



Estimating the Potential of Archaeo-historical Data in the Definition of Geomorphosites and Geo-educational Itineraries in the Central Po Plain (N Italy)

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Abstract

Alluvial plains represent preferable areas for human settling for their suitability to agriculture activities, and many studies strengthen the interpretation of floodplains as complex human–water systems. The Late Holocene development of the Central Po Plain has a long-lasting connection with anthropogenic activities. In the study area, human land and water management, in association with different Late Holocene climate phases, deeply affected the geomorphological evolution of the Central Po Plain. The geomorphological and archaeomorphological features detected in this study represent valuable datasets of information about the evolution of this portion of the Po Plain in the Late Holocene. This paper aims to quantify the potential of archaeological and historical data in contextualising the anthropogenic geomorphological features and reconstructing how man affected the natural geomorphological processes. Through a multi-disciplinary approach that combines archaeomorphological and geomorphological investigations, we identify visible and invisible landforms developed in four different historical periods, and that corresponds to potential “geoarchaeomorphosites”. In the study area, the modern landscape consists of a cultural palimpsest of four different palaeolandscape layers characterised by peculiar landforms. After an in-depth analysis of present and past geomorphic features deriving from the reciprocal interaction between human and floodplain dynamics since Prehistory, this study suggests geoconservation and valorisation practices. Finally, starting from potential geoarchaeomorphosites, four geo-educational itineraries are proposed to promote future geotourism projects of the area.

Keywords Archaeomorphology · Anthropogenic geomorphology · Fluvial geomorphology · Geoarchaeomorphosite · Geoarchaeology · Landscape changes · Central Po Plain · Late Holocene

Introduction

Human settlements, from small villages to the major metropolitan areas, represent the result of the reciprocal influence between natural processes (geological, geomorphological) and human actions over time. In the beginning, the local geomorphological characteristics have conditioned the settlement’s position (Benito-Calvo and Pérez-González 2015), but as time goes by more incisive

anthropic action has reworked and reshaped the landscape, modifying the natural range of geomorphic processes. The human impact on the environment often has consequences in terms of hazard and risk (Aquaotta et al. 2018), in dismantling landforms and in reworking/creating new ones. Nowadays, Man is considered the third important geomorphological agent (Li et al. 2017).

The interactions between geomorphological processes, climatic changes, environmental changes and human presence have generated the interest of different kinds of researchers, who are paying great attention to both geoheritage and geohazard–georisk in cities and urbanised areas. The recent literature on urban geomorphology (Cardarelli et al. 2004; Kleinhans et al. 2010; Rhoads et al. 2015; Ninfo et al. 2016; Pérez and Pidal 2016; Pica et al. 2016; Brandolini et al. 2017; Pica et al. 2017; Del Monte 2017), geoarchaeology (Pope et al. 2003; Fontana 2006; Lewin 2010; Ortalli 2010; Stefani and Zuppiroli 2010; Dall’Aglio et al. 2011; Van Dinter et al. 2017; Cremaschi et al.

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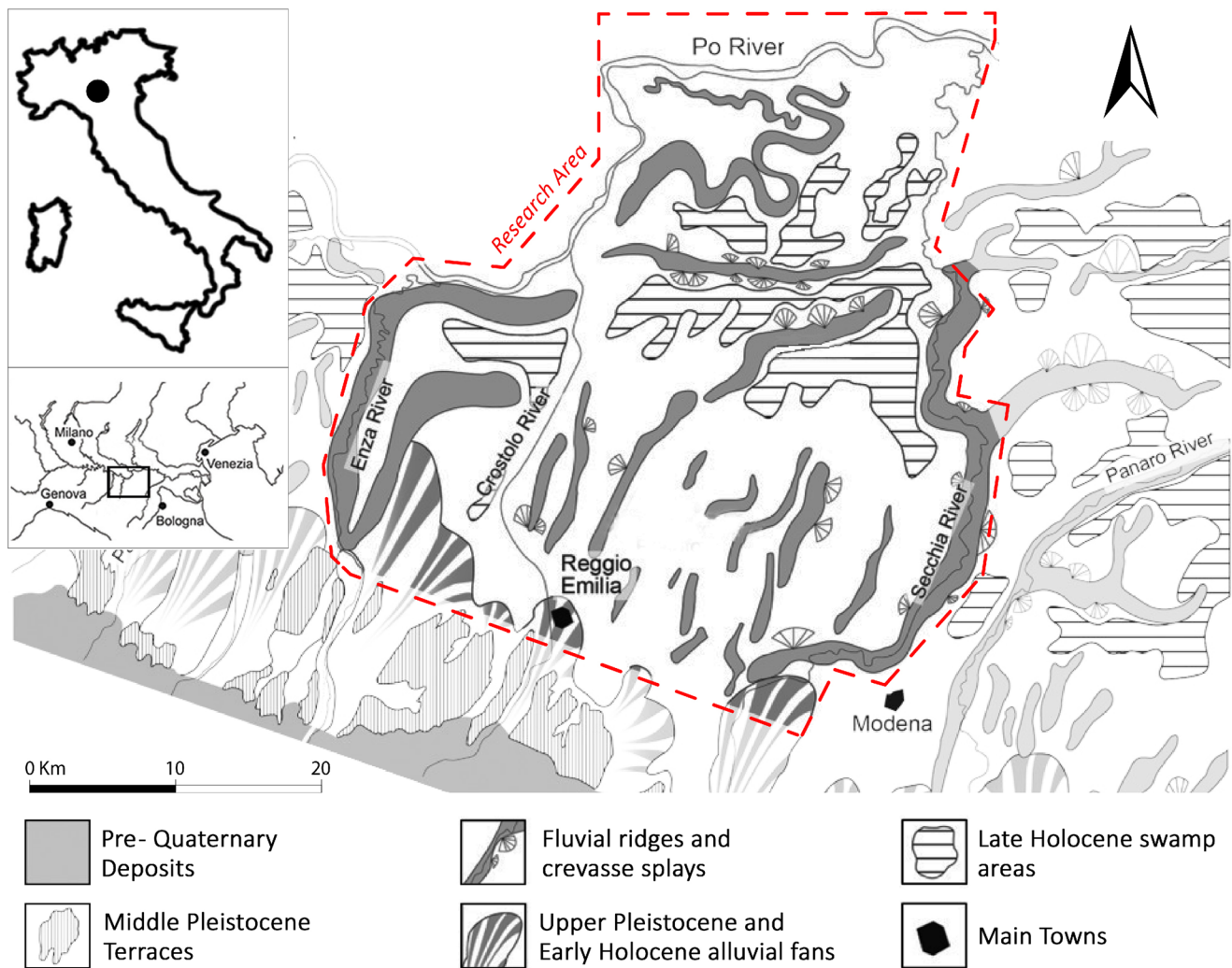


Fig. 1 Geomorphological context of the research area (modified from Cremaschi, M. et al. 2018)

2018; Mozzi et al. 2018) and geoheritage in urban areas (Del Monte et al. 2016; Pica et al. 2016; Dall’Aglia et al. 2017; Pelfini et al. 2018) highlights the impressive role of anthropogenic geomorphology in modifying landscapes (Szabó et al. 2010). All these disciplines underline the necessity of integrated research approaches to quantify the human impact on landscape evolution. Nonetheless, the progressive anthropogenic reworking of landforms is often missing geoheritage data. Clivaz and Reynard (2017) highlight the importance of inventory not only for present-day landforms and geosites (sensu Wimbledon 1996; Panizza and Piacente 1993; Pelfini and Bollati 2014) but also for the ones dismantled or hidden by human intervention. The two authors report that in the Rhone River valley (Switzerland), the river flood mitigation, industrialisation, intensive agriculture and urban development have profoundly modified channels and the surrounding areas, but some landscape features are still recognisable thanks to historical documentaries (historical maps, iconographic material, written archives, place names). Other

authors pointed out the application of the geohistorical approach as a tool of great relevance in reconstructing hydrogeomorphic dynamics (Perez and Pidal 2016) as well.

The current methodology to identify potential geomorphosites considers archaeological information as *Additional Values* (Brilha 2017; Bollati et al. 2017), but geoheritage and geoconservation studies emphasised the relevance of archaeological data (Giordano et al. 2016) in cultural geomorphosites (Niculiță and Mărgărint 2017) and geoarchaeoheritage sites (Taha and El-Asmar 2018) to promote geotourism. The close connection between archaeology, geoarchaeology and geomorphosite management was explored by Eric Fouache, who proposed the term *geoarchaeosite* to indicate a archaeological site located on a geomorphosite (Fouache and Rasse 2009). The same author also proposed the term *archaeo-geomorphosite* to define a geomorphosite with archaeological interest, and in which the geomorphological study has been prompted by historical and archaeological questions (Fouache et al. 2012).

Table 1 Main historical human-induced landscape transformations and their scale

Period	Land and water management	Scale
Protohistory	Canal networks to irrigate fields around the TC villages	Local
Roman	Cultivated land divided into square fields by a regular grid of roads and ditches	Regional
Medieval	Settlements located in a topographically higher position in the surrounding wetlands; silvopastoral sustenance practice	Local
Post-Medieval	Channelisation and wetland reclamation works	Regional

A very recent interdisciplinary and diachronic approach is represented by archaeomorphology, an analysis that synthesises aspects of geomorphology, archaeology and environmental history to study the anthropogenic effects on landscape evolution in the past (Vion 1989; Matteazzi 2014; Canfora and Di Luzio 2014). Archaeomorphology is focused on the study of human-made landforms and traces of territorial planning. It aims at analysing the historical development of landscape structures over time and embrace the idea of landscapes as cultural palimpsests (Orengo and Palet 2014).

The case study proposed in this paper offers a relevant example of anthropogenic geomorphology in Northern Italy. In the research area, geomorphological tools combined with

archaeo-historical data made it possible to reconstruct the Late Holocene interactions between humans and the environment, and their effects on the physical evolution of the Central Po Plain (Brandolini and Cremaschi 2018a).

This paper aims to reconstruct the main evolutionary landscape stages due to human activity in Central Po Plain through the identification of *visible* (landscape management evidence) and *invisible* (hidden features) landforms. A further goal is to evaluate the potential of archaeological and historical data in defining potential geomorphosites (sensu Panizza 2001; Reynard and Panizza 2005) to propose geo-educational itineraries in alluvial plains.

