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Flood risk and socio-ecological resilience in a Late Antique and Medieval countryside

Managing a post-Roman alluvial landscape in the Ravenna hinterland

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Introduction

1 The city of Ravenna, which was the capital of the Western Roman Empire and later of the Exarchate, is currently surrounded by a fertile and cultivated hinterland. However, this is the result of a long «conflictual» relationship between the environment and the human communities that inhabited this area. Indeed, the vast cultivated areas that are exploited nowadays were often reclaimed from woodlands and wetlands that had naturally formed. This has been possible thanks to a long history of land and water management practices that are still necessary today to prevent catastrophic floods and avoid the collapse of the local agricultural system.

2 The first to promote large scale projects were the Romans, laying out regular field systems bordered by channels that acted as collectors for the excess water (i.e. centuriation). This system started to malfunction towards the end of the Roman period in many areas of the Po Valley, and people during the Middle Ages often preferred to live on the higher and driest parts of the landscape, which were less subject to flooding (FICARA, 2006; MANCASSOLA, 2012; CURTIS et al., 2014; BRANDOLINI et al., 2020). However, these transformations were not passively accepted by the local communities, which instead had put in place mechanisms of adaptation and resilience throughout the Middle Ages to survive in a «hostile» and rapidly changing landscape. In fact, these mechanisms have been already documented in several areas of the Po valley, in particular in the plains of Reggio Emilia (MANCASSOLA, 2012; BRANDOLINI et al., 2018a), Modena (RUCCO et al., 2019; BRANDOLINI, 2020), Verona (CASTAGNETTI, 1977; SAGGIORO, 2010, 2012; SAGGIORO et al., 2012) and Comacchio (RUCCO, 2015, 2021). The

hinterland of Ravenna represents another area where the local socio-ecological systems had to react to the environmental crises that occurred after the Roman period. With this study, we specifically want to focus on the strategies of land division, land reclamation and flood resilience promoted during three main chronological periods (5th-7th c. CE; 8th-11th c. CE; 12th-13th c. CE.). Furthermore, we want to understand to what extent larger urban systems influenced the local communities. To reach these aims, we use a diachronic, multidisciplinary, and multiscalar approach, combining results of a post-doc research at the University of Bologna (Marco Cavalazzi, PhD) and a PhD research at Ghent University (Michele Abballe). The post-doc research focuses on the study of the evolution of the rural landscape in the Ravenna hinterland between the 12th-13th centuries, taking into account archaeological data and written sources[1]. The PhD research aims to reconstruct how the landscape was in Roman times and how it later evolved, integrating morphological analysis of digital elevation models, the study of aerial and satellite images and geoarchaeological fieldwork[2].

3 This approach is an element of novelty. The Italian landscape archaeology has been criticised for being mostly a "site" archaeology, thus focussing on the analysis of the archaeological sites, their connections and distribution, while neglecting the study of the environment (MILANESE, 2004, 62-64; STAGNO, 2018, 30). Recently the attention to this aspect is greater than in the past: for instance, in the Po Valley region, the number of geoarchaeological investigations is growing rapidly (RUCCO, 2015, 2020, 2021; BRANDOLINI et al., 2018a, 2018b, 2020; BIANCHINI et al., 2019; RUCCO et al., 2019; BRANDOLINI, 2020, 2021; ABBALLE, in press). Still, there is a lack of ongoing systematic artefact survey projects that can collect new archaeological information and cross it with the novel environmental and geological data.On the contrary, using new archaeological, geological and geographical data together with information from the written sources, we managed to shed light on some strategies of water management and land reclamation promoted by the local communities and to document the interferences that larger urban systems like Ravenna and Faenza had on the countryside.

Ravenna and its hinterland

4 The study area gravitates around the city of Ravenna (Fig. 1), which Emperor Augustus chose as the seat of the Roman fleet in the near location of Classe (CHEVALLIER, 1968; BOLLINI, 1990), and then became capital of the Western Roman Empire in 402 CE. The subsequent urban development created a strong economic and political relationship between the capital and a large hinterland (GNOLI, 2006; BAZZOCCHI, 2008; AUGENTI et al., 2010). Even after 476 CE, Ravenna continued to have a crucial role until the end of the Exarchate (mid-8th c. CE), as well as after, when the presence of the Archbishopric allowed the city to preserve a central role in the eastern part of the Po Valley region (CARILE, 1991 - 1992; VASINA, 1993).

5 Archaeologically, this importance of Ravenna is also testified by the excavations at Classe, the harbour of the city, that until the beginning of the 7th c., continued to be one of the main Mediterranean harbours, «capable of managing several imported goods that were intended to be distributed, more than simply supplying the inhabitants of the Late Antique capital» (trans. from AUGENTI et al., 2010, 610). At the same time, in some rural areas nearby Ravenna, a substantial increase in the human presence has been

recorded since the 5th c., like in the Decimano area (located south of Ravenna, see MANCASSOLA, 2008a) or north of Cesena (NEGRELLI, 2008, 237-256). On the contrary, inner areas of the Po Valley started to be abandoned already since the 3rd-4th c., including also urban settlements (e.g. *Veleia* or *Claterna*, WARD PERKINS, 1988; AUGENTI et al., 2015).

6 During this long period, several urban actors have played a major role in influencing the social-ecological systems of the hinterland of Ravenna. Firstly, the urban aristocracy of the Late Antique capital, then its archbishops and, in particular, from the 10th c., also the many urban monasteries that mainly developed from the patrimony of the Church of Ravenna. Later on, especially from the 12th c. CE, Ravenna and other cities located along the *Via Aemilia*, such as Imola, Faenza, Forlì and Rimini, started to affirm their control on this area of the Po Valley, often competing with each other to create their own civil district (VASINA, 1986). From a geomorphological point of view, the research area is located in the southeastern part of the Po Valley, around 15-25 km inland of Ravenna, and according to previous studies, has been shaped mainly by the rivers Santerno and Senio (FRANCESCHELLI et al., 2007). When flowing within the flat floodplain, these Apennine rivers naturally developed raised alluvial ridges made of sandy and loamy sediments, flanked by more depressed areas called backswamps, characterised by deposits of fine silts and clays left behind by flood events (CHARLTON, 2007).

