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Journal of Environmental Accounting and Management

Continued on the back materials

Continued from insider front cover

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Hidden Environmental Vulnerability in Relation to the Instability of two Medieval Monastic Communities and Consequences for Present Environmental Management Options

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Abstract

This paper aims at discussing the importance of environmental factors in the stability of communities at local scale. Two case studies, referred to two medieval monastic communities are chosen as historical examples, under low-carbon conditions, to show the effects of the interplay between a lack of Community Based Adaptation (CBA) and difficult or changing environmental conditions. The case studies refer to the monastery of Bobbio (Piacenza, Emilia-Romagna, Italy) and Castelletto Cervo (Biella, Piedmont, Italy). In particular, the first case shows a lack of transformation of harsh regulations to the difficult environmental conditions of that time, which leaded to a revolt inside the monastery. On the other side, the decline of Castelletto Cervo Cluniac priory depended upon a bad management of economic resources in a time of environmental variability, which affected the agricultural yield and the life of many villages in the considered area. The choice analyzing the case of two low-carbon communities (i.e.: before the XVI century, when the massive diffusion and use of coal modified these conditions) depends on the present international political will and plans of decarbonizing our societal lifestyles. This research highlights the hidden environmental causes behind the social instability and, in one case, the collapse of the community. Besides further reasons for historical interest, which are not deepened in this research, these case studies show that environmental factors are often unseen or neglected in planning the life of a community, also exerting a strong influence on real economy at local level. In order to develop appropriate policies to guarantee a long-term resilience for the socio-ecological stability of communities, an adequate monitoring of appropriate environmental and social parameters can sup-port planning activities.

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1 Introduction

The exponential growth of human activities has strong negative impacts with respect to the ecosystem and human health. Humans are crossing the existing planetary boundaries, increasing the risk of destabilizing the existing safe space for humanity. The depletion of resources, also experienced by past societies, might lead to the collapse of social structures. This, in turn, critically depends on available energy, since complex societies require energy from food and other external energy sources to survive, reproduce and improve their well-being. Thus, the lack of Energy Return On Investment (EROI or, sometimes, EROEI) plays an important role in societal stability (e.g.: Hall et al., 2009; Tainter and Patzek, 2012). As discussed by Tainter (1988), adaptation is related to problem-solving, which, in turn, is generally dependent on structural modifications of societies, which is an energy-demanding process. This adaptation depends on resilience, which is defined as "the capacity of a system to absorb disturbance and reorganize while undergoing change to still retain essentially the same function, structure, identity, and feedbacks" (Holling, 1973; Peterson et al., 1998; Walker et al., 2004).

Resilience at local level is defined as "existence, development and engagement of community resources by community members to thrive in an environment characterized by change, uncertainty, unpredictability and surprise" (Magis, 2010). Resilience doesn't depend only on resources availability. Instead, resilience relies on skills, experience, local knowledge and networks to undertake locally appropriate activities, which reduce its vulnerability (Dodman and Mitlin, 2013). Moreover, both environmental and economic and social and cultural factors, as well as their interplay, have an important role in establishing the possibilities of survival for any community. Community Based Adaptation (CBA hereafter) depends on the dynamic regulation of those factors. However, the effects of environmental conditions on human communities' well-being are often neglected. This also depends on the masking effect of technological evolution and easier access to resources. When such circumstances didn't exist, such as in the pre-industrial era, societies were more vulnerable to environmental conditions. Thus, considering the possibility of lower and more difficult access to depleting resources in the future, it would be important to consider these interplays.

The present paper is focus on two case studies, which highlight the potential dynamics of lack of CBA in connection to resilience. As main topic, the (in)stability of communities as a function of environmental conditions, which also alter the local socio-economic dynamic, is discussed. The study of sustainability and resilience through the lens of history becomes important, in particular when considering low-carbon communities, thus, before XVI century, when coal burning became relevant. In fact, many policies focus on the transition toward low-carbon societies nowadays. The opposite perspective (i.e.: reading history through sustainability and resilience) would be relevant, even if not discussed here. This work, which can be framed also within the context of post-processual historiography, aims at overcoming the tendency of interpreting historical phenomena, forgetting about the importance of environmental conditions in their dynamics. In the specific case, the lack of charisma in leadership and the economic mismanagement are considered to be the only causes of the decline for the studied communities.

While discussing the use of a comparative approach to derive some hints for present sustainability management, it is important to remark again the role of technological advancement in the present time. However, knowing how it looks like to manage (or mismanage) a low carbon community can help to foresee the potential problems, which might arise by wrong management practices. Moreover, it is assessed that a lack of theoretical and empirical knowledge exists in relation to sustainability strategies at local level, to empower local communities and to enable them in addressing both community issues and procedural concerns (Colleen and Reed, 2015). This is why such a study is relevant today.

The chosen case studies refer to two different Italian Christian monastic communities in the Middle Age, investigating on the lack of interplay among three main aspects of any community life: the environmental conditions; their economy and regulations. The first considered monastery, founded around 615 AD, is St. Columban Abbey, whose community was originally constituted by 24 monks, whose names were reported by Jonas of Bobbio (2000). The second monastery, i.e. the Cluniac Priory of Castelletto Cervo (NW Italy), funded in year 1083 AD, was constituted by at least eight monks, according to the available fragmentary information obtained from original archival sources (Destefanis, 2015). The choice of these two communities depends, first, on the partial availability of historical and archaeological researches, which also document the decline of the two communities, enabling the development of this study. These factors were previously defined as "monastic triangle" (Alciati and Casazza, 2017). Second, the possibility of comparison, which may be of interest for qualitative and quantitative researches, is simplified due to the uniformity of lifestyle within a given community. Moreover, comparative studies along time might be possible, under defined circumstances, due to the long-time preservation of internal regulations, defining the management of a community and its daily life. The special interests of the pre-industrial epoch are two. From one side, it allows a better knowledge about the regulating mechanism of a low-carbon community, particularly before the XVI century, during which the use of coal started to grow. On the other side, it allows to recognize the potential causes of failure of a lifestyle (the coenobitic Christian one), which showed a great stability potential, since it still exists after about 1,700 years, rooted on the concept of stabilitas, which parallels in many ways the concept of sustainability. Finally, the individuation of case studies, representing a lack of integration of components within a socio-ecological system on a local scale, can support better decision-making processes for the future.