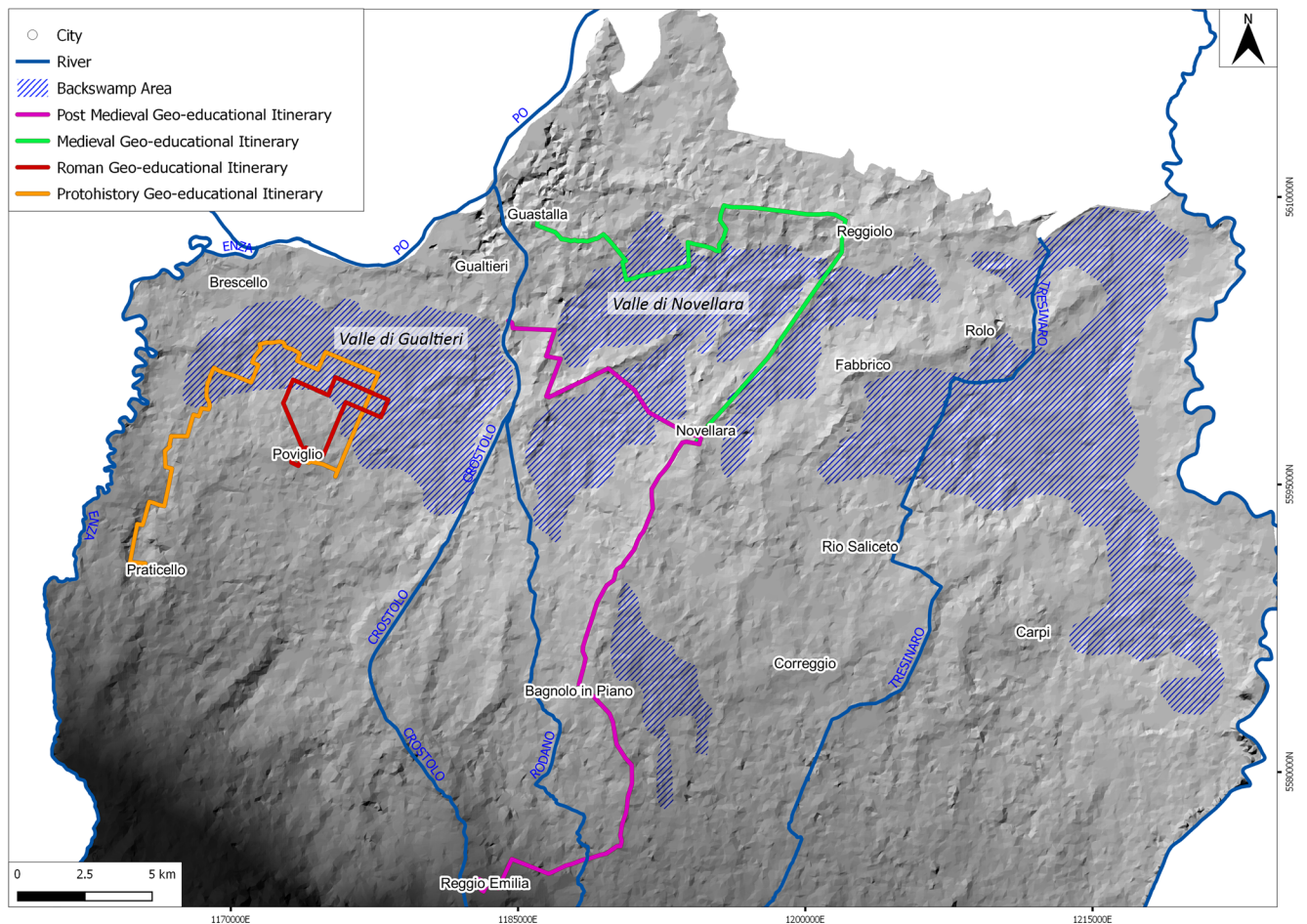


Fig. 2 Digital terrain model of the study area elaborated with software QGIS. In four different colours are indicated the four geo-educational itineraries (GEl) proposed

Table 2 For any geo-educational itinerary (Gel) are indicated the main fluvial geomorphological and archaeomorphological features, the potential geoarchaeomorphosites (GAMs) and the trail length and its travel time in three different transport modes: walking, cycling and driving

Geo-educational itinerary (Gel)	Fluvial geomorphology	Archaeomorphology	Potential geoarchaeomorphosites (GAM) h—hidden	Length (km)	Modes of transport and travel time
Protohistoric (Fig. 3)	Enza-Praticello Palaeochannel	TC buried villages and hydraulic structures	1. Praticello mound (h) 2. Mid-course of Praticello Palaeochannel 3. TC village <i>Le Grazie</i> (h) 4. TC village <i>Santa Rosa di Poviglio</i> (h) 5. TC village <i>Monticelli di Castelnuovo</i> (h)	36	Walking: 7 h 10' Cycling: 1 h 40' Driving: 45'
Roman (Fig. 8)	Accentuation of the sedimentary process of Apennine watercourse with consequent aggradation of the river beds (an effect of Roman land and water management)	<i>Centuriation</i> tracks: hidden/buried roads and ditches; regular grid restored in the Renaissance	6. Roman <i>centuriation</i> tracks 7. <i>Via Romana</i>	20	Walking: 4 h Cycling: 1 h Driving: 25'
Medieval (Fig. 10)	Backswamps; Tagliata Canal Crevasse splays; <i>Crustulus Vetus</i> palaeochannel	Tagliata Canal; land-fill ridges	8. The star-shaped medieval city of Guastalla 9. <i>Valli Nuove di Guastalla</i> (h) 10. Medieval hydraulic device on the <i>Tagliata Canal</i> landform 11. Medieval wetland between Novellara and Fabbrico (h)	37	Walking: 7 h 25' Cycling: 1 h 50' Driving: 45'
Post-Medieval (Fig. 17)	(Artificial) diversion of Apennine watercourses	<i>Fossa Alessandrina</i> canal; channelisation and wetland reclamation works	12. <i>Botte Bentivoglio</i> hydraulic device 13. San Bernardino Church— <i>Crustulus Vetus</i> palaeochannel 14. Post-medieval road along the Water-Mills canal 15. Bagnolo in Piano, artificial diversion of Rodano River in <i>Canalazzo Tassone</i> 16. Gavassa, <i>Naviglio di Correggio</i> Canal 17. Reggio Emilia, artificial diversion of Crostolo River (h)	50	Walking: 10 h Cycling: 2 h 30' Driving: 1 h

Background

Geomorphological Context

The research area is located in the Central Po Valley, few kilometres north of the Tuscan–Emilian Apennine margin, between the cities of Parma and Reggio Emilia, among the rivers Enza, Po and Secchia, and

the distal part of Holocene alluvial fans (Fig. 1, *Pre-Quaternary deposits*).

The Apennine fringe in this part of the Central Po Plain is still tectonically active, since it coincides with a complex belt of folded thrust fronts trending north–northeast developed during the Quaternary (Pieri and Groppi 1981; Barbacini et al. 2002; Gunderson et al. 2014; Cremaschi et al. 2018); as a result, the tectonic forces uplifted the mountain margin

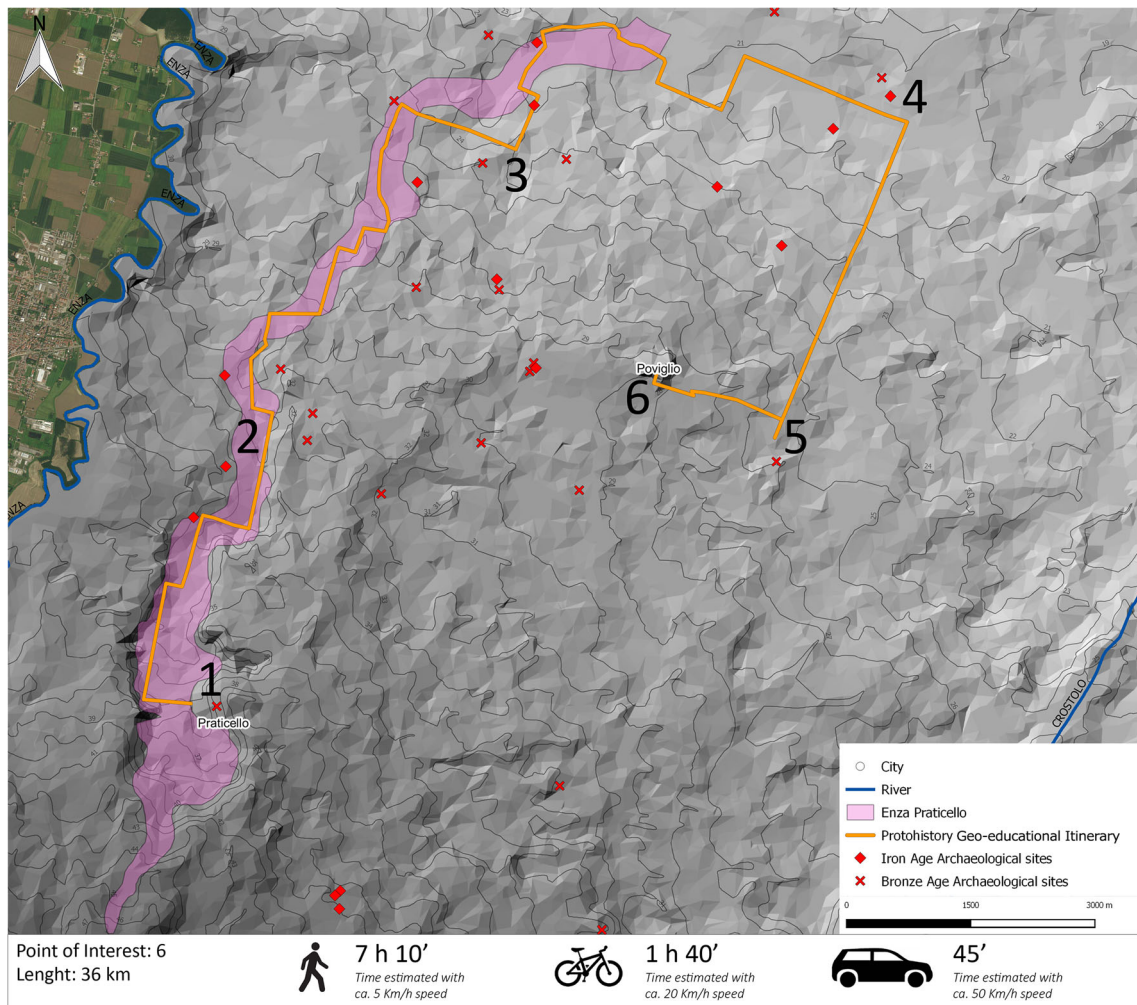


Fig. 3 Protohistoric geo-educational itinerary. Six points of interest along 36 km are proposed: 1—village of Praticello (GAM 1, Table 2), 2—mid-course of Praticello palaeochannel (GAM 2, Table 2), 3—Terramare Culture Village *Le Grazie* (GAM 3, Table 2), 4—Terramare Culture

Village *Santa Rosa di Poviglio* (GAM 4, Table 2), 5—Terramare Culture Village *Monticelli di Castelnuovo* (GAM 5, Table 2), 6—Poviglio Archaeological Museum

and lowered the plain in front of it (Scognamiglio et al. 2012). Since the Middle Pleistocene, the geomorphological consequence of these processes has been the formation of an apron of gravelly mega-fans and the deposition of fine alluvial sediments along their margin (Cremaschi 1987; Cremaschi Nicosia 2012; Cremaschi et al. 2018). Climatic fluctuations characterised by glacial and interglacial cycles in the Middle and Upper Pleistocene together with the recent tectonic processes influenced the shape, size and degree of preservation of those landforms (Rossi et al. 2002; Valloni and Baio 2009; Marchetti 2010; Gunderson et al. 2014). Remnants of Middle Pleistocene terraced fans, covered by thick polygenetic palaeosols and loess sheets, spread among the Apennine foothills (Cremaschi 1987; Busacca and Cremaschi 1998). A well-preserved system of Late Pleistocene to Holocene alluvial fans extends northward between the Apennine foothills and the Holocene plain (Cremaschi and Marchetti 1995; Castiglioni and Pellegrini 2001). As well explained in Cremaschi and

Nicosia (2012), their telescopic shape is a consequence of subsequent aggradation–entrenchment phases due to the alternation of glacial–interglacial periods: each aggradational cycle, indeed, implied an incision on the top of the previous fan, while a new one prograded in a more distal position. Fine fluvial deposits accumulated on the distal part of the Holocene alluvial fans during the transition between Atlantic and Sub-Boreal periods; their sedimentation occurred in a phase of climatic instability that followed the Holocene Climatic Optimum. Alluvial ridges of the Apennine water-courses connect the fringe of the Apennine alluvial fans with the Po floodplain (Cremaschi and Nicosia 2012).

