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Charcoal Kilns in the Northern Apennines (Italy): Forest Exploitation by Past Societies in Mountain Areas

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ABSTRACT

Anthracological analyses were carried out on charcoal platforms located in the Monte Cimone and Corno alle Scale mountain areas in the Tuscan-Emilian Apennines (Northern Italy), at high altitude. Analyses of charcoal fragments contained in these man-made structures have allowed the reconstruction of human-forest relationships over the last centuries, in particular the exploitation of forests for charcoal production. Comparison of our anthracological results with ethnobotanical and historical-social information has made possible an improvement in our knowledge of this activity that was fundamental for the past mountain economy.

1. Introduction

The current structure and characteristics of mountain beech forests in Italy are the results of long-term human-forest relationships that developed over centuries (Savoia, 1984; Nocentini, 2009). While in Italy today coppice and high forest management are found almost equally, in the Emilia-Romagna region, North Italy, it is coppice that prevails (about 80%), located mainly in its mountain areas (Regione Emilia-Romagna, 1983). The main reason for this situation has been the past charcoal production, recognizable by the bushy form of the trees due to their suckers and by the presence of abandoned man-made platforms within the undergrowth, places where ancient human societies had transformed the wood into charcoal.

Charcoal platforms are considered real archaeological sites and the anthracological study of the charcoal fragments contained in their substrate is able to provide information on the previous forest composition and on the history of forest exploitation and management practice.

Early studies about charcoal platforms were conducted in the Pyrenees (Davasse, 1992; 2000; Bonhôte *et al*., 2002). More recently, charcoal kiln studies have spread throughout Europe, particularly in Germany (*e.g.* Nelle, 2003; Pèlachs *et al.*, 2009; Ludemann, 2010; Paradis-Grenouillet, 2012; Deforce *et al.*, 2013; Knapp *et al.*, 2013; Rouaud, 2013; Tolksdorf *et al.*, 2015).

In Italy, charcoal kiln studies have been few, anthracological analysis on charcoal platforms having been carried out in the Ligurian Apennines (Montanari *et al*., 2000; Cevasco and Parola, 2013; Pescini *et al*., 2017). Other researches have focused on the census of charcoal platforms in Tuscany, Central Italy (Carrari *et al*., 2017).

This article presents the first anthracological analysis applied to charcoal platforms found in the Tuscan-Emilian Apennines at high altitude, specifically in the abandoned

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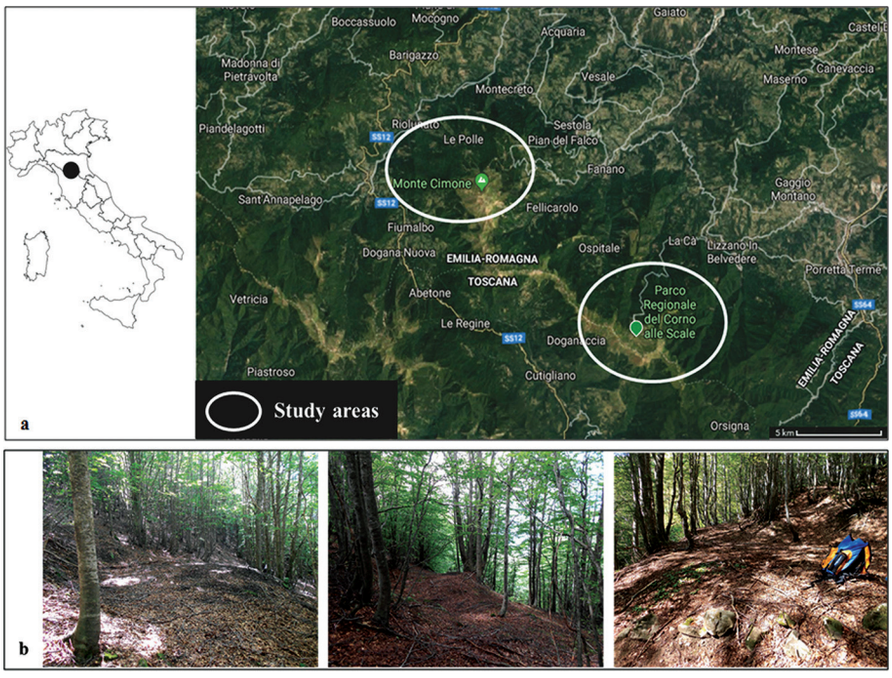

Figure 1. a) Location of Monte Cimone and Corno alle Scale study areas. b) Some abandoned charcoal platforms from the study areas.

coppice beech forests of Monte Cimone and Corno alle Scale mountain areas, close to the timberline (Figure 1). The objective of the research is to obtain information about the exploitation of forest resources and on the organization of the territory by past societies, as well as the possible role of the charcoal production activity on the position of the timberline.

