 and 2011 in Piazza Baracca, a major square located at the heart of Lugo. Here, marshland deposits were documented at a depth of 1.6 m (Figure 7.B), just below the late medieval and modern stratigraphy (Casadio 2011).

Finally, another massive dataset includes 400 non-continuous mechanical cores supported by geoarchaeological interpretations. These investigations were carried out in 2013 in several towns in Bassa Romagna, in connection with the activation of two natural gas storages in Cotignola and Bagnacavallo (Bucci 2013). Unfortunately, the method used did not allow for a collection of continuous undisturbed samples, hindering both depth and interpretation accuracy. However, for the number of boreholes and their depth (usually 12 metres), this report provides a prime information source on Holocene palaeosols and wetland deposits (Figure 7.C and D). Moreover, the whole dataset includes 49 layers with archaeological elements.

Aerial and Satellite Images Analysis

We used remote sensing essentially to better understand changes in the rivers network and, more in general, map possible traces of flood events. In fact, crop and soil marks

Table 2. Sources of aerial and satellite images used for this work and freely available online.

Source	Year	Type	Sensor
Ministero dell'Ambiente e della Tutela del Territorio e del Mare (MATTM)	1988–1989, 1994–1996, 2000, 2006–2007, 2012	Aerial	B/W (first 2 series), RGB (last 3 series)
Agenzia per le Erogazioni in Agricoltura (AGEA)	2008, 2011	Aerial	RGB and NIR
Google Earth Pro	2003 - 2020	Satellite	RGB
Microsoft Bing	2009 - 2020	Satellite	RGB
Esri World Imagery	2011 - 2018	Satellite	RGB
Consorzio telerilevamento agricoltura (TeA)	2014, 2017	Aerial	RGB

can highlight the presence of palaeochannels or crevasse splays due to the high content of sand that can cause differences in soil colour or stress on plant growth (Gilvear and Bryant 2016). The considerable number of sources of freely available aerial and satellite images undoubtedly helped this research (Table 2). Moreover, the more superficial geological deposits can be connected to specific flood processes, when their traces are precisely mapped.

In total, traces of at least four main alluvial processes have been recognised (Figure 5):

i) Palaeochannel of San Martino (Figure 5.A), departing from the present-day course of the river Santerno nearby Via Passo Regina, then flowing through the homonymous hamlet and finally disappearing below the Lugo industrial area;

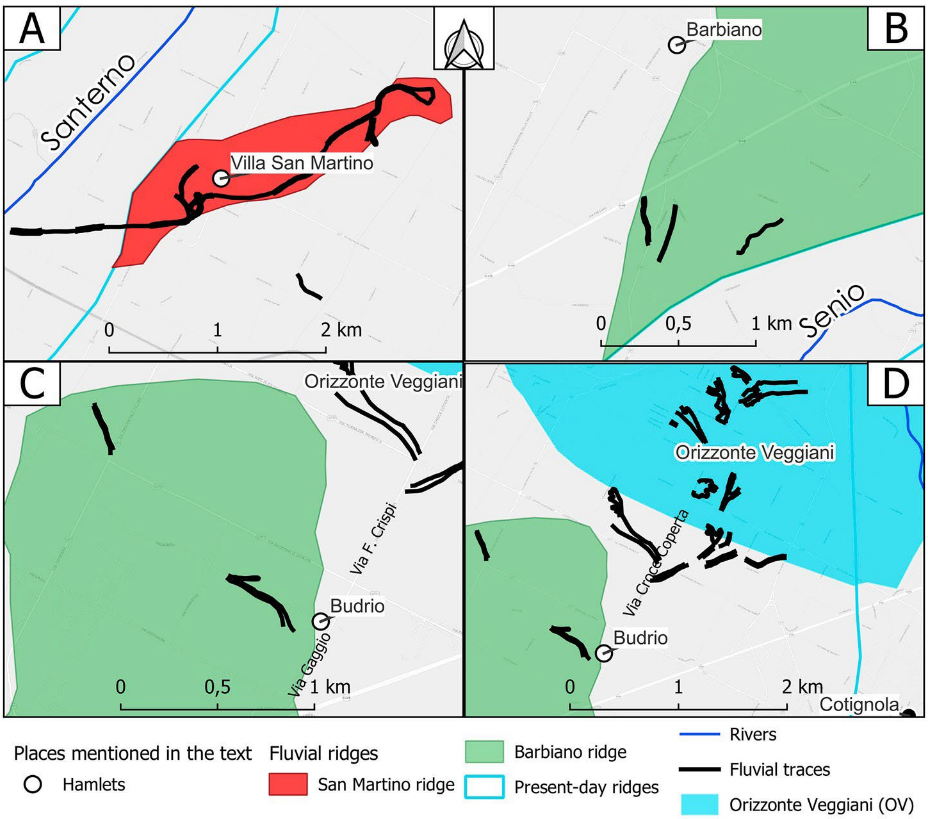

Figure 5. Detailed view of fluvial traces mapped by remote sensing, including those near the axis Via Gaggio-Via F. Crispi-Via Croce Coperta (Esri basemap, Copyright © Esri).

Figure 6. Drone photos over the Barbiano palaeochannel (A-B) and orthophoto with the digitised crop marks pertaining to *piantata* remains (C).

ii) Palaeochannel of Barbiano, recognised only south of this hamlet and possibly departing from the present-day course of the river Senio nearby Via Corriera (Figure 5.B). But it may also be originated from an older course of the river Santerno, when it used to join the Senio (Franceschelli and Marabini 2007). Interestingly, documenting this palaeochannel with drone photography in July 2021 (Figure 6), several channels and circular holes were discovered, likely interpretable as a traditional agricultural land use system called *piantata*, where herbaceous crops alternated with rows of vines intertwined with trees (Cazzola 1996, 140–144; Sereni 1961, 40–43);
iii) Palaeochannel of Budrio, moving with an east–west direction just south of the church of S. Maria di Budrio, and likely continuing through the parcel between Via Zagonara and Via Provinciale Felisio (Figure 5.C). As the one before, this likely originated from the river Senio or the roman/medieval course of the Senio-Santerno river;
iv) Palaeochannels di Croce Coperta, consisting of a series of smaller channels likely connected to a larger one, probably lying below the present-day roads of *Via Gaggio-Via F. Crispi-Via Croce Coperta* (Figure 5.D). Hypothetically, these features may have originated from the palaeochannel of Budrio, but it is difficult to say for sure.

Geoarchaeological Campaigns

The geoarchaeological data considered in this paper have been collected during three campaigns carried out between 2018-2020, using hand augering as the primary method. In addition, it was possible to study exposed sections during the ongoing excavations within the site of Zagonara (Fiorotto, Carra, and Cavalazzi 2020), and within a

