Water management and land use in the terramare and a possible climatic co-factor in their abandonment: The case study of the terramara of Poviglio Santa Rosa (northern Italy)

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Abstract

The terramare, archaeological sites generated by a civilisation which settled the centre of the Po plain since the Middle Bronze age, were abruptly abandoned at the end of the Recent Bronze age. The reason for this abandonment is still a matter of debate. In the context of a multi-causal explanation, this paper discusses a possible climatic factor, inferred from recent discoveries at the site of Poviglio Santa Rosa (northern Italy).

The culture of the terramare produced a systematic and intensive agricultural and pastoral exploitation of the environment and caused heavy deforestation.

Water was a critical resource and was carefully managed. The moat which typically surrounded most of the sites was meant to concentrate and redistribute water to the fields through a network of irrigation ditches. The study of the water wells discovered at the fringe of the terramara of Santa Rosa reveals a drop in the water table during the late Recent Bronze age, caused by a dry event of regional relevance.

Chronological contiguity, supported by the archaeological context between this occurrence and the abandonment of the terramare system, strongly suggests a causative link between the two events.

The climatic event, a minor episode in the history of the Holocene climate, nevertheless acted as a catalyst in a stressed environment whose resources were over-exploited by rising demographic pressure.

1. Foreward

In Italian Prehistory, the term “terramare” is used to indicate the banked and ditched villages, generally quadrangular in plan, of the Middle and Recent Bronze ages (c. 1650–1150 cal BC). Their name is derived from an old Italian term used to indicate the organic rich earth—\textit{terra marna}—of mounds quarried as fertiliser in the 19th century (Bernabò Brea and Mutti, 1994). The terramare are located mostly in the modern Emilia sub-region, but also in southern Lombardy and in south-western Veneto. About 200 sites have been found since the beginning of the researches carried out in the 19th century (Fig. 1). The terramare are the archaeological remains of a complex society whose subsistence was based on agriculture, pastoralism, handicraft and long-distance trade, connecting the Po plain to northern and eastern Europe and to the Mediterranean. The terramare settled the alluvial plain of the Po as of the 16th century BC. They underwent significant demographic growth during the second half of the 15th century BC—at their apogee—and were abandoned abruptly at about 1150 BC as a consequence of a societal collapse (De Marinis, 1975; Barfield, 1994; Balista and De Guio, 1997; Bernabò Brea and Cardarelli, 1997; Bernabò Brea et al., 1997; Cardarelli,1997; Pearce, 1998).

It is clear now that the collapse of the terramare system is not linked to the climatic deterioration at the sub-Boreal/sub-Atlantic transition (Cremaschi, 1991–1992), as was reputed by Säflund (1939), since this event is at least three
centuries more recent. The abandonment of the terramare appears to be broadly parallel to the collapse of the late Bronze age civilisations in the eastern Mediterranean (De Marinis, 1975). More recently, a multi-causal explanation in which environmental stress played a leading role has emerged (Cremaschi, 1991–1992; Barfield, 1994; Bernabo Brea et al., 1997; Pearce, 1998). Yet again, a recent discovery in the terramara of Poviglio Santa Rosa (Reggio Emilia—Italy) now suggests that a climatic event causing dry conditions may have contributed to the final abandonment of the sites. The environmental context in which this event occurred, strongly affected by human impact, will be discussed, with emphasis on the water resources, critical to the subsistence strategy of the terramare.

2. Terramare and hydrography

On the regional scale, the connection between the terramare and fluvial network is systematic: each site for which we have geomorphologic evidence is linked to a palaeochannel which was active during the life of the site (Ferri, 1996; Cremaschi, 1997; Balista, 2002).

For instance, in the Enza basin, in a central position with respect to the terramare region, five large sites located at regular intervals are lined along the palaeochannel of the Enza river, which during the Bronze age connected the Apennine fringe to the Po river (from South to North: Case del Lago Case Cocconi, Monticelli di Poviglio; 4—Case Cocconi; 5—Case del Lago; 6—Gaggio; 7—Fondo Paviani, 8—Castello del Tartaro; 9—Fabbrica dei Soci.