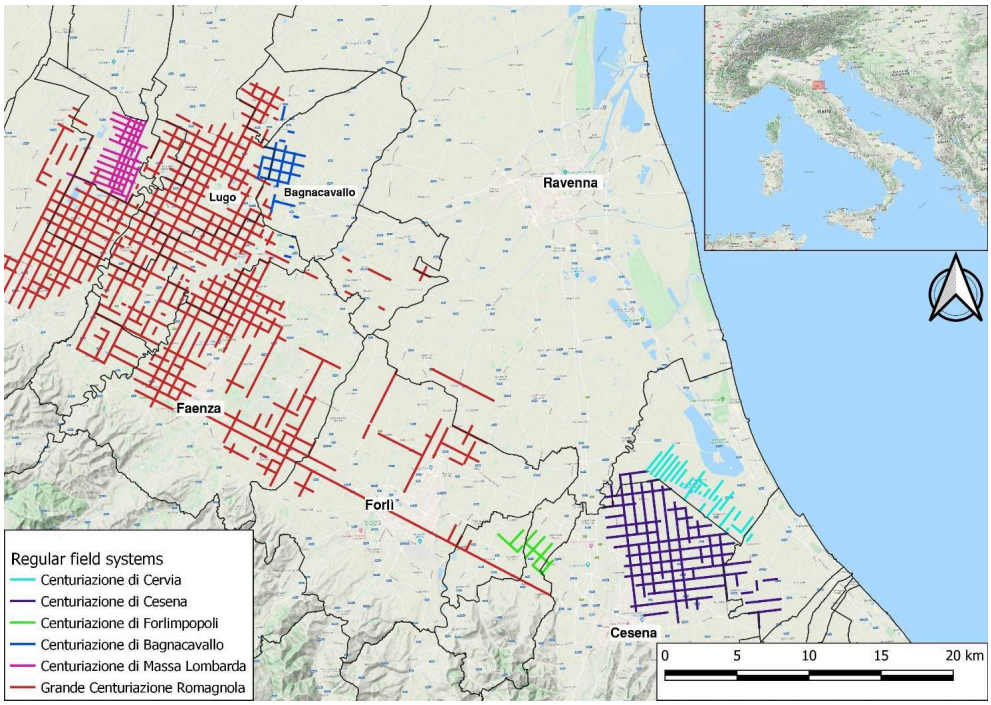
7 To limit the risks of flooding, the Romans realised the first large-scale land and water management project in the area (*centuriazione*), dividing the cultivated land into square fields delimited by roads and ditches (SETTIS, 1993; MUZZIOLI, 2010). Later on, due to an interplay of lack of maintenance of the irrigation systems, likely occurred towards the end of the Roman period, and the starting of a cooling climate phase known as Late Antique Little Ice Age (or LALIA: BÜNTGEN et al., 2011; CHRISTIANSEN et al., 2012), the waterlogged areas increased their extension and new marshy areas developed covering the previous Roman farmland with its rural sites. A local example of this regional phenomenon is the so-called *Orizzonte Veggiani*, a stratigraphic layer identified below the present town of Lugo that developed in the Early Middle Ages, often in the presence of wet conditions, and that covered Roman farmsteads with up to 5m of alluvium (FRANCESCHELLI et al., 2007, 119-120).

8 However, this worsening of the environmental conditions contrasts with the preservation of the local Roman regular field system, which represents one of the best-preserved examples in the Emilia-Romagna region. Previous studies already focused on possible ways to keep the system working or to restore it even after an abandonment phase (BOTTAZZI et al., 2008, 201; FRANCESCHELLI, 2008, 120; CHOUQUER, 2015, 126). Specifically for the area of Lugo, the monasteries of Ravenna have been suggested as the promoters for this process of «sewing up» the system (trans. from FRANCESCHELLI, 2015).

9 However, the area is characterised by the existence of other two regular field systems, the so-called *Centuriazione di Bagnacavallo* and *Centuriazione di Massa Lombarda*[3]. While the literature agrees on dating the second one to the 13th c., in relation to new settlers coming from Lombardy that arrived in the area in 1251 CE (MONTANARI, 2000), for the first two possible chronologies have been suggested: Late Antiquity (PASQUALI, 1975; BOTTAZZI, 1994) or Early Middle Ages (FRANCESCHELLI et al., 2007, 156-158). However, these two hypotheses were proposed when almost no archaeological and geological

data were available, so mainly relying on the written sources: the results of our fieldwork can potentially contribute significantly to the debate.

Fig. 1 - Study area, with major regular field systems and main nearby cities



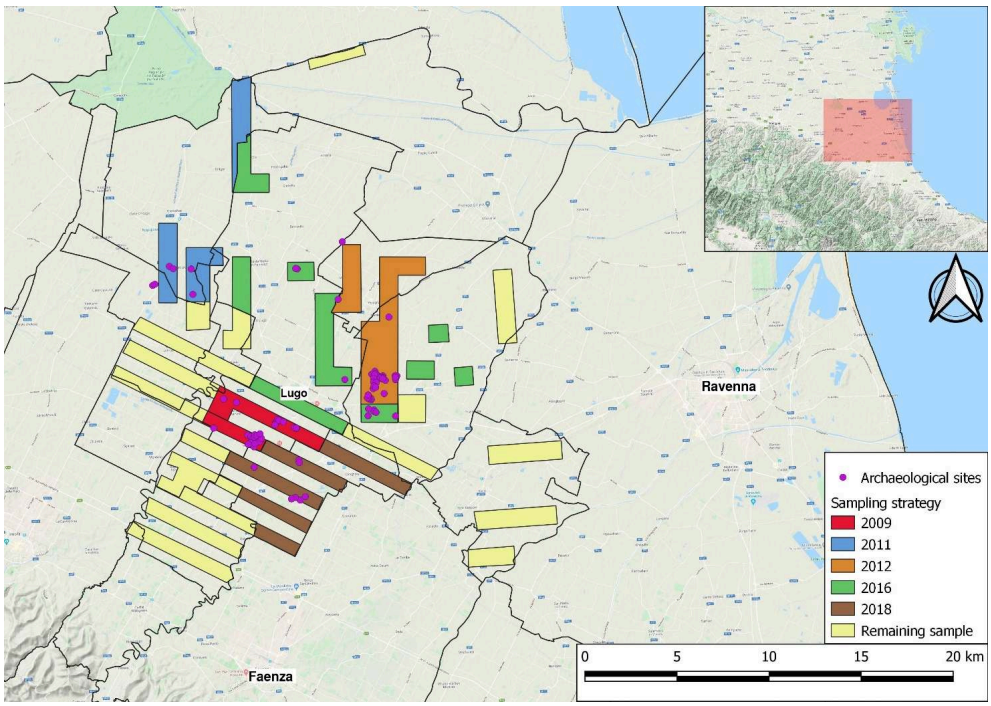
Methods and data

10 The archaeological dataset used for this study was collected during the landscape archaeological project «Bassa Romandiola», promoted since 2009 by the University of Bologna to investigate the north-western lowland of Ravenna[4]. The main method used by the project is artefact survey, later followed by geophysical surveys, geoarchaeological analysis, and large-scale excavations (CAVALAZZI et al., 2015, 2018).

