Mesolithic fuel use and woodland in the Middle Ebro Valley (NE Spain) through wood charcoal analysis

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Abstract

This work provides new data concerning plant use in prehistoric times at northeast of Spain. We present preliminary results from three Mesolithic settlements: Angel I (Ladruñán, Teruel), Esplugón (Sabiñánigo, Huesca) and Espantalobos (Quicena, Huesca). The study includes anthracological sequences from Pre-Pyrenees, Ebro Depression, and Iberian Ranges so that the geographical location of the sites covers a diversity of environments inside the Mediterranean region of vegetation. The aim of this work is to assess the influence of geographic and climatic factors in the availability of fuels and their implications for human management of these. According to pollen information, the Mesolithic, the last stage of an exclusively predatory economy based on hunting and gathering, is also a period of environmental change. Our preliminary results show that i) conifers, especially pine, either Mediterranean (*Pinus halepensis*) in drier areas or montane pines (*Pinus* type *sylvestris*) in higher elevations, appear as the most widely firewood used in all archaeological layers studied, ii) consumption of Quercus appears often but always with very low percentages, iii) the taxonomic diversity observed in the center of the valley contrasts with the specific poverty in mountainous areas where we only documented the consumption of pines and oaks. The last hunter-gatherer communities in the Middle Ebro Valley seem to have used opportunistic strategies of fuel management, and consumed a variety of wood species in the Early Holocene.

Keywords: Wood charcoal analysis; Epipalaeolithic/Mesolithic; Landscape evolution; Firewood exploitation; NE Iberia.

1. Introduction

The relationship between human populations and their environment is a topic of interest in archaeology both from a palaeoclimatic and a palaeoeconomic perspective. The number of archeobotanical studies focusing on Mesolithic sites has increased in recent years (Holden et al., 1995; Zapata et al., 2002; Aura et al., 2005; Holst, 2010; Berihuete and Lozovskaya, 2014; Gracheva et al., 2015; Jessen et al., 2015), and this has helped define the environmental conditions in which these people lived. Climatic conditions determine the vegetation cover and the availability of biomass resources around archaeological sites. Moreover, this stage of environmental change is especially interesting for archeologists because it is also a time of social change when Mesolithic culture developed and the transition towards the Neolithic occurred. Mesolithic is the last stage of an economy based on hunting and gathering and represents an important cultural transition. The process of neolitization in Europe occurs in different forms and rhythms. An increase in human activities and a subsequent modification of vegetation landscape occurred at the end of Mesolithic period. Neolithic technology (agriculture, shepherding, sedentarization, etc.) is incorporated by the hunter-gatherer systems. The Neolithic begins to appear in the Middle Ebro Valley without any break from the 8th millennium cal BP (Montes et al., 2006; Utrilla et al., 2009).

This work discusses vegetal landscapes surrounding Mesolithic settlements and the relationship between the last hunter-gatherer populations and their environment in the context of the Middle Ebro Valley (NE Spain). Charred remains are commonly recovered in archaeological contexts and are the sub-product of firewood combustion in the course of everyday activities and reflect the presence of certain forest communities in the near vicinity of archaeological sites (Chabal, 1988;

Smart and Hoffman, 1988; Vernet, 1991; Badal, 1992; Shackleton and Prins, 1992). Preliminary anthracological results from three archaeological sites chronologically placed from the second half of the 10th to the first half of the 8th millennium cal BP are presented and available palaeoenvironmental data (pollen and charcoal) are discussed in this paper. The Middle Ebro Valley is a territory characterized by an irregular orography (from cold and wet mountainous areas to semiarid lowlands) and climate has a decisive impact in the vegetation cover and the availability of firewood. The geographical location of the sites studied in this work covers a diversity of environments inside the Mediterranean region of vegetation: Pre-Pyrenees, Ebro Depression, and Iberian Ranges. The aims of this work were: (i) provide new regional data concerning plant use on a poorly documented area; (ii) provide a picture of the surrounding vegetation in Mesolithic settlements in the Middle Ebro Valley; and (iii) assess the influence of geographic and climatic factors on the availability of fuel and the implications for the human management of these plant communities.