2 Methods

2.1 Literature data analysis

This work is based on a multi-disciplinary review and reanalysis of the existing literature, archaeological evidence and documents (i.e.: manuscripts), which can be referred to the life of the communities under study, the surrounding environmental and economic conditions and the evidence of community social conditions along the considered time periods. The necessity of such an approach derives from the absence of available quantitative data – in particular, accounting ones – since the archival sources are dispersed. Consequently, the environmental and economic conditions are inferred from other sources. More in detail, signs of specific exposures to vulnerabilities were derived in relation to a sub-set of indicators, defined by Bennet et al. (2016). These are listed in Table 1. This systematization of relevant factors at community scale allowed to fix the criteria for the literature and searches.

In particular, the literature search was performed through 'Google Scholar' and "Web of Science" search engines, searching existing works focused on climate, environment, economy and monastic communities, separately referred to the areas and time under study. The time search, performed excluding the citations, was conducted, first, looking to the last 5 years and, then, removing the temporal limitation of the outputs. Moreover, the main existing monographies were consulted to study the state-of-the-art about the history and archaeological data about the two monasteries. Quantitative data were especially necessary to define the environmental conditions of the surroundings. In particular, geological and hydrogeological conditions and paleo-climatic studies, focused on the same areas of the monastic communities were relevant. The field and laboratory analyses of archeological finds, selecting only reviewed and published materials to avoid a lack of peer review, support the discussion of results. Monastic rules were previously investigated in detail with respect to the focus of sustainability. Results of this research are summarized in Alciati and Casazza (2018). Instead, the socio-economic contextualization could be developed only qualitatively, due to the fact that the main body of both the monastic archives is missing. The presence of such material (such as economic accounting of material flows, which is sometimes found in written records, might allow to study other communities in a deeper way.

2.2 Case studies

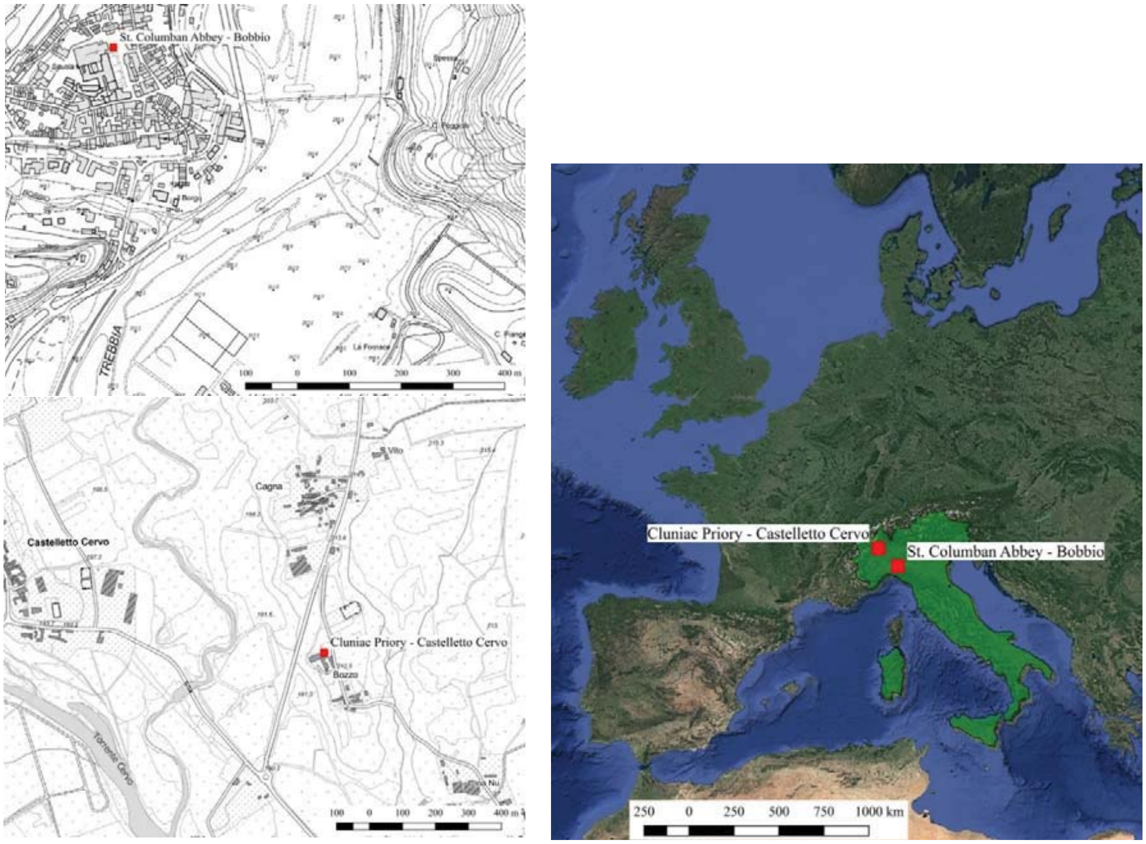
The first case study refers to the monastery of St. Columban in Bobbio (High Trebbia valley, Piacenza, Italy - 44°46'17.40" N, 09°23'11.04" E; 272 m a.s.l.). This study considers the period after the death of St. Columban, occurred in year 615 AD. The interest is focused on the potential causes of a revolt against the Abbot, Attala,

Table 1 Community-based drivers and exposures in relation to resilience (according to Bennet et al. (2016)).