11 Five campaigns of artefact survey allowed to investigate approximately 15% of the territory of Bassa Romagna sub-region (i.e. 78 sq. km of the whole context, namely 525 sq. km) and to document 71 archaeological sites, dated from Late Antiquity to the Modern Age (Fig. 2). The artefact survey was intensive and systematic (CAMBI et al., 1994, 161-179), with the archaeologists walking in parallel lines at a 10-metre distance from each other (Fig. 3.1), to collect any visible archaeological find such as pottery sherds, coins, etc[5] and recording their position with a handle GPS, like in a site-less survey[6].

12 In particular, we focused on the results collected in 2009, 2012, 2016 and 2018, in the territories of Lugo, Bagnacavallo and Cotignola.

Fig. 2 - Sample strategy of the Bassa Romandiola project and archaeological sites detected by the artefact survey (seasons 2009-2018)



13 Despite the promising results obtained by the project, we knew from the start that the study area was affected until the last century by several events of river diversion and by large reclamations projects, which are well-known thanks to the written sources and historical cartography (GAMBI, 1949). These transformations have profoundly changed the «Roman» and «medieval» landscape, with many areas now covered by later alluvial sediments that limit the chances to find archaeological sites using non-invasive methods as artefact survey. Abandoned fluvial ridges can represent exceptions to this phenomenon because, being originally raised on the floodplain, they are less prone to be later covered by alluvium. Therefore, these geomorphological landforms can be used to study past settlement patterns also through surface methods.

14 However, to better understand the original topography existing in the past, which undoubtedly influenced the settlement dynamics and the susceptibility to flooding events, geoarchaeological investigations have been recently included in the methods used by the project. So far, most activities have been carried out using a hand auger set from the Dutch company Eijkelkamp, because it is inexpensive, relatively quick and not too invasive (Fig. 3.2)[7]. However, this method has several limits, including the maximum reachable depth (usually no more than 5-6 metres) and the difficulty in collecting undisturbed samples for field interpretation and laboratory investigations (e.g. pollen or sediment analyses). To overcome these limits, three continuous mechanical corings were carried out in the area of the so-called *Centuriazione di Bagnacavallo*, where the alluvial sediments were likely to be thicker (Figs. 3.3-4). During the work in the field, the soil samples have been described paying particular attention to their estimated amount of sand, silt and clay content. Thus, it was later possible to divide the layers into two major categories: layers deposited by a nearby watercourse when the amount of sand is predominant (i.e. crevasse/levee) and layers deposited by a more distant watercourse when instead silt and/or clay are prevailing (i.e. floodplain =

dry environment; marsh/swamp = wet environment)[8]. Furthermore, possible evidence of pedological processes and/or anthropic activities have been documented, allowing us to recognise palaeosols covered by later alluvial events[9]. Finally, thanks to an analysis of all the archaeological data available for the study area, relative dating of the palaeosols and of the other intermediate layers was proposed.

15 For this paper, we considered the nine augers carried out south-southwest of the town of Lugo and two mechanical cores that were instead carried out with the so-called *Centuriazione di Bagnacavallo*, at the border between the towns of Lugo and Bagnacavallo.

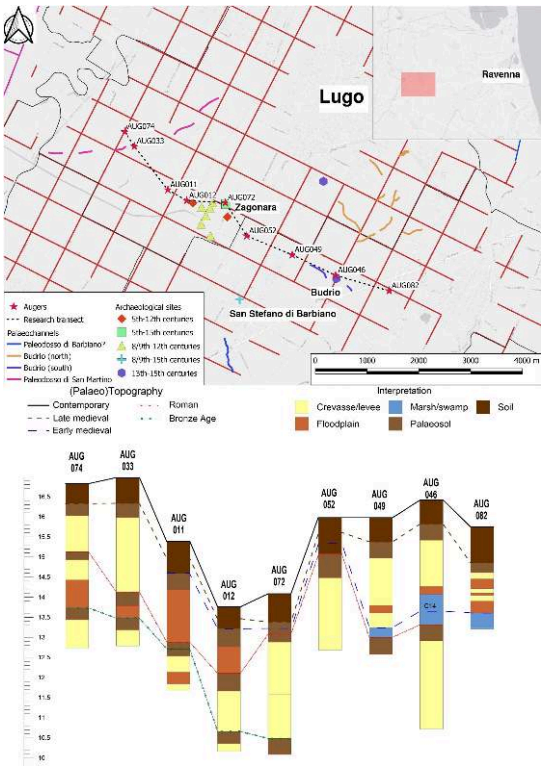
Figs. 3.1-4 - Different methods used: artefact survey (1), manual augering with soil samples (2), continuous mechanical coring (3) with an example of continuous soil sample (4)

Integrating archaeological and geological data

16 The first of the analysed zones is located to the south-southwest of the city of Lugo (Fig. 4.1). Here, on top of a fluvial ridge with a south-north orientation (*infra*), a parish church (i.e. *S. Stefano di Barbiano*) existed at least from the 9th c. CE (PASQUALI, 1993). At the beginning of the 13th c. the Commune of Faenza, an ancient *municipium* located along the *Via Aemilia* (to the south), founded ex-novo a fortified village (a *burgus novum*) called Zagonara, near the rural church of *S. Andrea* in *Zagonara*, that existed already since the 11th c. (TOLOSANO, 131; GADDONI et al., 1912, no. 771). The village was abandoned entirely in the 15th c. (MASCANZONI, 2004) and the site is now used for agricultural purposes and no standing structures survive. The area around the site of Zagonara was investigated by the landscape archaeology project «Bassa Romandiola» in 2009 through artefact survey (Fig. 4.1), allowing to identify the abandoned fortified late medieval village and its church. Furthermore, several sparse sites were detected in its surroundings, which mostly date from the 8th/9th, except two that show traces of earlier phases, dating back to the 5th-7th c. (CAVALAZZI, 2012, CAVALAZZI et al., 2018). These archaeological sites were located along the main parcel's limits (the *centuriatio*), and this allows us to assume the coexistence between this part of the centuriation and

the sites themselves. All these sparse sites around the village of Zagonara were abandoned in the 13th c., when the new village was founded; this site has been excavated since 2017. After five excavation campaigns, we brought to light the remains of the church and a large production area, together with traces of occupation that dates before the foundation of the village by the Commune of Faenza in 13th c. (CAVALAZZI, 2017; 2018; FIOROTTO et al., 2020).

