**Archeologia e Calcolatori**
**34.2, 2023, 225-246**
**doi 10.19282/ac.34.2.2023.12**

# LEGACY IMAGERY, CONTINUOUS SATELLITE MONITORING AND TARGETED DRONE SURVEYS FOR THE STUDY OF DESERTED MEDIEVAL FORTIFIED SETTLEMENTS IN THE HINTERLAND OF RAVENNA, ITALY

## 1. Introduction

A general phenomenon of nucleation of the rural population has been recorded in many regions of Western Europe during the Middle Ages, especially between the 8th and 13th centuries (Hamerow 2002, 121-124; Curtis 2013). However, many of these settlements have undergone a contemporary selection process, resulting in many becoming 'deserted' (Curtis 2014). The 'deserted medieval villages' historiographical theme developed significantly in the 1950s and 1960s, thanks to the interest generated across several disciplines, including history, geography, and historical demography (Rao 2011). Soon after, Italian medieval archaeology developed a strong interest in abandoned rural settlements, especially between the second half of the 1960s and early 1970s (Augenti 2016, 16-26). At first, this experience remained essentially limited to a few regions, namely Liguria, Tuscany, Sicily and Sardinia (Galetti 2012, 205), while for Emilia-Romagna and more generally for the Po Valley, a genuine interest in abandoned villages developed only in the 1980s with the work of Aldo Settia (1984). After him, the phenomenon of deserted villages in the Po Valley remained strictly connected to castles, namely sites with elements of fortification and the 'decastellamento process' causing their abandonment (e.g. Saggioro 2011; Gelichi, Librenti, Marchesini 2014).

Even with the increasing archaeological knowledge acquired in the area over the last two decades, most of the abandoned villages in the Po Valley that we know of are still classifiable as castles for their fortified nature. These are, in fact, often characterised by the presence of a motte surrounded by a combination of defensive elements like embankments, ditches, palisades and/or walls (Augenti 2016, 159). Many more examples of these types of fortified settlements have been discovered in various areas of the Po Valley, primarily through aerial archaeology (Wilson 2000; Rączkowski 2014), which has exponentially increased our ability to map and understand this site typology. Identifying anomalies in vegetation growth (= crop marks) or simply in the colour of the exposed bare soil (= soil marks) can allow us to quickly recognise prominent features like mottes and moats. At the same time, while LiDAR data helped reveal deserted medieval settlements in hilly and mountainous areas, like in the Basilicata region in Southern Italy (Masini *et al*. 2018; Masini, Lasaponara 2021), they are not always valuable for flat

areas with widespread mechanised farming, which may have led to the destruction of any original micro-relief. A recent and well-documented example is the levelling of the motte of Trifolce in Castel Guelfo (BO) that occurred only in 2003 (Librenti, Michelini, Molinari 2004, 29-30).

Despite some possible limitations, remote sensing helped us partially overcome one of the significant difficulties in locating early and high medieval sites, namely the diffuse use of perishable construction materials that hinder their general visibility (Settia, Marasco, Saggioro 2013), allowing us to map many deserted settlements across the Po Valley. Up to now, most of the known sites are located in the provinces of Verona (Saggioro 2010; Saggioro, Varanini 2013), Treviso (Grandi, Laudato, Masier 2013), Reggio Emilia (Mancassola 2006), Modena (Gelichi, Librenti 2008; Librenti 2018), and Bologna (Librenti, Michelini, Molinari 2004; Grandi 2010; Gelichi, Librenti, Marchesini 2014, 407-408; Librenti 2019).

The provinces of Romagna, a historical region that now constitutes the SE part of Emilia-Romagna, are missing from this list. Since a few decades ago, the lack of deserted medieval villages could have been explained by 20th century historiography that considered this region exceptional in the Italian peninsula due to a stronger Byzantine heritage. According to this assumption, this Byzantine tradition had supposedly prevented the development of the manor system based on *curtes* and the subsequent incastellamento (for a review, Settia 2018). However, both historical (Mancassola 2008a; Pallotti 2018) and archaeological (Mancassola 2008b; Negrelli 2008) studies have questioned this previous reconstruction in the last two decades, proving that both phenomena also spread in Romagna, albeit with their peculiar characteristics.

In addition, previous studies have successfully listed an impressive number of castles in the Romagna region, trying to locate them through place names and historical cartography and reconstruct both their birth and abandonment (Mancini, Vichi 1959; Montevecchi 1970; Augenti, Ficara, Ravaioli 2012; Ravaioli 2015). However, remote sensing has never been used extensively to map this site typology, despite some fortuitous but exceptional discoveries already hinted at its potential, like the features mapped over the sites of Fusignano Vecchio (Cani, Zaccari 1991) and S. Maria in Castellaccio (Abballe, Cavalazzi 2021), the fortress of Cervia Vecchia (Augenti *et al*. 2020), and several abandoned castles located NW of Imola (Librenti, Michelini, Molinari 2004; Grandi 2010; Librenti 2016).

In an attempt to try to bridge this knowledge gap, a large number of legacy images spanning the last 40 years has been exploited to investigate the whole study area in search of archaeological features, especially over known or hypothetical castles. The number of datasets of aerial (national and regional) and satellite (provided free of charge by private companies)

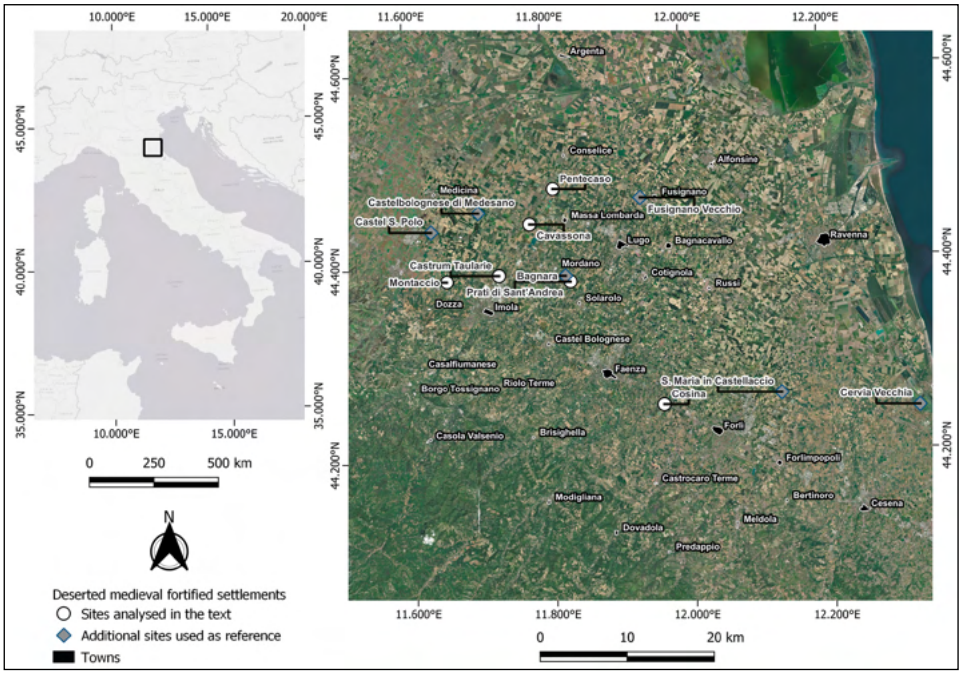


Fig. 1 – Study area with main towns and all deserted medieval fortified sites discussed in the text.

images is constantly increasing, dramatically boosting our chances that an archaeological site had been documented during a favourable period for crop/soil marks formation. For instance, excellent conditions usually present when grasses like wheat or alfalfa grow during summer when less water is available for the plants (Wilson 2000). Moreover, additional high-resolution images can be captured at no cost nowadays, thanks to the spread of commercial drones, targeting acquisition campaigns at the optimal period. However, optimal planning is yet primarily theoretical because it is not always possible in practice to predict the best times for the formation of crop marks, which are caused by complex soil-plant-weather-human interactions acting at a local scale that are not entirely foreseeable.