In the study area, the alluvial ridges of the Enza and Crostolo rivers, emerging from the flat floodplain, flank depression areas occupied by swamps during Medieval Times. These depressions, or backswamps (Charlton 2007; Szabo et al. 2010), are characterised by deposits of fine silts and clays settled after flood events.

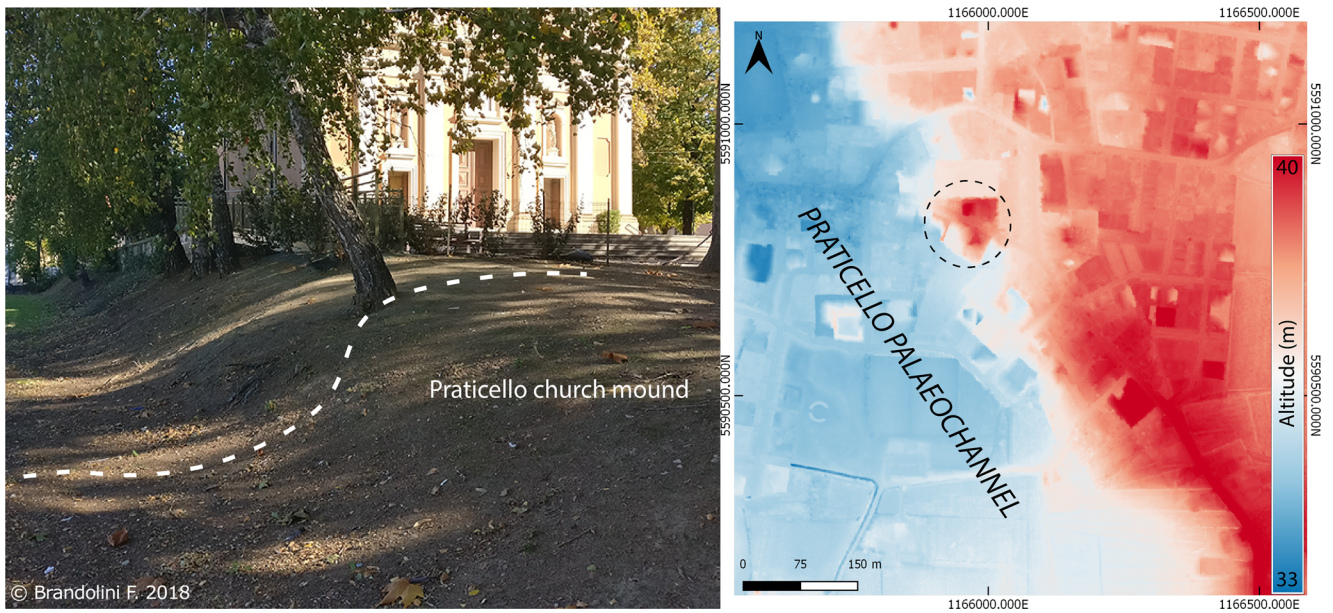


Fig. 4 Protolithic geo-educational itinerary, geoarchaeomorphosite 1: the town church of Praticello (on the left) settles on an earth mound (dashed circle on the right) along the Enza-Praticello Palaeochannel

Archaeological–Historical Context

The human-induced landscape transformation conditioned the natural evolution of this portion of the Central Po plain since Protohistory, and the main environmental, historical phases of the study area (Table 1) are presented here.

The first conversion of the natural landscape by human action is dated to the Bronze Age (the seventeenth and the mid-fourteenth centuries BC). In this period, the alluvial fan was fully stable and, on its surface, some of the most prominent Terramare Culture (hereafter *TC*) villages in the Po Valley were established (Bernabò Brea et al. 1997, Bernabò Brea and Cremaschi 2004; Cremaschi et al. 2006). The TC



Fig. 5 Protolithic geo-educational itinerary, geoarchaeomorphosite 2: mid-course of the Enza River Praticello palaeochannel



Fig. 6 Protohistoric geo-educational itinerary, geoarchaeomorphosite 4: *Santa Rosa di Poviglio* (Bronze Age Terramara Culture Village). On the left, the aerial image of the hidden archaeomorphological features: earth

ramparts and moat. On the right: two pictures were taken in the 90s during archaeological campaigns led by Università degli Studi di Milano (Italy)

villages were surrounded by a moat connected to an adjoining watercourse through a canal network to irrigate the cultivated

fields around the site (Mele et al. 2013). The human occupation of the Po Valley in the Iron Age (eighth to third centuries



Fig. 7 Protohistoric geo-educational itinerary, geoarchaeomorphosite 5: *Monticelli di Castelnuovo* (Bronze Age Terramara Culture Village). On the left, aerial view of the hidden archaeomorphological features

(modified from ©Google Earth 2018). On the right, the same hidden landforms visible at ground level

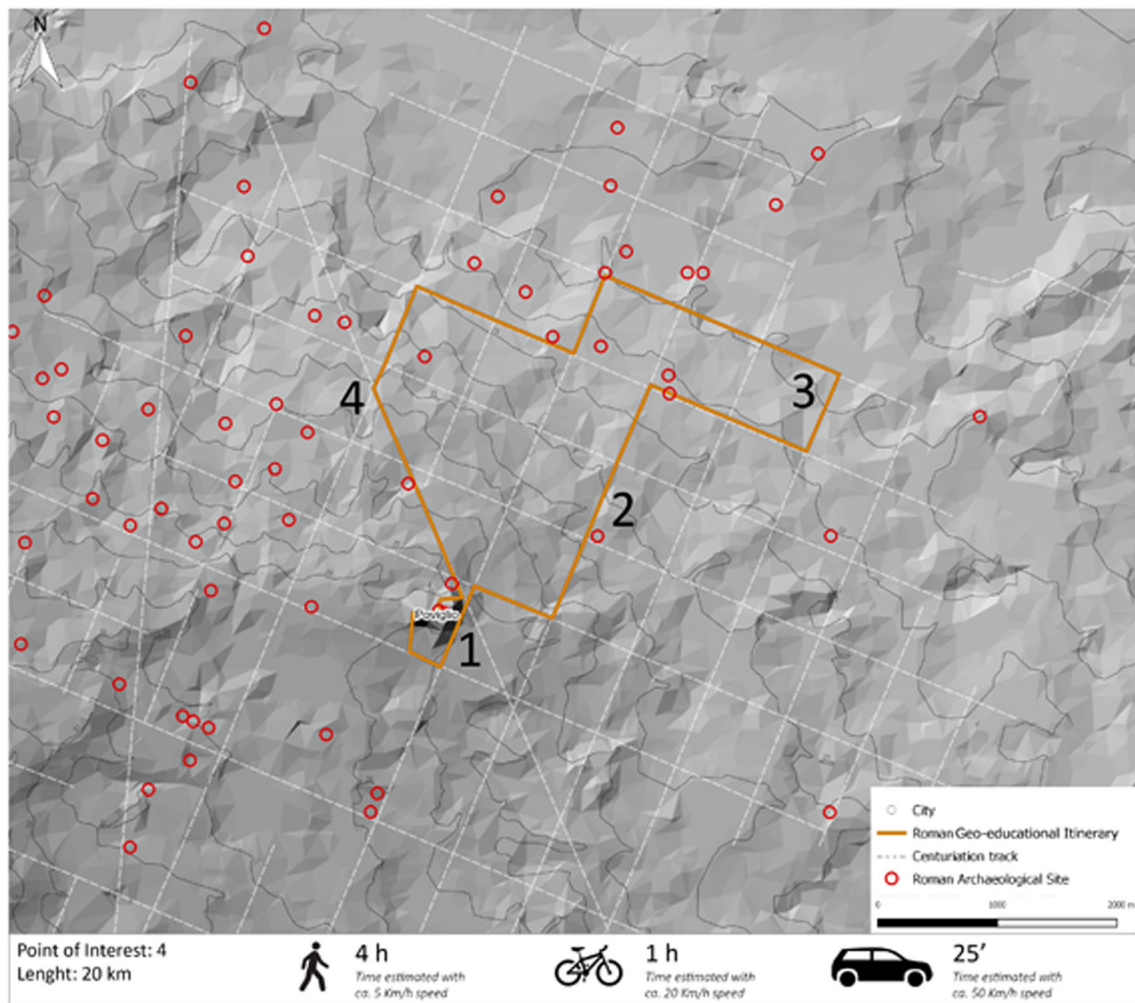


Fig. 8 Roman geo-educational itinerary. Four points of interest 20 km are proposed: 1—Poviglio Archaeological Museum, 2—Roman centuriation tracks (GAM 6, Table 2), 3—outcrop of Roman archaeological material, 4—Via *Romana* (GAM 7, Table 2)

BC) is known for sporadic archaeological findings on the surface of the alluvial mega-fans and along the course of palaeochannels. Ceramics types led to identifying a few of these sites as belonging to the Etruscan culture (Malnati 1988).

In the first century BC, the Romans colonised the Po Valley and deeply modified the natural landscape, dividing the cultivated land into square fields by a regular grid of roads and ditches (Settis and Pasquinucci 1983; Bottazzi 1985; Bottazzi 1987). The remnants of this land management system, known as centuriation, in some cases are still recognisable in present-day cultivated fields or in buried soil marks and crop marks (Brandolini and Cremaschi 2018b). The considerable archaeological data testify that numerous Roman farms (i.e. *villae rusticae*) spread in the countryside among the major *municipii* (i.e. cities) of *Mutina*, *Regum Aemilia* and *Augusta Parmensis* (i.e. Modena, Reggio Emilia and Parma) until the fourth century AD (Bottazzi et al. 1995).