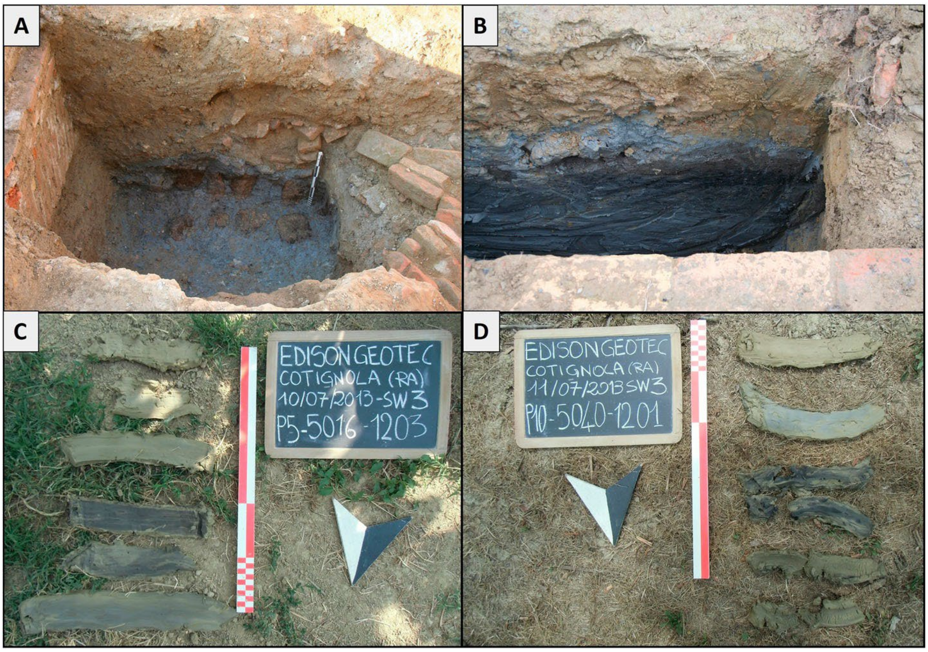

Figure 7. Selected images from archival archaeological reports: A. SU 36 marshland layer covered by a considerable quantity of charcoal fragments (SSUU 34-35) interpreted as tree branches carefully placed to drain the area, from Piazza V. Emanuele II excavation (Molinari 2013); B. SSUU 1146–1147 marshland deposits with wooden posts used as the foundation of later structures, from Piazza Baracca (Casadio 2011); C-D non-continuous cores with palaeosols and wetlands deposits (Bucci 2013).

construction site near Lugo train station (for 2018–2020 campaigns, see Abballe 2021b; for Zagonara sections, see Abballe 2020; for Cantiere, see Supplementary Material).

The results of the investigations (Figure 8), partially discussed in previous papers, can be summarised in five main achievements.

Firstly, it has been possible to map a palaeosol around the site of Zagonara castle, usually buried between 1 and 2 m, only partially decarbonated and characterised by the frequent presence of brick fragments (Abballe 2020). Although in the absence of certain archaeological data, a Roman date has been assumed for this palaeosol (PR), as it was buried also near late antique and medieval sites outcropping on the surface.

Secondly, it was hypothesised that the fluvial ridge of Barbiano (Franceschelli and Marabini 2007, 31, no. 6) may have also experienced a possible pre-Roman phase, substantially raising the landscape with mostly sandy deposits (Abballe 2020). This was possible by combining the results of the first two augering campaigns with the data collected during the watching brief around San Martino (Casadio 2015).

Thirdly, an older palaeosol was mapped around the site of Zagonara castle, usually buried deeper than 3 m, and often completely decarbonated (Abballe 2020). This palaeosol is probably correlatable with the Geosuolo Formellino (GF), a palaeosurface discovered in other areas of the plain north of Faenza and datable to the Bronze Age (Franceschelli and Marabini 2007, 104–107).

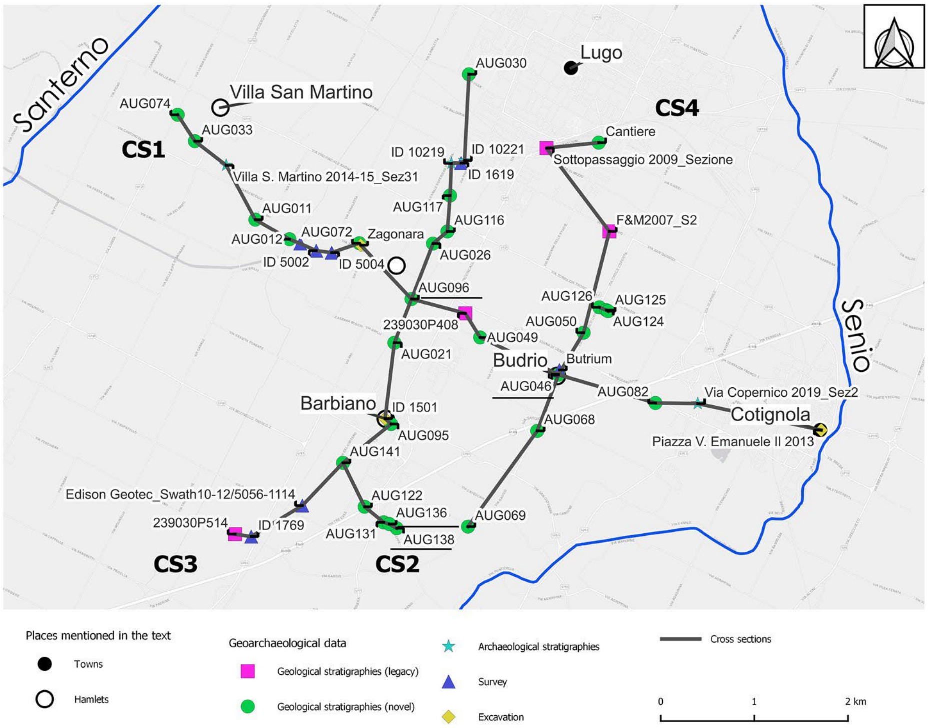

Figure 8. Geoarchaeological investigations with four main stratigraphic transects (CS1-CS4) and archaeological sites considered. Underlined augering names indicate provenance of radiocarbon dated samples (Esri basemap, Copyright © Esri).

Fourthly, a usually silty-clayey layer below more than 2 m of sandy deposits was mapped in the surroundings of the rural church of Budrio, between Zagonara and Cotignola. This possible marshland layer seemed to have formed under water-saturated conditions, ensuring a good preservation of vegetal remains and was preliminary dated to the 11th-12th centuries CE (Abballe and Cavalazzi 2022).

Fifthly, it has been possible to confirm a hypothesis recently proposed according to which a larger channel may lie below the present-day roads of *Via Gaggio-Via F. Crispi-Via Croce Coperta* (Abballe and Cavalazzi 2022). This hypothesis is based on the fluvial traces mapped by remote sensing that all seem to depart from this axis, which may have acted as the primary sedimentary source for all the palaeochannels mapped in the surroundings (Figure 9.A). This hypothesis seems to be confirmed by looking at the sediment textures documented below the present-day channel, just next to Via Francesco Crispi, which are utterly different from those below the palaeochannels to the west (Figure 9.B). The sediments recorded below the artificial channel are very coarse, much more than anyone would expect to find in a smaller irrigation canal, not directly connected to the main hydrography. They are even coarser than the sediments in correspondence with the crevasse splays, where the water stream usually carries the heavier sediments. Thus, these medium sand sediments may fill a vacuum in the local stratigraphy, corresponding to a larger channel, now mostly filled up.