In response to these historical and methodological shortcomings, this paper firstly discusses the significant contribution that legacy aerial and satellite data can provide to studying deserted fortified settlements, allowing the mapping of defensive elements and reconstructing the general morphology of six medieval sites in the broader hinterland of Ravenna, in Northeast Italy (Fig. 1). Secondly, it presents the results of a combined approach between continuous remote surveillance via PlanetScope multispectral images at 3 m

resolution (Planet Team 2017) and subsequent targeted data collection via drone survey to document at higher resolution crop/soil marks barely visible in the satellite data.

## 2. Materials and methods

The first part of the research involved a systematic inspection of all aerial and satellite images freely available online (Fig. 2), searching for possible crop and soil marks in the study area and specifically on known/hypothetical locations for deserted medieval sites based on published literature. As these legacy images were consulted online or on QGIS as basemaps, it was impossible to carry out advanced image processing techniques or calculate indices. The approach used to enhance images was to increase the contrast and/or brightness to facilitate the interpretation.

The second phase consisted of targeted remote surveillance over selected sites using almost daily PlanetScope satellite data at 3 m resolution. Images were acquired with a minimum of four bands (eight after August 2021) ranging from 455 to 888 nm, allowing True (RGB) and False Colour (NirRG) visualisations, as well as NDVI computation, to further emphasise possible features. This satellite-based remote surveillance was carried out between 2020-2022, from June to September, which proved to be the most fruitful for the formation of archaeological marks based on the previous analysis of legacy data.

Once possible marks were identified in the PlanetScope images, a targeted drone flight was carried out in the days immediately after to document any features at higher resolution, to confirm what had already been seen in the legacy data and potentially identify new elements. The drone employed in the field was a DJI Mavic Pro 2 with a 20-megapixel Hasselblad optical camera. In the case of Cavassona, a targeted artefact survey was carried out to collect dating materials to interpret this site correctly. The surveyors walked 1 m apart and recorded each find with a Garmin GPSMAP 64S handheld GPS (for more information on survey methodology, Cavalazzi *et al*. 2018; Cavalazzi, Abballe, Ferrari 2022).

## 3. New data on deserted medieval fortified settlements

### 3.1 *Pentecaso*

The first site considered corresponds to Pentecaso, an abandoned castle that the local tradition places 4 km southern than Conselice (Fig. 1). The earliest mention of the place-name dates to 1145 CE, when the written sources recall an *ecclesia Sancti Iohannis in Pantagase*. A century later, settlers from Lombardy were granted permission to move into the area in 1262. However,

| Source | Year | Type | Sensor |
|---|---|---|---|
| Istituto Geografico Militare Italiano (IGMI) – Volo GAI (Gruppo Aeronautico Italiano) | 1954/1955 | Aerial | B/W |
| Ministero dell'Ambiente e della Tutela del Territorio e del Mare (MATTM) | 1988/1989<br>1994/1996<br>2000<br>2006/2007<br>2012 | Aerial | B/W (first 2 series)<br>RGB (last 3 series) |
| Agenzia per le Erogazioni in Agricoltura (AGEA) | 2008, 2011 | Aerial | RGB<br>NIR |
| Consorzio telerilevamento agricoltura (TeA) | 2014, 2017 | Aerial | RGB |
| Compagnia Generale Riprese Aeree (CGR) | 2018, 2020 | Aerial | RGB<br>NIR |
| Google Earth Pro | 2003 – 2021 | Satellite | RGB |
| Microsoft Bing | 2009 – 2020 | Satellite | RGB |
| Esri World Imagery | 2011 – 2018 | Satellite | RGB |

Fig. 2 – Analysed historical and legacy images with provider, temporal coverage, type of systems and sensors.

a fortification attempt is recalled only around the end of the 13th century, promoted by the Communes of Imola and Faenza. After this mention, the site of Pentecaso apparently disappeared from the written sources (Pancino 1995, 63-65).

The legacy data revealed an impressive number of crop marks only on 8th August 2017 (Fig. 3a): an articulated crevasse splay coming southbound from a palaeochannel of the Santerno river, probably deactivated around the 13th century CE (i.e. *paleodosso di S. Patrizio*, Franceschelli, Marabini 2007, 33); a regular subdivision of the field through rectangular plots of around 170×100 m interpretable as paddies mapped by the Catasto Austriaco (1853) when rice cultivation was widespread in the area (Pancino 1995, 162-168); a 65×65 m square, 10 m wide, characterised by a lighter colour, delimiting an inner part measuring around 0.2 hectares, interpretable as an embankment now levelled where compacted soil hinders vegetation growth. If the presence of an apparent embankment seems to confirm the fortified nature of Pentecaso, its limited dimensions make it difficult to imagine a large population living within the fortifications, which was probably meant to protect more significant elements like the church or a possible local authority headquarter and/or provide shelter to the rural population only when necessary.

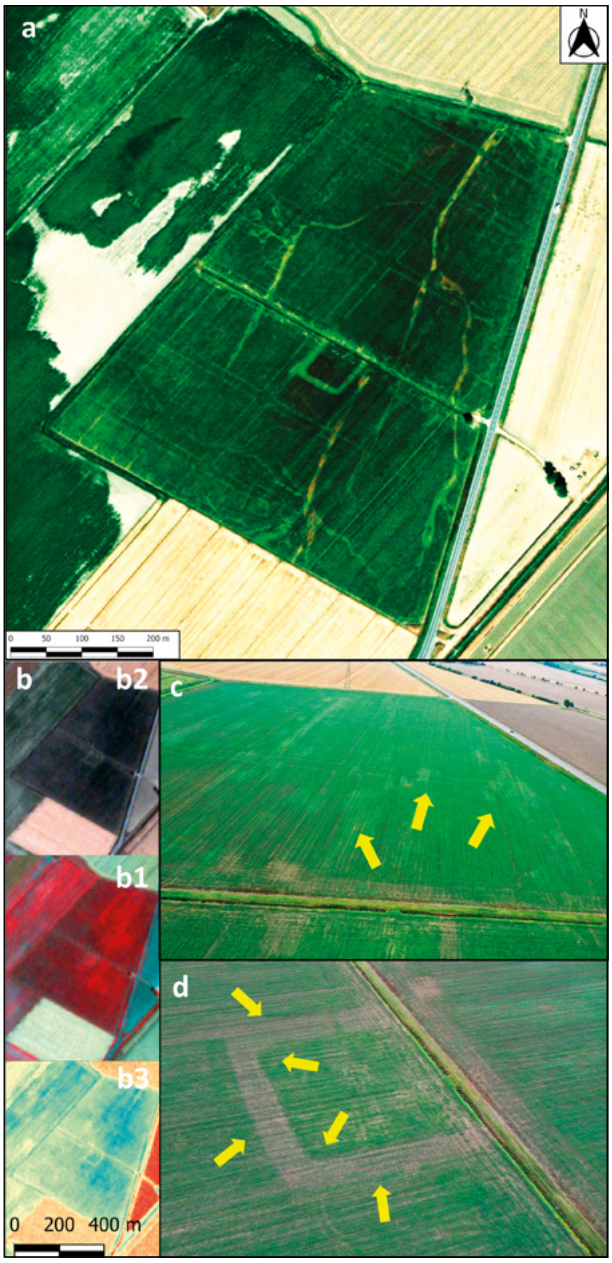


Fig. 3 – Site of S. Giovanni in Pentecaso with anthropogenic elements highlighted by arrows: a) WV03 satellite image captured on 8th August 2017 provided by ESRI; b) PlanetScope image of 24th July 2021 in RGB (b1), False Colour (b2) and NDVI (b3) visualisations; c-d) drone images of 27th July 2021.