Fig. 1. Distribution of the Middle and Recent Bronze age sites in northern Italy. (1) Archaeological sites, (2) banked and ditched sites, (3) terramare covering pile-dwellings sites, (4) Holocene palaeochannels, (5) Pleistocene moraines, (6) Pre-Holocene terraces, (7) Upper Pleistocene outwash fans and (8) Holocene alluvial plain. Terramare quoted in the text: 1—Motta Balestri; 2—Santa Rosa; 3—Monticelli di Poviglio; 4—Case Cocconi; 5—Case del Lago; 6—Gaggio; 7—Fondo Paviani, 8—Castello del Tartaro; 9—Fabbrica dei Soci.
Recent geomorphologic research based on an examination of aerial photographs has confirmed the model which can be applied to most of the sites (Mutti, 1993; Ferri, 1996; Cremaschi, 1997). An impressive example is constituted by the Fabbrica dei Soci site (Balista and De Guio, 1990–1991, Cremaschi, 1997) which is located North of the Po in the plain South of Verona. The site (Fig. 3), rectangular in plan and surrounded by an earth rampart, was built close to a palaeochannel of the Tartaro river, from which an artificial drainage was abducted to feed the moat surrounding the terramara.

Where river courses were not easily accessible, minor drainage and phreatic pools were also used. The terramara of Case del Lago, the largest (22 ha) of the terramare system, was built in connection with a large phreatic pool, which was not exhausted during the Bronze age. Today it has been harnessed by the waterworks to supply the city of Reggio Emilia (Cremaschi, 1997).

Management of water was not limited to the capture and adaptation of natural streams, but also encompassed artificial ditches and channels for irrigation. In the case of the Castello del Tartaro (Balista, 1997; Cremaschi, 1997)—Grandi Valli Veronesi, North of the Po—the irrigation channels were conducted outward from the moat of the site to distribute the water to cultivated fields. This case is not isolated, similar evidence having been recently discovered in several sites, as in the terramara di Gaggio (Modena) (Balista et al., 2003). At Case Cocconi (Bronzoni and Cremaschi, 1989), the terramara, 15 ha wide, is included in a concentric belt about 60 ha wide (Fig. 4). This area, probably devoted to specialised agriculture, was delimited by a deep ditch, excavated during the Bronze age and still perfectly perceivable in the present landscape. A peripheral ditch was recently observed (Bernabò Brea and Mutti, unpublished) also in the Case del Lago terramara.

Water resources appear to have been critical for the subsistence of the terramare. In the country outside the sites, the existence of a network of irrigation ditches originating from the moats demonstrates that these structures, beyond defensive purposes, were mostly planned to collect and channel the water, and redistribute it to irrigate the fields.

3. Land use

The average density of the terramara settlements is one site per 25 km², and in some areas, it rises to one site per
10 km². This estimation is to be regarded as minimum as large areas of the Po plain were buried by later flooding and they may hide sites at present inaccessible to investigation (Cardarelli, 1989; Cremaschi, 1991–1992).

Owing to the high concentration of sites and the fact that for each of them the primary economy was intensive agriculture (Cremaschi, 1991–1992; Cardarelli, 1997; Forini, 1997) and local pastoralism (De Grossi Mazzorin and Riedel, 1997; Riedel, 2004), a strong exploitation of the land surrounding the sites is to be expected.

Pollen analyses indicate that an open landscape surrounded the terramare from the Middle Bronze age onward. This has been proven by the pollen diagram recently obtained from the site of Parma (Valsecchi, 2004/2005), which dates back to this period both on the base of the archaeological (Catarsi Dall’Aglio, 1989) and of radiocarbon dates, recently obtained (Fig. 5). The deforestation rate is rather high all along the stratigraphic sequence (NAP—non-arboreal pollen—from 60% to 80%), and anthropogenic indicators, cereals particularly, are well represented everywhere.

However, when we compare the deforestation rate in the region of the terramare during the Middle and Recent Bronze age (XVI–XII centuries BC) (Ravazzi et al., 1992, 2004, Bandini Mazzanti et al., 1996; Cardarelli, 2004) to that of the surrounding regions—as indicated by the pollen records from southern Switzerland, northern Italy and peninsular Italy (Fig. 6)—we perceive that the terramare area appeared as a wide, artificial clearing, surrounded by dense forests. A tendency toward a more open environment appeared, during the final Middle Bronze age, in the stratigraphic sequence of the terramara of Montale (Cardarelli, 2004), and the pollen record from the infilling of the ditches of the terramara Santa Rosa at Poviglio indicates that, during the Recent Bronze Age, the deforested area spread significantly (AP—arboreal pollens—rate decreasing from 27% in Middle Bronze age to 19% in Recent Bronze age) (Ravazzi et al., 2004).