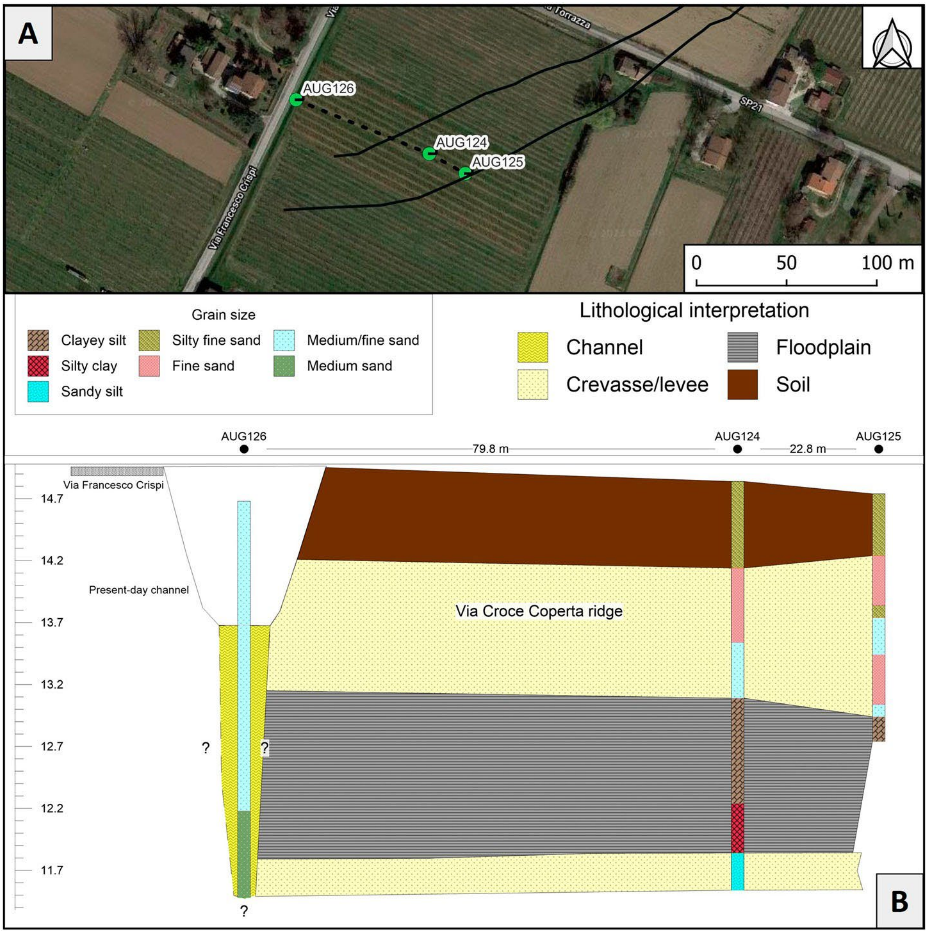

Figure 9. Detailed view of fluvial traces pertaining to Via Croce Coperta palaeochannel with augers location (A) and stratigraphic cross section (B) up to Via F. Crispi (Google Satellite basemap, Copyright © Google).

Radiocarbon Dating

In total, four ^{14}C dates are used for this study, including three novel ones (Table 3, see also Supplementary Material).

The first one comes from the higher level of the marshy layer recorded in AUG046 in Budrio (Cotignola) and dates to the 11th-12th centuries CE, providing a chronology for the late existence of this wetland before being reclaimed.

Roughly to the Roman periods are instead both dated samples from AUG136 and AUG138, just south of Barbiano (Cotignola). Both charcoal samples were retrieved from flooting the clayey silt sediments collected at a depth of 4.6-5 m, from a likely palaeosol later affected by swamping. This chronology fits well with the finding of a sigillata sherd in the dated layer from AUG136.

Lastly, the sample from AUG096, just north of Barbiano (Cotignola), gave back an 8th/9th-century chronology for a floodplain layer at a depth of 4.3-4.5 m, located under thick sandy deposits of a fluvial ridge.

Archaeobotanical Macroremains Analysis

This analysis aimed to study macro botanical remains from medieval wetland contexts to reconstruct their vegetation cover and look for traces of human exploitation of these environments. Three sediment samples were collected from an exposed section within a construction site in Lugo (Cantiere), while seven samples came from a hand auger in front of the church of Budrio (AUG046). The higher level of the wetland layer recorded in Budrio (2.3-2.5 m) dates to the 11th-12th centuries CE as shown by ^{14}C dating (Table 3), similarly to the higher layer from Cantiere (4.6 m) based on the stratigraphic correlation to the level dated in Sottopassaggio 2009 (see CS4). Due to the sampling methods, the bulk samples from Cantiere were much larger (around 10 l) than those from Budrio (0.2 l). All samples were washed over 0.2 and 0.1 mm sieves to detect very small plant remains, charcoal and other resi- dues (e.g. brick fragments, bone fragments). All macro remains were identified to the lowest possible taxonomic level using various standard identification guides (see Sup- plementary Material).

The carpological assemblage (Table 4) from Budrio (AUG46) contains fragments of *Vitis vinifera* in almost all layers, except in S7 and S8 that were almost sterile, while in Lugo (Cantiere) vine seeds were recorded in only one sample at 4.6 m (6 seeds and 19 fragments). Sample S5 of Budrio (2.63-2.88 m), which is the one with more vine seeds (28 fragments and 1 pedicel), also presents other *taxa*, both charred and mineralised. Assemblages from the Cantiere site are far more variegated, with a mixture of herbaceous species and woody plants. All three samples from this site are characterised by a huge amount of *Chenopodium* sp. (981 fruits in total), which can grow under a wide range of soil conditions (Latałowa, Kupryjanowiczand, and Nalepka 2004, 273) and are often over-represented due to high seed productivity (Fuller 2020, 246).

Anthracological materials are present in almost all samples (Table 5), generally more in Budrio (83) than Cantiere (22). Both sites show the presence of a mixed oak forest-hygro- philous wood (*Salix/Populus* group mixed with *Q. robur*-common oak, *Fraxinus*-ash and *Alnus*-alder) with a fairly extended shrub layer (*Prunus spinosa*-wild blackthorn and *Prunus avium*-wild). Fruit trees are also present in Butrio, including walnut (*Juglans regia*), chestnut (*Castanea sativa*) and rowan (Maloideae cfr. *Sorbus*), while *V. vinifera* appear in both sites (1 in Budrio and 12 in Lugo).

Table 3. Radiocarbon dates considered for this work and carried out by Beta Analytics (Beta) and Royal Institute for Cultural Heritage of Bruxelles (RICH), calibrated with OxCal 4.4 using the IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve.

Sample	Depth	Material	Lab code	Date BP	Date cal (95.4% probability)
Budrio18-AUG46-S1	2,35 – 2,5 m	Seed (*Vitis vinifera* L.)	Beta-531205	920±30 BP	1035AD (88.8%) 1180AD, 1188AD (6.6%) 1210AD
Barbiano20-AUG136-S3	4,6 – 5 m	Charcoal	RICH-29682	1890±28BP	78AD (95.4%) 230AD
Barbiano20-AUG138-S2	4,6 – 5 m	Charcoal	RICH-29683	2180±33BP	366BC (92.7%) 148BC, 136BC (2.7%) 112BC
Barbiano20-AUG96-S1	4,3 – 4,5 m	Charcoal	RICH-29410	2593±28BP	812BC (95.0%) 759BC, 678BC (0.5%) 674BC

Table 4. Results of carpological analysis per sample from AUG046 and Cantiere site.