2. Biogeographical context

The Ebro Valley is located in northeast Spain (Fig. 1). It is a territory surrounded by three high mountain ranges, the Pyrenees to the north, the Iberian Ranges to the south, and Catalan Coastal Ranges to the east. The central depression has an average elevation of 400 m a.s.l. and forms a large plain crossed by one of the largest rivers in the Iberian Peninsula, the Ebro, which rises in the Cantabrian Mountains and flows to the Mediterranean. Present-day climate is characterized by cold and dry winters, very hot summers, low rainfall, and high insolation and evapotranspiration. This territory is characterized by an irregular north-south orography, from the cold and wet Pyrenees peaks to the lowlands with semi-arid areas. A high variability of ecosystems is present (from Euro-Siberian to Mediterranean) as a result of strong topographic, climatic, and geographic gradients and a mosaic of different types of soils (mainly composed of limestone, marl, and gypsum). The current plant landscape is also characterized by this variability. The Pyrenean foothills are dominated by cloud forest with oak (*Quercus petraea, Quercus humilis*), beech (*Fagus sylvatica*), fir (*Abies alba*), hazel (*Corylus avellana*), lime (*Tilia cordata*) and Scots and mountain pine (*Pinus sylvestris, Pinus uncinata*). The Iberian foothills are dominated by meso-xeric forest with juniper (*Juniperus communis, Juniperus sabina*), oak (*Quercus pyrenaica, Quercus faginea*), beech (*Fagus sylvatica*) and cluster, black, and Scots pine (*Pinus pinaster, Pinus nigra, Pinus sylvestris*). In the lowlands, vegetation covers less than 50% of the territory, which is dominated by agricultural fields and steppe. An arid area is dominated by dry woodland with Aleppo pine (*Pinus halepensis*), Kermes oak (*Quercus coccifera*), and Spanish juniper (*Juniperus thurifera*), as well as shrub formations with species such as mastic (Pistacia lentiscus), wild olive (*Olea europaea* var. *silvestris*) and rosemary (*Rosmarinus officinalis*) (Blanco et al., 1997; Pérez Bujarrabal, 2009).

Fig. 1. Location map: description and altitude of (i) each site studied in this paper (1e3): 1-Esplugón, 800 ma.s.l.; 2-Espantalobos, 500 m a.s.l.; 3-Ángel I, 735 m a.s.l.; (ii) other published wood charcoal analysis mentioned in this paper (4e7): 4-Forcas II, 480 m a.s.l.; 5-Cabezo de la Cruz, 428 m a.s.l.; 6-Los Baños, 515 m a.s.l.; 7-Rambla de Legunova, 760 m a.s.l.; and (iii) archaeological (AeE) and off-site (FeN) polen sites referred to on the text: A- Peña 14, 760 m a.s.l; B- Los Baños, 515 m a.s.l.; C- Secans, 360 m a.s.l.; D-Botiquería de los Moros, 360 m a.s.l.; E- Pontet, 320 m a.s.l.; FPortalet, 1890 m a.s.l.; G- Tramacastilla, 1640 m a.s.l.; H- Basa de la Mora, 1914 m a.s.l.; I- Estanya, 670 m a.s.l.; J- La Salineta, 325 m a.s.l.; K- La Playa, 340 m a.s.l.; L- Gallocanta, 995 m a.s.l.; M- Villarquemado, 987 m a.s.l.; N- Ojos del Tremedal, 1650 m a.s.l.