2. Study area

The studied charcoal platforms are located close to the timberline (between 1500 and 1700 m asl) in abandoned coppice beech forest, in the mountain belt. In particular, they are located on the northwest slope of Monte Cimone, on the west slope of Monte Corno alle Scale and on its southern side (the southwest slope of Monte Cornaccio) (Figure 2). The study area borders two climatic regions: Continental Europe to the north and Mediterranean region to the south (Colombo *et al*., 2000). Mean annual temperature is about 2°C and mean annual precipitation ranges from 693.3 mm (registered at the Monte Cimone meteorological station) to 2500 mm (registered in the other mountain stations at lower elevations) (Şerban *et al*., 2007; Alessandrini *et al*., 2010). The fresh and humid climatic conditions with the

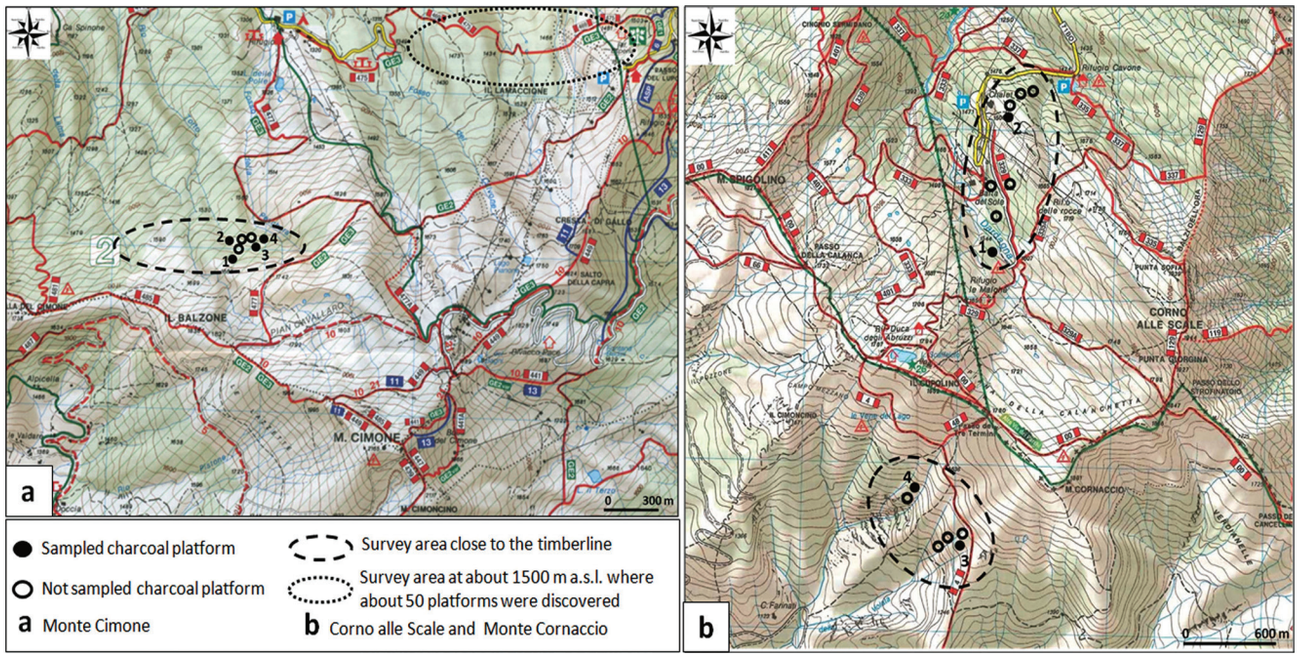

Figure 2. Location of charcoal platforms.

relatively abundant rainfall of this mountain belt favours the maximum spread of beech (*Fagus sylvatica* L.), which forms very extensive woods, where it is predominant and accompanied by the presence of other species such as *Acer pseudoplatanus* L., *Sorbus aucuparia* L., *Laburnum alpinum* (Mill.) Bercht. & J. Presl and *Abies alba* Mill. (Ferrari, 1989; Tomaselli *et al*., 1996; Alessandrini *et al*., 2010). The timberline reaches 1700 m asl at Monte Cimone and 1600 m asl at Corno alle Scale, both on the north and south slope. Inside the forests there may also be meadows and pastures dominated by *Nardus stricta* L. and shrub communities dominated by Ericaceae and Fabaceae, which are shrub plant associations involved with forest reconstruction processes in areas previously deforested and used as pasture (Alessandrini *et al*., 2010). From the mid-19th century until the post-World War II era, the climatic zone of the beech had been involved in conifer reforestation, performed with local species such as *Picea abies* (L.) H. Karst. and *Abies alba*, but also with non-native species, such as *Pinus nigra* J.F. Arnold, *Pinus mugo* Turra, *Larix decidua* Mill. and *Pseudotsuga menziesii* (Mirb.) Franco (Bagnaresi, 1983; Geri, 1992; Tomaselli *et al*., 1996). Above the timberline there are pasturelands dominated by *Vaccinium* heathland and *Nardus stricta* meadows (Geri and D'Addario, 1997; Geri, 1992, Ferrari *et al*., 1992; Alessandrini *et al*., 2003; 2010) still used today although much less than in the past (Albani, 1964). Below the beech belt there is a hilly belt dominated by oak forest, woods with prevalent *Ostrya carpinifolia* Scop. and *Castanea sativa* Mill. (Geri, 1992; Tomaselli *et al*., 1996). The study areas are located in two regional Parks: Parco del Frignano and Parco del Corno alle Scale.