LEGEND		SITE	AUG 046 (BUDRIO, COTIGNOLA)							CANTIERE (LUGO)		
*	*mineralised*	Sample	S2	S3	S4	S5	S6	S7	S8	140	170	190
FR	*Fossil remain*											
+	> 10 fragments	Depth	2.30-2.50 m	2.50-2.63 m	2.63-2.75 m	2.75-2.88 m	2.88-3.00 m	3.00-3.10 m	3.90-4.00 m	4.30 m	4.60 m	4.80 m
		Interpretation	marsh/ swamp	marsh/ swamp	marsh/ swamp	marsh/ swamp	marsh/ swamp	marsh/ swamp	crevasse/ levee	floodplain	marsh/ swamp	marsh/ swamp
Family	Taxon	*FR*	n. of fossils	n. of fossils	n. of fossils	n. of fossils	n. of fossils	n. of fossils	n. of fossils	n. of fossils	n. of fossils	n. of fossils
Adoxaceae	*Sambucus ebulus* L.	fruit				2*	1*					
Adoxaceae	//	frag.				1*						
Adoxaceae	*Sambucus nigra* L.	stone									14	1
Adoxaceae	//	frag.									1*	1
Apiaceae	*Torilis* sp.	composited fruit									1	
Brassicaceae	*Brassica* sp.	fruit								1	1	1
Caprifoliaceae	Valerianella dentata (L.) Pollich	seed								3		
Chenopodiaceae	*Chenopodium* sp.	fruit								160	783	18
Euphorbiaceae	*Euphorbia helioscopia* L.	seed				1						
Fabaceae	*Trifolium* sp.	seed									1	
Fabaceae	*Vicia* sp.	seed									5	
Lamiaceae	*Marrubium vulgare* L.	fruit									18*	
Lamiaceae	*Salvia officinalis* L.	seed				1						
Lamiaceae	*Stachys arvensis* L.	fruit									1*	
Poaceae	*Triticum dicoccum* L.	grain				1						
Polygonaceae	*Rumex* sp.	fruit								1	2	
Polygonaceae	*Fallopia dumetorum* (L.) Holub	fruit								1	1	
Polygonaceae	*Polygonum* sp.	fruit									1*	
Ranunculaceae	*Ranunculus* sp.	fruit								4		
Rosaceae	*Rubus fruticosus* L.	stone									2*	
Rosaceae	*Potentilla* sp.	stone									1*	
Vitaceae	*Vitis vinifera* L.	seed		3*	6*						6	
Vitaceae	//	frag.	1*	5*	1*	28*	2*				19	
Vitaceae	//	pedicel				1						
Indet.										3		
//		frag.									4	
Charcoal			2	18	17	90	40	+	+		24	1
Wood											+	+
Shells										+	+	+

Table 5. Results of anthracological analysis per sample from AUG046 and Cantiere site.

	SITE	AUG 046 (BUDRIO, COTIGNOLA)				CANTIERE (LUGO)	
	Sample	S2	S3	S5	S6	170	190
	Depth	2.30-2.50 m	2.50-2.63 m	2.75-2.88 m	2.88-3.00 m	4.60 m	4.80 m
	Interpretation	marsh/ swamp	marsh/ swamp	marsh/ swamp	marsh/ swamp	marsh/ swamp	marsh/ swamp
Family	*FR*	n. of fossils	n. of fossils	n. of fossils	n. of fossils	n. of fossils	n. of fossils
Araliaceae	*Hedera helix* L.		1	1			
Betulaceae	cfr. *Alnus* sp.			2	2		
Caprifoliaceae	*Lonicera* sp.			1			
Celastraceae	*Evonymus* sp.		2	3			
Fabaceae	*Genista/Cytisus* sp.			2			
Fagaceae	*Quercus robur* L.		4	7			
Fagaceae	*Quercus* sp.				9		
Fagaceae	cfr. *Quercus* sp.		1			1	
Fagaceae	*Castanea sativa* L.		1	10	4		
Fagaceae	cfr. *Castanea sativa* L.		1				
Fagaceae	*Fagus* sp.			2	1		
Juglandaceae	*Juglans regia* L.	1			4		
Juglandaceae	cfr. *Juglans regia* L.			3			
Oleaceae	*Fraxinus* sp.				1		
Oleaceae	cfr. *Fraxinus* sp.			1			
Ranunculaceae	cfr. *Clematis* sp.			1			
Rosaceae	Maloideae		1	6	2	5	1
Rosaceae	Maloideae cfr. *Malus* sp.					1	
Rosaceae	Maloideae cfr. *Sorbus* sp.			1			
Rosaceae	*Prunus* sp.		2	6	2		
Rosaceae	*Prunus spinosa* L.	1		1			
Rosaceae	*Prunus avium*				1		
Salicaceae	*Salix/Populus* sp.		2	14	4	1	
Salicaceae	*Salix* sp.			1			
Sapindaceae	*Acer* sp.					1	
Ulmaceae	cfr. *Ulmus* sp.			1			
Vitaceae	*Vitis vinifera* L.			1		9	3 (wood)
	Pith/Bark				1		
	Undet		1	6	4	6	
	Undet. Curl wood? Fungus?			1			
	Root wood?			1	1		

Historical Archival Research

The analysis of archival documentation aimed to identify indications for land reclamation processes that might link to the events indicated by the georchaeological data. Thus, we analysed both published and unpublished documents from the *Archivio di Stato di Ravenna*, dated to the 11th-13th centuries CE. In this section, we focus on a set of 4 parchments for a total of 9 rental contracts concerning land plots located near Budrio and Lugo (1178-1266 AD, Table 6), which gave interesting data about the processes analysed. In particular, in 1266, the *gastaldus* of the monastery of S. Maria in *Portus* of Ravenna, namely the administrator of the rural farm, rented wooded lands near Budrio, Lugo, and S. Agata to several people. These contracts lasted at least for 12 years, with only the tithe of the crop requested as payment. This request was very advantageous for the tenants, who were protected in the event of a poor harvest as they did not have a fixed rent to pay.

Table 6. Archival rental contracts considered in this paper, held in the Archivio di Stato di Ravenna.

	Date	Subjects	Type of contract	Object	Topical date	Archival location
1178	[..] 10	John, Palmerius, Bretaninus, sons of […],	chartula donacionis	donate to Peter of Bulgarellus, a land equal to 1 'tornatura' in the parcel named […] in the territory of the church of S. Agata and Imola	Bagnarola of Budrio	Archivio di Stato di Ravenna (ASRa), Canonica di S. Maria in Porto, 0560
1212	September 24	Buonagiunta 'prior Celle Volane'	pactum	gives for 69 years to Drudolus 1 ' tornatura' of land in Budrio, in the territory of the church of Barbiano and Imola for a yearly rent of 1 denarius of Ravenna	Cunio	ASRa, Canonica di S. Maria in Porto, Pergamena n° 0906
1266	December 13	Buonapars from Russi, 'gastaldus' of S. Maria in Porto	pactum	gives to Domenic son of Clement from Lugo a land in the territory of the church of S. Agata and Imola, for the tithe of products	Bagnarola of Budrio	ASRa, Canonica di S. Maria in Porto, Pergamena n° 1861a
1266	December 14	Buonapars from Russi, 'gastaldus' of S. Maria in Porto	pactum	gives to Peter [… …] a woodland in the parcel 'Runtadelli' in the territory of the church of S. Agata and Imola, for the tithe of products	Bagnarola of Budrio	ASRa, Canonica di S. Maria in Porto, Pergamena n° 1861b
1266	December 14	Benvenuto the blacksmith, 'gastaldus'of S. Maria in Porto	pactum	gives to Dominic "de Portu de S. Agatha" and to Ugolinus son of Gisella a land in the parcel 'Tufanigo' in the territory of the church of S. Agata, for the tithe of products	Cavaseda	ASRa, Canonica di S. Maria in Porto, Pergamena n° 1861c
1266	December 14	Benvenuto the blacksmith, 'gastaldus'of S. Maria in Porto	pactum	gives to Ugolinus "de Vidriano" a woodland in the parcel 'Cavaseda' in the territory of the church of S. Agata and Imola, for the tithe of products	S. Agata	ASRa, Canonica di S. Maria in Porto, Pergamena n° 1861d
1266	December 14	Benvenuto the blacksmith, 'gastaldus'of S. Maria in Porto	pactum	gives to Ugolinus [… …] from S. Agata a woodland in the parcel 'Cavaseda' in the territory of the church of S. Agata and Imola, for the tithe of products	S. Agata	ASRa, Canonica di S. Maria in Porto, Pergamena n° 1861e
1266	December 14	Benvenuto the blacksmith, 'gastaldus'of S. Maria in Porto	pactum	gives to Guidottus from S. Agata a land in the parcel 'Cavaseda' in the territory of the church of S. Agata and Imola, for the tithe of products	S. Agata	ASRa, Canonica di S. Maria in Porto, Pergamena n° 1861f
1266	December 14	Benvenuto the blacksmith, 'gastaldus'of S. Maria in Porto	pactum	gives to Guido from Bagnarola for 12 years a woodland in the parcel 'Cavaseda' in the territory of the church of S. Agata and Imola	Cavaseda	ASRa, Canonica di S. Maria in Porto, Pergamena n° 1862a

More in general, these documents seem to attest to an ongoing process of land reclamation and deforestation, particularly strong at the half of the thirteenth century CE. This process was promoted by the S. Maria monastery, which facilitated it adopting low rental fees in natural products instead of money. Nevertheless, the reclamation and deforestation practices were carried out by local laymen (probably small and medium land-owners), who rented the lands.