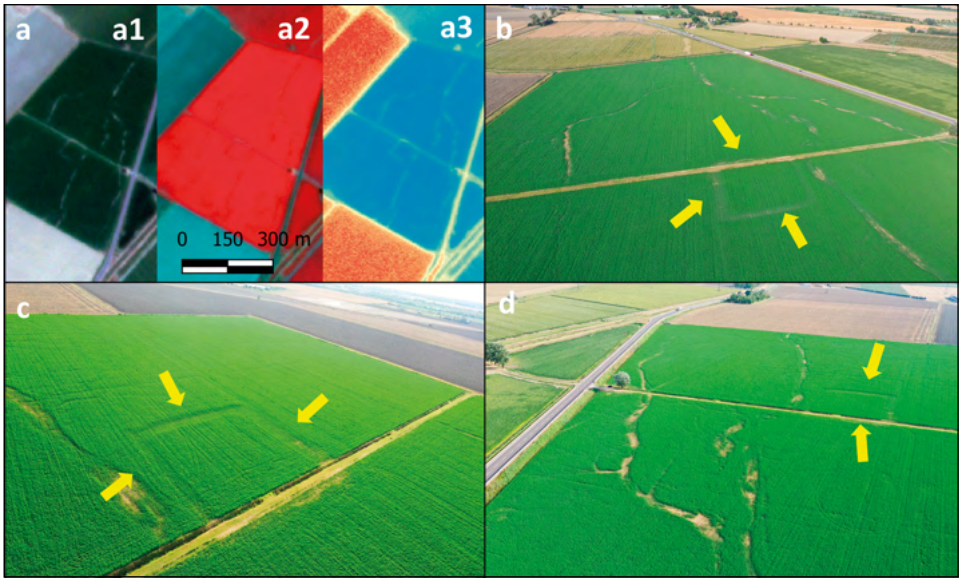


Fig. 4 – Site of S. Giovanni in Pentecaso with anthropogenic elements highlighted by arrows: a) PlanetScope image of 6th August 2022 in RGB (a1), False Colour (a2) and NDVI (a3) visualisations; b-d) drone images of 8th August 2022.

Considering the results of the combined remote-field analysis, the large square feature was recognised on PlanetScope images of 24th July 2021 (Fig. 3b), while the subsequent drone shots also documented the rice paddies remains (Fig. 3c-d). A year later, both square feature and crevasse splay were recognisable on PlanetScope images of 6th August 2022 (Fig. 4a), whose presence was confirmed by the drone survey together with the rice paddies partitioning elements (Fig. 4a-c).

### 3.2 *Cavassona*

The second site analysed is called Cavassona, after the 19th century toponym attested by IGM Primo Impianto in the area, located in the municipality of Imola (Fig. 1). Several crop and soil marks had already been recognised through Google satellite images (Chouquer 2015, 134-135), suggesting the presence of a rectangular feature measuring around 85×50 m, bordered at least on the N side by a possible defensive embankment circa 8 m wide, now levelled. This embankment may have had one ditch on each side, making the whole defensive structure circa 18 m wide, possibly connected by a small canal to a larger palaeochannel for water intake (Abballe, Cavalazzi 2021).

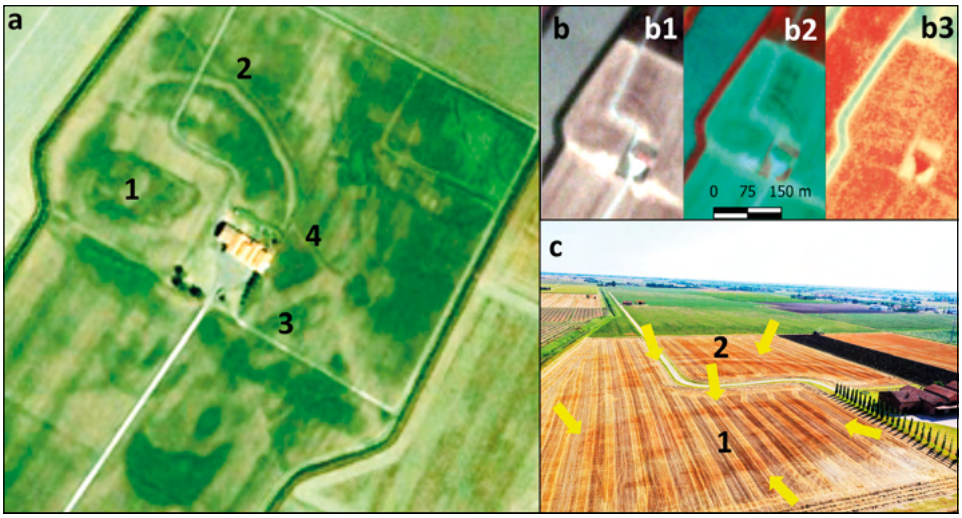


Fig. 5 – Site of Cavassona: a) Google Earth image of 23rd September 2003 with motte (1), defensive system (2), natural palaeochannel (3) and smaller anthropogenic one (4), connecting the former watercourse with the moats of Cavassona (modified from Chouquer 2015, 134-135); b) PlanetScope image of 10th July 2020 in RGB (b1), False Colour (b2) and NDVI (b3) visualisations; c) drone image of 14th July 2020 with levelled motte (1) and fortified system (2) visible as soil marks and highlighted by arrows.

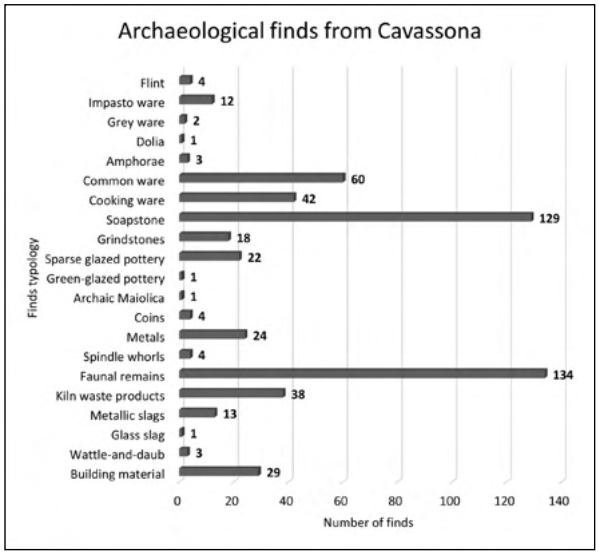


Fig. 6 – Column chart with the finds collected during the survey of Cavassona moated site in 2020.

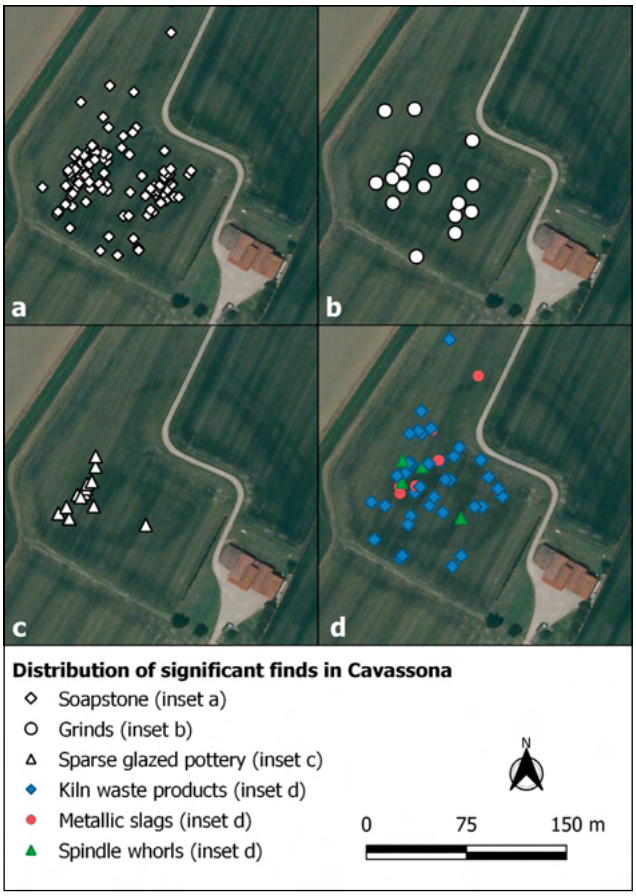


Fig. 7 – Distribution of significant finds: a) fragments of soapstone vessels and b) grindstones imported from the Alpes; c) sparse glazed pottery sherds; d) indicators of productive activities (MATTM 2012 imagery as base map).