Drivers			Exposure
Classification	**Sub-classification**	**Category**	**Type**
Biophysical	Climate change	Physical properties	Extreme weather events
			Variable precipitation patterns
			Changing atmospheric temperature
	Other environmental	Hazards	Earthquakes, fires, floods
		Land-based	Fresh water use
			Pollution and garbage
Socioeconomic	Demographic	Population	Gentrification
			Changing age/sex distribution
		Migration	Permanent/temporary migrations
		Health	Chronic illness/acute diseases
			Mental, emotional, spiritual health
	Economic	Macroscale economic	Changing patterns of consumption
			Changing livelihood opportunities and dependencies
		Cost and credit	Changing food costs
			Rising livelihood costs
	Infrastructure and technology	Basic services/social infrastructures	Roads
	Governance and policy	Changing governance institutions and structures	Organizational jurisdictions and mandates
			Decision making structures, processes (centralization, inclusion, scale) and legitimacy
			Societal norms and values
		Changing regulations	Changes in tenure and rights (property, harvest, access, management)
			Natural resource management
			Market-driven changes in allocations and harvesting
		Conflict and security	Conflicts between groups and resolution mechanisms
	Socio-cultural	Traditions, knowledge and values	Changing value systems
			Loss or re-invigoration of traditional practices
		Networks and relationships	Organizational networks – bridging social capital

after the death of the founder of the community. The second case refers to the Cluniac priory of Castelletto Cervo (Biella, Piedmont, NW Italy - 45° 31’ 20.28” N, 8° 13’ 35,40” E; 216 m a.s.l.) in the time range from the XII century AD to the XV century AD. The reason of interest is its economic decline, until its suppression. Figure 1a and Figure 1b indicate the location of the two monastic communities. In particular, the Figure 1(a) represents the positions of St. Columban Abbey (upper figure) and of Castelletto Cervo Cluniac priory (lower figure) within the Technical Regional Map layers of Emilia-Romagna region (for St. Columban abbey) and Piemonte Region (for Castelletto Cervo Cluniac priory). Trebbia river (upper figure) and Cervo river (reported as ‘Torrente Cervo’) locations are also reported in the figure. Figure 1(b) reports the positions of the two monasteries, having Google satellite map as background and Italy shapefile (green) as intermediate layer. Scales are reported in the figures.

These two case studies attracted our attention for different reasons. With respect to the first one, the main



(a) (b)

Fig. 1 The location of St. Columban Abbey (Bobbio, Piacenza, Italy) and the Cluniac Priory of Castelletto Cervo (Biella, NW Italy) – Figure 1(a) represents the positions of St. Columban Abbey (upper figure) and of Castelletto Cervo Cluniac priory (lower figure) within the Technical Regional Map layers of Emilia-Romagna region (for St. Columban abbey) and Piemonte Region (for Castelletto Cervo Cluniac priory). Trebbia river (upper figure) and Cervo river (reported as 'Torrente Cervo') locations are also reported in the figure. Figure 1(b) reports the positions of the two monasteries, having Google satellite map as background and Italy shapefile (green) as intermediate layer. Scales are reported in the figures.

work investigating the causes of the occurred revolt hypothesizes the lack of charisma of Abbot Attala in managing the revolt, originated by the harshness of the monastic rules applied to the community (Dunn, 2008). Nonetheless, these regulations were chosen freely by the same monks, who were responsible for the revolt. Moreover, the decision of leaving a monastery was generally heavily punished. The second case, instead, refers to a smaller community, a Cluniac priory, whose decline was caused by a bad management of economic resources (Destefanis, 2015). It is, however, amazing how these critical conditions occurred within just three years. In addition, despite the documented improvements in management, as periodically reported by the available sources, the monastery's fate didn't change at all. With respect to both cases, the reduced availability of documental sources, while limiting the presence of direct witnesses, stimulated the investigation on the local 'boundary conditions', which now potentially suggest a different narrative of the facts. In the case of Bobbio, this fact is also suggested by the existing investigations about rural settlements following the decline of the Roman Empire. In particular, the declining commerce and agricultural activities lead to the abandonment of villages and to the growth of sparse rural settlements, based on cohabitation and basic subsistence (Cinieri and Zamperini, 2013). Similar observations were also reported in the literature in the area surrounding Castelletto Cervo priory.

3 Results

3.1 Biophysical drivers

3.1.1 St. Columban Abbey, Bobbio

The monastic site is located at the crossroads of different paths: one toward Genua and the Tuscia area; another toward Piacenza and the Po valley; and a third toward the northern areas and urban centres, such as Pavia. The main and secondary paths along the Trebbia valley, which also crossed the site of Bobbio, were already known prior to and during the Roman age. This is evident because of the large number of archaeological sites. The Trebbia (with the accent on the e Trèbbia; Latin: Trebia) river, after which the valley is named, is one of the four main right-bank tributaries of the river Po, the other three being the Tanaro, the Secchia and the Panaro. The 1,150-square-kilometre (440 m^2) drainage basin is divided among Emilia-Romagna, 770 km^2 (300 m^2), Liguria, 349 km^2 (135 m^2), and Lombardy, 31 km^2 (12 m^2). Its principal tributaries are the torrents Aveto and Perino (from the right) and the torrent Boreca (from the left). From its source the river flows north-east for 118 km (73 mi) until it reaches the Po, just to the west of Piacenza. The Alta Val Trebbia ("High Trebbia Valley") includes the valley down to Bobbio. The northern Apennines – the mountain area where the site is located – are a belt of NE-SW mountains on the coast of NW Italy folded by transverse thrusting from sedimentary rock.