3. Archaeological background

The Mesolithic cultural period in the Middle Ebro Valley has been extensively studied and many sites have been excavated (Barandiarán, 1976; Mazo and Montes, 1992; Rodanés et al., 1996; Barandiarán and Cava, 2000; Montes, 2002; Utrilla et al., 2003; Utrilla and Rodanés, 2004; Utrilla et al., 2009; Rodanés and Picazo, 2013; Utrilla and Mazo, 2014). We know of a large network of rock-shelters (Alday, 2006; Utrilla et al., 2009) but very few open-air sites (Rodanés and Picazo, 2013). Depending on the technological evolution of the lithic component we can distinguish three phases within this period (Barandiarán and Cava, 2000; Alday, 2002; Utrilla, 2002; Cava, 2004): Microlaminar Epipalaeolithic/Sauveterrian (laminar industries) developed between 13th to the mid-11th millennium cal BP; Denticulate Mesolithic (denticulate and notched flakes) from the late 11th to 9th millennia cal BP; and Geometric Mesolithic (laminar industries with geometrics) from second half of the 9th millennium to the first half of the 8th millennium cal BP. The majority of archaeological sites studied and discussed in this work correspond to the Geometric Mesolithic cultural period although some of the studied archaeological layers belong to the Denticulate Mesolithic (Table 1).

The rock-shelters are mainly seasonal with the main function being hunting halts where it is common to find overlapped hearths that show different occupation periods and can provide valuable palaeoecological information and on the fuel management. Though interest in human occupation patterns and possible climate influence has increased in recent years, anthracological data available for this territory is partial and isolated (Badal, 2004, 2013; Alcolea, 2014; Montes et al., 2015b). In this work, we present preliminary results from three of these seasonal settlements in rock shelters that cover a diversity of environments (Fig. 1).

The northernmost archaeological site is located in the External Pyrenees Ranges. Esplugón (Sabiñánigo, Huesca) is a deep rock shelter situated in the Guarga Valley (800 m a.s.l.). Excavations ongoing since 2009 have revealed a large and complete archaeological sequence at least from the Neolithic to the Mesolithic. All levels at this site show a great density of charred remains. Our study focuses on two archaeological layers from the Geometric Mesolithic deposit: 3 inf. (7784 ± 59 cal BP) and 4 (8428 ± 26 cal BP). Both are characterized by the almost exclusive domain of microliths which would suggest a specialization in hunting activities (Utrilla et al., 2012, 2015).

In the lower area, Espantalobos (Quicena, Huesca) is a shelter located on the side of a cliff very close to Huesca town (500 ma.s.l.). The site is between the Pre-Pyrenean foothills and Central Ebro Depression. The deposit comprises two archaeological layers: c (8242 ± 54 cal BP) identified as Mesolithic Geometric and e (8771 ± 123 cal BP) which can be interpreted as a hinge between both Mesolithic phases (Montes et al., 2015a). In Espantalobos an exclusive characterization of the site as hunting ground is discarded due to the scarcity of stone tools and animal remains. The presence of denticulate, choppers and rabot leads researchers to assume that other activities (such as the work on wood and vegetables) took place.

Ángel I or Arenal de Fonseca (Ladruñán, Teruel) is a shelter with rock paintings located in the basin of Guadalope in the Iberian Ranges (735 m a.s.l.). It has revealed a large archaeological sequence from Gravettian to Neolithic. Radiocarbon dating confirmed that level 8d corresponds to Denticulate Mesolithic (9402 ± 71 cal BP) and level 8c corresponds to Mesolithic Geometric (8269 ± 54 cal BP). The considerable presence of unretouched lithic remains accompanying stone tools and faunal in both layers is remarkable (Utrilla and Domingo, 2002; Utrilla et al., 2003).