The remote surveillance allowed the identification of the defensive system and central rectangular feature as soil marks on 10th July 2020 (Fig. 5b), not visible in the NDVI visualisation (Fig. 3b). On 14th July 2020, a first drone survey was carried out to confirm the presence of the soil marks over the stubble field (Fig. 5c) and to plan a systematic artefact survey to collect dating material to overcome the lack of previous historical and archaeological data on this site. More than 600 finds were collected, mostly dated to the Early/High Middle Ages (Fig. 6), although there were also some Bronze and Iron Ages finds (Abballe, Cavalazzi 2021).

These finds (Fig. 6), mainly clustered near the feature interpretable as a levelled mound (Fig. 7), suggest the presence of a settlement very well connected to the trade networks of the time, considering the impressive number of fragments of soapstone vessels (Fig. 7a) and grindstones in garnet chlorite schist (Fig. 7b) of alpine provenance, and a significant quantity of sparse glazed pottery (or 'vetrina sparsa') sherds (Fig. 7c). Local production activities are attested by spindle whorls for weaving (three out of four are glazed), slags and kiln waste products (Fig. 7d). Among the oldest finds we can count a 9th/10th centuries cooking sherd 'tipo Piadena' (Mancassola 2005), while three Lucchese coins suggest occupation during the 11th/12th centuries (Moretti, Cantatore 2021), disrupted within the 13th century as indicated by the minimal number of Maiolica and Green-glazed wares.

The *castrum de la Fracta*, *castrum Aquevive*, and *castrum Bolegnano* known in the sources but whose location is doubtful (Montevecchi 1970), could all be identifiable with site of Cavassona, but a precise attribution is not yet possible. However, we have a better understanding of the geomorphological transformations that occurred around the 13th century near Cavassona, where several river breaches led to a substantial rise of the otherwise flood-prone landscape. The area was soon after organised through a regular field system around the newly founded centre of Massa Lombarda (Abballe 2022).

### 3.3 *Castrum Taularie*

The third site is *castrum Taularie* (Fig. 1), attested four times between 1126/1130 and 1215 CE, until the place name ceased to be associated with a fortification changing to *curte Taularia* in 1226 and then *Villa Vidigliani* in the 14th century (Montevecchi 1970). The possible location of *castrum Taularie* was suggested to be near the farmhouse known as Castellaccio around 4 km N of Imola (Montevecchi 1970) and supported by the identification of medieval finds (Librenti 1994, 168, fig. 46). Still, no clear evidence for the site morphology or any defensive elements had ever been identified.

The systematic study of all legacy data allowed us to recognise a clearly visible positive crop mark in Via Bicocca at the hypothetical site of the abandoned castle, identifiable in a Google Earth image of 16th June 2017. This L-shaped feature is at least 160 m long and 8 m wide (Fig. 8a), and it is characterised by a darker colour, due to a healthier vegetation growth than the rest of the field. The shape and characteristics of this crop mark suggest identification as a ditch, which presumably retains more water and helps vegetation growth. The considerable width of this linear feature made it recognisable also in the PlanetScope images when it was clearly evident again as a positive crop mark on both 11th July 2020 (Fig. 8b) and 12th July 2021 (Fig. 8c). During the two subsequent drone flights, it was possible to confirm the

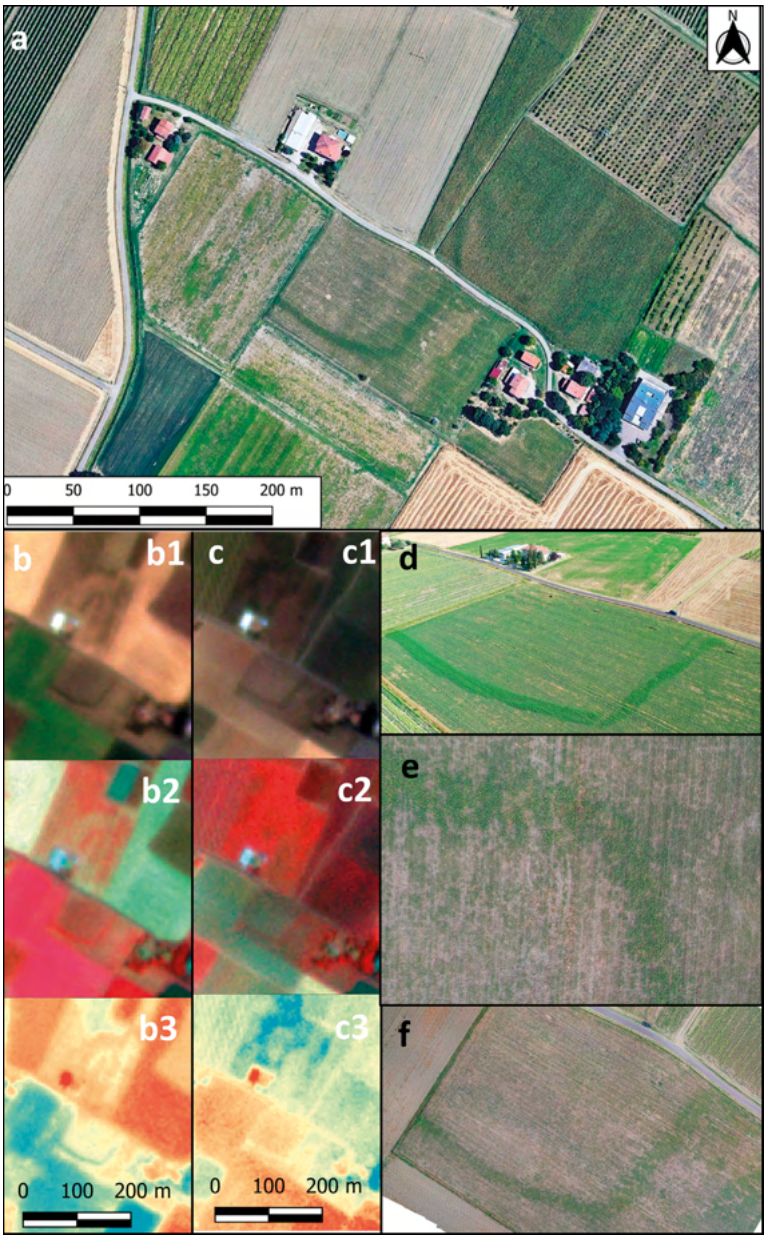


Fig. 8 – Site of *castrum Taularie* with section of moat visible: a) satellite image captured on 16th June 2017 provided by Google Earth Pro; b-c) PlanetScope images of 11th July 2020 and 12th July 2021 in RGB (b1-c1), False Colour (b2-c2) and NDVI (b3-c3) visualisations; d) drone image of 14th July 2020; e-f) drone vertical image and orthophoto of 18th July 2021.