From a geological point of view, the area of Bobbio is rich in sediment, that eroded from the mountains and deposited in the alluvial fans and terraces in the Po valley. Diking has prevented much of the flooding. However, due to confinement of deposition within the stream beds, significant parts of the stream presently run entirely above ground, in places as high as rooftops. Such a development occurred over the previous thousand years (Bollati et al., 2011). The native rock differs between the two banks. On the left bank, the rocks are mainly sedimentary, while, on the right, rocks they are both sedimentary and metamorphic (ophiolite, serpentinite, basalt, jasper). An area for the extraction of salt (from salty waters), was located near the monastery, close to the falls of Carlone. There it was possible to extract salt either through evaporation or by boiling the water. This practice was first used by Romans and, then, by the Lombards. In fact, this site is also known as the well owned by the Lombard nobleman, Sundarit, whose property he shared with the monastery (Cantino Watagin et al., 2000; Murialdo, 2011). Looking at the characteristics of the Bobbio area, it is possible to find ophiolites (i.e., an igneous rock consisting largely of serpentine) in the soil, while we must also note the presence of salt nearby, due to the availability of salty water (Scelsi and Gattinoni, 2009). These facts represent a strong partial limitation to the fertility of the area.

The conditions of abandonment of the territory, as described by Jonas, when St. Columbanus arrived with his community about one year before his death, also constitute a limitation for the survival of the community. The archaeobotanical data from northern Italy already show an agricultural world in crisis in urban and rural sites (Castelletti and Maspero, 1998; Castelletti and Motella De Carlo, 1999; Castiglioni et al.; 1999; Nisbet, 1999; Augenti et al., 2006). Considering the territory of the Trebbia valley and the surrounding areas, in the early Middle Ages, following the fall of the Roman Empire, a process of heavy decline of commerce and of agricultural activity started, with the resulting abandonment of the Roman roads. The society found itself downsized to a semi-natural economy, reutilising the old rural villas as places for organising local activities. Thus, village communities were developed according to cohabitation rules that were based on the communal exploitation of the territory, while the economy was agrarian and self-supporting, based on horticultural farming, on small grain fields, or on viticulture(Cinieri and Zamperini, 2013). This is exactly the situation that St. Columbanus and his monks found, when they first came to Bobbio, where the wood was thick and the site of the future monastery was difficult to access owing to the harsh path, according to Jonas.

Another factor, in connection to the adverse environmental conditions, is related to the occurrence of flooding event. This evidence also appears in a description of a miracle performed by the abbot Attala: the diversion of the flooded river Trebbia. It must be recalled that miracles were mainly reported considering first and foremost its direct or indirect importance with respect to the survival either of a person or of a community. In our case, it is about the risk of flooding of the monastery and the destruction of its mill. In fact, Jonas describes a turgid flow of waters, common for the Alpine rivers and catchments, transporting both lithic and vegetal debris, which was shaking the mill structure due to its power: “When during a certain period the small river, which we mentioned above, named Bobbio, which flows with violence and with massive amounts of waters, as usual for the torrents descendent from the peaks of the Alps and increased by the rainfalls, so this, inflated due to the stone cliffs and the amount of trees, accumulated an excessive force and came to erode the mill of the monastery because of the speed of its flow and to flood now every time this whole workshop: hearing that noise, the keeper of the mill, named Agibodus, went to the mill to see if so much pressure might lead to a certain amount of damage”. This description of what is known under the name of ’solid transport’ is not uncommon to that area, while the high sediment load is also demonstrated by the geological characteristics of the area. The comparison with the same phenomenon occurring in the Alps might depend upon the experience of Jonas, who was born in the area of the Susa valley (NW Italy), where such events occur frequently due to the geological characteristics of the surrounding mountains. Furthermore, starting from the 4th century AD, the fluvial system was in a metastable equilibrium, while the alluvial fans had the tendency to aggrade, mainly as a concurrent consequence of bad climatic conditions and as a sign of the loss of the land preservation systems in the mountain catchment areas (Cremonini et al., 2013). The fact is confirmed also by Taricco et al. (2015),who extrapolated the Po River (i.e.: the largest watercourse in Northern Italy) last 2 millennia discharges before year 1917, showing that a period of high discharge was recorded also around and shortly after 600 AD.

A significant sign of change in climatic conditions in the period of transition between the Late Roman Empire and the early Middle Ages is the reversion from arable to pasture lands, which affected regions as far apart as Italy and Poland and cannot be ascribed merely to the political and fiscal dislocation of the ancient world, but should be understood as one effect of the climatic anomaly (Cheyette, 2008). In the area of the monastery, climate records indicate that a cold anomaly (i.e., a mean relative minimum temperature) occurred between 300 AD and 500 AD, where different dynamic processes such as meltwater flux into the North Atlantic, low solar activity, explosive volcanic eruptions, and fluctuations of the thermohaline circulation likely played a major role (Wanner et al., 2011). The period of foundation of the Bobbio monastery is characterized by a transition from a cold-wet period, whose effects were still partially present, to a warm-dry period, as witnessed by the Northern-Hemisphere temperature patterns (Ljungqvist et al., 2012). This fact is also confirmed by a pollen analysis, which indicates contemporaneous phases of forest clearances and of intensified land use around 700 AD which coincided with periods of a warmer climate, as recorded by the Alpine dendroclimatic and Greenland oxygen isotope records (Tinnera et al., 2003).