17 Two kilometres east of this zone, the survey 2018 discovered the site of another abandoned fortified village, known as Budrio (Fig. 4.1), that was also founded by the commune of Faenza at the beginning of the 13th c. (TOLOSANO, 131)[10]. Compared to the nearby area around the site of Zagonara, here no pre-existing archaeological sites were identified: this 13th-century village represents the only settlement known and that was probably abandoned between the 14/15th c.Figs. 4.1-2 - Study area located south-southwest of Lugo: with augers, geoarchaeological research transect and archaeological sites (1); section including a description of the augers and models of the evolution of topography during five chronological periods (2)

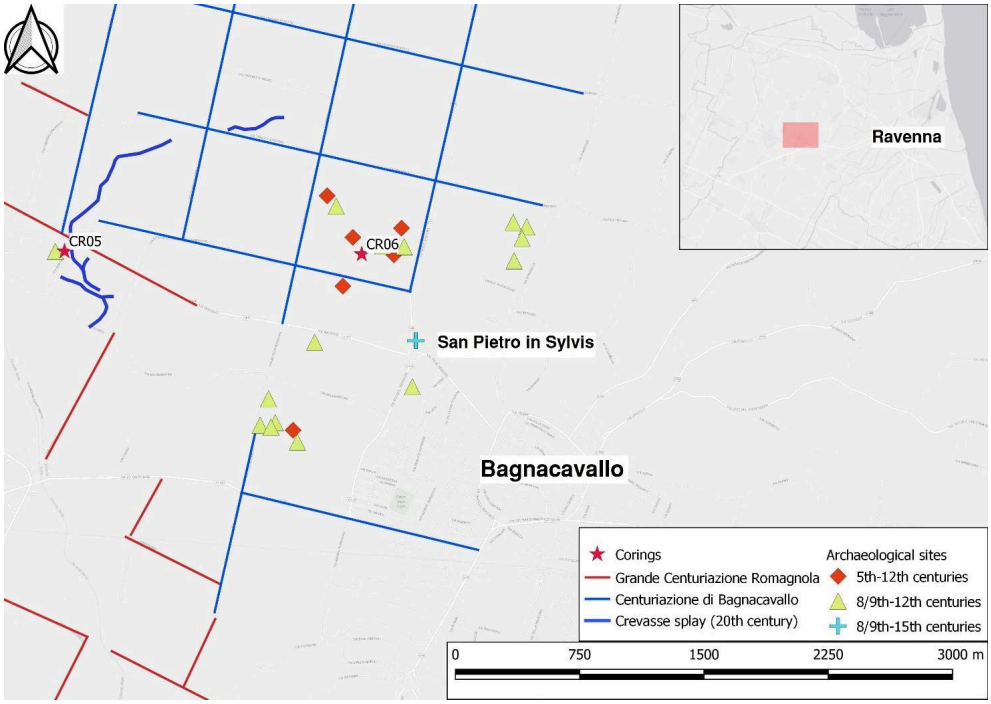


18 To better understand how this area evolved during the late Holocene and better assess the artefact survey results, a research transect was designed crossing the whole plain between the rivers Santerno and Senio (Fig. 4.1). Here, we present an interpretation of the most significant augers also proposing a possible model of the topographical changes that occurred after the Bronze Age, which had likely influenced the settlement patterns (Fig. 4.2).In the western half, it has been possible to follow for a few km the trend of a palaeosurface (AUG074-072, green line) dated to the Bronze Age (i.e. *Geosuolo Formellino*: FRANCESCHELLI et al., 2007, 104-107), that stands at a quite high elevation, due to the presence of the already known *Paleodosso di Bagnara* (FRANCESCHELLI et al., 2007, 29-30) and later keeps decreasing moving eastwards. Later on, a significant change in the topography happened at the centre of the study area, where around 2-3 metres of sandy deposits were found between AUG072 and AUG052. Previous studies

already raised the hypothesis that a fluvial ridge was present, called *Paleodosso di Barbiano*[11], on which the homonym church is located (*S. Stefano* in *Barbiano*). This ridge was tentatively dated to the Late Antiquity/Early Middle Ages due to the absence of previous archaeological sites in the area (FRANCESCHELLI et al., 2007, 31). Although the lack of final data, we would suggest an older dating for this alluvial ridge mainly formed already before the start of the Roman period (red line), thanks to the reanalysis recently carried out of all the geoarchaeological data available at the moment (ABBALLE, 2020).