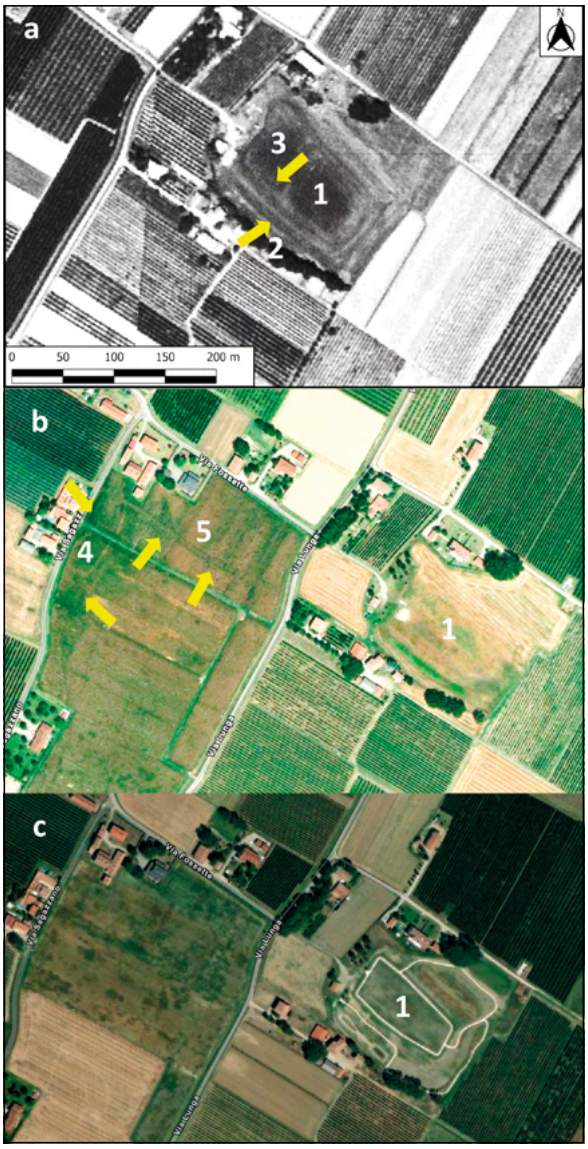


Fig. 9 – Site of Prati di Sant'Andrea/Bagnara Vecchia (1) and main elements highlighted by arrows: a) b/w legacy aerial image provided by Mattm (1996) suggesting the presence of a system with double moat, an external one (2) and a more internal one (3); b) WV03 satellite image captured on 8th July 2017 provided by ESRI with crop marks of a possibly natural palaeochannel along Via Segazzano (4) and a possible anthropogenic one (5), connecting the former watercourse with the moats of Bagnara Vecchia (1); c) WV02 satellite image captured on 29th July 2021 provided by ESRI documenting the site of Bagnara Vecchia (1) after the establishment of a natural restoration area and archaeological site.

presence of the positive crop mark in the alfalfa, healthier and slightly higher in correspondence with the possible negative evidence (Fig. 8d-f).

### 3.4 *Prati di Sant'Andrea/Bagnara Vecchia*

The fourth investigated deserted medieval site is the motte of Prati di Sant'Andrea, also known as Bagnara Vecchia (Fig. 1), attested in the sources as *curtis* from the 9th century and then as castle *Balnarie* from the 12th century. The site was supposedly destroyed in 1222 by the Communes of Faenza and Bologna (Augenti, Ficara, Ravaioli 2012, 82), with the surviving population probably relocated towards the nearby settlement of Bagnara, the present-day historic centre (Augenti, Ficara, Ravaioli 2012, 79-81). The site has been excavated since 2005 by the local Soprintendenza and has recently been converted into a natural restoration and archaeological area called *Ai prati di Sant'Andrea*.

The presence of a defensive moat was already known, as it was still recognisable in the field. Still, the study of legacy images has enabled new elements of crucial relevance to be mapped. Firstly, a second internal ditch inside the one already known can be seen in an aerial b/w image from the 1990s (Fig. 9a). Both features are characterised by a darker colour compatible with a filled negative feature, albeit only archaeological excavations could assess whether they were functioning simultaneously or if they belong to different chronological phases. Secondly, a possible artificial canal 7 m wide can be seen in a WV02 satellite image captured on 29th July 2021 provided by ESRI (Fig. 9b, n. 5), originating from a much larger palaeochannel (Fig. 9b, n. 4), running parallel to Via Fossette for 200 m and potentially joining the (double) moat system of Bagnara Vecchia (Fig. 9b, n. 1). If what we mapped was indeed the canal supplying water to the medieval moat system, this means the palaeochannel along Via Segazzano was not ultimately filled up at the time (Fig. 9b, n. 4), although it is probably the silting watercourse that in the Bronze Age created a significant fluvial ridge in the area, known as *paleodosso di Bagnara* (Franceschelli, Marabini 2007, 29-30).

The importance of these legacy images becomes even clearer when we consider the recent transformations undergone by the site to create the natural area. This new configuration is visible in the most recent Google Earth and ESRI images (Fig. 9c) and could prevent marks formation in the coming years.

### 3.5 *Cosina*

The fifth castle is Cosina, attested by the chronicler Tolosano from Faenza between 1199 and 1220 CE (Rossini 1936, 115-117, 130-131). The location of this abandoned site has been suggested near the farmhouse Piazzetta (Fig. 1), where emerging structures had been seen during ploughing

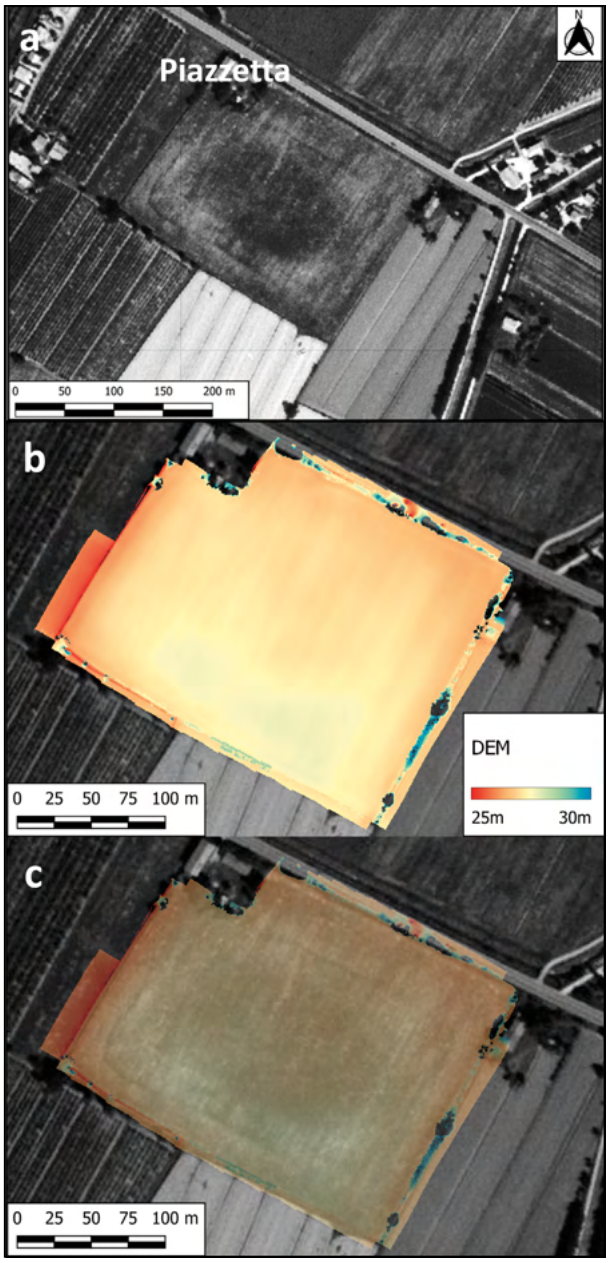


Fig. 10 – Site of Cosina: a) b/w legacy aerial image provided by Mattm (1996) suggesting the presence of a planned site with quadrangular defensive system; b) DEM generated from drone survey on 9th October 2020; c) combined view of DEM and aerial photo.

(Montevecchi 1970, 187), but also further W along Via Carbonara where the toponym *Castellaccium Cosine* is recalled in 1454 and 1524 (Augenti, Ficara, Ravaioli 2012, 147-148). However, an aerial photo from the 1990s allows us to dispel these doubts by showing a rectangular feature of 140×80 m right next to the Piazzetta farmhouse (Fig. 10a). It is characterised by a darker colour, possibly caused by a high organic matter content. Furthermore, a more prominent mark, apparently only a couple of metres wide, seems to enclose the whole site, which measures 200×130 m and occupies a total area of around 2.6 ha. The relatively limited width of this second mark, also characterised by a darker colour, suggests a ditch, which could have had a defensive purpose through the presence of a wooden palisade.

Remote surveillance did not result in the detection of crop marks, which may not have occurred during the three years 2020-2022. Still, a drone photogrammetric survey was carried out to verify the possible presence of a motte in correspondence with the central rectangular feature. As can be seen from the generated DEM (Fig. 10b) and the combined visualisation with the aerial photo (Fig. 10c), no micro-relief of archaeological significance can be currently recognised at the site. If a motte did exist, it was levelled by successive agricultural ploughing, similar to what probably happened at Cavassona (§ 3.2).

### 3.6 *Montaccio*

The sixth and last site is the *castro quod vocatur Solustra*, mentioned for the first and only time in 1106 CE, whose location has been recognised in the toponym Montaccio, a small mound next to the Sellustra stream at the border between Imola and Dozza (Fig. 1). This hypothesis seems to be confirmed by the finds collected by artefact surveys: soapstone sherds, broadly dated to the Middle Ages (Merlini 1997, 298-305), but also Archaic Maiolica suggesting occupation still after the first half of the 13th century (Librenti 1994, 171).