Meanwhile, several volcanic eruptions affected the climatic conditions. Powerful volcanic eruptions injected large amounts of sulphur dioxide into the stratosphere, that converted into sulphate aerosol, thereby altering its radiative properties and leading to short-term (1-3 years), global-scale cooling at the surface. Together with well-documented episodes of atmospheric acidification, volcanic emissions also caused the so-called dry fogs, consisting of a more or less dense and reddish mist composed of foul smelling gases and aerosols that might have appeared and persisted when the relative humidity was low (Camuffo and Enzi, 1995). The volcanic aerosol load alters the precipitation regime, increasing the number of intense events, which have a higher impact on the soils, increasing both the probability of flooding and the risk of debris/mud flows or landslides. (Diodato, 1999; Gillett et al., 2004). These effects are surely possible, due to the geological characteristics of the Bobbio area. With respect to the period of the revolt, several written and oral sources describe the effects of volcanic eruptions, the most important of which was the one in 626 AD (Stothers and Rampino, 1983; McCormick et al., 2007; Baillie and McAneney, 2015). In particular, the most recent records identify two periods of volcanic eruptions: the first between 619 AD and 622 AD and the second between 624 AD and 626 AD (Sigl et al., 2013; Sigl et al., 2014). Finally, the sum of these and other concurring effects, evidenced also by new paleoclimate data, has now supported identification of the interval from 536 to about 660 AD as the Late Antique Little Ice Age (LALIA). Buñtgen et al., 2016). The LALIA, which also contributed to the shaping of watercourses and slopes strongly influencing the hydrogeological evolution of this area (Tropeano and Turconi, 2004), could have played an important role in the availability of energy resources, considering both food and primary energy sources, thus affecting the EROI for the community. In any event, this factor merits further investigation.

3.1.2 Cluniac Priory, Castelletto Cervo

The Cluniac Priory of Castelletto Cervo (Biella, NW Italy) is found in the Southwestern terrace area, surrounded by Ostola river (West) and Ravanella river (East). This area is characterized by fluvial deposits of glacial origin, altered by 3-meters thick yellow clay deposits, which can be attributed to the Riss fluvio-glacial epoch (Compagnoni and Piana 2015, p. 38). This surface is connected to the pre-alpine area of Biella, which has a mixed nature (i.e.: sedimentary, igneous and metamorphic). Toward North, in the meridional sector, some terraces are found, locally called 'baragge', made of sandy and pebbly soil covered by a layer of superficial silt. This sector is very fertile and highly irrigated due to its lower quota with respect to the surrounding water courses (Ardizio 2015b, p. 40). Riverbed areas have also a third sector, corresponding to the hills between Gattinara and Biella (NE with respect to the priory location), defined by a dense hydrographic network.

The hydrographic basin of Sesia river, within which Castelletto Cervo is also located, has a total surface of about 3,038 km^2 (4% of the surface with respect to the Po river basin). About 45% of this area falls is mountainous. The Sesia and its tributaries – Mastallone, Sessera and Cervo with its tributary, Elvo – originate from the orographic group of Mount Rosa (Pennine Alps). More specifically, the river Cervo, whose name originates from the Germanic word *Saar* (river or stream), has a total surface of about 1,024 km^2 mainly characterized in its upper part by a mountain morphology, with altitudes reaching quotas higher than 2,000 m a.s.l., narrow valleys of fluvio-glacial origin, with accentuated slopes mainly covered by woods. Actually, in its first part, the river Cervo and its tributaries are characterized by very incised beds, having a relevant solid transport, with prevalent high-size granulometry. It is important, however to consider that the quality of these data should be further detailed historically through a morphological investigation, as even the conditions of solid transport could be changed over time. Downstream, the area assumes a terraced morphology, changing from branched to monocursal. Lateral bars and, subordinately, longitudinal bars and stable islands are found along the river. The highest areas, located in the Northern sector, are characterized by vast plateaus, largely covered by spontaneous vegetation. In particular, prevalent herbaceous coverings were found, interspersed with sparse woodland patches (oaks, birches, hornbeam), shrubby areas and small wetlands (alders, willows, marsh vegetation) (Ardizio 2015a, p. 42). While their agricultural exploitation was difficult due to the scarcity of water, plain areas were fertile and workable, due to their relative ease of irrigation (Borasio 1929, p. 275). The exploitation of mountain area was supported by a dense road network, which played a key role in defining the economic value of lands, due to the possibility of connection with the Alpine territories. In fact, transhumance was quite frequent in the area, in particular for religious congregations, whose patrimony was distributed from plains to the mountains (Guglielmotti 1999, p. 66; Ardizio 2015b, p. 135).

With respect to climatic conditions, from year 900 to year 1350, temperatures rose in much of the world. Environmental responses, as well as cultural ones, were not lacking in the period, known as the Medieval Climate Anomaly (MCA), even if their characteristics and intensity were variable from place to place (Millar and Woolfenden 1999). This fact emerged also in a more recent study, which shows the differentiation in paleoclimatological proxies. In particular, it appears that the Little Ice Age was more uniformly distributed, between XIV and XIX centuries AD, than MCA, which occurred between IX and XIV centuries AD (Soon and Baliunas 2003). Another research, which focused on winter temperatures, showed the high frequency of cold winters during the XIV century, in particular for the following years: 1305-6; 1322-3; 1354-5; 1363-4; 1476-7 (Pfister et al., 1996). Cold winters also occurred before, during years 1149-50, 1204-5, 1233-4 (Pfister et al., 1998). The same work reported the years with warm and dry winters: 1186-7, 1205-6, 1289-90. In parallel, drought episodes occurred in the Euro-Mediterranean area during the medieval period: 1237-1253; 1312-1329; 1351-1356 (Cook et al., 2016). It is known that, during these years, paleobotanical data indicate that aquifers lowered during two distinct periods: 820-1075 e 1220-1360 (De Beaulieu et al., 2005). Later, between 1360 and 1540, this trend was reversed due to the beginning of LIA, as suggested by the same study. As remarked in the previous sub-section, volcanic activity plays and active role in defining the climatic conditions, known their indirect influence on human activities (Kostick and Ludlow, 2015). Ten major volcanic eruption signatures were observed during the XIII century, six in the XIV century and 5 in the XV century (Sigl et al., 2013). In particular, among the events recorded in two proxies (one in Greenland and one in Antarctica), the most relevant occurred in the following years: 1229-32; 1257-61; 1285-88; 1330-32; 1344-48; 1389-91; 1453-54; 1458-61. Finally, the assessment of paleo-hydrological conditions derived from Wirth et al. (2013). In particular, strong variations were observed, with major peaks during the XIII century. The seasonal distribution of events showed that Summer (129 events, 26.2%), followed by Autumn (312 events, 63.4%), were the periods with most frequent flooding occurred. On the other side, Spring (18 events, 3.7%) and Winter (33 events, 6.7%) were less relevant.