2.1 Economic history of charcoal production in the Monte Cimone and Corno alle Scale mountain areas

Among the multiple uses of these forests for human needs during the last centuries, such as supply of firewood, supply of timber for construction and trade, and creation of pastures with deforestation, charcoal production has been the anthropic activity that has most influenced the current state of these forests (Bagnaresi, 1989; Minghelli, 1989; Giacobazzi, 2013; Rosa, 1978; Rombaldi and Cenci, 2013).

In the study area, most of the woods (80%) are strongly marked and shaped by their past as source for charcoal production (Savoia, 1984), that is, the woods consist of coppice, many of them abandoned and destined to a reconversion to high forest (Bagnaresi, 1983). Abandoned charcoal platforms are easily visible among the undergrowth (Figure 1b).

The reasons for transforming wood into charcoal were practical ones: charcoal is much lighter than wood (Roversi, 1972; Rosa, 1981; Rosa, 1982; Mordini and Mordini, 1994; Rombaldi and Cenci, 2013) and during carbonization the loss of the volume can exceed 70% of the starting wood mass (Schenkel *et al*., 1997). Moreover, charcoal has a calorific value which can reach 7300 kilocalories, much higher than wood (Baroni and Telleri, 1987).

Charcoal was traded and used as fuel, both for domestic needs (heating and cooking) and industry (Mucci, 2004; Rombaldi and Cenci, 2013; Mordini and Mordini, 1994; Tonelli, 1895; Savoia, 1984). Often charcoal production was the main source of profit for the mountain inhabitants (Rombaldi and Cenci, 2013).

From the 1950s the production of charcoal decreased and eventually disappeared from these mountains (Albani, 1964; Bernardi, 1978; Savoia, 1984).

2.2 Charcoal production in the mountains

In order to interpret the results from an anthracological study of the charcoal platforms, it is necessary to know all phases of charcoal kiln construction and operation. Through historical sources and oral testimony from the last charcoal burners it is possible to learn all the stages of charcoal production and the charcoal burner's lifestyle. In 2010, the CAI (Italian Alpine Club) in collaboration with the association *Appennino*

Figure 3. Typical hut of charcoal burners (Il Massaro, 1969; Govi, 1936).

Cinemafestival made an historical reconstruction of charcoal kilns as well as a video concerning an interview with the last charcoal burner of the Modena mountains, Mr Orlando Bettini (Fregni and Maccaferri, 2010). If not otherwise indicated, the reported information about this activity pertains to this video.

Charcoal production on a single platform lasted several days, and thus the charcoal burners would build a hut within the forest (Figure 3) made of wood, stones, and earth, and covered with moss, branches and clods of earth (Poli Bini, 1982), typically called "plicci" in the Bologna Apennines (pers. comm., Ettore Scagliarini, 2017). Within the hut a bed