Although the location of the site seems to be settled, questions remained about its chronology and morphology. A legacy b/w aerial photo from the 1990s (Fig. 11a) allows us to define almost completely the limits of this motte, probably surrounded by a defensive element. Within this large defensive structure, maybe an embankment, there is a smaller feature just a few metres wide characterised by a darker colour, most likely a small ditch, maybe hosting a palisade.

The remote surveillance did highlight some features on 3rd August 2022 (Fig. 11b), especially on the northern edge of the field, visible mainly in the RGB image (Fig. 11b, n. 1) and somewhat less clear in the NDVI visualisation (Fig. 11b, n. 3). However, it was only in the subsequent drone acquisition in the field on 6th August 2022 that a wide range of evidence appeared (Fig. 11c). We can recognise the possible extent of the fortified site in its entirety (Fig. 11c, see arrows), as well as part of the ditch that encircled it that led to

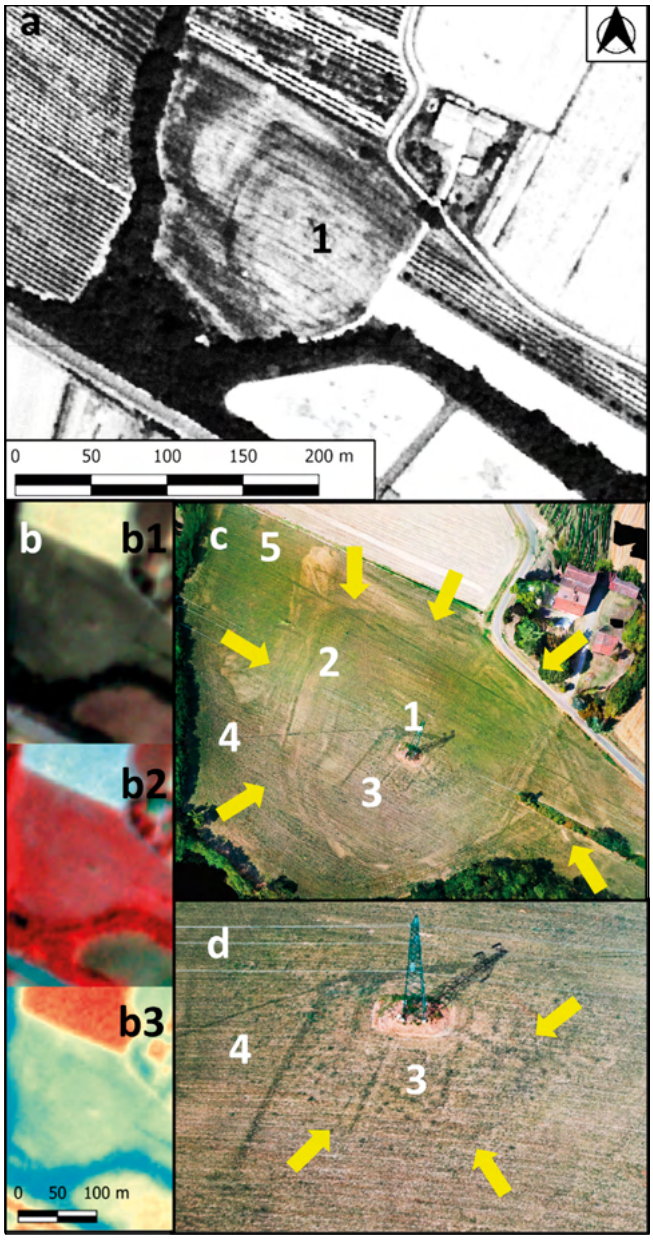


Fig. 11 – Site of Montaccio: a) b/w legacy aerial image provided by Mattm (1996) suggesting the presence of a defensive system; b) PlanetScope image of 3rd August 2022 in RGB (b1), False Colour (b2) and NDVI (b3) visualisations; c-d) drone orthophoto and oblique image of 6th August 2022 with main historical features highlighted by arrows (2-3) and possible modern utilities (4-5).

a distinct positive crop mark (Fig. 11c, n. 2). Also modern traces of underground utilities are visible (Fig. 11c, n. 5), including a gas pipeline laid down in 2011 (Fig. 11c-d, n. 4) as observable in Google Earth images of 30th March 2011. However, some of the linear traces in the centre of the site appear to be archaeological in nature (Fig. 11c-d, n. 3), untouched by the pipeline works, and matching the crop marks documented by Maurizio Molinari through oblique aerial photographs already in the 1990s (Librenti, Michelini, Molinari 2004, 27-28, 43).

## 4. Discussion

### 4.1 *The value of legacy images for deserted medieval sites*

The new results discussed demonstrate the potential of the ever-growing number of aerial and satellite image time series collected over the past decades, freely and often easily accessible. These data can help shed light on changes in the landscape (e.g. past river network, Abballe, Cavalazzi 2021), but also on a variety of archaeological sites differing in morphology and chronology, including the deserted medieval fortified settlements discussed in this paper. The systematic study of these remotely sensed data has allowed us to map new defensive elements for six abandoned sites, known mainly by the written sources but whose location was often still hypothetical, making it possible to define their shape and extent in almost their entirety. These data fill a considerable knowledge gap concerning the medieval castles in the hinterland of Ravenna, compared to other neighbouring regions where these sites are much better known, mainly due to the extensive exploitation of remote sensing data (cfr. § 1).

From a historical-archaeological point of view, knowing more about the castles' layouts in this area allows us to make some additional considerations. Rectangular or even square plans are typical for castles of *seconda generazione* (i.e. 12th/13th centuries CE, Augenti 2018), suggesting careful planning like in Cosina and Pentecaso, but also at other nearby sites (Fig. 1), such as Castelbolognese di Medesano, Castel S. Polo (Grandi 2010; Librenti 2019) and Fusignano Vecchio (Cani, Zaccari 1991). Archaeological research found evidence for changes in the pre-existing settlement patterns due to these new foundations in the area northwest of Ravenna (i.e. Bassa Romagna, Cavalazzi *et al.* 2018) and in the near eastern Bologna province (Librenti 2019).

These changes mainly involved further nucleation of the rural population and widespread abandonment of *prima generazione* castles for which a clear preference seems to be recognisable for (sub-)circular fortifications, like in Cavassona. A similar pattern would also be recognisable in Montaccio and *castrum Taularie*, which may have already existed before the beginning of the 12th century when we have the first references to their

existence, but not specifically to their birth. Thus, there is a great need for accurate chronological data to better frame these processes, only hinted at here, but it would be essential to repeat the same systematic study in other areas in Italy and Europe where current knowledge on abandoned medieval settlements is lacking, possibly only due to limitations of previous research.

### 4.2 *Continuous satellite monitoring for planning optimal field surveys*

The paper presents innovative methodological aspects, being among the earliest to evaluate the potential of high temporal frequency PlanetScope satellites for archaeological purposes, specifically in the ability to highlight crop and soil marks indicative of buried features (McGrath *et al*. 2022). The potential of this recently deployed commercial constellation of satellites is significant if compared to the much more employed Sentinel-2, as they offer higher resolution both spatially (3m vs 10m) and temporally (almost daily vs five days revisit time). Moreover, the six cases of deserted medieval fortified settlements discussed above have been used to further test the potential of these 3m satellite images, which allow almost real-time assessment of the land use/land cover over a selected location (with a one-day delay at most between image acquisition and its availability) and nearly every day if no clouds are present on the area.

As mentioned, we monitored six case studies remotely and continuously until possible crop or soil marks could be detected from the PlanetScope data. Once identified, a field verification was carried out via drone flight. The on-site verification documented additional features not visible (or easily interpretable) in the 3m images because of their dimensions, which are smaller than the spatial resolution of the satellite data. For example, the internal partitions of the paddy fields at Pentecaso were not visible in the satellite data (Figs. 3b, 4a), whereas they emerged clearly from the drone photographic documentation (Figs. 3c, 4c-d). Even more surprising are the results from Montaccio, where the satellite data showed very faint differences in vegetation growth (Fig. 11b), while the drone flight mapped both the layout of the site and possible internal structures, as well as modern features (Fig. 11c-d).