Integrated Approaches

The various data collected with the different methodologies that we have just described will now be crossed with each other to gather new insights into the physical and environmental characteristics of the ancient landscapes and how they have changed over the last three millennia. Moreover, shedding more light on these changes also allows us to make a deeper analysis of the geomorphological biases that have conditioned our archaeological survey.

Palaeolandscape Reconstruction

Four cross sections have been created to better understand the evolution of the palaeolandscape, based on all stratigraphic data available from the different sources (for the results of 2018–2020 geoarchaeological campaigns, see raw data in Aballe 2021b). Two are oriented W-E, with a long one across the whole plain between the Santerno

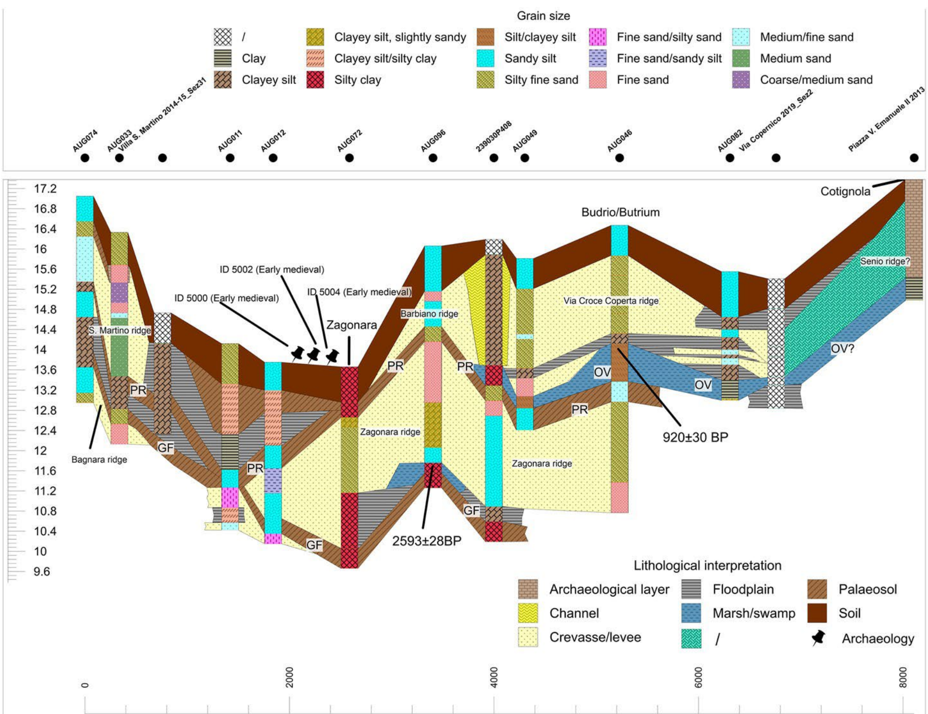

Figure 10. W-E stratigraphic cross section (CS1) across the plain between Santerno and Senio rivers (PR = Roman palaeosol; GF = Geosuolo Formellino; OV = Orizzonte Veggiani).

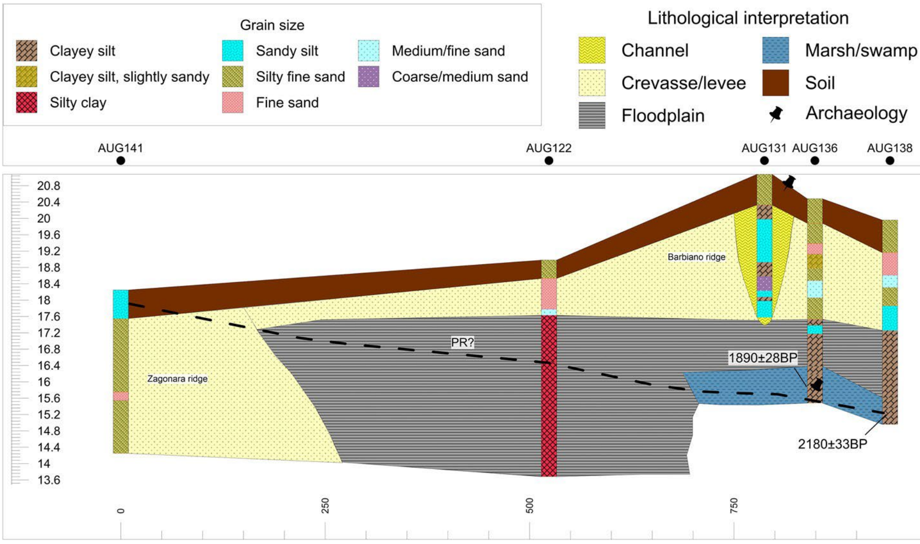

Figure 11. W-E cross section (CS2) in correspondence with the Barbiano ridge (the dashed line indicates uncertainty in the stratigraphic correlation).

and Senio rivers passing by Zagonara castle (Figure 8.CS1 and Figure 10), with a smaller one focusing on the Barbiano ridge (Figure 8.CS2 and Figure 11). The other two are instead oriented S-N, and they cross the whole plain between Barbiano and Lugo, one passing more to the west (Figure 8.CS3 and Figure 12) while the other to the east across Budrio (Figure 8.CS4 and Figure 13).

Specifically for the area around Zagonara (Figure 8.CS1 and Figure 10), the integration between new geoarchaeological and archival data allows us to draw two main conclusions. Firstly, it seems possible to confirm a Roman chronology for the ridge passing between Barbiano and Zagonara, hereinafter called ‘Zagonara ridge’. It is possible to suggest this chronology thanks to the radiocarbon dating from AUG096. In fact, the sandy deposits from this ridge buried a silty clay layer, possibly formed in (partially) waterlogged conditions dated to the 8th/9th century BCE (Table 3), while they lay below a palaeosol that is likely datable to the Roman period (PR). This dating is also crucial because it seems to confirm the Bronze Age chronology already proposed for the deeper decarbonated palaeosol, most likely corresponding to the GF. Secondly, it seems possible to follow a medieval wetland layer spread across the whole eastern study area. This was likely documented in a legacy geological core (239030P408, see Supplementary Material) located next to the Zagonara and Barbiano ridges and possibly in correspondence with a palaeochannel identified by remote sensing. This layer has also been identified in three augers below and around Budrio, and likely up to Cotignola city centre, as documented within a trial trench in Via Copernico and during the excavations in Piazza V. Emanuele II. According to our ^{14}C date from AUG046 (Table 3), this could have been covered from the eleventh century onwards, by sandy deposits left behind by the flood activities connected with the Barbiano and Croce Coperta palaeochannel. At the same time, the reclamation of this wetland must have happened most likely before 1217 CE, when the castles of Cotignola and Budrio were founded (Augenti, Ficara, and Ravaioli 2012).