3.2 Socio-economic drivers

3.2.1 St. Columban Abbey, Bobbio

The initial core of the monastic property covered a surface area of about 4 miles. In order to give an esteem of food sufficiency for Bobbio monastic community a simple calculation can be made, as previously done for another case (Ghisellini and Casazza, 2016). In particular, calculations are derived knowing the approximate productivity for wheat and durum (used as sample crops), as well as the mean metabolic need for an adult human ($1.4*10^2$ W). At that time, wheat caloric content ($1.69*10^7$ J/kg), had average mean productivity, considering 1 harvest per year of 1.5-2 t/ha (Doughty and Field, 2010). The same study reported also the caloric content (1.47*107 J/kg) and mean productivity (0.10-0.5 t/ha) for durum. In parallel, the size of the community should be known. A general research showed that the size of many communities ranged between 12 and 20 monks, while an important community would have 40 monks and those with 50 or 60 monks were exceptional (Dubois, 1982). Thus, considering an exceptional community size (this is done conservatively as an excess esteem, since real numbers are missing), the community size, in the years following its foundation (when the revolt occurred), could be up to 50 people. Since the real numbers, however, are not known, the considerations that follow are only a first approximation, necessary for an esteem of land surface necessary for the survival of a community. When founded, the monastery of Bobbio had an available surface area of 4 miles (i.e., about $2.8*10^7$ m^2). The energetic (metabolic) need for feeding the monks during one year was $1.68*10^{11}$ J (this number is obtained by multiplying the energetic need of 1 man for 1 year for the number of inhabitants of the monastery). Considering the available data, it is possible to determine that a surface area of $7.44*10^4$ m^2 would have been necessary, in the case of wheat cultivation (0.26% of the available surface area) or $7.44*10^4$ m^2, in the case of durum cultivation (3.17% of the available surface area) for feeding the monks of Bobbio. An additional surface area would have been necessary too for cultivating cereals, used for beer production, which was usually consumed, according to Jonas' writings and to the monastic rule of St. Columbanus. This means that, theoretically, the available surface area was sufficient for starving the monks. However, monks complained about the scarcity of food in relation to the strict observation of the rule.

This fact suggests the necessity to look further to the content of the norms in relation with the legitimization of the Abbot's power. In fact, a relative harshness for a monastic rule (or, better, of its application) was quite obvious, as it was at that time, when the monastic life option, as well as the acceptance of a new member within a community wasn't immediate. Moreover, such signs cannot be searched either in poverty or prayer or obedience or silence, which were common strongholds for monastic rules and lifestyle. Instead, the harshness of rule application should be searched in relation to daily life need, i.e. considering work or food.

Considering our specific case, St. Columbanus wrote two Rules: the 'Regula Monachorum' and the 'Regula Coenobialis' (Murdoch Walker, 1970). The first and earlier one was probably written during his staying at Luxeuil (591/593–610), while the second was written later (de Vogüé et al., 1989). In a section of 'Regula Monachorum', with respect to food, we find that "the food be poor and in the evening [. . .] that may not burden the stomach and stifle the mind [...] Therefore we must fast daily, just as we must feed daily". Then, comes the section regarding poverty, which states: "Therefore, while they have much in heaven, on earth they should be satisfied with the small possessions of utter need". Another section, which could reflect the harshness of the Rule, is about mortification: "The greatest part of the monks' rule is mortification, since indeed they are enjoined in Scripture"; "But though this training seem hard, namely, that a man should always hang upon the lips of the other"; "Of mortification, then, there is a threefold reason for this: not to disagree, not with the tongue speak as one pleases, do not go anywhere with complete freedom". Finally, the section about monk's perfection states: "The monk will live in a monastery under the discipline of one father and in company with many, for learning lowliness from one and patience from another. In fact, one will teach the silence and another, the gentleness. He will not do what he wants or eat what he likes, he will have what he will receive, he will do the duty of his work being subject to whom he won't. Let him come weary to his bed and sleep walking, forced to rise while his sleep is not yet finished. Let him be silent when suffering offences, let him fear the superior of the monastery as a lord, love him as a father, believe that whatever he commands is healthful, or for any opinion of an elder, to whose duty it belongs to obey and fulfil what he is bidden". The 'Regula Coenobialis' contains elements of penance and punishment, typical of the additions, that were made to solve the practical problems related to the management and the instabilities within a community. Apart from the recitation of the Psalms, the most common punishments mentioned in the 'Regula Coenobialis' were: blows (mentioned 37 times); having only one bread and water (27 times) and flagellation (11 times).