These few but significant results demonstrate the potential of this combined approach to target research efforts by only planning field activities when the best state of use (e.g. presence of plants such as wheat or alfalfa) and climatic conditions (e.g. periods of drought) align. Thus, we could overcome a significant limitation of aerial archaeology, which is the apparent randomness in the appearance of archaeological traces that could easily slip out during fieldwork activities. Potentially this approach could also be used on sites with less obvious features, not at all recognisable from satellite data, by estimating the best period for marks formation on

the basis of the field land use and regional climatic and moisture data. This strategy could significantly increase the effectiveness of a single drone operator/archaeologist who can often only study a handful of sites per season, allowing the study of more contexts and greatly enhancing the possibility of collecting valuable data.

## 5. Conclusion

The results presented highlight the high value of legacy aerial and satellite images for identifying and understanding deserted medieval fortified settlements, especially in flat areas where these large sites emerge more easily as crop and soil marks. At the same time, the affordability of drones and the increased temporal coverage provided by satellites such as Sentinel-2 (every five days, provided by the European Space Agency free of charge) and higher-resolution PlanetScope (almost daily, commercial data but often accessible equally free for research purposes), opens the possibility of remotely estimating the best period for new targeted captures, at a higher resolution more significant for archaeological purposes. This approach could also be tested on less prominent sites by combining land use and meteorological data. Moreover, drones equipped with multispectral or thermal cameras could significantly enhance the likelihood of identifying archaeological features across various typological and chronological sites, increasing our knowledge and optimising research efforts.

Michele Abballe
Department of Archaeology, Ghent University
michele.abballe@ugent.be

*Acknowledgements*

This work was supported by personal grants awarded to the author in the form of a Doctoral Scholarship by the Bijzonder Onderzoeksfonds UGent (BOF) under Grant number BOF.FJD.2017.0002.01 and two Grants for long stays abroad by the Research Foundation Flanders (FWO) under Grant numbers V421419N and V430720N. Access to PlanetScope images was granted through Planet Education and Research Program (Images 2020-2022 Planet Labs PBC). Authorisations for the fieldwork were granted by the Ministero della Cultura - Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Bologna e le province di Modena, Reggio Emilia e Ferrara (no. 14787-A of 10/07/2020) and Soprintendenza Archeologia Belle Arti e Paesaggio per le province di Ravenna, Forlì-Cesena e Rimini (no. 9044-P of 15/07/2020). The two surveys carried out in 2020 were directed by Prof. Andrea Augenti with the scientific coordination of Dr. Marco Cavalazzi, who are warmly thanked together with the students from the University of Bologna involved. All drone images are available online at https://doi.org/10.5281/zenodo.8042146.

## REFERENCES


Abballe M. 2022, *Geoarchaeological mapping of medieval wetlands and their reclamation in the hinterland of Ravenna: Two case studies from Massa Lombarda (RA) and Villafranca di Forlì (FC)*, «ArcheoLogica Data», 2, 42-62 (https://www.mappalab.eu/wp-content/uploads/2022/03/03_abballe.pdf).

Abballe M., Cavalazzi M. 2021, *Morphometric analysis for geoarchaeological research: From testing different methods to results verification in the Romagna plain*, «Archeologia e Calcolatori», 32, 1, 117-136 (https://doi.org/10.19282/ac.32.1.2021.07).

Augenti A. 2016, *Archeologia dell'Italia medieva*le, Rome-Bari, Laterza.

Augenti A. 2018, *Castelli, incastellamento e archeologia*, in A. Augenti, P. Galetti (eds.), *L'incastellamento: storia e archeologia. A 40 anni da Les structures di Pierre Toubert*, Spoleto, Fondazione Centro Italiano di Studi sull'Alto Medioevo, 17-37.

Augenti A., Ficara M., Ravaioli E. 2012, *Atlante dei beni archeologici della provincia di Ravenna. Vol. 1: Il paesaggio monumentale nel Medioevo*, Bologna, Ante Quem.

Augenti A., Bondi M., Cavalazzi M., Fiorini A., Sericola M. 2020. *Archeologia dei paesaggi nel territorio ravennate: il progetto Cervia*, «Archeologia Medievale. Cultura materiale, insediamenti, territorio», 47, 115-139.

Cani N., Zaccari S. 1991, *Fusignano Vecchio. Risultati delle ricerche*, Fusignano, Tipografia Cornacchia & Minguzzi.

Cavalazzi M., Abballe M., Benato A., De Felicibus M. 2018, *Archeologia dei paesaggi in Bassa Romagna. Il Progetto Bassa Romandiola (2009-2016)*, «Archeologia Medievale. Cultura materiale, insediamenti, territorio», 45, 317-334.

Cavalazzi M., Abballe M., Ferrari A. 2022, *Landscape archaeology in the Ravenna hinterland: The survey at Cotignola (RA), 2018*, «Fasti On Line Documents & Research: Survey», 18 (http://www.fastionline.org/docs/FOLDER-sur-2022-18.pdf).

Chouquer G. 2015, *Les parcellaires médiévaux en Émilie et en Romagne. Centuriations et trames coaxiales. Morphologie et droit agraires*, Paris, FIEF.

Curtis D.R. 2013, *The emergence of concentrated settlements in Medieval Western Europe: Explanatory frameworks in the historiography*, «Canadian Journal of History», 48, 2, 223-251 (https://doi.org/10.3138/cjh.48.2.223).

Curtis D.R. 2014, *Coping with Crisis: The Resilience and Vulnerability of Pre-Industrial Settlements*, Rural Worlds, London, Routledge.

Franceschelli C., Marabini S. 2007, *Lettura di un territorio sepolto: la pianura lughese in età romana*, Bologna, Ante Quem.

Galetti P. 2012, *Fra archeologia e storia: tipologia di insediamenti scomparsi in area emiliano-romagnola*, in F. Panero, G. Pinto (eds.), *Assetti territoriali e villaggi abbandonati (secoli XII-XIV)*, Cherasco, Centro Internazionale di Studi sugli Insediamenti Medievali, 205-232.

Gelichi S., Librenti M. 2008, *Carpi nell'alto Medioevo. Il contributo dell'archeologia alla storia del popolamento*, in P. Bonacini, A.M. Ori (eds.), *Storia di Carpi. La città e il territorio dalle origini all'affermazione dei Pio*, Modena, Mucchi, 209-230.

Gelichi S., Librenti M., Marchesini M. (eds.) 2014, *Un villaggio nella pianura: ricerche archeologiche in un insediamento medievale del territorio di Sant'Agata Bolognese*, Firenze, All'Insegna del Giglio.

Grandi E. 2010, *Il Bolognese orientale tra primo incastellamento e nuove fondazioni (secc. X-XIII)*, «Archeologia Medievale. Cultura materiale, insediamenti, territorio», 37, 47-60.

Grandi E., Laudato M., Masier S. 2013, *Fortificazioni in terra e legno nella Marca occidentale: i casi delle motte di Castelminio di Resana e Castello di Godego*, «Archeologia Medievale. Cultura materiale, insediamenti, territorio», 40, 155-166.

Hamerow H.F. 2002. *Early Medieval Settlements: The Archaeology of Rural Communities in North-West Europe, 400-900*, Medieval History and Archaeology, Oxford, Oxford University Press.

Librenti M. 1994, *Tracce di insediamenti altomedievali nella pianura centuriata*, in *Archeologia del territorio nell'Imolese*, Imola, Grafiche Galeati, 168-172.

Librenti M. 2016, *Territorio e insediamento tardomedievale tra Emilia e Romagna*, «Archeologia Medievale. Cultura materiale, insediamenti, territorio», 43, 57-77.

Librenti M. 2018, *I castelli in area emiliana: alcune riflessioni*, in S. Campagnari, M. Librenti, F. Foroni (eds.), *In loco ubi dicitur Vicolongo. L'insediamento medievale di Santo Stefano a Novi di Modena*, Novi di Modena, Gruppo Studi Bassa Modenese, 41-44.