An increase in the clearance of woods follows a main change in the settlement pattern. In their early phases, the terramare were generally no bigger than 2 ha, while in the Recent Bronze age, within a general increase in the density of sites, several reached considerable dimensions: Case del Lago 22 ha (Bernabò Brea et al., 1997); Fondo Paviani 16 ha (Balista, 1997), Santa Rosa 7 ha (Bernabò Brea and Cremaschi, 1997).

Recent work in palaeobotany has focused on the concept of the pollen source area and its importance when interpreting spatial representation of human activity (e.g. Sugita, 1994, 1998; Dumayne-Peaty, 2001). The Relevant Source Area (RSA—the area from which the pollen deposited at a site comes from) calculated for the terramara of Poviglio indicates that the area deforested and cultivated around the site was 1 km wide during the Middle Bronze age and expanded to 4 km during the Recent Bronze age (Ravazzi et al., 1992; Ravazzi et al., 2004).

When we extend the information obtained from Poviglio to the other sites of the Enza basin, we observe that the open areas around the individual sites intersect, indicating
that wood cover became very scarce or completely absent over most of the area (Fig. 7).

Enhanced needs of cleared land for food supply, compelled by the rising demographic pressure (Bernabò Brea et al., 1997; Cardarelli, 1997; Bernabò Brea and Cremaschi, 2004a), can be regarded as a main cause of such intense deforestation.

High demand of timber for building purpose was a further determining factor of the deforestation: the terramare were made mostly of wood. The houses of the Santa Rosa terramara during the Middle and Recent Bronze ages were built on posts (Bernabò Brea and Cremaschi, 2003), and more than 10,000 trees per hectare may have been required for their construction.

Furthermore, signs point to stressed resources during the late Recent Bronze age. A land evaluation procedure (FAO, 1976; Kammersmans et al., 1985) applied to the soils of the Enza basin for cereals (Cremaschi, 1991–1992) indicates that the productivity was suitable for the hypothesised annual demand of a village during the Middle Bronze age, but possibly inadequate to answer the requirement of growing population during the late Recent Bronze age.

During the Recent Bronze age, in the terramara of Santa Rosa, the houses were no longer built on piles, but set on the ground according to the block-house technique, which needs less wood (Bernabò Brea et al., 2003; Bernabò Brea and Cremaschi, 2004a). This change in construction technique occurred in the frame of the same cultural context and is contemporary to the maximum extent of the deforested areas. Therefore, it may be interpreted as evidence of strong reduction, or even exhaustion of wood suitable for building purpose. A similar trend in depletion of wood availability, consequent to highly demanding construction technique, is also recorded in the early-middle Bronze age sites of the south-western Germany (Billamboz et al., 1988).

All these circumstances persuade to hypothesize an environmental scenario in which the possibility of finding new land to expand agriculture and pastoralism was strongly reduced and the resources of the already exploited area dramatically subsided.

4. The hydraulic systems in the terramara of Santa Rosa: a drop in water availability at the final stage of the site

Detailed information about the exploitation of water resources in the terramare comes from the site of Poviglio Santa Rosa, located 5 km South of the present course of the Po river, and under excavation since 1984 (Bernabò Brea and Cremaschi, 2004b). The site, as clearly seen in the aerial photograph (Fig. 8), is delimited by two strips of
clear-coloured soil consisting of the earth ramparts built during its last phase. The smaller village (Villaggio Piccolo) to the North is the oldest part, founded during the Middle Bronze age. A U-shaped rampart delimits the larger part of the site (Villaggio Grande), which mostly dates to the Recent Bronze age (Cremaschi et al., 1994).

The hydraulic system was discovered at the southern part of the Villaggio Grande in coincidence with the palisade and the connected structures located at the very fringe of the site and in the peripheral moat, just outside of it (Fig. 9).

In correspondence with the palisade, and distributed along it, 45 large water wells were found, dug inside the loamy clay ground of the terramara. They were excavated to reach two sand layers acting as aquifers at the depth of 2 and 3 m, respectively, from the base of archaeological deposit (Pizzi and Cremaschi, 2004).