4. Materials and method

As we have said is common to find overlapped hearths in these Mesolithic shelters. Sometimes, the existence of combustion structures in the archaeological sites is obvious, but other evidence of domestic fire may be reduced to hard-to-see scattered remains on the surface, requiring recovery strategies for sampling and processing sediment. Scattered charcoal is the result of consecutive combustion events and it is a good indicator of the surrounding vegetation as it reflects successive collections of firewood (Chabal, 1997). It constitutes a valuable source of information about the environment and the activities of human groups in the past, but this information is only extractable with appropriate methods (Chabal et al., 1999; Badal et al., 2003). In this work, charred wood assemblages have been recovered following various strategies for sampling and processing sediment:

Table 1. Radiocarbon dates from (i) the archaeological layers studied in this paper after Utrilla et al. (2009, 2012, 2015) and Montes et al. (2015a,b) and (ii) other published wood charcoal analysis mentioned in this paper after Utrilla and Rodanés (2004), Rodanés and Picazo (2013), Utrilla and Mazo (2014), Montes et al., (2015b). Radiocarbon dates have been calculated using the calibration curve CalPal2007_HULU and the 1 sigma range is given. MD (Denticulate Mesolithic); MG (Mesolithic Geometric).

i) At Esplugón we followed specific sampling strategies in order to recover archaeobotanical material. The excavated area comprises 8 m^2. A manual collection of visible botanical remains found during fieldwork was accompanied by a screening of all the sediment through a 2 mm mesh with water. Wood charcoal remains from Esplugón are currently under analysis. We report here on the preliminary results of the anthracological study of Mesolithic levels. Charred wood identified in this work corresponds to scattered remains around hearths or combustion areas.

ii) At Espantalobos all the sediments excavated were systematically processed by water flotation in order to recover the charcoal remains and a 2 mm mesh was used. Several large fragments were also individually picked by hand. Both archaeological layers show a greater density of charred wood remains and large hearths and combustion areas. Wood charcoal remains analyzed in this work were all recovered during the 2013 field season from an excavated area of 12m^2.

iii) In Ángel I we analyzed botanical remains collected by hand during fieldwork between 1989 and 1991. The scarcity of analyzed fragments is explained by the lack of sampling strategies to recover archaeobotanical remains. The study of only hand-picked materials involves the risk of favoring those species that were more frequent and less fragmented.

Charcoal fragments were stored and studied in the laboratory following the standard methods developed in wood charcoal analysis. For the taxonomic identification of specimens, each fragment was manually broken by the method described by Vernet (1973). The anatomical patterns of each wood species were observed along three sections (transverse, tangential, and radial). For anthracological analysis, we used a Nikon Optiphot metallurgical dark/bright field incident-light microscope that enables magnification factors of 40-600. Botanical identification was possible by referencing wood anatomy atlases for both non-charred (Schweingruber, 1990; García Esteban et al., 2003) and charred wood (Vernet et al., 2001) and current carbonized woods from the reference collection. Nomenclature follows the guidelines in *Flora europaea* (Tutin et al., 1980). The effects of several pre-depositional and postdepositional processes have also been registered during charcoal analysis.

5. Results

A total of 1338 wood charcoal fragments were analyzed in this work (Table 2). We identified 16 different taxa. The composition of charcoal assemblages studied in this work is quite diverse and various plant communities are represented. From Esplugón, we analyzed 500 wood charcoal fragments. Only four taxa were documented: *Pinus* type *sylvestris, Quercus* sp. deciduous, Rosaceae Prunoideae, and Rosaceae Maloideae.

Scots pine type (*Pinus* type *sylvestris*) accounts for over 90% of wood charcoal remains (Fig. 2). Angiosperms are very sporadic in the Esplugón sequence. However, deciduous oak (*Quercus* sp. deciduous) is present in both Mesolithic levels (>3%). The rose family (Rosaceae) is also recognized in both levels, with a single fragment of Prunoideae in level 4 and Maloideae in level 3 inf.