Application of the aforementioned points certainly supports Jonas' explanation about the cause of the revolt. Nonetheless, this would be partially insufficient, since the rule was usually learnt and accepted by the monks before stably entering into a community. Furthermore, the revolt didn't occur centuries after the death of St. Columbanus, but when part of the original community involved in the foundation of the monastery was still alive and present. This is why the environmental context becomes important, in order to understand the living conditions of the Bobbio monastery at the time of Attala.

3.2.2 Cluniac Priory, Castelletto Cervo

Archaeobotanical materials (woods, coals, seeds / fruits) recovered in the area of the priory revealed the prevalent use of deciduous oak timber, even if chestnut trees were prevalently cultivated in the woods owned by the monastery (Rottoli, 2015). The use of mixed oak woods was also documented. Alder was used for the construction of a water pipeline. Carpological surveys revealed the cultivation (or consumption) of barley, wheat, oats, rye. Millet and bread were used in the later period, as evidenced by the same findings.

For the Middle Ages, the fragmentary and discontinuous documentation reveals interesting peculiarities (Ardizio, 2015b). In fact, during the XIII century, between the villages of Varallo and Parone, specialized crops, such as vines and flax, were cultivated. In addition, the vineyards, were also present in Castelletto during year 1260, as well as in Carpignano and Ghemme and in other lands, which belonged to the priory. Moreover, in the village of Greggio, in year 1439, the priory, in addition to the church of Santo Stefano *extra villam*, possessed 6 fields placed in the inhabited area, as well as 4 mills (in Varallo, Castelletto, Ghislarengo and Carpignano) and a press in the castle of Carpignano (Ardizio, 2015c). Two more small mills, documented in two writings of years 1083 and 1225, were recorded in unknown places.

Faunal remains in the cloister area revealed the presence of small domestic mammals and small poultry (Catagnano, 2015). Moreover, fragments of pigs, sheep and goats, horses (1 case) and cattle (22 cases, distributed in different historical periods) were found. The same study hypothesized that the presence of very young sheep and goats was related to the production of milk and more tender cuts of meat, as well as for the exploitation of both wool and meat, in the case of adult individuals. Moreover, in the case of sheep and goats, it is necessary to take into account the existing practice of transhumant breeding, as previously reported. Finally, the strong presence of pigs indicates a mainly silvo-pastoral economy, in a context in which vast wooded or uncultivated areas offered vast grazing areas.

Ceramic was produced within the monastery, as witnessed by about 1400 fragments (Botalla Buscaglia 2015). Ceramics without coating, which do not require special processing, were prevalent. Furthermore, an articulated metallurgical production activity is also evident (Iacone, 2015). In particular, iron and copper alloys processing, which can be associated with melting of semi-finished products or material to be re-melted.

Nothing directly reveals the causes of economic decline of Castelletto Cervo priory. Consequently, surrounding conditions, starting from agriculture, should be investigated. Due to the lack of more information about local on agricultural activities, it is necessary to analyze the agricultural productivity in the broader Italian context. According to Federico and Malanima (2004), in the pre-industrial age (1300-1800), the output per worker was inversely proportional to the population. As observed, a growth of 1% in the population would cause a productivity drop of 0.27%. The Italian population grew, between X and XI centuries, up to a peak, which was reached around 1300. Later, population size was stable, despite the effects of the pestilence of 1348-9, and, then, collapsed of about 40%, between 1350 and 1400. The same research showed that individual productivity, calculated as the ratio between gross output and labor force, increased of 0.05% from the XI century to the beginning of the XIV century. This trend was also supported by the growth of temperatures, which, in turn, allowed to extend the existing cultivations to many hilly areas. This growth, instead, had a reverse in the XIV century. Thus, during the second period of economic fragility of the priory, there was a gradual decline in labor productivity.

At the same time, also population growth stopped. In the same area of Castelletto Cervo, many villages were abandoned. This is quite peculiar, thinking about the fact that it is the most fertile part of the territory. Moreover, in the same region, many farms grew up previously, during the XII and XIII centuries, while strong deforestation also occurred (Rao, 2011). The same author, looking to the history of abandoned villages (like Gazzo and Desana), assessed the appearance of such a phenomenon from the second half of the XIII century. In particular, this occurred before the year 1348 plague, which, in combination to several war episodes during the second half of the XIV century, sharpened a process, that was already in progress. According to the same study, the epidemic wave did not have a structural or trigger role in the abandonment process. This is also confirmed by the fact that abandonments occurred after the middle of the century had mostly a temporary nature. Revitalization occurred only from the XV century, after the priory abandonment. In parallel, the first economic crisis of the monastery was recorded by documents in the same period of this wave of depopulation (starting from 1280). Rao (2011), during his investigations, found that archival sources reported great difficulties in finding manpower to cultivate the lands, which were gradually abandoned. Wood deforestation lost its convenience, in particular for plots of land far from villages. Even ecclesiastical bodies and major land owners tended to leave also arable lands uncultivated, due to the recorded poor yields. Thus, case it is plausible that also the yields of land, owned by the priory of Castelletto Cervo, suffered from several crises. However, the taxation level for the monastic properties didn't change (Ardizio, 2015c).

4 Discussion

A multi-disciplinary analysis of two historical case studies allowed to demonstrate the weight of different environmental factors with respect to the stability of two different communities, i.e. the monastery of St. Columban in Bobbio (Piacenza, N Italy) and the Cluniac priory of Castelletto Cervo (Biella, NW Italy). A first reason of interest, behind the scope of this work, would be to investigate how these data are interconnected with and linked to religious data and religious history. Thus, further researches will be necessary to answer to this topic. Another reason for interest, behind the purpose of this work, would be the importance ranking and interplay of survival and faith as reasons for living within a community. In particular, a provocative research question could be formulated in the following way: "Was survival the main driver in the context of monastic communities, while faith was the way for attributing a meaning to this life choice? Or was faith the main driver, adjusting the practical rules of life according to the need of survival, while respecting the indications given by faith?". These science questions can be discussed according to two levels: (1) The real and historical level of monastic community/organization and how monks organized their community; (2) The analysis level: how researchers can put different disciplines and methods into a dialogue? With which goals?