The fill of these water wells, clayey in texture, displays complex stratigraphy consisting of organic material, laminated deposits and material fallen from the walls, which indicates that the wells collapsed and were re-excavated several times during their life. In the last phase, they were used as reservoirs and finally sealed by dump. The archaeological evidence included in them (Cremaschi and Pizzi, in press) indicates that they were used for a long period from the late Middle Bronze age (about 1400–1330 cal BC), the period of the foundation of the Villaggio Grande, up to its apogee, in the Recent Bronze age (1330–1170 cal BC).

Some of the wells are interconnected by small ditches, dug out in order to bring the water outside the site, in the direction of the peripheral moat, and not inside the village.

This is particularly clear for the well-denominated US (Stratigraphic Unit) 2206, which is located close to the south-western gate of the village. A ditch is conducted from the upper limit of the well with the purpose of bringing water rising from the water table to fill some cisterns opened inside the moat (Fig. 10).

Outside the palisade, to the South, is the moat surrounding the village (Fig. 11). While still apparent in the present topography, it is almost sealed by sediments...
which were deposited long after the abandonment of the terramara, during the Roman and the Medieval periods. The Bronze Age stratification included inside the moat is very thin, clayey and deprived of sedimentary structures, indicating both that the ditch was kept clean and that it was not occupied by running water.

When excavated, the moat appears to be about 30 m wide, but not very deep. While the outer bank is smooth, the inner is steep, in the shape of a slope (glacis) obtained in remodelling the fringe of the fluvial ridge on which the village was built, and is lined by a V-shaped ditch (Fig. 11).

Surprisingly, its bottom has been found riddled with pits. On a surface of 1500 m²—which has been unearthed up to now—30 pits have been found. Some are clustered and interconnected and may represent hydraulic systems to distribute the water at the outer part of the terramara. Most of them are water wells: they are about 2.5 m deep, and reach a sandy aquifer, which lies 5 m under the topographic base of the site—this means 2 m deeper than the wells in the enclosure. The fill of these wells is generally rather homogeneous, clayey in texture and poor in organic matter, and it includes very scarce archaeological material. The wells appear to have been excavated in a very short time. In two cases, they are interconnected, and in this case, the deepest well is also the last to have been dug, indicating that they were frequently re-excavated with the purpose of following the descending water table’s fringe (Fig. 12).

The archaeological material, while scarce, is rather significant, as it consists exclusively of sherds dating back to the final phase of the Recent Bronze age. It can be concluded, therefore, that the wells inside the moat were dug when those of the palisade were already deactivated:

![Fig. 9. Santa Rosa terramara (RE). The DTM (Digital Terrain Model) of the southern fringe of the Villaggio Grande after the 2004 field season. The palisade is interrupted by the gate which is 4 m large. Notice the wells in correspondence with the fringe of the village and inside the moat. Darker shadow corresponds to deeper areas (survey C. Putzolu).](image_url)
they might reflect the need to reach a deeper aquifer as the upper ones might have been exhausted.

5. A dry episode at the end of the Santa Rosa terramara

To understand better the environmental meaning of the event which led to the deactivation of the wells on the fringe, the whole hydrographic system of the terramara has to be taken into consideration (Fig. 13).

The Po river, ever neighbouring the site when it was active, was the main source for the aquifers feeding the terramara. The maximum depth reached by the water wells found in the Villaggio Piccolo (Cremaschi and Bernabò Brea, 2004) and by those of the Villaggio Grande is almost the same. The wells in the moat, on the contrary, reached about 2 m deeper. This means that the level of the water table was almost stable throughout the Middle Bronze age and the Recent Bronze age (a time interval about three centuries long), but it dropped abruptly during the final phase of the village, in the late Recent Bronze age (in a time interval less than 50 years long). As this event cannot be attributed to a river avulsion, due to the fact that the Po river during the Bronze age was deeply entrenched inside the plain (Cremaschi, 2004), the drop of water tables has to be attributed to a depletion of the river flow, consequent to a dry event which reduced precipitation rate and water availability. As the local level of the water tables is strictly connected with the flow of the Po river, which is the main hydrological collector of a considerable part of northern Italy, the dry event observed in Poviglio is likely to have had a regional relevance.