In the fifth century AD, the crisis of the Western Roman Empire and the lack of maintenance of the irrigation systems (Squatriti 1998), associated with a cooling climate phase (Lamb 1995; Hoffmann 2014), led to the progressive waterlogging of the Po Valley.

The waterlogging process of the area continued until the tenth century AD, influencing the human sustenance and settling practices. According to historical–archaeological data, Early Medieval (sixth to tenth century AD) sites settled on the fluvial ridges, in topographically higher and strategic positions in the surrounding wetlands (Brandolini et al. 2018): silvopastoral practice partially replaced agriculture, and the wetlands were exploited for fishing as well as for transport by boat (Tiraboschi 1824; Drei 1924; Settia 1984; Bottazzi et al. 1995; Squatriti 1998; Settia 1999). Between the tenth and the fourteenth century AD, the European population grew progressively and almost tripled, increasing the demand for cultivated lands (Hoffmann, 2014). Cereal grains gained a more significant role in the diet

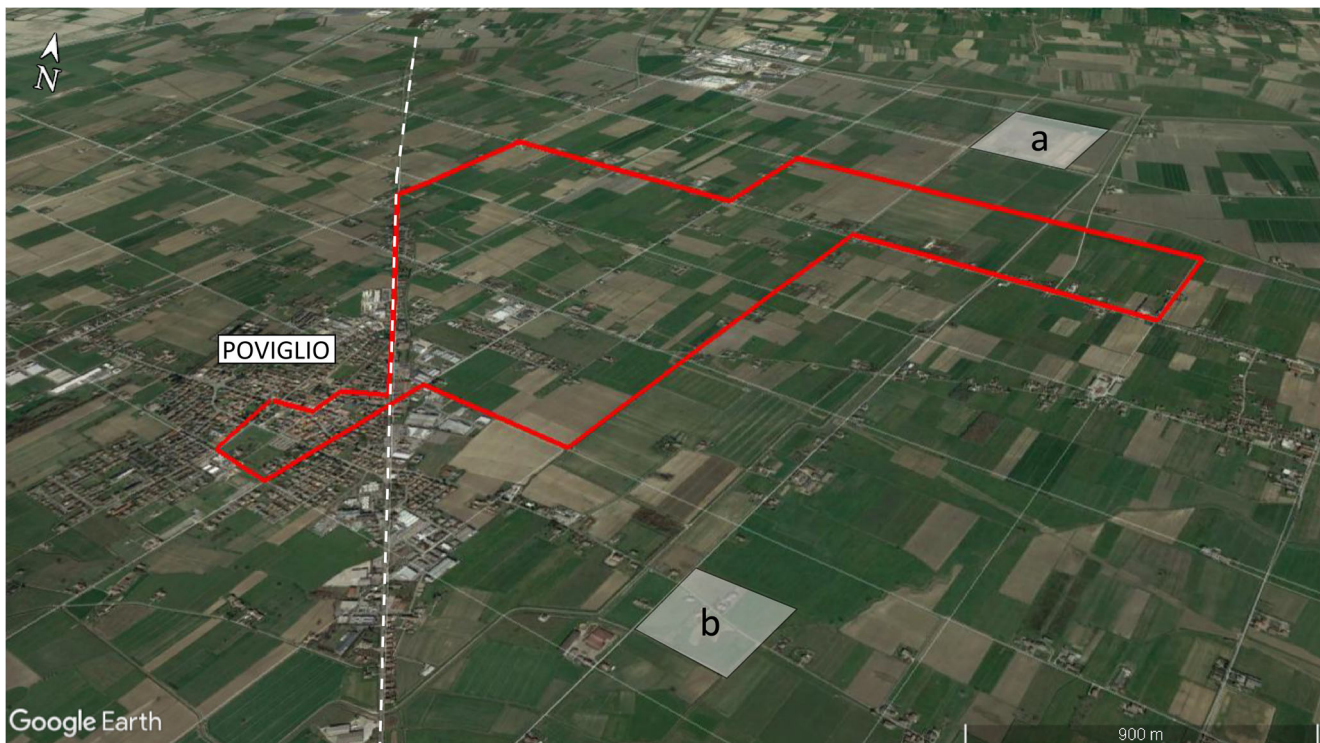


Fig. 9 Bird's eye view of the Roman archaeomorphological features. The dashed line indicates the *Via Romana* (GAm 7, Table 2). The solid white lines indicate the Roman centuriation track still visible on the terrain. The two white squares indicate the position of the two TC villages of *S. Rosa*

di Poviglio (a) and *Monticelli di Castelnuovo* (b). The red line corresponds to the Roman Gel proposed (modified from ©Google Earth 2018)

and the agrarian regime compared to the centuries before, leading the human enterprise to reconfigure the medieval natural landscape to agricultural purpose: clearance of forests and wetland reclamation shaped the Po Valley (Brandolini and Cremaschi 2018a).

In the study area, channelization and reclamation works started in the tenth century AD (Affò 1786; Affo'1792; Tiraboschi 1824; Cantarelli 1882; Mancassola 2012) and increased between the twelfth and the thirteenth centuries (Fumagalli 1985, Fumagalli 1999; Fumagalli 2014; Rao 2016), promoted both by monasteries (Fumagalli 2007; Ambrosini De Marchi 2010; Rao 2016) and by private landowners (Brandolini and Cremaschi 2018b).

Large-scale ground reclamation is dated to the Renaissance and is known in the literature as *Bonifica Bentivoglio*, by the name of its promoter, the lord of Guastalla Cornelio Bentivoglio. The *Bonifica Bentivoglio* drainage system reclaimed a large portion of the swampy meadows and was renovated and updated many times in the Modern Age: between the seventeenth and the nineteenth centuries, many homesteads were settled in the reclaimed farmland (Baricchi 1989). The ground reclamation of this portion of the Po Plain continued after the Renaissance and was complete only in the twentieth century AD (Mori 1923; Gabbi 2001; Saltini 2005), resulting in the modern completely artificial landscape.

Materials and Methods

Many authors have underlined the importance of integrated approaches in urban and cultural landscapes (Butzer 2008; Giordano et al. 2016), with studies on geomorphological heritage with assessment, inventories, cartography (Reynard et al. 2017), multi-temporal cartographic and photographic comparison, geo-thematic cartography and documentation (Faccini et al. 2017), specific legend (Faccini et al. 2017; Bollati et al. 2017), LiDAR data (Hofler et al. 2015), archaeostratigraphic data, geographic information system format and database (Amato et al. 2018), dendrochronological reconstructions (Cremaschi et al. 2009; Bollati et al. 2018) and dendrochemical analysis (Kocic et al. 2014; Vezzola et al. 2017), sedimentology, malacology, palaeontology and archaeology (Bkhairi et al. 2014), historical maps, written archives, digital terrain model and iconographic sources (Clivaz and Reynard 2017).

This study has been performed using both geomorphological tools and archaeological–historical data. The geomorphological literature on the Central Po Valley (Cremaschi and Marchesini 1978; Cremaschi et al. 1980; Castaldini 1989; Castiglioni et al. 1997; Castiglioni and Pellegrini 2001; Marchetti 2002) constituted a useful starting point in association with a preliminary remote sensing analysis performed by

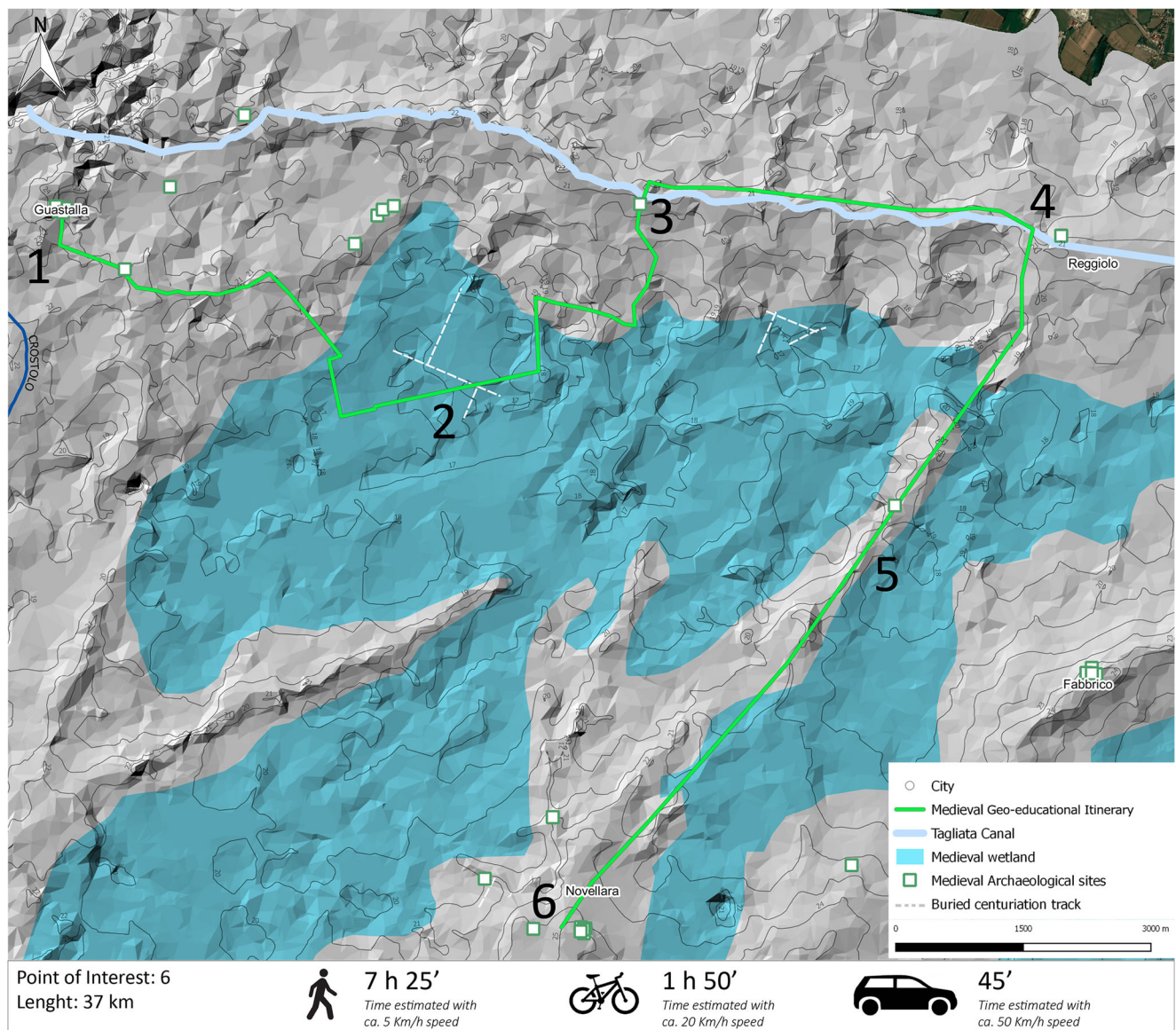


Fig. 10 Medieval geo-educational itinerary. Six points of interest along 37 km are proposed: 1—the star-shaped Medieval city of Guastalla (GAM 8, Table 2) and 2—*Valli Nuove di Guastalla*: inside the medieval wetlands. Here, buried Roman centuriation tracks have been detected

(GAM 9, Table 2); 3—Medieval hydraulic device on Tagliata Canal (GAM 10, Table 2); 4—the Medieval city of Reggiolo; 5 backswamp waterlogged in Medieval Times between Novellara and Fabbriolo (GAM 11, Table 2); 6—the Medieval city of Novellara

using both Google Earth and Bing maps images (acquisition date, 2016–2018) and UAV images.