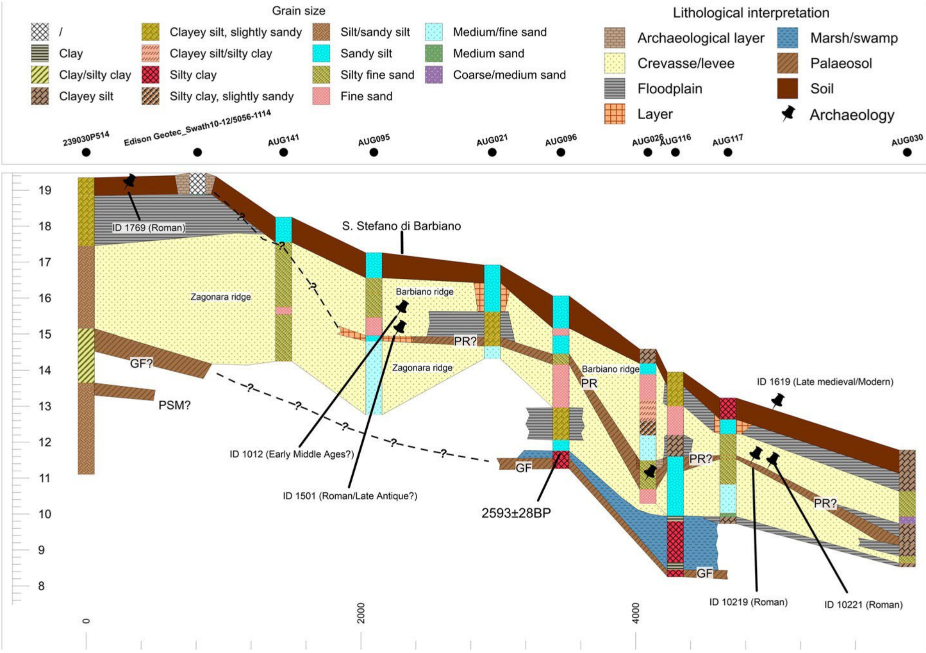

Figure 12. Western S-N cross section (CS3) between Barbiano and Lugo (PR = Roman palaeosol; GF = Geosuolo Formellino; OV = Orizzonte Veggiani; PSM = *Palaeosuolo San Martino*, a palaeosol associated with the Neolithic occupation of the area; the dashed line indicates uncertainty in the stratigraphic correlation).

The second W-E transect specifically focused on the Barbiano ridge, to understand whether this was built in two different phases, before and after the Roman period (Figure 8.CS2 and Figure 11). This working hypothesis was based on the fact that the area of Barbiano appeared already raised in Roman times. However, after having investi- gated the palaeochannel responsible for its formation in AUG131 and its immediate sur- roundings, it is clear that the Roman level has been deeply buried here, around 2.5 m western of the channel (AUG122), while up to 4.5 m deep eastern of it (AUG136 and AUG138). But while the more superficial sediments are indeed relatable to crevasse/levee facies, the lower ones are pertaining to floodplain and marsh/swamp environments, for their grey-bluish colour typical of waterlogged sediments. Therefore, these wetland layers may represent the southernmost evidence for the extension of the OV. But at the same time, we may safely reject our original working hypothesis that a watercourse had continuously stood there, from before the Roman period until the Middle Ages.

Following these results, a new auger was carried out to assess whether a second ridge could be mapped further west, and in fact, a completely different stratigraphy has been documented in AUG141, characterised by 4 m of mostly sandy sediments. The thickness of these sandy deposits makes it more reasonable to believe that we were nearer to the watercourse responsible for the creation of the Zagonara ridge. The finding of a Roman farm (ID 1769) may support this since its remains were discovered through field survey not far from AUG141 (Figure 8.CS3 and Figure 12). This reconstruction would explain the non-burial of the sites found around Zagonara, since the pre-Roman ridge passing

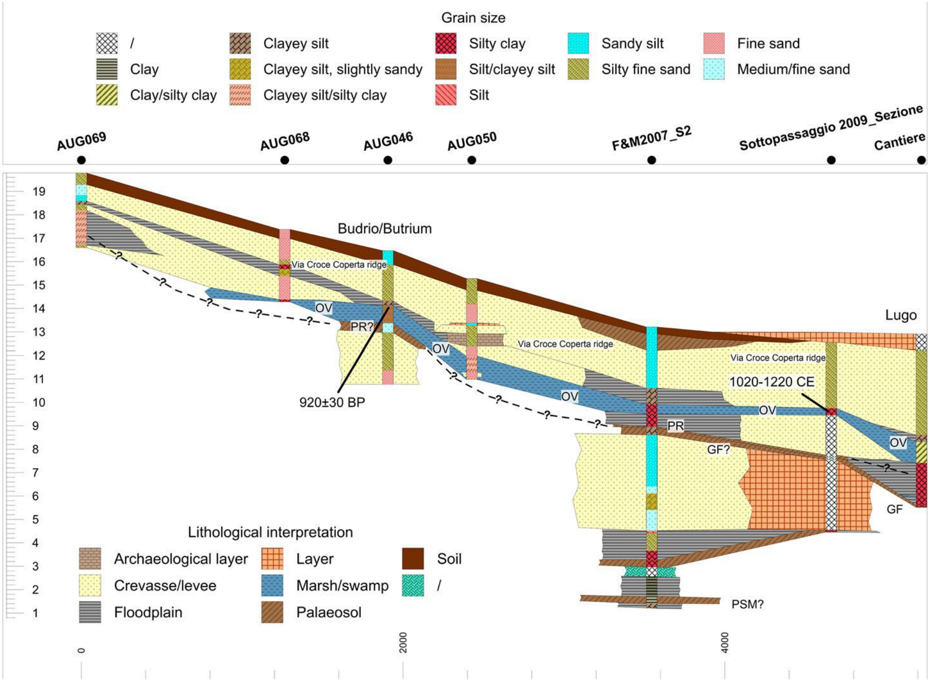

Figure 13. Eastern S-N cross section (CS4) between Budrio and Lugo (PR = Roman palaeosol; GF = Geosuolo Formellino; OV = Orizzonte Veggiani; PSM = stands for Palaeosuolo San Martino, a palaeosol associated with the Neolithic occupation of the area; the dashed lines indicate uncertainty in the stratigraphic correlations).

in the area may have blocked the new sediments deposited by the Barbiano palaeochannel, which arrived from the opposite side.

Finally, the most interesting data are visualised in the fourth transect (Figure 8.CS4 and Figure 13). If geoarchaeological investigations already suggested this lateral continuity, the matching of the radiocarbon dates obtained from AUG046 and Lugo (Sottopassaggio 2009; from Marabini and Vai 2020, 71) allows to completely rewrite the extent of the so-called Orizzonte Veggiani (Figure 14). This has been documented further south than the location of coring S2, where the limit was firstly placed by Franceschelli and Marabini 2007. Notable is also that this layer was covered by mostly sandy deposits, which can be safely connected to the several channels that built up the Via Croce Coperta ridge thanks to remote sensing. The reclamation of this wetland must have happened approximately between the 12th and the beginning of the 13th centuries CE, since we found the possible archaeological remains of the castle of *Butrium* (1217-?) in the immediate surrounding of AUG046 (Abballe and Cavalazzi 2022).

Methodological Implications for the Study of Hidden Landscapes

In light of the geological reconstructions presented above, it is possible to better understand the environmental transformations that happened within this lowland and assess the geomorphological biases affecting the results collected by the Bassa Romandiola project.