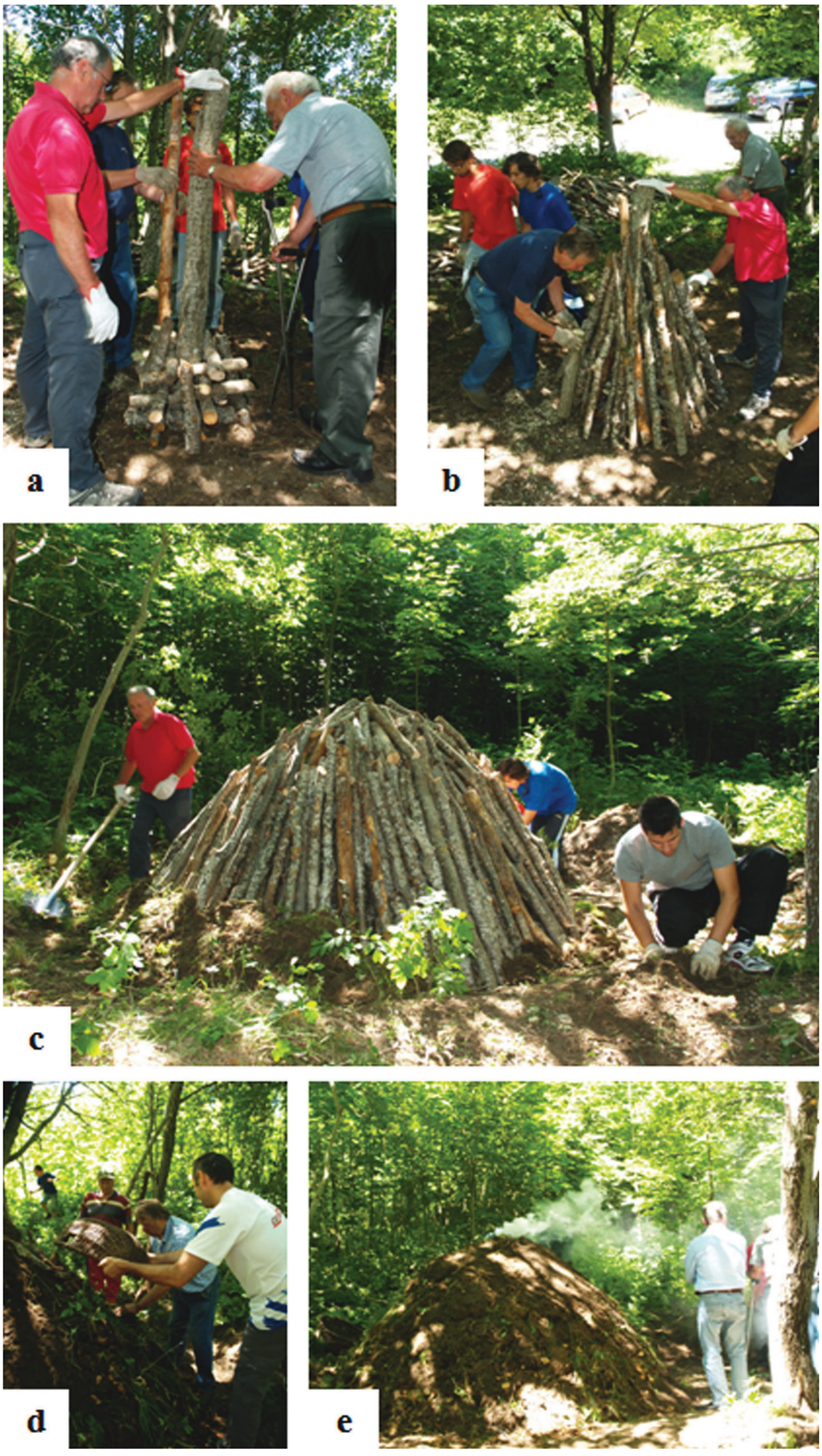

Figure 4. Construction phases of a charcoal kiln.

made of brushwood and leaves, called "rapazzola", would be made (Poli Bini, 1982).

Charcoal production started with the creation or the rearrangement of an ancient platform: a portion of land from the upper slope was removed and placed below on the downhill slope; if the slope was very steep, a dry stone wall was built downhill. The construction of a charcoal kiln would start with the planting of a wooden pole, called "cavicchio", in the middle of the platform. Around the pole was interwoven the so-called "castellina" made of wooden rods (Figure 4a). Seasoned wood was arranged around the "castellina" (Figure 4b) to build a dome-shaped woodpile (Figure 4c) that could have a diameter of 3–4 m or even more and a height that could exceed 3 m. Carbonization is an incomplete combustion process that occurs when there is very little oxygen. For this reason, the kiln covering would be made waterproof. The woodpile was wrapped by a "camicia" formed of fine wood, which was covered with stony and grassy clods for the first 50 cm from the ground; the remaining surface was covered first with wet leaves collected in the undergrowth (called "patricia") and then with earth (Figure 4d). The waterproof layer would be 5–10 cm thick.

The ignition of the charcoal kiln occurred by dropping embers (small pieces of wood called "mozzi") into the chimney formed by the removal of the central pole (Figure 4e). This operation was made by the "meo", a name attributed to the youngest charcoal burner who would have been the one responsible for preparing meals. To control the carbonization process, the quantity of oxygen entering the woodpile was regulated by the opening and closing of holes, called "cagnoli" in Modena and "arfummi" in Bologna (Il Massaro, 1969), that were arranged in rows, one at ground level and another at a height of 50 cm. The timing of charcoal production ranged from 3–4 days (for the smallest charcoal kilns) to 10–12 days (for the largest ones). The wood charcoal would be ready when the smoke coming out from the holes was sky blue. The charcoal was then collected and packed for transport. To evaluate the charcoal quality, the charcoal burners and the merchants used to wet a charcoal fragment with saliva; if it became white as milk it was of high quality (Fregni and Maccaferri, 2010).