The digital terrain model (DTM, 0.5 m of resolution) of the research area has been elaborated with the software QGIS starting from the national DEM (1 m of resolution) produced from high-resolution LiDAR ([Geoportale Nazionale](#)) and regional elevation checkpoints (m. a.s.l.) ([Geoportale Emilia Romagna](#)).

The archaeological evidence has been collected through literature (Degani 1974; Cremaschi et al. 1980; Baricchi 1989; Bottazzi et al. 1995; Mancassola 2012) and regional web database searches and during field surveys. The eighteenth and nineteenth century transcriptions of medieval accounts and parchments (Bolognini 1780; Affo' 1792;

Tiraboschi 1824; Cantarelli 1882) constituted a valuable starting point in the analysis of the historical documents along with the twentieth century editions of medieval documents kept at the Parma and Reggio Emilia National Historical Archives (Torelli 1921; Drei 1924).

The historical–archaeological data (documents, historical maps, place names, archaeological excavation reports) were added to the DTM and allowed us to date and contextualise the landforms detected.

The archaeomorphological analysis of historical–communication routes and their definition constituted an advantageous approach to understand the landscape evolution dynamics. The landscape cultural palimpsest (*sensu* Orengo



Fig. 11 Geoarchaeomorphosite 8 (Table 1): the Medieval star-shaped city of Guastalla. (modified from ©Google Earth 2018). The white dashed line represents the Medieval geo-educational itinerary proposed

and Palet 2014) of the study area was analysed and decomposed defining four different environmental layers, each with peculiar geomorphological and archaeomorphological features developed in four historical time periods: Protohistory, Roman Era, Medieval Times and Post-Medieval Period. Each layer constitutes the base to propose potential geomorphosites and to define four geo-educational itineraries (Garavaglia and Pelfini 2011) (hereafter Gel) to promote geoconservation and valorisation practices on the palaeolandscapes detected.

Finally, in this study, the term *geoarchaeomorphosite* (hereafter GAm) indicates any geomorphosite (sensu

Panizza 2001; Reynard and Panizza 2005) resulted by human-induced landscape changes and for which the archaeo-historical data are essential to (1) comprehend its genesis and development and (2) evaluate its scientific and cultural/historical values.

Results

The four Gels proposed have been reported on the DTM elaborated (Fig. 2). Each Gel is articulated in multiple-stop trails that connect the potential GAm proposed. Table 2



Fig. 12 Geoarchaeomorphosite 9 (Table 2): Valli Nuove di Guastalla. Roman buried centuriation tracks. On the left, aerial view. The white dashed line corresponds to the Medieval geo-educational itinerary

proposed (modified from ©Google Earth 2018). The red square (Stop n.2 in the itinerary) corresponds with the terrestrial view acquisition point (on the right)



Fig. 13 Canal Tagliata. The white dashed line indicates the Medieval geo-educational itinerary proposed between stops 3 and 4. The red square indicates the geochaemorphosites 10 (Table 2) where a Medieval hydraulic device is located on the Tagliata Canal (Fig. 13).

The light blue line indicates the Tagliata Canal watercourse. The white squares highlight the crevasse splays developed between the thirteenth and fourteenth century AD (modified from ©Google Earth 2018)

summarises the main geomorphological and archaeomorphological elements detected, the potential GAm (both hidden and not hidden) and the trail length and its travel time in three different transport modes: walking, cycling and driving.

Henceforward each Gel is presented in detail.

Protohistoric Geo-educational Itinerary

In the Protohistoric Period, the human enterprise was limited to settling in the most favourable landscape places without modifying its natural shape in large scale. The geomorphological features dated to Protohistory are the results of the meandering nature of the Apennine rivers and creeks.

The Protohistoric Gel follows the path of the river Enza's Praticello palaeochannel (Fig. 3) that represents the most relevant Protohistoric landform in the area. The itinerary starts from the little town of Praticello from which the Enza river palaeochannel takes its name: here (Fig. 3, n. 1) at ground level is perceivable the palaeochannel slope detected in the DTM (Fig. 4). Also, in Praticello village, Tirabassi (1996) believes that the mound (GAm 1, Table 2) where the town church is located corresponds to a Bronze Age settlement: no archaeological data confirms this hypothesis; this is because in Medieval Times the Bronze Age mottes were often re-used to settle fortified villages or churches, making it difficult to detect Protohistoric evidence. Even though the land and water management seems not to have affected the natural development of the Praticello palaeochannel, this landform is strongly

linked with human Protohistoric settlements. In fact, along with these geomorphological features, many archaeological findings related to the Bronze Age TC (sixteenth to twelfth centuries BC) have been reported in the last decades (see Degani 1974; Cremaschi et al. 1980; Bottazzi et al. 1995). The TC is considered the first urbanisation occurrence in the history of Po Valley for sites capillarity and its complex structural villages. The land and water management activities of this culture were limited to clearance and channelisation for agricultural purposes around the villages. No large-scale anthropogenic practices occurred in Protohistory times, at least no one that altered the natural physical evolution of the landscape. The archaeological excavation of the TC sites (see Bernabò Brea et al. 1997, Bernabò Brea and Cremaschi 2004; Cremaschi et al. 2006; Mele et al. 2013) unearthed complex water systems both to irrigate the cultivated fields and to defend the villages.

Through dirt roads, the Protohistoric Gel reaches the second stop (Fig. 3, n. 2), located in the mid-course of the Enza River Praticello palaeochannel (GAm 2, Table 2). In this area (Fig. 5), archaeological excavations and survey reported both Bronze Age and Iron Age finds: their distribution along the palaeochannel banks seems to confirm that this fluvial geomorphological feature was still active in the Pre-Roman Era. As mentioned previously, after the decline of the TC, due to climatic and ecological causes (Bernabò Brea et al. 1997), the Po plain was abandoned and recolonised only centuries later, at the beginning of the eighth century BC. During the Iron Age (seventh to third centuries BC), the human settling was



Fig. 14 Medieval hydraulic device on the Tagliata Canal. Point of interest n. 3 along the Medieval geo-educational itinerary proposed

scattered in rural locations and not concentrated in larger fortified sites as in the Bronze Age. In addition, in this period, human enterprise did not affect the morphological development of the environment. The Iron Age drainage systems detected consist of local land and water management activities related to small/medium farmholds (Dall’Aglia 2014).

The Protohistoric GeI continues to the place called “*Le Grazie*” (Fig. 3, n. 3). Here (GAm 3, Table 1), the archaeological survey reported the existence of a little TC village settled on a motte. The next stops, *Santa Rosa di Poviglio* (Fig. 3, n. 4) and *Monticelli di Castelnuovo* (Fig. 3, n. 5), are buried Bronze Age settlements. These archaeomorphological features are buried remnants of the ancient landscape and represent potential hidden geomorphosites (Brilha 2017; Clivaz and Reynard 2017). The TC village of *Santa Rosa di Poviglio* (GAm 4, Table 2) has been widely studied since the 1980s,

and complex hydraulic structures have been discovered (see Bernabo’ Brea and Cremaschi 2004; Cremaschi et al. 2006; Mele et al. 2013) (Fig. 6). *Monticelli di Castelnuovo* (GAm 5, Table 2) has never been excavated so far, but the aerial images and ground survey suggest an archaeological context very close to *Santa Rosa di Poviglio* (Fig. 7).

The Protohistoric GeI ends at the Poviglio Archaeological Museum (Fig. 3, n. 6) that exposed the TC archaeological materials.

Roman Geo-educational Itinerary

The Roman colonisation in Central Po Plain started in the second century BC and constituted the first large-scale landscape structuration in the Po Valley. Between second century BC and sixth century AD, the area was drained and converted to farming with the onset of centuriation, a division of the cultivated land by a regular grid of roads and ditches. The centuriation tracks are the most relevant archaeomorphological features of the Roman Period. The significant amount of archaeological data available for that period (see Bottazzi et al. 1995) (Fig. 8) reveals that the Roman colonisation occupied ridges and palaeochannels already active during the Bronze Age, overlapping to the Protohistoric landforms. In the Roman Period, for instance, the Enza River abandoned the Praticello palaeochannel that was turned in cultivable land.

Furthermore, the natural geomorphological development of the Apennine watercourses was modified by the construction of artificial levees that increased the load sediment discharge of the Po River and its tributaries. The Roman drainage system was oriented in order to ease the water outflow from the small ditches to the main channels, avoiding the risk of flood events (see Dall’Aglia and Franceschelli 2007; Dall’Aglia 2014).

The proposed Roman GeI consists of a path along the centuriation tracks: it starts from the archaeological museum in Poviglio (Fig. 8, n. 1) where Roman artefacts are exposed.

The plain degrades progressively from Poviglio to the village of Fodico (Fig. 8, n. 2): here (GAm 6, Table 2), centuriation tracks are well preserved also because they have been renovated in the Modern Age during land reclamation works. Walking through the modern fields from Fodico to stop n. 3 (Fig. 8, n. 3), the plain degradation is still perceivable as it follows the geomorphological shape of the *Valle di Gualtieri* backswamps. Often, ploughing activities in the area reveal outcrops of Roman archaeological material: here (Fig. 8, n. 3), a large amount of bricks and pottery fragments suggests the presence of a buried Roman settlement.

The Roman GeI comes back to Poviglio (Fig. 8, n. 4). The Roman roadway network often survived after the decline of the Western Roman Empire not only as cultivated field limits but also as pathways. The diagonal axis from *Brixellum* (i.e. Brescello) to *Regium Aemilia* (i.e. Reggio Emilia), for



Fig. 15 Medieval historical map that shows the landscape before the Renaissance land reclamation project. (AsMo 52, XVIIIsec. Modena National Historical Archive – “Congregazione delle Acque e delle Strade, Reggio e Reggiano”). (Adani et al. 1990)

instance, played a crucial role in the Post-Roman Era, surviving until nowadays with the name of “*Via Romana*” (i.e. Roman Road) (GAm 7, Table 2) (Fig. 9). The Roman roads are the most relevant archaeomorphological features of the Roman period in the area.