In the whole alpine region, there is evidence of a dry phase during this period. Drop in lake levels is recorded in the Garda region at Lago Lumecone (Valsecchi et al., 2006). Lake level falls are also recorded in the Swiss plateau and in the Jura mountains (Magny and Richoz, 1998; Magny, 2004; Holzhauser et al., 2005). During this period, the alpine glaciers were in a short withdrawal phase (Rothlisberger, 1986). A dry event at 3100 cal yr BP is not in contrast with the palaeoclimatic record from ice cores of Greenland. A well-pronounced peak is recorded in the melt water diagram of the Agassiz Ice Cap core (Fisher and Koerner, 2003) and a negative peak of delta O\textsuperscript{18} can be seen in the GISP and GRIP cores (Dansgaard et al., 1993; Meese et al., 1994). They both indicate a period with higher temperatures which may have resulted in enhanced aridity at middle latitudes.

The end of the occupation of the Santa Rosa site is contemporary with the general abandonment of the terramara. As the drought documented at the site had a regional extension, there is a clear contiguity between these two events, and we may assume a causative link between them (abandonment of the terramare and dry event) and infer that the climatic event may have acted as a catalyst to promote the abandonment of the terramare. In order to explain how a climatic event, quite minor in the frame of the Holocene climatic change, may nonetheless have...
contributed to and probably determined the collapse of a well-settled cultural system, we should understand that it saddled an environment already stressed by human exploitation. Several years of drought may have acted negatively on the basic sources of food, reducing soil fertility and rendering the feeding and watering of animals extremely difficult. A limit may have been reached, beyond which there was no possible answer to the demand for resources by a rising population, and the area became unsuitable for life and was rapidly abandoned.

6. Conclusive remarks

As far as the management of the environment is concerned, the terramare culture represented a unique experiment, though unsuccessful, in the context of the European Bronze age. In contrast, with a tendency toward decline in all the regions of Europe (Berger et al., 2000), the culture of the terramare produced a systematic and intensive exploitation of the environment, quite early for northern Italy. Intensive agriculture, pastoralism and the architecture of the sites, demanding large amounts of wood, were made possible by heavy deforestation of the whole Po plain, rendering it an artificial steppe devoted to cereal crops.

Water was a critical resource, strictly linked to the primary economy. The moats surrounding most of the sites were probably conceived to concentrate water and redistribute it to the surrounding country through a network of irrigation ditches. The hydraulic system discovered at the

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**Fig. 12.** Santa Rosa terramara (RE) Three interconnected wells inside the moat. (a) Plan and (b) DTM. Notice that the later well (US 6133) is also the deepest one (survey C. Putzolu).

**Fig. 13.** Cross section N-S of the terramara Santa Rosa (RE). Comparison between the water table levels during the Middle Bronze age and the final Recent Bronze age as indicated by the water wells depth. (1) Position of the cross section in the site map, (2) sand layers holding aquifers, (3) fluvial deposits (laminate sand/silt) of the Po palaeochannel, (4) shifting level of the water table: light-grey Middle and Recent Bronze age; dark-grey late Recent Bronze age and (5) the depth of the wells of the terramara.
fringe of the terramara of Santa Rosa, consisting of large water wells and interconnecting ditches, suffered a clear drop in the water table level during the late Recent Bronze age, and in the final phase of the occupation of the site coincided with the abandonment of all the sites in the terramare region.

The hydrological crisis recorded at Santa Rosa is the local expression of a regional dry event which is also recorded in the Alpine area and beyond, in the North Atlantic area.

The chronological contiguity, supported by the archaeological context, between the collapse of the terramare system and the dry episode recorded in Poviglio, suggests a causative link between the two events.

The period of dry climate affected an environment already stressed by over-exploitation of natural resources by a large demographic increase, and its consequences on the sources of the primary economy (soils and livestock) may have rendered the area unsuitable for living and caused its abandonment.

The case of the terramare rise the question of the role of short climatic changes in societal collapse which appears to have been a primary agent in several cases from the Mediterranean area, Middle East and meso-America over the Holocene (Weiss, 2000; De Menocal, 2001; Weiss and Bradley, 2001; Catto and Catto, 2004).

The present research confirms a multi-causal explanation for the terramare disappearance, in which the climatic component, after the recent discovery in Santa Rosa, appears likely to have played a role. Nevertheless, the main factor still remains the environmental stress induced by anthropogenic over-exploitation of resources and uncontrolled demographic pressure. This interpretation is further supported by the fact that in the areas surrounding the terramare, which were marginal during the apogee, the civilisation (specifically the Apennine and the Veneto plain), there was no break in occupation and the local cultures of the Final Bronze age overcame the crisis which was fatal to the terramare (Bernabò Brea et al., 1997; Bietti Sestieri, 1997).

References


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