3. Material and methods

The anthracological study included a survey of charcoal platforms in the study areas, a sampling from eight platforms, and the isolation of charcoal for anthracological analysis and radiocarbon dating.

3.1 Charcoal platforms survey

Charcoal platforms were surveyed during periods of prospection near the timberline, both in the wooded and open areas, as well as at lower elevations (1500 m asl). The surveys were performed within 0.21 km^2 on the northwest slope of Monte Cimone, within 0.18 km^2 on the west slope of Monte Corno alle Scale, and within 0.21 km^2 on the southwest slope of Monte Cornaccio (Figure 2). For each platform, geographical coordinates were noted, as well as the larger and smaller diameter, and state of conservation. After the surveys, 4 platforms located at Monte Cimone (Carbo MC-1, MC-2, MC-3 and MC-4; no, 1, 2, 3 and 4 in Figure 2a) and 4 others from Corno alle Scale (Carbo CS-1, CS-2, CS-3 and CS-4; no, 1, 2, 3 and 4 in Figure 2b) were chosen near the timberline to be sampled: they are quite distant from each other inside the prospection area in order to obtain more complete information from a spatial point of view. They range from 50 to 70 m between each other at Monte Cimone, and from 400 to 700 m at Corno alle Scale.

3.2 Charcoal platforms sampling

The sampling point of each platform (a cuadrat of 50 cm side) was located between the centre and the periphery to avoid the collection of charcoal fragments from the embers used to light the woodpile and charcoal pieces too fragmented by the charcoal burners' activity around the charcoal kiln (Rouaud, 2013). After the removal of the leaf layer of undergrowth (1–2 cm), samples were taken approximately every 5 cm, from the surface to the end of the black carbonized layer (Davasse, 2000; Paradis-Grenouillet, 2012; Rouaud, 2013). For each layer, from 1 to 3 kg of sediment were collected.

3.3 Anthracological analysis and radiocarbon dating

Sediment samples were sieved under a running water jet with sieves of mesh size 5 and 2 mm. Taxonomic identification, made for all the sampled layers, was performed under an incident light microscope (100X, 200X, 500X) by observing the transversal, tangential and radial sections of charcoal pieces. The identification was supported by the use of wood anatomy atlases (Jacquiot *et al.*, 1973; Schweingruber, 1990; Vernet *et al*., 2001).

Estimation of the diameter of starting trunks or branches was made by observing the curvature of the growth rings visible on the charcoal fragments. According to Marguerie and Hunot, (2007) and Cabanis and Marguerie (2013), the curvatures were classified into three categories: weakly, moderately and strongly curved.

Characteristics of charcoals that could give information about the state of the wood before carbonization were noted: radial cracks, vitrification, fungal hyphae and insect galleries (Marguerie and Hunot, 2007).

Because of the great homogeneity in the taxonomic identification, we considered that the analysis of 50 charcoals (randomly selected), from each sampled level were sufficient to represent a whole sample.

To detect the former period of activity of a platform, we selected a charcoal from the bottom layer (Nelle, 2003; Rouaud, 2013) for radiocarbon dating. To make the dating coincide with the moment when the tree and its branches were cut, we selected charcoals with bark (Davasse, 2000). AMS ^{14}C dating was carried out at the Centre de Datation par le Radiocarbone (Lyon) for the 4 platforms of Monte Cimone, and at the Centro di Datazione e Diagnostica (University of

Salento) for the 4 platforms of Corno alle Scale. The dates were calibrated as BP and AD on the base of the data set Intcal13.14c (Reimer *et al*., 2013).

4. Results

During the survey, 7 charcoal platforms were discovered on the northwest slope of Monte Cimone, 8 on the west slope of Monte Corno alle Scale and 6 others on the southwest slope of Monte Cornaccio. The presence of many platforms was also observed at lower altitudes, at about 1500 m asl, in the Monte Cimone area (Figure 2).

The 8 studied charcoal platforms present different degrees of conservation. The 4 platforms of Monte Cimone (Carbo MC-1, MC-2, MC-3 and MC-4) and two of the west slope of Monte Corno alle Scale (Carbo CS-1 and CS-2) show an excellent state of conservation, despite them being located at