Medieval Geo-educational Itinerary

In the passage from the Roman period to the Middle Ages, the landscape profoundly changed as revealed by archaeomorphological analysis.

The waterlogging of the *Valle di Gualtieri* and *Valle di Novellara* (Fig. 2) occurred in the Post-Roman period and affected human sustenance and settling practices until the tenth century AD. At the end of the Roman Empire, lack of maintenance on the Roman drainage and hydraulic systems had severe implications for the environment with frequent channel diversions that affected the southern tributaries of

the Po River. The Roman embankments themselves accentuated the Holocene sedimentary processes of the Apennine water courses with consequent aggradation of the river beds (see Marchetti 2002; Dall’Aglio 2014); it constituted one of the primary causes of the diversion of rivers and creeks in the Post-Roman period. The Crostolo River, for example, started to flow in the *Valle di Novellara* backswamp, inundating vast Roman farmland areas (Brandolini and Cremaschi 2018a). When the population decreased, many Roman farms were abandoned, and alluvial sediments often buried the centuriation road and ditches.

According to historical–archaeological data, the early medieval settlements (sixth to tenth centuries AD) concentrated on the fluvial ridges in the new palustrine landscape. These topographically higher positions around the swampy meadows were strategic to control the waterways and the sustenance resources. The *castrum* represents the typical early medieval age settling pattern (Brandolini et al. 2018): a village



Fig. 16 Medieval geo-educational itinerary, point of interest n. 5. The black arrows indicate a portion of the medieval swamps of Valle di Novellara (GAm 11, Table 2)

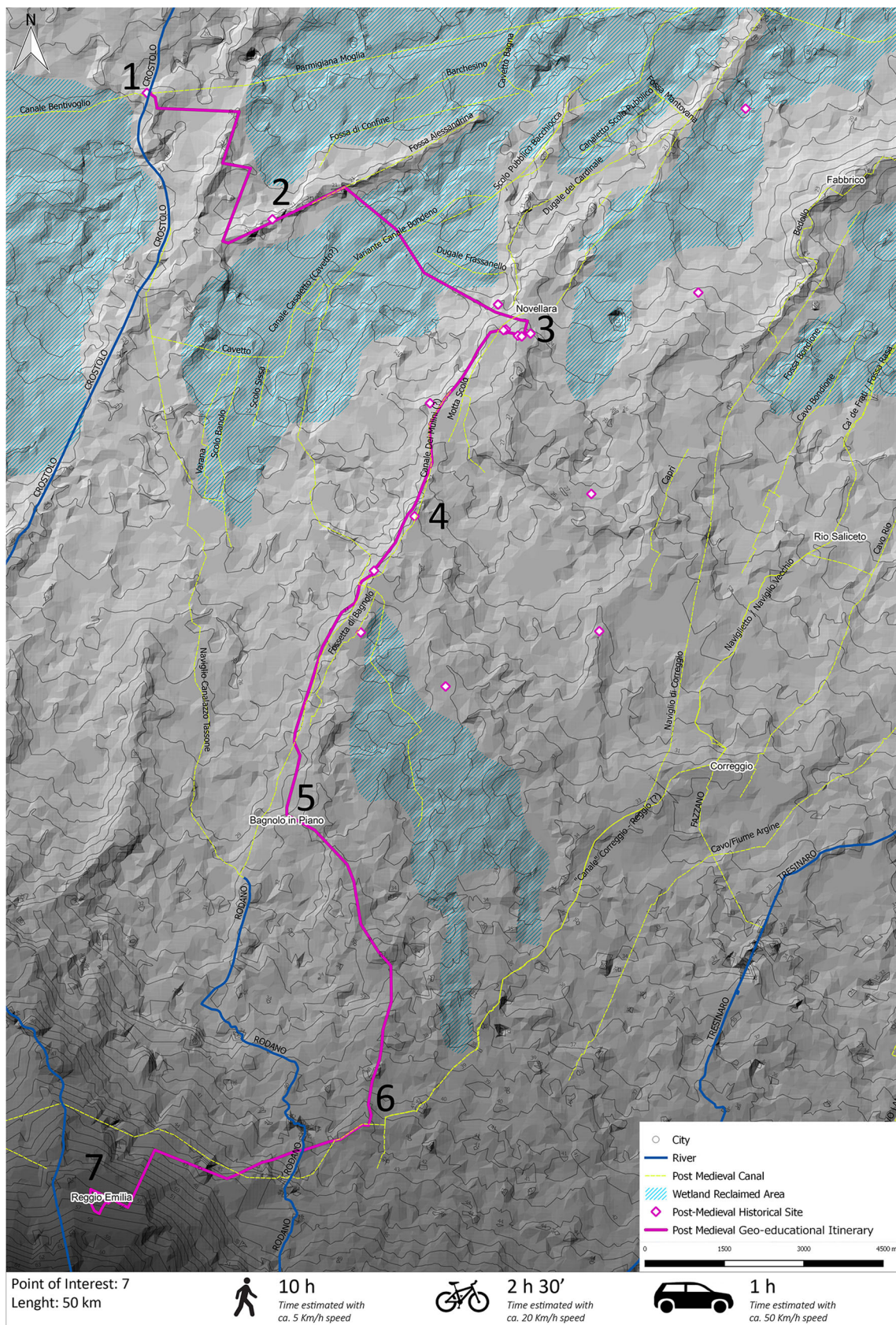
often raised around a previous Roman *villa rustica* or a church and fortified with earth ramparts, wooden fences and moats. In the research area, these fortified villages (or *castra*) are known only by historical documents (Tiraboschi 1824; Torelli 1921) and constituted the first core of the further Late Medieval and Renaissance towns: es. *Castrum Popilii* – Poviglio; *Wardestalla Castrum* – Guastalla; *Luciaria Castrum* – Luzzara; *Castrum Gualtieri* – Gualtieri; *Faurice Castrum* – Fabbriano; *Brixellum Castrum* – Brescello; *Nuvellare curtis* – Novellara.

The Medieval GeI starts from Guastalla (Fig. 10, n. 1), one of the most important cities settled in the Early Middle Ages with the name of *Wardistalla*. This town (GAm 8, Table 2) is characterised by a star-shaped frame developed in Medieval Times and still well preserved in the modern urban plant (Fig. 11).

From here, the path goes downhill to the medieval swamps. This area (Fig. 10, n. 2) today is known by the name of “*Valli Nuove di Guastalla*” (i.e. *the new Guastalla Valleys*) (GAm 9, Table 2). It corresponds to the deeper part of the medieval swamp developed in the Valle di Novellara backswamps and was reclaimed only at the beginning of twentieth century AD (Gabbi 2001; Saltini 2005). As previously mentioned, the centuriation tracks have often been buried by alluvial sediments during the Early Medieval Age (sixth to tenth century AD), a consequence of frequent flood events. Here, aerial image analysis reveals the remnants of few centuriation regular grids. These crop marks and soil marks are relevant evidence of hidden archaeomorphological landforms, cultural

landscape features active in the past and now buried under more recent geomorphological elements. In this portion of the study area, the overlapping of different geoheritage cultural layers is visible: first Roman tracks, then medieval swamp sediments and, finally, the present-day rural drainage system (Fig. 12).

From the medieval swamp, the path climbs up to the Tagliata Canal ridge (Fig. 10, n. 3), the most prominent archaeomorphological features developed in Medieval Times. This landform is the result of the channelisation enterprise started in the twelfth century AD and is the most relevant geomorphological feature developed in Medieval Times in the research area. In 1218, the allied cities of Cremona and Reggio Emilia started the construction of this new waterway parallel to the Po River in order to avoid paying commercial fees to the rival city of Mantova (Cantarelli 1882; Affò 1792; Tiraboschi 1824). The fluvial ridge of this canal is still recognisable in the landscape, and its shape is the result of both natural and human events. The medieval chroniclers reported that the opening of the Tagliata Canal had negative implications for the environment, with frequent floods in the surrounding farmland between the thirteenth and fourteenth centuries AD (Cantarelli 1882; Affò 1786; Affò 1792). The results of these historical flood events are the crevasse splays detected in the DTM (Fig. 8) and using aerial images (Fig. 13). Also, it is interesting that the place names of villages located along the Tagliata canal still remember the occurrence of floods: es. *Fangaia* (from “*Fango*” → “*Mud*”, refers to alluvial sediments) or *Villarotta* (“*Villa Rotta*” → “*Breach Ville*”,



◀ **Fig. 17** Post-Medieval geo-educational itinerary. Seven points of interest along 50 km are proposed: 1—Botte Bentivoglio hydraulic device (GAM 12, Table 2), 2—San Bernardino Church along the *Crustulus Vetus/Fossa Alessandrina* ridge (GAM 13, Table 2), 3—Novellara, 4—Post-Medieval road along the Mills Canal (GAM 14, Table 2), 5—Bagnolo in Piano (GAM 15, Table 2), 6—Gavassa (GAM 16, Table 2), and 7—Reggio Emilia historic center (GAM 17, Table 2)

refers to a crevasse splay event). Moreover, the DTM (Fig. 2) reveals elongated straight landforms that are likely to be the results of anthropic activities of flood management to obtain new farmland filling the swampy meadows with alluvial sediments: these anthropic geomorphological features have been called landfill ridges by Brandolini and Cremaschi (2018a). GAM 10 (Table 2) is located at the mid-course of the Tagliata Canal, in an area where it is possible to visit a still-standing medieval hydraulic device (Fig. 14), not far from crevasse splays resulted from Late Holocene floods.

Following the canal watercourse, the medieval town of Reggiolo (Fig. 10, n. 4) can be reached; it was settled in tenth century AD as a fluvial port, and then in thirteenth century AD, it was turned into a stronghold to control the trades along the Tagliata Canal.

In the 16th map of the two swamps, drawn before the Renaissance large-scale land reclamation project

(Fig. 15), the hydrological and channelised system, as should have appeared in Late Medieval Times (eleventh to fifteenth century AD), is represented. The map shows that roadways integrated the waterways medieval communication networks. Although canals and rivers were preferred to land routes in Medieval Times for safety reasons, new roads were built along the course of the main waterways: one of those was Reggio Emilia–Bagnolo in Piano–Novellara–Reggiolo and two roads along the Crostolo River and the Tagliata canal.

The proposed Medieval GeI follows the medieval road reported in the historical map that connected Reggio Emilia to Reggiolo through the city of Novellara. We propose point of interest n. 5 (Fig. 10, n. 5) where the modern national road follows the medieval historical path along the medieval *Linarola canal*: it was renovated in the eighteenth and nineteenth centuries and now is part of the 20th drainage system (Fig. 16). Looking at the fields from here, the dark soil zones are the areas where there used to be medieval swamps before the Renaissance wetland reclamation. The Medieval GeI ends in the city of Novellara (Fig. 10, n. 6): this town, founded in ninth to tenth century AD, settles on a fluvial ridge, a strategic higher position to control waterways in Medieval Times.