From Espantalobos, we identified 650 wood charcoal fragments. The charcoal record is the most diverse among the sites. A total of 13 different taxa were documented, including Aleppo pine (*Pinus halepensis*) which was absent at other mountainous sites. Aleppo pine, around 50%, is the main taxa at level c of Espantalobos (Fig. 2). The presence of junipers (Juniperus sp.) is also remarkable at level c, around 20%, and is the most represented taxon at level e, above 30%. Angiosperms are a very important component in the record of Espantalobos, and maples (*Acer* sp.) are the most abundant taxa among the angiosperms, above 20% at level e. Also identified in the charred wood were box (*Buxus sempervirens*), ash (*Fraxinus* sp.), mastic (*Pistacia* sp.), evergreen oak (*Quercus coccifera/ilex*), buckthorn/narrow-leaved (*Phillyrea/Rhamnus*), rosemary (*Rosmarinus officinalis*), poplar/willow (*Populus/Salix*) and Leguminosae, Rosaceae Prunoideae, Rosaceae Maloideae, and Monocotiledoneae in the family or classes rank.

From Ángel I we studied 188 wood charcoal fragments. The list of taxa documented is very small. Only conifers, *Pinus* type *sylvestris* and *Juniperus* sp., were identified in this sequence. Pines were the main taxon recorded (Fig. 2). At level 8c, is the only taxon documented. Junipers, around 25%, were also identified at level 8d. In this case, the sample size or sampling strategies (charcoal collected by hand) may be the cause of the taxonomical poverty. It is possible that dominant taxa were overrepresented.

In summary, all the assemblages were dominated by conifers (Fig. 2). Different pine species played a fundamental role in all the assemblages studied in this paper. Both evergreen *(Quercus coccifera/ilex*) in Espantalobos and deciduous oak (*Quercus* sp. deciduous) in Esplugón were also recognized. A single assemblage studied in this paper, Espantalobos, shows a large biodiversity in the anthracological record.

The effects of pre-depositional and post-depositional processes observed during charcoal analysis were typical alterations in archaeological wood charcoal (Théry-Parisot, 2001; Badal and Carrión, 2004; Allué et al., 2009; Moskal et al., 2010; Théry-Parisot et al., 2010; Théry-Parisot and Henry, 2012; Chrzazvez et al., 2014): presence of radial cracks, reaction or wood tension, biogenic alterations and vitrification. One of the most remarkable is the presence of varying degrees of vitrification (Fig. 3) in some of the studied charcoal assemblages reaching 30% in some cases (real vitrification). The usual rates for this kind of registration are around 5-7% (Zapata, 1998; Thery-Parisot, 2001) regardless of the species to which they belong (expected vitrification). Vitrification is a phenomenon of fusion and homogenisation of the charcoal cellular walls. Although the conditions that generate it are unknown, it is clear that is produced during combustion process and associated with determinate burning conditions.

Table 2. Absolute and relative frequencies of the taxa identified in each site studied in this paper: Eplugón, Espantalobos and Ángel I.

6. Landscapes and availability of firewood

6.1. Palaeoenvironmental framework (pollen and charcoal)

The first point of the discussion focuses on a comparison of the archaeobotanical data. The number of palaeonvironmental studies focusing climate history and vegetation in the middle Ebro valley has increased noticeably during recent years (González-Sampériz et al., 2010; Pérez-Sanz et al., 2013; Aranbarri et al., 2014). Pollen sequences from non-anthropic contexts show high resolution and long sequences. By contrast, the Early Holocene pollen-sequences from archaeological sites cover only short chronological periods (López-García et al., 1991; López García, 1992; López-Garcia and López-Saez, 1996, 2000; González-Sampériz, 2004a,b; Iriarte, 2013). In the same manner, charcoal studies until now are partial and isolated for this chronology (Badal, 2004, 2013; Alcolea, 2014; Montes et al., 2015b).