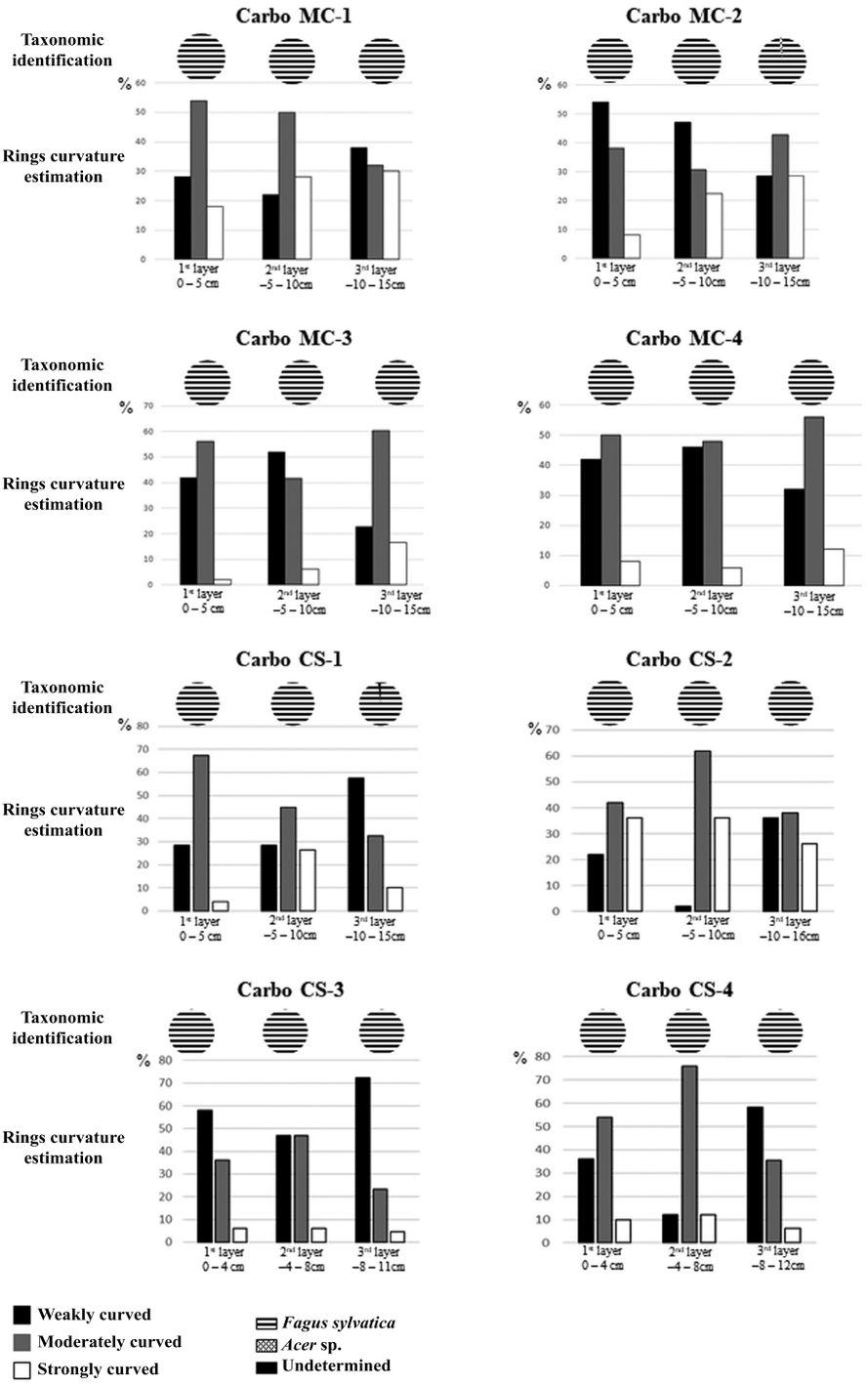

Figure 5. Dentro-anthracological results of charcoal platforms analysis.

points of steep slope which could favour erosion. Carbo CS-3 (at a point of more gentle slope) and CS-4 (on a very steep slope), sampled on the southwest slope of Monte Cornaccio, present a good and a fair state of preservation, respectively. The platforms have common features:

- In their downstream part there are not any supporting dry walls but only some boulders placed with the same aim.
- They have a semi-oval shape: from 4.5 to 6.5 m in the larger diameter (perpendicular to the upstream-downstream direction) and from 3.5 to 5 m the minor diameter (along the upstream-downstream direction).
- They are devoid of arboreal vegetation because of the hostile micro-habitat created by a substrate rich in charcoal which prevent forest recolonization (Carrari *et al*., 2016); also shrubby and herbaceous vegetation is absent, except for MC-2, covered by grass and moss, and for CS-1, covered by blueberry.
- They present dark charcoal layers from 11 to 16 cm thick that are not interrupted by light colour layers without charcoal, as observed in other research studies (*e.g.* Montanari *et al*., 2000; 2002; Rouaud, 2013).
- They have dark layers that are very rich in large charcoal pieces in a good state of conservation.
- They contain charcoal pieces with few but large radial cracks.
- Concerning growth ring curvature, the moderately-curved category prevails in all the platforms, except for Carbo CS-3, where the weakly-curved category prevails. Carbo CS-2 has a high percentage of fragments with strong growth-ring curvature compared to all the other platforms (Figure 5).