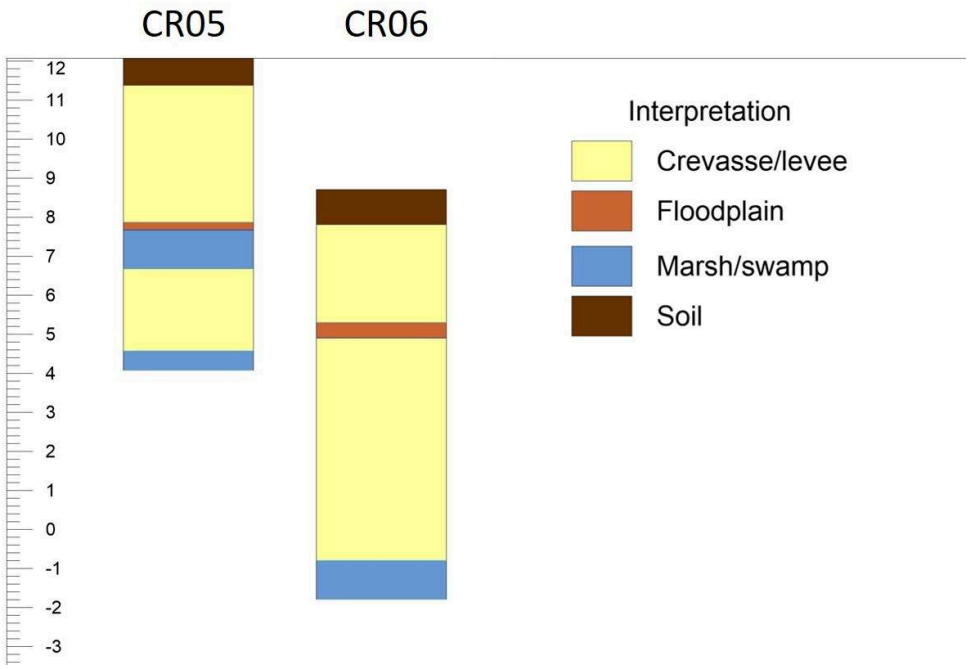
19 The creation of this ridge, with the original channel probably located not far from AUG052, would explain why the two surrounding areas have experienced a completely different story during the Middle Ages. The western part remained relatively stable (blue line), with little traces of intense alluvial events and a vital settlement pattern, especially during the Early and High Middle Ages, as documented by the artefact survey. The eastern part instead experienced the formation of marsh/swamp after the Roman period (likely from the 6th c. CE)[12] that lasted until the 11th/12th c. CE, according to the C14 dating of a seed of *Vitis vinifera* L. coming from AUG046[13]. Only after this moment, an intense alluvial event has deposited up to 2 metres of sandy deposits resulting in a heightening of the landscape (brown line), close to the present elevation (black line). According to the written sources, it is safe to say that this must have happened before 1217 CE, the year when the *Castrum Butrium* was founded, according to a contemporary historian (TOLOSANO, 131). From the analysis of several freely available sources of aerial and satellite images, traces of possible watercourses that could be linked to this event are clearly visible in the area, both north and south of the present church of Budrio (Fig. 4.1). The fact that almost all the northern crevasse splays start from the same axis along *Via Gaggio-Via F. Crispi-Via Croce Coperta*, makes us think that anthropic intervention could have played a role[14].Lastly, it is more complicated to date the post-Roman event that further raised the western part of the study area, especially between AUG074-AUG033: the resulting fluvial ridge is already known in the literature as *Paleodosso di San Martino* (FRANCESCHELLI et al., 2007, 33). For now, it is not yet possible to further refine its chronology, but the palaeochannel responsible for the formation of this ridge has been identified, so future investigations could aim to fill this gap (Fig. 4.1). The second zone analysed stands near another parish church called *S. Pietro in Sylvis*, which is located 1 km northwest of the town of Bagnacavallo and has been documented since the 8/9th c. CE (BUDRIESI, 1999). The area is characterised by a regular field system (Fig. 5), which has a different orientation compared to the main system, the latter known as *Grande Centuriazione Romagnola*. This sample was investigated in the 2012 field campaign of the survey (DE FELICIBUS, 2017; CAVALAZZI et al., 2018) when several late antique sites (5th-7th c.) were detected. The settlement pattern evolved starting from the 8th/9th c. when some nucleated sites appeared both in the proximity of the pre-existing late antique sites, both in other areas apparently not before settled (Fig. 5). The area occupied by this kind of nucleated settlements was not wide, maximum equal to 45.000 sq. m. This is a different trend compared to the one documented in the area around Zagonara, where in the same period, a sparse settlement pattern survived, in continuity with what also happened in the Roman period. Later on, both areas share a similar fate with these sparse rural settlements abandoned during the 13th c. CE. In this case, the rural population was probably attracted by the nearby castle of Bagnacavallo, which became the main settlement of this area, since the 11th c. (PASQUALI, 1995, 160-161).

Fig. 5 - Study area located north-northwest of Bagnacavallo, with corings and archaeological sites



20 Before the survey, previous studies already hypothesised the presence of possible different fluvial ridges in the area (FRANCESCHELLI et al., 2007, 31-32, nos. 7-8-12), so artefact survey could potentially give back interesting results, as it did. However, to better understand the recent evolution of the study area, two cores were realised in August 2019 near some of the sites discovered, which have clearly confirmed the presence of fluvial ridges, which correspond to the crevasse/levee layers (Fig. 6). Considering that we have no archaeological data coming from excavation, we can still use the data from the survey to hypothesise a relative chronology for the development of this small area. Since late antique sites (5th-7th c.) were recorded nearby CR06, this area must have remained geomorphologically stable since at least that period. The occurrence of periodic flood events cannot be excluded, rather it is highly likely and we probably have evidence for these from the analysis of the aerial and satellite images, that shows a large crevasse splay (Fig. 5), which seems to be datable to the beginning of 20th c[15]. Nevertheless, the discovery of these archaeological sites suggests that the floods have not significantly affected the area, at least in terms of sedimentary intake. Then, comparing this core to CR05, the first element that stands out is a c. 3 m difference in elevation. If we consider that next to this last core, in 2016 a sparse site dated to 11th/13th c. was located, this elevation difference could testify to the activation of a different fluvial ridge closer to this area in a later period.

Fig. 6 - Description of the two corings carried northwest of Bagnacavallo



21 Especially after having proposed this last interpretation, it becomes necessary to underline the limits of our datasets. On the one hand, the artefact survey suffers from several biases that can mislead historical reconstructions (AMMERMAN, 1981; ALLEN, 1991; ALCOCK, 1999; SAGGIORO, 2003; BANNING et al., 2017), e.g. the ones caused by the intensity of the survey[16] or the visibility of the sample area[17]. Anyhow, in our study areas the settlement distribution responds to homogeneous trends; this reinforces our considerations and interpretations, which seems to be coherent and responding to an actual historical situation, despite all the limits mentioned above.

22 Biases due to visibility are even more relevant in an alluvial environment as the Po Valley since the deposition of fluvial sediments can raise the local topography and completely hide archaeological sites. To overcome this limit, we defined a geoarchaeological campaign to better understand the regional geomorphology evolution. This approach has given excellent results in the first area, to the south of Lugo, where archaeological data from the excavation were already available. The same results are more difficult to reach in the second area, where the only archaeological data were collected by artefact survey. Therefore becomes clear, especially for this second area, the need for absolute dating for some crucial layers that could help us to create a more robust model. In the meantime, the two augering transects presented in this paper, based on a reanalysis of all the data available at the moment, show a realistic representation of how the two areas selected for this study evolved during the late Holocene, which helps us to better understand the evolution of the settlement patterns. Lastly, they represent a working hypothesis to direct the collection of new data in order to confirm our reconstructions.