Fig. 18 Geoarchaeomorphosite 12 (Table 1): the “*Botte Bentivoglio*” hydraulic device at the intersection between Crostolo River and Parmigiana Canal



Fig. 19 Medieval historical map that shows the landscape after the Renaissance land reclamation project. (AsMo 53, XVIIIsec. Modena National Historical Archive – “Congregazione delle Acque e delle Strade, Reggio e Reggiano”). (Adani et al. 1990)

Post-Medieval Geo-educational Itinerary

In sixteenth century AD, a large-scale land reclamation project promoted by the lord of Guastalla Cornelio Bentivoglio profoundly transformed the medieval environment. The project started in 1560 and consisted in the construction of a hydraulic device called *Botte Bentivoglio*, located at the intersection between the Parmigiana channel and the Crostolo River. This structure allowed the Parmigiana canal to pass under the Crostolo River and to drain waters from the two valleys in the Secchia River (Mori 1923; Gabbi 2001; Saltini 2005). The Post-Medieval GeI starts at the *Botte Bentivoglio* (Fig. 17, n. 1). The Renaissance building was renovated in eighteenth century AD as mentioned by a 1760s epigraph: it remembers renovation works that occurred to the *Botte* after a Po River severe flood event. This location (Fig. 18) is the perfect synthesis of

geomorphological and historical–archaeological evidence and represents the most important archaeomorphological feature of the Renaissance landscape in the area.

A map dated to 1698 (Fig. 19) represents the hydrographical landscape situation of the study area after the Bentivoglio land reclamation works, and historical documents report details about the opening of new canals and the upgrading of medieval ones. The channelisation in Post-Medieval times was promoted both for commercial and agriculture reasons (Bolognini 1780; Badini 1990).

After crossing the Crostolo River, the path moves southward, to the *Crustulus Vetus* palaeochannel (Fig. 18, n. 2). This geomorphological feature developed in Medieval Times when the Crostolo River, as said before, flowed into the Valle di Novellara backswamp (Brandolini and Cremaschi 2018a). This palaeochannel was abandoned in the Renaissance when the Crostolo River was artificially diverted in the Po River. In the seventeenth to eighteenth centuries AD,



Fig. 20 Geoarchaeomorphosite 13 (Table 1): *Crustulus Vetus* palaeochannel in the modern farmland. The San Bernardino seventeenth-century church represents stop n. 2 in the Post-Medieval geo-educational itinerary proposed

historical documents and maps report that a drainage canal (*Fossa Alessandrina*) was excavated on the *Crustulus Vetus* ridge (Cremaschi et al. 1980; Brandolini and Cremaschi 2018a). The San Bernardino seventeenth-century church represents the stop n. 2 in the Post-Medieval GeI proposed (Fig. 20).

The Post-Medieval GeI continues to Novellara crossing a portion of the Medieval swamp (between stops 2 and 3). Here, Post-medieval canals as the artificial *Bondeno canal* are still active and allow the farmlands to be irrigated and drained. The town of Novellara (Fig. 18, n. 3) continued its growth during the Renaissance and Modern Age as a strategic centre of the

Fig. 21 Geoarchaeomorphosite 17 (Table 2): the artificial diversion of the Crostolo River in the Reggio Emilia historic city centre. The course of the Crostolo River was artificially diverted outside Reggio Emilia during the Roman age and in the years AD 1250 and AD 1571, largely because of westward stream migration (modified from ©Google Earth 2018)

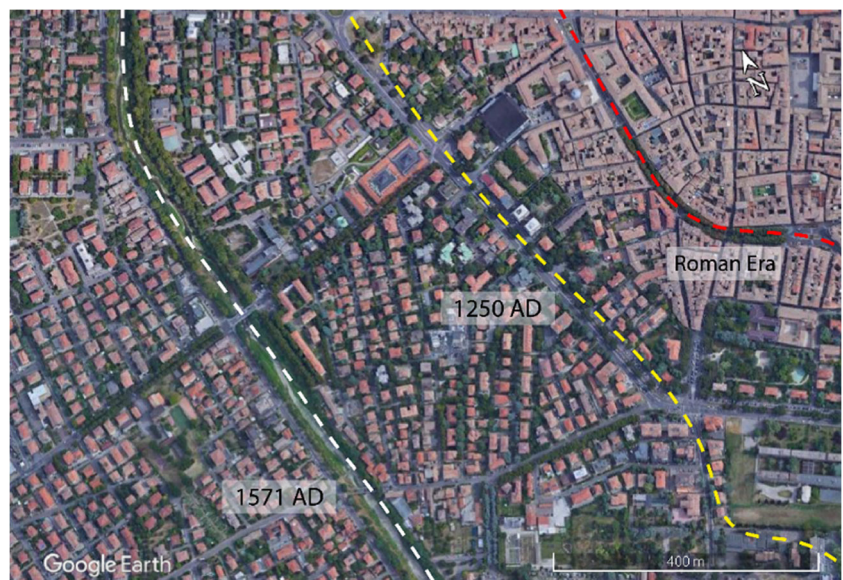


Table 3 Comparing the definitions of anthropogenic geomorphology by Szabó (et al. 2010) and archaeomorphology by Orengo and Palet (2014)

Discipline	Definition	Reference
Anthropogenic geomorphology	is the study of the role of humans in creating landforms and modifying the operation of geomorphological processes such as weathering, erosion, transport and deposition.	Szabó et al. 2010
Archaeomorphology	is focused on the study of human-made landscape forms and traces of territorial planning, such as roads, field systems, terraces or water channels. It aims at analysing the historical development of landscape structures over time and embraces the idea of landscapes as cultural palimpsests.	Orengo and Palet 2014

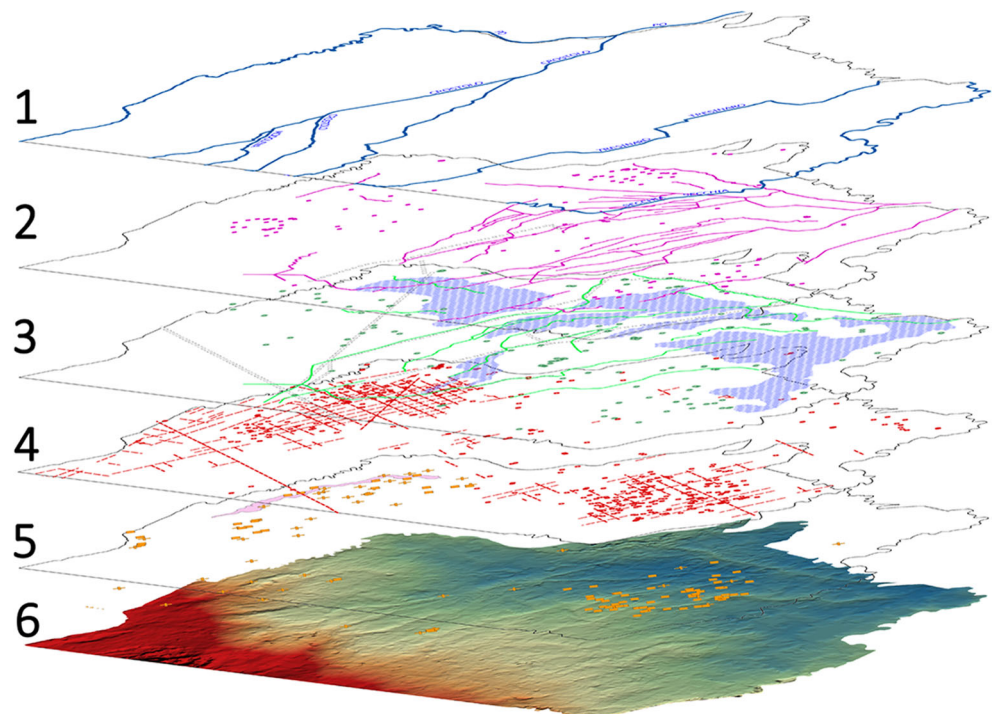
Central Po plain. In the Post-Roman period, new roads and canals were built from Novellara to Reggio Emilia, and some parts of this connection network are still active and walkable (Fig. 18, n. 4). At the medieval town of Bagnolo in Piano (Fig. 18, n. 5) the Post-Medieval GeI goes East to Massenzatico and Gavassa (Fig. 18, n. 6), two little centres reported in the Post-Medieval historical maps. Here, the Post-Medieval GeI meets the remnants of the canal and the road that connected Reggio Emilia to Correggio. This canal was probably part of the *Navigli* (i.e. canals) waterways network in Medieval and Renaissance times but was deeply modified by later drainage works. In addition, close to Gavassa, the Rodano creek flows (Fig. 18, n. 6). This Apennine watercourse was artificially channelled in the *Canalazzo Naviglio* in the sixteenth century AD, and nowadays, it still flows in the Crostolo River through the canal *Canalazzo–Tassone*. The Post-Medieval GeI ends in Reggio Emilia City, the main centre of the Medieval and Post-Medieval radial communications network. The final part of the itinerary follows *Corso Garibaldi*, a road built on a

Medieval Crostolo River palaeochannel (Fig. 21). The city was very recently studied also by an urban geomorphology point of view by Cremaschi et al. (2018).

Discussion

The complex interrelations between natural landscape dynamics and human activities have been widely treated in environmental reconstruction as well as in urban geomorphological studies. A key concept in the study of anthropised landscapes is the definition of hidden landforms and hidden geosites as partially or completely invisible geomorphological features that have been covered or destroyed by urban infrastructures (Reynard et al. 2017; Clivaz and Reynard 2017). In the case of alluvial plains, the proposal of geo-educational itineraries for geoheritage is more challenging because, very often, fluvial landforms are difficult to be perceived at ground level because of the low relief of such features.