Taking these case studies as historical examples, they demonstrate the necessity of considering the adaptation of communities to environmental conditions (in fact, CBA was missing in the two case studies) in order to guarantee their survival. This is why, considering the present unsustainable societal lifestyle and the high rate of resources depletion, CBA should be carefully planned, starting from the environmental conditions, as soon as possible. Thus, the discussion can be extended to any local community. In particular, there are three major points, which should be underlined: (1) Environmental factors are often unseen or neglected in planning the life of a community, as often evidenced by the scientific literature; (2) Environmental factors can exert a strong influence on real economy, often hidden by technological development and easy access to resources; (3) The lack of adaptation of regulations to environmental conditions might ultimately result in social unrest or collapse. Consequently, three questions emerge: (1) How can longer-term environmental factors be appropriately detected? (2) How can a community be responsive with respect to environmental variability?

The responsivity and stability of a community depend on its resilience, which, in turn is coupled with so-called slow variables (Biggs et al., 2012). In particular, these might include biophysical parameters, like soil composition or climate factors. In parallel, examples of social variables could include the legal systems, values, culture and traditions. Considering the exposure factors (Table 1), some environmental and socio-economical parameters can be monitored. Extreme weather events, precipitation and temperature patterns, natural hazards (mainly including fires and floods), fresh water characteristics, pollution and garbage belong to the first group. Instead, population size and density, GDP, cost of products, as well as governance quality assessment belong to the second group.

Different forecast techniques to detect weather anomalies are already operational, as well as under study. Examples include tools to detect short-term irrigation demand fluctuations or daily reference evapotranspiration (these parameters are relevant for agriculture), to predict Maximum Temperature Extremes, as well as techniques to predict short-term climate variations or to operatively develop drought projections (Richman and Leslie, 2014; Perera et al., 2015; Borona et al., 2016; Le et al., 2017). Flash flood nowcasting (i.e.: intensive-observation-based very short term forecasting) is now possible, thanks to the integration of appropriate technologies with short-term response meteorological models (Furquim et al., 2014; Silvestro et al., 2015; Caseri et al., 2016; Smith et al., 2016; Vincendon et al., 2016). Early fire detection is nowadays feasible, integrating computing with remote sensing techniques (Cerotti et al., 2014; Dimitropoulos et al., 2015; Hua and Shao, 2017). Real-time water quality can be assessed through the integration of remote sensing, newly developed technologies and with the aid of bio-indicators (Bennet and Hills, 2015; Xia et al., 2015; Blaen et al., 2016; Lega and Endreny, 2016; Casazza et al., 2017; Ferrara et al., 2017; Teta et al., 2017). Traditional and innovative pollution monitoring networks are available for assessing the concentration of pollutants (e.g.: De Nazelle et al., 2013; Hasenfratz et al. 2014; Casazza, 2015; Castell et al., 2015; Kumar et al., 2015; Snik et al., 2015; Jerrett et al., 2017). Waste spatial location, basic characteristics and volumes can be assessed thanks to different technologies, which include the use of multispectral sensors for remote/proximal sensing, as well as geophysical instruments, whose data can be integrated into spatial GIS representations (Lega and Napoli, 2008; Lega and Persechino, 2014; Errico et al., 2015; Di Fiore et al., 2017).

With respect to socio-economic indicators at local scale, a study indicates that some biophysical and economic factors have the tendency of being coupled (Conrad and Cassar, 2014). In particular, they are: (1) emission amount per unit GDP; (2) The amount of managed waste per unit GDP; (3) Land use per unit GDP. With respect to the last indicator, another research highlighted some economic and environmental connections, which might influence soil degradation (Salvati et al., 2014): (1) Population increase, leading to soil sealing); (2) Industrial growth, leading to soil pollution; (3) Intensive agriculture, leading to soil compaction; (4) Population reduction, leading to soil erosion. A further study identified three socio-economic drivers correlated with land quality (Salvati et al., 2017): (1) the regional differentiation in income, education and job market, (2) the elevation divide (distinguishing coastal from inland districts); (3) the urban-rural gap. Finally, a further correlation between biophysical and socio-economic factors emerged in a recent paper, which showed the correlation between water consumption and GDP for prefecture level cities in China (Du and Sun, 2017). Further studies might be necessary to highlight the existing connections between socio-economic factors and environmental pressures at local scale. This is the necessary premise to define suitable and effective integrated indicator systems to assess the quality of life and the resilience of a community at local scale.

5 Conclusions

Considering two historical case studies as examples, this research highlights the often-neglected environmental causes behind the social instability of communities. In our case studies, referred to two medieval Christian monastic communities, both located in Italy, the lack of Community Based Adaptation (CBA) leaded to an internal conflict, in the case of Bobbio, and to the collapse of the community (in the case of Castelletto Cervo). Paradoxically, besides the historical interest of these historical case studies, it is known by the literature that long-term environmental factors are still partially considered as secondary in planning the life of a community, also exerting a strong influence on real economy at local level. Instead, in order to develop appropriate policies to guarantee a long-term resilience for the socio-ecological stability of communities, an adequate monitoring of appropriate environmental and social parameters should be developed to support planning activities. Considering the present relevance of big data for the growth of smart and sustainable communities, further researches, comparing pre-industrial and present case studies could stimulate the definition of efficient indicator systems and solutions, also based on traditional ecological knowledge, to accelerate the transition toward equitable and sustainable post fossil carbon communities.

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