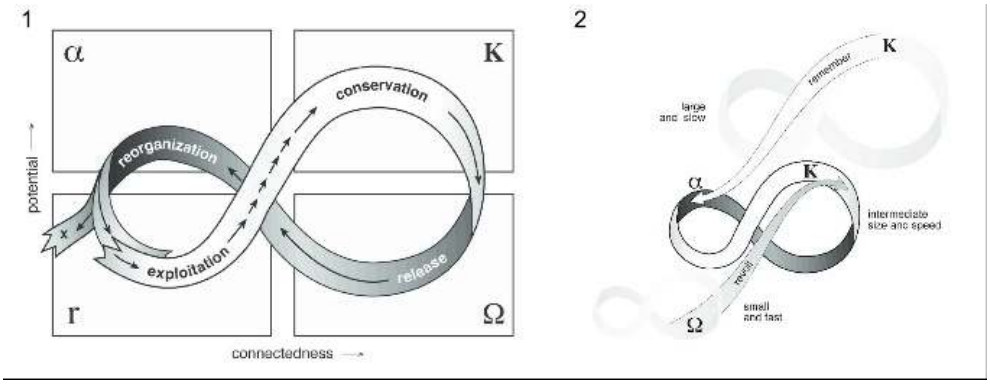
Interpretation

23 After having presented the data collected and given a first geomorphological overview of the evolution of the two study areas, we offer three more complex and refined social-ecological interpretations for specific historical periods: 5th-6th c.; 9th-11th c.; 12th-13th c. CE. These are based on the resilience theory by C.S. Holling (1973) as the main interpretative framework, which allowed us to exploit our datasets better thanks to the corroboration with some crucial information coming from the written sources[18].

24 According to this theory, a socio-ecological system is never fixed and motionless. In a dynamic movement, it passes through four different functions in a sort of circular evolution: 1. growth («R» function, in which «rapid colonisation of recently disturbed areas is emphasised»; GUNDERSON et al., 2002, 33); 2. conservation («K» function, in which «slow accumulation and storage of energy and material are emphasised»); 3. release («Omega» phase, when the capital's accumulation, i.e. the resources, «become increasingly fragile» or «overconnected», «until suddenly released»); 4. reorganisation («Alfa» phase, in which the system minimises the loss and reorganises itself and the «nutrients» -in ecological terms- for the next phase of exploitation). In this framework, the resilience of the system is the capacity to react to external stress, and to go through these different phases, adapting itself.

25 Obviously, our dataset was collected into a local scale, inside a sub-regional context (a level located between what David Clarke defined as semi-micro level and macro level, 1977). Anyhow, at this level, we can detect the influences of bigger socio-ecological systems based in the main urban centres: Ravenna, between the 5th and 11th c. CE; Faenza, between the 12th-13th c. CE. It is clear, as in the «Panarchy» framework - an updated and multiscalar vision of C.S. Holling theory (Fig. 7.1-2, GUNDERSON et al., 2002, 7) -, that also historical socio-ecological systems function at multiple scales, with several interactions between these different levels, in a hierarchic and dynamic relationship. On the one hand, the bigger levels, larger and slower to change, can influence the smaller systems, diffusing the accumulated memory of the system's dynamics («remember connection»). On the other hand, the lower levels, faster and smaller, can experiment and test innovative solutions when triggering a crisis («revolt connection»).

Figs. 7.1-2 - On the left (no. 1) the four ecosystem functions of the resilience framework - r, K, Ω, and α - (from GUNDERSON et al. 2002, fig. 2-1, 34 -); on the right (no. 2) the panarchical connections (from GUNDERSON et al. 2002, fig. 3-10, 75)



26 The functions of these complex multilevel systems in our field of research were very similar to the ones that currently interest our contemporary systems if, for instance, we focus on adaptive water governance. Indeed, B. Cosens and L. H. Gunderson (2018, 313) recently said: «with the onset of Anthropocene, global and regional changes in biophysical inputs to these systems will challenge their capacity to respond while maintaining functions of water supply, flood control, hydropower production, water quality, and biodiversity».

Reacting with strength: urban aristocracy and late antique land-reclamation

27 The area near Bagnacavallo and the church of S. Pietro in Sylvis is where we can clearly detect specific dynamics in action immediately after the end of the Roman Age since the presence of sparse settlements dated to the 5th-7th c. CE shows the capacity of the system to react to a crisis. These settlements exploited an area corresponding to a raised fluvial ridge that likely developed towards the end of the Roman period, therefore offered shelter from subsequent flood events. Later on, in the same area the church was founded around the 9th c. CE (probably already from the 8th c.) and at the same time, there was an increase in the number of sites. These elements demonstrate the capacity of the local socio-ecological system to react to a previous crisis (an «Omega» phase) and to reorganise itself immediately after.

28 From the analysis of some contemporary written sources, we can see that this answer of the local system could actually have a connection with a larger socio-ecological system, which we can probably interpret as a «remember» connection. In particular, we refer to some elements highlighted by Gianfranco Pasquali (1995, 186-190), who analysed two 6th c. papyri that document transactions of lands in this area:

- The landowners were part of the urban elite of Ravenna (*foeminea* and *viri clarissimi, honesti* or *devoti*), acting transactions of very high value[19];
- In the area *limites pubblici* still survived (i.e. the public division of land with streets and channels), as well as the public administration and circumscriptions (a *pagus* and the *districtus civitatis*);
- A *silva* is also mentioned, testifying the presence of non-agricultural lands, maybe in the form of wetlands;
- Some of the owners were of Gothic origin with public functions (fleet officers, members of the court) and probably received these lands from one of the kings of the Ostrogoths.

29 Therefore, after a relevant crisis between the 3rd and 4th c. and natural extreme events that occurred probably between the 5th and the beginning of the 6th c., the area of Bagnacavallo was immediately exploited by the urban elites, certainly also through water governance actions. It is not sure if the so-called *Centuriazione di Bagnacavallo* was outlined, or started to be outlined already in this period, but it is certain at least that these landowners, acting in this extreme and marginal environment[20], had to deal with the management of water drainage and had to deploy infrastructures for flood prevention. At the same time, we cannot also exclude the intervention of public authorities linked to the city of Ravenna or the mentioned *Pagus*. These supra-local levels could possess the knowledge to activate a «remember» connection, allowing the reorganisation of this area, assuring its success.