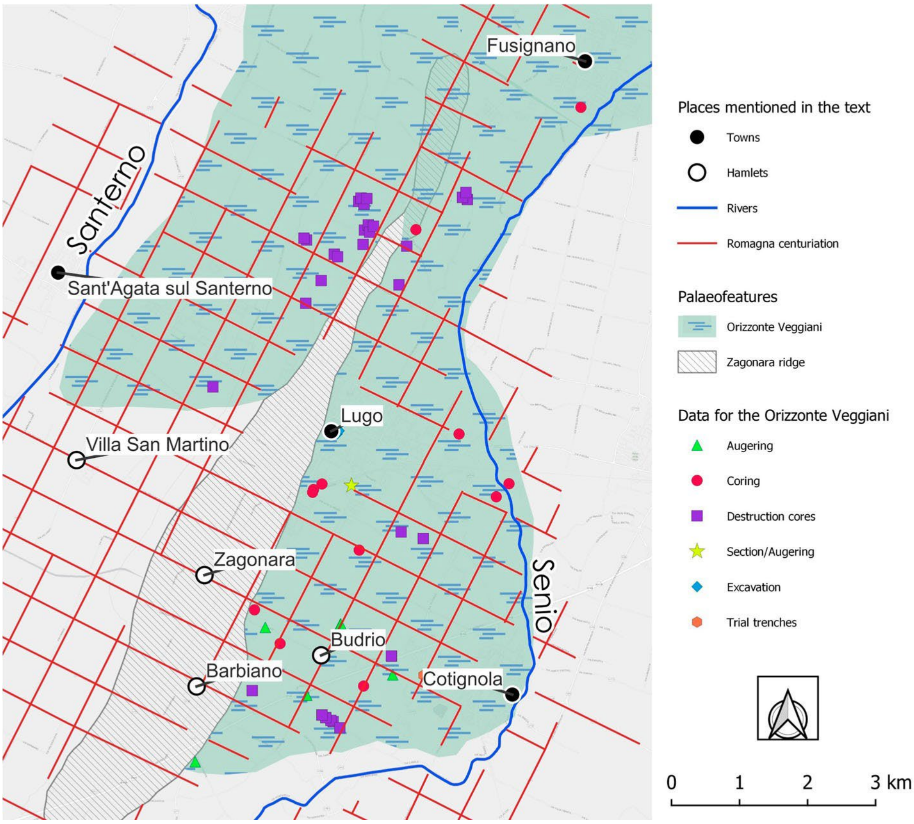

Figure 14. Refined mapping of the Orizzonte Veggiani, with indicated the data types attesting it and the superimposed medieval centuriation. Also shown is the Zagonara ridge, mostly buried by later deposits (Esri basemap, Copyright © Esri).

The most straightforward situation is undoubtedly the area between Budrio, Cotignola and Lugo. Despite the seemingly perfect survival of the centuriation (Figure 2), an intense fluvial activity hit the whole area, causing the deposition of more than two metres of alluvial sediments. As said above, our geochronological data place this process somewhere after the eleventh century CE. This seems to fit perfectly with the results of the field survey of 2018, which specifically focused on this area. The finding of Archaic Maiolica, the oldest pottery class, suggests that the occupation of this landscape started around the Late Middle Ages since this class began to appear in the second half of the thirteenth century CE (Librenti 1994, 171). However, we have to admit that considering the small number of sites recorded, only around the church of Budrio, we are basically relying more on their absence than presence. Doing so can be tricky since geomorphological biases are not the only ones that could have affected our survey, but also observer and visibility biases may have played a role in hindering our results (for biases in landscape archaeology research, see Van Leusen 2002, 45–47; Feiken 2014, 3–10). However, in this case, there is strong correspondence with the stratigraphic data, so much so that, even if we decide to resurvey the area, it is very implausible that we will be able to find any early medieval or older sites outcropping on the surface. We can be quite sure of this since both the Roman (PR) and medieval (OV) palaeosurfaces are buried more than two metres deep across the whole area (Figure 8.CS4 and Figure 13).

More complex is the situation concerning the western half of our case study, between Barbiano, Villa San Martino and Lugo, passing by Zagonara. The southern part of this territory has been protected by law since 2009, thanks to the preservation of the Roman centuriation system (*Paesaggio protetto della Centuriazione*, Regione Emilia-Romagna). This happens even though the few known Roman archaeological sites were always deeply buried, from around two metres between Bagnara and Villa San Martino, up to five/six metres further north (i.e. below Lugo). However, integrating the results from both field surveys and geoarchaeological investigations allows us to outline a more articulated history of this landscape. In fact, an important role was played by the Zagonara ridge, whose identification allows us to understand why the oldest archaeological data were recorded nearby Zagonara, at the moment standing at the lowest point (Figure 8.CS1 and Figure 10). Now it is clear that this area must have stood higher in the landscape during the Roman period, strengthening an aspect that we had already pointed out (Cavalazzi and Mancassola 2021, 68). In fact, scattered late antique and early medieval rural settlements identified in 2009 seemed to be oriented in accordance with the centur- iation axes. The absence of considerable alluvial deposits makes this hypothesis very plausible since roads and canals may have survived up to today. This is not to say that these infrastructures did not require continuous maintenance, but it was probably never necessary to build them from scratch as it may be needed after the accumulation of metres of deposits, like in the eastern half of the study area. Thus, although the Roman palaeosurface is not buried at such great depths as previously thought (i.e. more than 3.5 m according to Franceschelli and Marabini 2007, 78, fig. 53), geological data show that subsequent fluvial activities have nevertheless buried this palaeosol and the potential sites associated with it. This is why the Roman sites still continue to elude us. A subsequent fluvial activity can be surely recognised in the palaeochannel mapped south of Barbiano (Figure 5.B and Figure 6). However, it is not easy to establish a chronology for this event for now, but some data might help us to narrow down the time frame. On the one hand, the church of Barbiano seems to have been raised through time as the finding of cappuccina tombs (uncertainly dated somewhere between the Roman and late antique periods) and column bases, respectively at a depth of 2.5 (ID. 1501) and 1.8 m (ID. 1012), seems to suggest (Augenti, Ficara, and Ravaioli 2012, 221–222, id. 219). On the other hand, we could suggest that this flood occurred before the thirteenth century, given that the only identified site during the 2018 campaign in the surroundings dates to this period. As in the case of Budrio, we are relying on the absence of data, a slippery slope, but one that cannot be overlooked when studying an area with a high rate of vertical growth.

Characterisation of Wetland Vegetation

Based on the palaeolandscape reconstructions, we can discuss together the results of the archaeobotanical analyses from both sites. As said above, the samples come from the so-called Orizzonte Veggiani, a geological layer formed in water-saturated conditions, thus interpretable as the remains of a former wetland. Therefore, based on the combination of both carpological and anthracological analyses, we could develop some early hypotheses on the vegetation characterising this possible wetland. However, it must first be pointed out that, as samples are taken from depressed areas where river waters converge after a flood, the remains may have been transported from somewhere else. This natural process could explain the presence of some plant remains that are not usually found at such low altitudes, such as Fagus-beech in Budrio (AUG46).

Taking these limitations in mind, both assemblages seem to be coherent due to the predominance of certain plants, although the two contexts investigated are very different from each other. Very impressive is the number of vine seeds found in Budrio, in a stratigraphy extending for 70 cm (Table 4). This high number would suggest a prolonged presence of this type of plant in the area. It cannot be excluded that these were naturally growing there since this phenomenon has been recently recorded in Punta Alberete, one of few wetlands still standing around Ravenna (Biagini et al. 2014). On the contrary, they could attest to a first attempt to exploit these areas once they were in dry conditions. However, we have to admit that data are still scarce, and comparisons with similar medieval contexts are lacking (a few exceptions are: Bosi et al. 2015; Rucco et al. 2019). The Cantiere site instead is domi- nated by fruits of *Chenopodium*, which together with remains of *Trifolium*, *Vicia*, *Ranun- culus*, could testify to the presence of meadows, possibly periodically flooded (Table 4). In particular in sample 170, from the wetland deposits (Tables 4 and 5), also seeds and charcoal fragments are present, perhaps describing a similar use of the area as it may have happened in Budrio.