Librenti M. 2019, *Settlement dynamics in the rural Bolognese area between the Late Middle Ages and the Modern Era*, in S. Gelichi, L. Olmo-Enciso (eds.), *Mediterranean Landscapes in Post Antiquity: New Frontiers and New Perspectives*, Oxford, Archaeopress, 38-63.

Librenti M., Michelini R., Molinari M. 2004, *Catalogo delle fortificazioni in terra e legno nella pianura bolognese orientale*, in *Fortificazioni altomedievali in terra e legno: ricerche territorio e conservazione 3. Convegno nazionale (Castel San Pietro Terme 2002)*, Roma, Istituto Italiano dei Castelli, 25-47.

Mancassola N. 2005, *Le ceramiche grezze di Piadena*, in S. Gelichi (ed.), *Campagne medievali. Strutture materiali, economia e società nell'insediamento rurale dell'Italia settentrionale (VIII-X secolo)*, Mantova, SAP, 143-171.

Mancassola N. 2006, *Interpretazione del dato di superficie altomedievale in area padana. Il territorio a Sud di Ravenna e a Nord di Reggio Emilia*, in N. Mancassola, F. Saggioro (eds.), *Medioevo, paesaggi e metodi*, Mantova, SAP, 115-146.

Mancassola N. 2008a, *L'azienda curtense tra Langobardia e Romania: rapporti di lavoro e patti colonici dall'età carolingia al Mille*, Bologna, CLUEB.

Mancassola N. 2008b, *Le forme del popolamento rurale nel territorio Decimano dalla caduta dell'Impero Romano all'anno Mille*, in M. Ficara, V. Manzelli (eds.), *Orme nei campi. Archeologia a sud di Ravenna*, Firenze, All'Insegna del Giglio, 89-104.

Mancini W., Vichi F. 1959, *Castelli rocche e torri di Romagna*, Bologna, ALFA.

Masini N., Gizzi F.T., Biscione M., Fundone V., Sedile M., Sileo M., Pecci A., Lacovara B., Lasaponara R. 2018, *Medieval archaeology under the canopy with LiDAR. The (re)discovery of a medieval fortified settlement in Southern Italy,* «Remote Sensing», 10, 1598 (https://doi.org/10.3390/rs10101598).

Masini N., Lasaponara R. 2021, *On the reuse of multiscale LiDAR data to investigate the resilience in the late medieval time: The case study of Basilicata in South of Italy*, «Journal of Archaeological Method and Theory», 28, 1172-1199 (https://doi.org/10.1007/s10816-020-09495-2).

McGrath C.N., Cowley D.C., Hood S., Clarke S., Macdonald M. 2022, *An assessment of high temporal frequency satellite data for historic environment applications. A case study from Scotland*, «Archaeological Prospection», 1-16 (https://doi.org/10.1002/arp.1890).

Merlini F. 1997, *La circoscrizione plebana di S. Maria in Sellustra ed il territorio nord-occidentale della diocesi imolese tra l'VIII e il XIII secolo*, in *La pastorale sacramentale in Emilia Romagna nei secoli XVI-XX: Atti del Convegno (Imola 1991)*, Cesena, Badia di Santa Maria del Monte, 291-305.

Montevecchi F. 1970, *Repertorio dei castelli, rocche e torri*, in P. Gazzola, G.F. Fontana, D. Berardi (eds.), *Rocche e castelli di Romagna*, 1, Bologna, Edizioni Alfa, 139-400.

Moretti D.L., Cantatore M.F.A. 2021, *La circolazione del denaro lucchese tra Appennino tosco-emiliano e Po: secoli XI-XII. Un primo bilancio sulla base di fonti scritte e materiali*, in M. Sozzi (ed.), *Aspetti di storia della Toscana attraverso monete e medaglie*, Bari, Edizioni D'Andrea, 39-59.

Negrelli C. 2008, *Dalla tarda Antichità all'alto Medioevo (V-IX secolo)*, in S. Gelichi, C. Negrelli (eds.), *A misura d'uomo. Archeologia del territorio cesenate e valutazione dei depositi*, Firenze, All'Insegna del Giglio, 237-256.

Pallotti R. 2018, *Castelli e poteri signorili nella Romagna settentrionale (secoli XI-XIII)*, Cesena, Società editrice 'Il Ponte vecchio'.

Pancino C. 1995, *Conselice di Romagna. L'infelice situazione*, Ravenna, Longo.

Planet Team 2017, *Planet Application Program Interface: In Space for Life on Earth*, San Francisco, CA (https://api.planet.com).

Rączkowski W. 2014, *Aerial Archaeology*, in C. Smith (ed.), *Encyclopedia of Global Archaeology*, New York, Springer, Cham, 33-38 (https://doi.org/10.1007/978-1-4419-0465-2_1504).

Rao R. 2011, *Nuovi borghi, villaggi abbandonati e genesi del paesaggio: selezione insediativa e processi di diserzione nel Vercellese bassomedievale*, in R. Comba, R. Rao (eds.), *Villaggi scomparsi e borghi nuovi nel Piemonte medievale*, Cuneo, Società per gli Studi storici archeologici ed artistici della provincia di Cuneo, 21-38.

Ravaioli E. 2015, *L'insediamento fortificato in Romagna tra fonti scritte e dati archeologici (VIII-XVI sec.): le province di Forlì-Cesena e Ravenna*, Bologna, Bononia University Press.

Rossini G. (ed.) 1936, *Magistri Tolosani Chronicon Faventinum (aa. 20 a.C.-1236)*, Rerum Italicarum Scriptores, 28, 1, Bologna, Zanichelli.

Saggioro F. 2010, *Paesaggi di pianura: trasformazioni del popolamento tra età romana e Medioevo. Insediamenti, società e ambiente nella pianura tra Mantova e Verona*, Firenze, All'Insegna del Giglio.

Saggioro F. (ed.) 2011, *Nogara: archeologia e storia di un villaggio medievale (scavi 2003-2008)*, Roma, Giorgio Bretschneider.

Saggioro F., Varanini G.M. 2013, *Motte, recinti e siti con fossato nel territorio veronese: dati e riflessioni tra fonti scritte e archeologiche (IX-XIV secolo)*, «Archeologia Medievale. Cultura materiale, insediamenti, territorio», 40, 133-144.

Settia A.A. 1984, *Castelli e villaggi nell'Italia padana. Popolamento, potere e sicurezza fra IX e XIII secolo*, Napoli, Liguori.

Settia A.A. 2018. *Castelli, incastellamento e fonti scritte*, in A. Augenti, P. Galetti (eds.), *L'incastellamento: storia e archeologia. A 40 anni da Les structures di Pierre Toubert*, Spoleto, Fondazione Centro Italiano di Studi sull'Alto Medioevo, 3-16.

Settia A.A., Marasco L., Saggioro F. (eds.) 2013, *Fortificazioni di terra in Italia. Motte, tumuli, tumbe, recinti. Atti del Convegno (Scarlino 2011)*, «Archeologia Medievale. Cultura materiale, insediamenti, territorio», 40, 7-187.

Wilson D.R. 2000, *Air Photo Interpretation for Archaeologists*, Stroud, Tempus.

ABSTRACT

The nucleation of the rural population was a widespread phenomenon during the Middle Ages that interested many areas of Western Europe. However, many of these sites are now deserted with the underlying phenomena causing these abandonments not always easy to reconstruct. Archaeologists have been interested in these medieval settlements since the middle of the 19th century, and remote sensing has played a decisive role in mapping hundreds of them. This also applies to many parts of the Po Valley but not the Romagna plain, where hundreds of medieval sites are known but almost exclusively based on written sources. However, the increasing availability of aerial and satellite images offers a valuable opportunity to bridge this knowledge gap. The systematic study of legacy images allowed the mapping of new defensive elements and reconstruction of the general plan of six deserted medieval fortified settlements in the broader hinterland of Ravenna. PlanetScope 3m resolution images were later exploited to continuously monitor these sites during periods prone to crop marks formation to detect the presence of wide crop/soil marks (e.g. ditches). Six successful field verifications demonstrate that these 'coarse' images are sufficient to plan drone surveys that can allow the mapping of additional smaller features.