Fig. 22 Landscape cultural palimpsest. 1—modern river watercourse, 2—Post-Medieval archaeomorphological features, 3—Medieval geomorphological and archaeomorphological features, 4—Roman archaeomorphological features, 5—Protohistorical geomorphological and archaeomorphological features, 6—digital terrain model



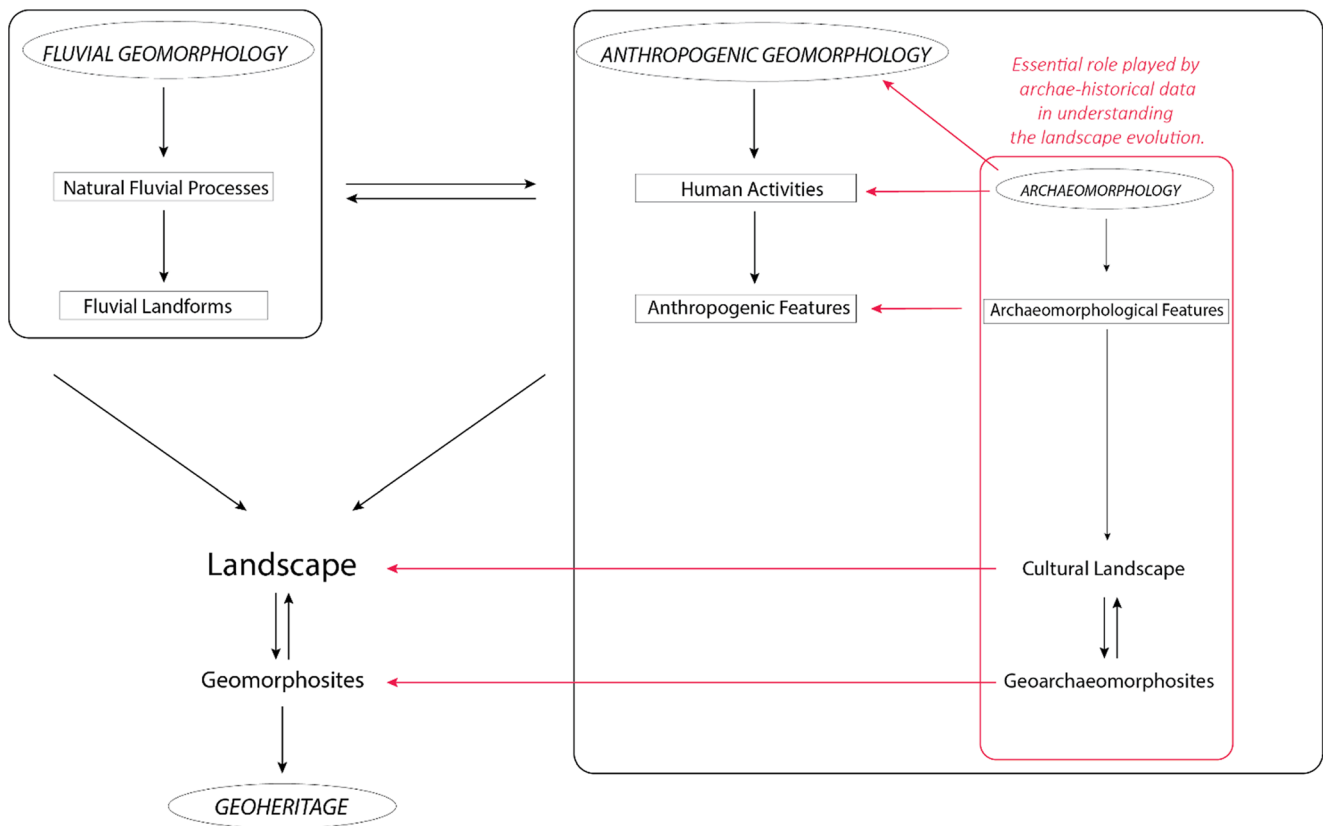


Fig. 23 Conceptual map that shows the archaeomorphological approach has been integrated into the geoheritage study of this portion of the Central Po Plain

In the research area, Man acted as a landscape-modifying agent since the Protohistoric era, and the ancient anthropogenic landforms are often buried or destroyed by later human activities. The result of this complex man–environment interaction is a superimposition of different anthropogenic and geomorphological features developed in the last fifteen centuries. Archaeology and environmental history played a crucial role in the understanding of this complex system of anthropogenic–geomorphological features: for these reasons, we emphasise how archaeomorphology overlaps in part with anthropogenic geomorphology and underlines human features with more precision. The study objects of the two disciplines are indeed very similar (Table 3), but the approaches are different: archaeomorphology emphasises the role of archaeological and historical data in the study of past human impact on the landscape while anthropogenic geomorphology underlines the human role in shaping the landscape and in affecting geomorphic processes. Archaeomorphology may be considered as a subset of anthropogenic geomorphology focused on the recognition of past human landforms through the use of archaeo-historical data.

In the research area, without any historical and archaeological data, it would have been impossible to know *how*, *why* and sometimes *when* human activities influenced the natural landscape evolution creating human-made landscape features

(or archaeomorphological features) such as roads, canals, embankments or field systems. In this portion of the Central Po plain, the result of the mutual interaction between humans and the environment consists of a cultural palimpsest of archaeomorphological (es. Protohistoric buried settlements, Roman centuriation tracks, Medieval and Post-Medieval roads and ditches) and geomorphological landforms (es. palaeochannels, backswamps and crevasse splays) (Fig. 22).

In Protohistory, the TC settlements appeared as earth mounds (3–4 m high) emerging in the flat floodplain, but they were deliberately razed in nineteenth century AD because the local farmers believed that the dark and high-organic soil of those mounds was suitable to fertilise fields. The TC archaeological sites represent hidden archaeomorphological features: they are recognisable only from an aerial view or with ground survey during ploughing periods. These hidden features can represent potential GAs because they testify two different phases of land use in this portion of the Po Plain in the past: (1) human settlements in the Bronze Age and (2) land management activities in the Modern Age (nineteenth century AD).

Furthermore, in Roman Times, the establishment of a regular grid of roads and ditches (i.e. centuriation) had such a high impact on reshaping the natural landscape that large portions of the Roman drainage system are still recognisable in

the fields. More important, the Roman embankments accentuated the Holocene sedimentary processes of Apennine watercourses with consequent aggradation of the river beds (Marchetti 2002; Dall’Aglia 2014), and when the Roman Empire collapsed, the lack of maintenance on drainage systems and fluvial dykes had severe consequences on the environment with frequent diversions of rivers and creeks in the backswamps. *Valle di Gualtieri* and *Valle di Novellara* used to be wetlands, but today, only through archaeo-historical data could we valorise these areas as hidden GAmS. Also, in the Middle Ages, channelisation and flood management conditioned the geomorphological development of Tagliata Canal and Crostolo River (Brandolini and Cremaschi 2018a): the exploitation of fluvial sediments to reclaim wetland areas modified the geomorphological process of transport and deposition. The results of such activities were the increase of flood hazards between the thirteenth and fourteenth century AD and the development of archaeomorphological features (landfill ridges, sensu Brandolini and Cremaschi 2018a). As observed by Sellier (2013) and Clivaz and Reynard (2017), the detailed study of place names can help in understanding geomorphological processes, and along the Tagliata Canal, the place names still remember the occurrence of floods. Starting from sixteenth century AD, the Medieval wetlands were progressively reclaimed: again, the human enterprise profoundly modified the geomorphological processes, creating a new human-made landscape.

Our research points out the relevance of using an archaeomorphological approach to understand the landscape evolution of the study area better. Moreover, here, we use the term *geoarchaeomorphosites* (GAmS) as the archaeo-historical data represent relevant information in the definition of the potential geomorphosites proposed, especially in case of hidden GAmS (es. Protohistoric TC settlements). According to the current geoheritage methodology (Brilha 2017; Bollati et al. 2017), the archaeological information is considered as *Additional Values* in the definition of geomorphosites, but here, this kind of data have proved their potential to propose GAmS and geo-educational itineraries in an alluvial environment (Fig. 23). The terminology proposed by Eric Fouache to indicate archaeological sites that are integrated into the aesthetic landscape (*geoarchaeosite*; see Fouache and Rasse 2009) and to define geomorphosites with archaeological interest (*archaeo-geomorphosite*; see Fouache et al. 2012) surely allows proposing complex or composed geomorphosites with high cultural value. Nevertheless, in our case study, the archaeo-historical data had an “active” role in the understanding of the landscape geomorphological evolution, while in Fouache and Rasse (2009) and Fouache et al. (2012), it is evidenced as an additional value (*geoarchaeosite*) for some geomorphosites or a prompt (*archaeo-geomorphosite*) to geomorphological studies. For this reason, we proposed the term *geoarchaeomorphosites* to indicate any

geomorphosites derived by the dynamic interaction between natural (mainly fluvial) and human events (es. Protohistoric TC settlements, Roman regular field system, Medieval canals and artificial river diversions) and for which the archaeo-historical data are crucial to assess its genesis and development during different historical times, and to enhance the geomorphosites’ scientific and cultural/historical values.

Conclusion

The analysis performed in this study led to the identification and contextualisation of the palaeolandscapes developed in the past.

Landscape features identified by an archaeomorphology-based study constitute a cultural, geomorphological and historical archive of today’s landscape and play an essential role in the definition of geo-educational itineraries. The local landscape may be not conceived only as the array of the geographical–geomorphological characteristics or as an assemblage of ecosystems in mutual interaction: landscape, in cultural terms, refers to the human experience and to the anthropogenic activities that modified the physical world surroundings. Hence, the analysis of archaeo-historical and cultural factors that influenced the landscape development is fundamental.

The results of this research point out the high potential of using archaeo-historical data in the definition of geo-educational itineraries, especially in a fluvial environment as the Central Po Plain. Here, the fluvial landforms are hardly recognisable at ground level because of their low relief and the human intervention that occurred through the past centuries: historical documents and archaeological records allowed disentangling the different cultural layers that form the modern cultural landscape palimpsest. Moreover, in this study, we evidence the potential *geoarchaeomorphosites* (GAmS) deriving from the interferences of human actions on the natural geomorphological dynamic and the role of archaeo-historical data to understand the genesis and development of such landforms.

As here discussed, the close connection between anthropogenic geomorphology and archaeomorphology in geoheritage studies underlines the great potential of archaeo-historical data in understanding the role of humans in shaping the landscape acting directly on fluvial processes.

The proposed four geo-educational itineraries (GeIs) allow (i) presenting the current landscape as the result of a continuous man–nature interaction, (ii) valorising geomorphological and archaeomorphological landforms through the definition of potential GAmS and (iii) promoting the conservation of this landscape cultural palimpsest.

Through GeIs, it should be possible to spread academic topics such as landscape changes, human–environment

interaction, landscape valuation and conservation to a wide non-academic audience. Indeed, to enhance the role of the researcher and the impact of scientific research on society is fundamental to make people understand science results. In the case of the Gels proposed in this paper, a practical future perspective may be the development of a mobile app for public geotouristic fruition in the area. The application of GeoGuide mobile apps has been successfully tested in the urban contexts (Pica et al. 2018, Gambino et al. 2019) where they contribute to the promotion of the links between cultural and geological heritage. Apps are environmentally sustainable since they do not have any physical impact on the field.

Moreover, apps could be updated with information about touristic facilities (such as accommodations, local cuisine, local temporary events, etc.) with a positive impact on the local economy (Gálvez et al. 2017). Future perspective may include a cooperation with the local authorities to create an app useful to describe the Gels; georeference each GAM to ease its approachability; provide historical, geomorphological and cultural information for each GAM; and enhance the perception of the hidden and the highly human-disturbed GAMs through virtual reality (VR) and augmented reality (AR) tools (Mota et al. 2018). Mobile applications represent useful instruments for geotouristic projects as well as for geo-educational projects (Bollati et al. 2014; Pelfini et al. 2018) in order to enhance the personal perception of the past landscape evidence.

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