More in general, the few data available might suggest exploitation of these areas for vine cultivation, while traces of cereal production seem to be lacking (only 1 fragment of *Triticum dicoccum* in total). If this were true, the reasons for this choice could be not only practical but almost 'forced'. On the one hand, sowing cereals in a flood-prone field would have been extremely risky, while on the other hand, it would perhaps have been even impossible to plough extremely clayey soil with the technologies of the time, namely the wooden scratch-plough, also known as *ard* (Brandolini and Carrer 2020, 5, with references). Planting a vineyard would certainly have been less risky because the farmer's life did not depend on its harvest and at the same time would have required less extensive agricultural work, apart from digging holes to accommodate the seeds and some subsequent maintenance. Moreover, modern comparisons from Venice Lagoon show how vines can survive momentary floods, while Roman sources already attested this practice of wine production in wetlands contexts from the Po Valley, including in Ravenna (Van Limbergen 2020, 96).

Medieval Wetland Reclamation Processes

The last issue we would like to focus on is the reclamation process that had substantially changed the area between Cotignola, Budrio and Lugo, already by the first half of the thirteenth century CE. The combination of archaeological and geological data allowed to narrow down the time frame when this process could have happened, but how it took place and by whom it was promoted remain unclear.

About how this reclamation took place, remote sensing and targeted augers suggest that anthropogenic forces played a significant role in directing the sedimentation above the OV by channelling murky waters along the axis *Via Gaggio-Via F. Crispi-Via Croce*

Coperta. Something similar has been suggested for the *Tagliata Canal* east of Guastalla (Reggio Emilia), an artificial channel excavated in 1218 CE that is characterised by crevasse splays on both sides. According to the authors, the 'crevasse splays are the results of medieval flood management practices intended to reclaim the backswamp of Valle di Novellara' (from Brandolini and Cremaschi 2018, 10). We believe something very similar also happened in our case study, even though crevasse splays can be recognised through remote sensing and not by geomorphometric analysis. Similar reclamation processes by exploiting turbid waters are at the basis of the extensive land reclamation effort that interested the Ravenna plain in modern and contemporary times, using a method called *colmata* (more recently Cazzola 2021). But new pieces of evidence for the same period (12th-13th centuries CE) have been recently collected from both Massa Lombarda and Villafranca di Forlì, even though evidence of anthropogenic control over these events is more tenuous there (Abballe 2022). Evidently, once this phase of river deposition was over, the new farmable land was divided through the construction of roads and canals, taking the characteristic shape typical of the Roman centuriation system (Figure 2). This likely occurred by extending the existing axes, according to the model of *transmission latérale* already theorised by Chouquer (2015, 125–129). But this could have happened only if some of the original channels were still functioning, likely in the area around Zagonara, as we already stated.

The other aspect worth dwelling on is the correspondence that seems to exist between the site of Budrio and this new fields system, which leads us to believe that the site was founded simultaneously with or after the agrarian delimitation (Abballe and Cavalazzi 2022). Specifically, written sources seemed to help us a lot in this regard since a contemporary chronicler from Faenza reported on two interesting pieces of information, both occurring in 1217 CE. The first is the foundation of a series of castles, including Budrio, Zagonara, and Cotignola. The second is the excavation of *fossata magna et profundam ad liberandum districtum eurom et ad derimandum aquas inutiles atque superfluas usque in valles*, literally large and deep channels to free their territory and to convoy the useless and redundant waters towards the wetlands (from Tolosano 1936, 130–131).

These few lines seem to clarify all our doubts, except that some other elements may undermine this straightforward reconstruction. Firstly, the toponym Budrio is attested already in 1178 CE (Table 6). Secondly, also the town of Lugo is perfectly aligned according to this fields system, so the same reasoning as for Budrio applies. However, Lugo does not appear in the long list of castles founded by Faenza in 1217 CE, likely because this castle was already existing with his *burgus* at the time (Rossini 1938). Thirdly, the sources tell us that Faenza tried several times to secure possession over Lugo at the expense of the archbishop of Ravenna, even leading to its destruction in 1218 CE (from Tolosano 1936, 133–134). Still, we do not have evidence of prolonged control over the site and the area further north since the regular field system extends almost as far as Fusignano (Figure 2). Furthermore, they seem to suggest that this reclamation was a long process, perhaps taken up by different territorial lords if the monasteries of Ravenna were still promoting the reclamation of this territory in 1266 CE. In short, the sources can help us only up to a certain point to reconstruct when and who promoted this process, but it seems clear that a key role was played by municipal authorities, whose imprint on the territory becomes evident especially from the 12th and 13th cen- turies (Menant 2014, 37–39).

Conclusion

The integrated analysis has added significantly to our understanding of the physical and cultural evolution of this portion of the Ravenna hinterland. By crossing surface data from field surveys and remote sensing with geological stratigraphies, it was possible to comprehend how complex the local sedimentary sequences are, with significant variations. This apparently homogeneous and static landscape, marked by its orthogonal agricultural divisions, is actually a multifaceted palimpsest that was deeply modified by both natural and anthropogenic forces and was strongly unstable from the geomorphological point of view. This instability after the end of the Roman period led to different and original water management solutions, from redesigning a pre-existing layout as in Lugo, to creating new ones as in Bagnacavallo (Abballe and Cavalazzi 2022) or Massa Lombarda (Abballe 2022).

At the same time, limitations in knowledge have also emerged that would not be easy to answer even if we wanted to. For example, we have narrowed down the circle of potential promoters for this large-scale agrarian rearrangement using Roman standards. Still, we will probably never be able to state who did it without a doubt. What can certainly be done is to continue collecting paleoenvironmental proxies to characterise the Orizzonte Veggiani, one of the few well-preserved off-site medieval landscape contexts which could help to understand the past land-use and land-cover, also of areas far from the main archaeological sites. So far, the evidence gathered could suggest agricultural activities carried out in this context, even beyond our expectations, so new research should be promoted there in the near future. This is possible since the OV is buried deeper than agricultural and construction works usually reach, unlike most medieval 'soils', which correspond to the present ground level and thus have been usually destroyed. The same limitation does not apply to older palaeosols, which are well preserved under metres of deposits. Our field experience tells us that macro botanical remains are rarely found within these layers, but this problem could be overcome by crossing the study of microcharcoal and pollen assemblages (Bianchini et al. 2022).

More in general, this approach aimed to overcome also some limitations caused by the current land use of the landscape, where there is a predominance of fruit orchards and vineyards. This characteristic undermines the field survey results and prevents, in most cases, any large-scale geophysical surveys. Nevertheless, it has been possible to understand better the geomorphological biases that affect our archaeological knowledge. Thus, we showed how integrated approaches can say a lot about challenging study areas such as the Po Valley and reclaimed landscapes in general.

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Additional Information

Michele Abballe contributed to the following sections: Geomorphological Context, Archaeological Archival Research, Aerial and Satellite Images Analysis, Geoarchaeological Campaigns, Radiocarbon Dating, Palaeolandscape Reconstruction, Methodological Implications for the Study of Hidden Landscapes, Characterisation of Wetland Vegetation, Medieval Wetland Reclamation Processes, and Conclusion. Marco Cavalazzi contributed to the following sections: Introduction, Historical and Archaeological Context, Archaeological Field Survey, Historical Archival Research, and Implications for the Study of Hidden Landscapes. Celeste Fiorotto contributed to the following sections: Archaeobotanical Macroremains Analysis and Characterisation of Wetland Vegetation. Figures 1, 2 and 5–14 were made by Michele Abballe, while. Figures 3 and 4 by Marco Cavalazzi.

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