Taxonomic identification shows almost exclusively *Fagus sylvatica* (Figure 5). Only in Carbo MC-2 was a charcoal of *Acer* sp. identified.

Radiocarbon dates are rather recent (Table 1). Carbo CS-2 is the oldest, dated 1390–1477 AD, *i.e.* between the end of the 14th and the end of the 15th century. All the other charcoal platforms, overall, cover a period that spans from 1616 to 1948 AD, *i.e.* the beginning of the 17th to the mid–20th century.

5. Discussion

The study of the charcoal platforms, when compared with the historical sources and ethnological information, is capable of providing new knowledge concerning the human-forest relationship over the last centuries.

5.1 Spatial analysis of the platforms' distribution: complementarity between forest exploitation and pastoral activities

During their time in use, charcoal platforms are always located inside the forest or near to the timberline (Davasse, 2000). In our study areas, their presence just below the current timberline suggests that this ecotone did not undergo any altitudinal regression since the 15th up until the 20th century.

Many of the charcoal platforms in our study areas were operating concurrently with important periods of sheep and goat breeding. Indeed, examining the number of sheep and goats present in the study area over time (*e.g.* Roversi, 1983; Gruppo Studi Capotauro, 2012; Rombaldi and Cenci, 2013), it emerges that there was a high number of sheep and goats during the 18th–20th centuries (Benatti, 2018). Nevertheless, at the time of the pastoral apogee, the forests just below the pasturelands (1700 m asl at Monte Cimone and 1600 m asl at Corno alle Scale) were not deforested to leave space for such grazing activity, despite the grazing being very intense. This suggests a well-managed exploitation of the two main resources of these mountains: pastures and woodland. Such complementarity between pastoral activities and forest exploitation has also been observed in other European mountain areas (*e.g.* Davasse and Galop, 1990; Davasse, 1992; Paradis-Grenouillet, 2012; Bal *et al*., 2015). Many of the current European wood-pasture systems have experienced a period of traditional multifunctional management; one that has been historically guided by local needs and has generally involved the grazing of livestock, but also the use of raw material provided by the forest, such as products from coppicing (Hartel and Plieninger, 2014).

5.2 Beech exploitation

The almost totality of *Fagus sylvatica* in the taxonomic identification could suggest a preference for this wood species

Table 1. Radiocarbon dates with probability, altitude and geographic coordinates of charcoal platforms.

Study area	Charcoal platform name	Age BP	Age cal BP (2 σ)	Age cal AD (2 σ)	P (%)	Elevation (m a.s.l.)	Latitude/Longitude
Monte Cimone	Carbo MC-1	245±30	269–320 BP	1631–1681 AD	54.30%	1700	44°12.176′N–10°41.188′E
	Carbo MC-2	225±35	142–219 BP	1731–1809 AD	42.20%	1689	44°12.238′N–10°41.190′E
	Carbo MC-3	205±30	142–218 BP	1731–1809 AD	50.10%	1684	44°12.240′N–10°41.251′E
	Carbo MC-4	165±30	131–230 BP	1720–1819 AD	49.30%	1704	44°12.221′N–10°41.241′E
Corno alle Scale	Carbo CS-1	227±45	136–224 BP	1726–1814 AD	37.00%	1598	44°7′27.39″N–10°48′52.27″E
	Carbo CS-2	490±45	474–560 BP	1390–1477 AD	86.50%	1568	44°7′49.47″–N 10°49′1.78″E
	Carbo CS-3	237±45	258–334 BP	1616–1692 AD	34.10%	1507	44°6′27.44″N–10°48′45.84″E
	Carbo CS-4	134±45	169–282 BP	1797–1948 AD	54.40%	1524	44°6′38.11″N–10°48′33.74″E

by the charcoal burners, or, at least during the operational period of the study platforms, that beech was probably the only dominant tree species in the high mountains of our study areas. In fact, although some plant species are more suitable than others for producing charcoal, the charcoal burners usually used all the woody plants available to them near their platforms (Montanari *et al*., 2000; Nelle, 2003). *Abies alba*, whose past presence is attested by palynological studies for the whole Holocene and by soil charcoal for the Late Holocene (Watson, 1996; Vescovi *et al*., 2010a; 2010b; Compostella *et al*., 2013), was not found in the charcoal assemblages of our study platforms. As in many other Italian mountain areas, the presence of monocultures of beech woodland could be due to the management practice of coppicing – repeated over time – that would lead to the elimination of other tree species (such as *Abies alba*), transforming the mixed woods into uniform beech woods (Andreatta, 2008; Nocentini, 2009).