The continuity through the early Middle Ages: monasteries, peasants and local owners

30 Starting from the 8th-9th c., until the 12th c., we can observe an increased number of settled sites both in Bagnacavallo and Lugo, with no break or crisis in the settlement patterns clearly detectable during this long period. Furthermore, geomorphology profoundly influenced the settlement choices, with the prominent fluvial ridges often chosen for placing both religious sites (as *S. Pietro* in *Sylvis* or *S. Andrea* in *Zagonara*) and fortified settlements (as the castle of Bagnacavallo).

31 Specifically for the area of Zagonara, the archaeological sites were distributed along the main elements of land division (i.e. the *cardi* and *decumani* of the centuriation). This demonstrates that a land division of ancient origin still existed in the period, preserved likely through a process of vertical transmission (CHOUQUER, 2015).

32 Previous historical researches (PASQUALI, 1995; MANCASSOLA, 2008b) highlighted additional elements that contribute to our understanding:

- Large monastic estates developed from the 8th-9th c. in Ravenna area, that continued to grow in the following centuries, thanks to the donations from the Church and the Archbishops of Ravenna as well as from the urban aristocracy;
- Fortified castles started to appear in the investigated area from the 10th c. (also RONCHINI, 2006);
- The environment conserved a mixed aspect, with agricultural landscape units mixed with forest and humid zones (also FIOROTTO, 2018);
- Several monastic farms were present there, which likely acted as the main actors for both water management and land reclamation processes. The most common were the *massae*, large and compact farms, frequently located at the limits of the uncultivated lands, while the *curtes*, the bipartite farms of the manorial system, were rarer.
- From the 11th-12th c. expressions of personal and familiar territorial powers started to emerge, centred on the control of castles (*castrum cum curtis*, i.e. a castle centre of a civil district; also PALLOTTI, 2018);
- Surely starting from the 12th c. (probably also before), the peasants were obliged by the owners to inhabit the parcel they cultivated; this is why they were named «supersedentes» (= *those who live upon*) in the contracts.

33 These additional elements help us to refine our interpretative framework: the reorganisation of the system was not due to natural agents but to a socio-economic transformation, consisting in the birth of the urban monastic estates and their being connected to the rural areas, through local administrators, *clientes* and peasants. There was no dramatic shift from the Late Antique system and this new cycle continued without a crisis in growth («R» phase) and conservation («K» phase) functions until the 11th-12th c., when the situation rapidly changed. The anthropic actors (monasteries, local elites, and peasants) in this long cycle can be defined as K-strategists, an expression used in ecology for the species that tend to have slower growth rates, acting in «an arena of contest competition», while R-strategists species are characterised by rapid growth in «an arena where scramble competition succeeds» (GUNDERSON et al., 2002, 33). The functioning of the system was probably assured also by: limited flood events and other environmental stress caused by natural agents, at least until the 11th-12th c.; the memory of the knowledge of previous cycles concerning the adaptive mechanisms, especially regarding water governance.

The great revolution? Urban communes managing the landscape

34 The situation seems to completely change between the second half of the 12th and the 13th c. CE. Our geoarchaeological data showed as this period is characterised by several flood events in the area of Budrio, but similar phenomena could have also occurred near San Martino (Lugo) and Bagnacavallo, if we accept the dating proposed by previous studies for the formation of some fluvial ridges (FRANCESCHELLI et al., 2007). Therefore, this general hydrological instability could be related to a cycle of climate instability known as Medieval Climate Anomaly (LÜNING et al., 2019). These events could have probably caused the abandonment of several sites north of Budrio and Zagonara, as it seems possible to deduce from the available historical sources. This is likely the case of castles like *Bassianica* and *Sancti Ilari*, which were located approximately in the areas where the present city of Lugo stands nowadays. From an archaeological point of view, it is clear that this period coincides with a radical reorganisation of the settlement pattern since all the sparse settlements in the area of Zagonara and Bagnacavallo are abandoned.

35 From the historical sources, it is clear that new actors started to play a significant role in the countryside since the second half of the 12th c.: the urban communes and the new urban elites (PASQUALI, 1995; PALLOTTI, 2018). As happened in other zones of central and northern Italy (DE VERGOTTINI, 1929; MUCCIARELLI et al., 2009; CAVALAZZI, 2019), the near urban communes of Faenza, Imola, Forlì, and Ravenna, started to affirm their territorial authority (the *districtus*) on their nearby countryside, with our study area that became a conflict zone between the city of Faenza, Ravenna and Imola. The political phenomenon materialised on the landscape in different ways:

- In 1217 the commune of Faenza founded several new fortified villages, such as Budrio and Zagonara, strategically placed along the northern border of its district (CAVALAZZI, 2021);
- This intervention included several actions to ensure the water drainage in the lower part of its district, including excavating channels to reclaim new farmable land[21]. This was probably carried out through a process of lateral transmission (CHOUQUER, 2015), resulting in a new regular field system very similar to the Roman centuriation;
- Other public authorities (the commune of Imola, the count of Bagnacavallo, the bishop of Imola, and the archbishop of Ravenna) adopted similar behaviours, starting to exploit woodlands and wetlands like in Massa Lombarda and Villafranca di Forlì, often in association with the founding of new settlements (ABBALLE, in press) or the reinforcement of pre-existing ones, such as Bagnacavallo, deeply influencing the rural population (also CAVALAZZI et al., 2018).

36 It is clear that the commune of Faenza was an agent of stress for the local system due to its deep interventions on the local socio-ecological system. This organisation was put in place through various lines of actions starting from the settlement patterns that evolved from sparse to nucleated. Water governance also had a major role, increasing the exploitable agricultural area at the expense of biodiversity[22]. Thus, the creation of these new fortified villages, at the border of its district, was not only to control the area from a political and military point of view (FASOLI, 1942), but also to reclaim land to exploit (SETTIA, 1991) and assure new resources to the city of Faenza. The broad and robust intervention in this area of a public authority with its large amount of resources (with a «remember connection») defined a new trajectory for the local system, with a

relevant shift from a still successful previous trend. This massive and swift intervention responded to what before we defined «K-strategists»' behaviour.