The taxonomic identification agrees with what has been affirmed by the last charcoal burners of the Modena Mountains (Fregni and Maccaferri, 2010) and with the historical sources, reporting that, during the modern and contemporary age, the wood used to produce charcoal was beech only (Tonelli, 1895; Carpani, 1972; Rombaldi and Cenci, 2013). The fragment of *Acer* in Carbo MC-2 could have originated from a maple tree near the platform and have been used to light the woodpile. An inhabitant of the Bologna Mountains, a descendant of charcoal burners, was able to confirm that maple was considered a bad wood to produce charcoal (pers. comm., Ettore Scagliarini, 2018).

Probably, the beech wood used in the studied charcoal platforms was previously seasoned: as suggested by the few but large radial cracks in the charcoal fragments (Théry-Parisot and Henry, 2012). The last charcoal burner of Modena Mountains affirms that wood was cut in spring, seasoned for 4–5 months, and transformed into charcoal in September (Fregni and Maccaferri, 2010).

5.3 Uses of charcoal

The thin dark charcoal layers could be due to the scarce and occasional use of these platforms. Close to the villages there are platforms with very thick dark layers of some tens of centimetres; furthermore, those platforms at the highest altitudes were probably utilised by the poorest of mountain families in order to obtain charcoal for domestic needs, whereas charcoal production for industry and trade was located closer to the villages (pers. comm., Ettore Scagliarini, 2018). Wood diameter estimation suggests that the utilised woods had a medium-large diameter, and thus the exploitation of these forests was restricted or well managed over time. Nevertheless, it must not be excluded that the erosion due to the steep slopes may have reduced the charcoal layers. The platforms discovered at about 1500 m asl on the northwest slope of Monte Cimone (Figure 2), in an area of little or very gentle slope, have dark layers that can reach 20–25 cm thick.

The oldest platform, Carbo CS-2, shows percentages of fragments of small calibre (diameter) greater than other platforms. This can suggest a repetitive and intense charcoal production that could have led over time to smaller log diameters. The operating period of this platform (15th century) coincides with the iron mining and industry of the Garfagnana (a part of Tuscany region, bordering with Modena province). This metallurgical industry led to timber shortages and the consequent transfer of this activity towards the Reggio Emilia and Modena Mountains (Lodovisi, 2006). It can be supposed that the charcoal fuel for the functioning of the forges also came from distant areas, such as our study area. Exploitation of the natural resources of the Garfagnana used many roads and mule tracks that favoured the transport of goods such as wood charcoal (Lodovisi, 2006; Pelù, 2006).

During the 19th century, the studied charcoal platforms may have supported the exploitation of the iron and copper mines of the Bologna Mountains and the functioning of the related ironworks and metal foundries. In addition, the activity of the metalworkers and the production of lime, gypsum plaster and glass may have employed charcoal produced in the platforms analysed in this study (Carpani, 1972; Bignardi, 1980; Gruppo Studi Capotauro, 2012; Rombaldi and Cenci, 2013). Part of this charcoal may have been traded with the Emilia-Romagna plain and nearby Tuscany (Tonelli, 1895; Roversi, 1972).

The platform CS-4, which operated up until the mid-20th century, may have provided charcoal for the fuel needs caused by the two world wars, in particular by the energy crisis of the Second World War (Moreno and Montanari, 2008). Confirming the importance of charcoal production during war periods, the last charcoal burners of the Modena Mountains stated that they were exempted from conscription (pers. comm., Orlando Bettini, 2017).

6. Conclusions

Spatial analysis of the platforms' distribution has highlighted the existence of a spatial organization that includes both the forest and pasture resources as observed elsewhere (*e.g.* Davasse and Galop, 1990; Davasse, 1992) and a timberline that appears to be very stable, at least during the last few centuries. The charcoal was derived exclusively from seasoned wood obtained from coppice beech forest and it was used for many domestic and industrial needs.

Archaeobotany being useful in the reconstruction of cultural landscapes (*e.g.* Mercuri, 2014), this research has contributed to the study of mountain cultural landscape evolution as already shown by other studies in mountain and plain areas (*e.g.* Davasse, 2000; Montanari *et al*., 2000; Bosi *et al*., 2015). Combined with information from archaeobotany, the ethnobotanical and historical information is useful to better interpret the anthracological results and to improve our knowledge of charcoal production, a key activity for past societies and an important component of the historical-cultural heritage of the Apennines. As the charcoal production has now been completely abandoned, many

people have focused their interest on the cultural aspects of this activity. In the year 2017, a day conference (*Carbonaie e Carbonai*; speaker A. Benatti) about the charcoal platforms study, followed by a thematic mountain excursion, was organised by the Italian Alpine Club (the oldest and largest association of mountaineers and mountain enthusiasts in Italy), in particular the section of Sassuolo (province of Modena). This event was extremely appreciated by all the participants.

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