Conclusions

37 Using archaeological and geological data combined with the written sources, we analysed how socio-ecological historical systems reacted to natural and anthropogenic stress factors after the Roman period. In particular, we were able to follow the importance of flood-risk management practices on the success of the local systems for all the three different periods analysed. However, these local systems were substantially helped by the intervention of the larger systems represented by urban authorities, through a «remember» connection, as defined by the Panarchy theory. In particular, during crises like extreme flood events, which occurred especially during the 5th-6th c. and the 12th-13th c. CE, this connection with the cities of Ravenna and Faenza seems to have been essential to assure the resilience and subsequent reorganisation of the local systems. This probably means that, in a particular situation of crisis, in a marginal and extreme landscape like the one investigated the local resources are not enough to assure a complete reorganisation of the local system, with a strong «revolt» connection. Anyhow, the intervention of urban agents (elites, authorities, landowners) was an expected response here, in the area examined, as well as in other areas of the Po plain, where the urban networks in several cases survived (even if radically transformed) after the end of the Roman Age, strongly joining at several levels the urban centres to their countryside.

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NOTES

1. This post-doc research was carried out by Marco Cavalazzi, it started in July 2018 and ended in July 2019; the title is «The impact of the birth of urban districts on rural landscape (12th - 13th c.): an historical and archaeological research» and it has been renewed and a second phase is now in progress. It has been funded by the Comitato per i Beni Culturali del Comune di Lugo, the Cotignola and Lugo communes, and with Climate Kic Action funds (European Institute of Technology, 2015); anyhow the artefact survey dataset was collected in different field seasons, starting from 2009 (CAVALAZZI et al., 2018).
2. This doctoral research is carried out at the Department of Archaeology of Ghent University (January 2018 - January 2022), within a Joint Doctoral Programme in Arts and Humanities with the University of Verona. The title of the project is «Geoarchaeology and palaeoDEMs modelling to assess the archaeological potential of Ravenna and its hinterland». The research is funded by the Special Research Fund of Ghent University (BOF), while the fieldwork carried out in 2019 was also funded by a grant of the Research Foundation – Flanders (FWO).
3. Novel geoarchaeological data are available from the area of the so-called *Centuriazione di Massa Lombarda*, see ABBALLE, in press.
4. The field director of the project is one of the authors (Marco Cavalazzi), while the scientific director is prof. Andrea Augenti from the Department of History and Cultures. The project is funded by several institutions: the towns of Lugo, Cotignola, Conselice, and Fusignano, the Fondazione Flaminia, the Centro di Studi sulla Romandiola Nord Occidentale, the Fondazione Cassa di Risparmio e Banca del Monte di Lugo.
5. Except building materials, such as bricks or roof tiles.
6. THOMAS, 1975; CAMBI et al., 1994: 256-257; ORTON, 2000, 81; the GPS used was a Garmin 60Cx, later replaced by a Garmin 64s.
7. The methodology is explained more in detail in ABBALLE, in press. Furthermore, all data generated through hand augering are available in the accompanying dataset.
8. This interpretation is based on the facies-lithology relationship proposed for the Holocene geological record of the Po Plain by AMOROSI et al., 2017, 102, fig. 2.
9. This was done also applying hydrochloric acid (HCl) to the soil sample to roughly establish the amount of calcium carbonate ($CaCO_3$) still present, which naturally decreases with increasing exposure to weathering. The amount of carbonate was established based on the intensity of the effervescence observed and it was measured in a range of 0-4, following the guidelines developed for the CARG project and keeping in mind that usually levels between 0-2 testify the occurrence of pedological processes for a prolonged period (http://www.isprambiente.gov.it/it/progetti/suolo-e-territorio-1/progetto-carg-cartografia-geologica-e-geotematica/linee-guida).
10. The location *Budrio* appeared in the written sources only from the end of the 12th c.; the toponym is associated with the term *villa* (an open settlement) only from the half of the 13th c., therefore after the foundation of the village by the Faenza commune (REGESTO ROSSINI, 597).
11. Part of the paleochannel that formed this ridge could have been mapped south of the study area, see Fig. 4.1.

12. It seems likely to associate this wet environment with the *Orizzonte Veggiani*, whose formation was dated to the 6th c. CE: FRANCESCHELLI et al., 2007, 115-154, 148-151.
13. The seed comes from a soil sample from the depth 2.35-2.50 m; Beta-531205 [920±30 BP; 1028-1184 (95.4%) cal CE].
14. A similar interpretation has been proposed for the Tagliata Canal in Reggio Emilia, where although the crevasse splays have a recognizable relief (BRANDOLINI et al., 2018b).
15. The local community still has memories of this flood event.
16. The intensity of the survey is the energy applied by archaeologists in the artefact survey; it takes into account the ratio between surface examined and time spent (CAMBI et. al., 1994, 136-144).
17. The visibility quantifies the possibility to identify an artefact (CAMBI et. al., 1994, 151-158).
18. See REDMAN, 2005 for the use of the Resilience theory in archaeology.
19. See on this argument also ASSORATI, 2015, 78-80; FRANCOVICH ONESTI, 2007, 11 and 18.
20. The wetlands to the north of this area, known both from the written sources and modern cartography, were reclaimed only from the Late Middle Ages onwards.
21. « ...fossata magna et profunda ad liberandum districtum eorum et ad derimandum aquas inutiles atque superfluas usque in valles...» (TOLOSANO, 131); see also FRANCESCHELLI et al., 2007, 154; 163-164.
22. On the relevant role of Communes and City-states on the water management in their districts in 12th-15th c., with particular attention to the west part of the Po valley, see CAMPOPIANO et al., 2015.

ABSTRACTS

In this paper we used archaeological and geological data and information from the written sources to understand how socio-ecological systems reacted to several ecological crises that occurred after the Roman period. The region investigated is the northwest hinterland of Ravenna, a sub-region known today as Bassa Romagna. Like other parts of the Po Valley, this area was primarily characterised by the presence of wetlands and woodlands, ultimately reclaimed only in the 20th century. A multidisciplinary approach allowed us to understand better which phenomena of anthropic persistence and practices of land reclamation were put in place after ecological crises, often linked to flood events. In particular, water management processes emerge as a key element for the success of the socio-ecological systems acting in the area, starting from Late Antiquity to the Late Middle Ages. Furthermore, we investigated the relationship between local systems and larger urban ones, like Ravenna and its hostile commune of Faenza, and how these directly influenced the countryside.

INDEX

Keywords: landscape archaeology, geoarchaeology, flood resilience, land division, land reclamation, Ravenna

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