In the Pyrenean highlands, pollen records reveal a great climatic instability associated with profound changes in vegetation for the Early Holocene. Successive cold events (9.8, 8.8, 8.3 cal ka BP) are recorded in Basa de la Mora (1914 m a.s.l.) (Pérez-Sanz et al., 2013). Portalet (González-Sampériz et al., 2006) (1802 m a.s.l.) and Tramacastilla sequences (Montserrat-Martí, 1992) (1668 m a.s.l.) reveals special relevance of conifers and broadleaved elements that are well-represented. Mesophytes recorded a decline with the 8.2 aridity event with the high values of birch. For the Pre-Pyrenaean foothills only the Estanya Lake sequence (Pérez-Sanz, 2014) is available. In these mid-mountain areas, the abundant Early Holocene precipitation and higher winter temperatures produced an expansion of woody and mesophilous taxa (mainly *Corylus*) in a steppe landscape marked by seasonality and aridity. In archaeological contexts different sites in the Arba de Biel basin provide charcoal and pollen data. The Peña 14 (González-Sampériz, 2004a) (760m a.s.l.) intra-site pollen data reveals a great development and variety of tree taxa in the Denticulate Mesolithic (9356 ± 125 cal BP). *Pinus* type *sylvestris* woodland was dominant with oak and hazel accompanied by Mediterranean (*Olea-Phillyrea, Quercus ilex* and *Buxus*) and deciduous taxa (*Ulmus, Salix, Viburnum, Fraxinus*). The Mesolithic geometric level (8474 ± 73 cal BP) showed a slight reduction in meso-thermophytes frequencies. Anthracological data revealed that Pinus type sylvestris is the only documented taxon in all Mesolithic levels from different sites in the Arba de Biel basin even in the largest assemblage of Rambla de Legunova (ca. 8000 cal BP). The *Pinus* type *sylvestris* dominates also Mesolithic levels of Esplugón (800 m a.s.l.) although they appear oak and shrubby taxa. The same applies in the Forcas II (Alcolea, 2014) (480 m a.s.l.) charcoal record. This site is located at a lower altitude but also in an area of mountain influence.

Charcoal records at low altitudes, outside the mountainous influence, reflects an open landscape with Mediterranean pines, junipers, and Mediterranean shrubby taxa. Evergreen oaks (*Quercus coccifera/ilex*) appear in the most recent level from Espantalobos (8242 ± 54 cal BP) and Cabezo de la Cruz (7803 ± 53 cal BP) (Badal, 2013). At Espantalobos, we also identified high frequencies of mesophilous, mainly maples. Intra-site pollen-records such as Cabezo de la Cruz (428 m a.s.l.), Pontet (320 m a.s.l.), Secans (360 m a.s.l) and Botiqueria de los Moros (360 m a.s.l.) (López-García et al., 1991; López García, 1992; López-Garcia and López-Saez, 1996, 2000; Iriarte, 2013) and off-site pollen-records such as La Salineta (325 m a.s.l.), La Playa (340 m a.s.l.), Laguna Guallar (336 ma.sl.) and Hoya del Catillo (260m a.s.l.) (Davis, 1994; Valero-Garcés et al., 2000, 2004; González-Sampériz et al., 2008) reflect a patchy landscape with pine forests, evergreen oak and juniper, as well as different stages of development and retreat of deciduous taxa. Shrub formations with Mediterranean taxa (*Buxus, Oleaceae*) and riparian vegetation (*Salix, Populus, Alnus, Corylu*s) are important elements. Low Artemisia and Chenopodiaceae percentages are documented in non-anthropic sequences while a high percentage of this herbaceous component as seen in archaeological contexts.

In the South, palaeoenvironmental data are limited. In the Los Baños archaeological site (515 m a.s.l.), Mediterranean landscapes with both types of *Pinus, Juniperus* and *Quercus coccifera/ilex*, are attested by charcoal records (Badal, 2004) accompanied by mesotermophilous elements and a limited presence of riparian vegetation in the pollen record (González-Sampériz, 2004b). At Ángel I (735 m a.s.l) the charcoal records show only *Pinus* type *sylvestris* and juniper. In northern and southern areas of the Iberian Range, open conifer forest was abundant. At Villarquemado (987 m a.s.l.), Gallocanta (995 m a.s.l.) and Ojos del Tremedal (1650 m a.s.l.) (Bujarchs et al., 1996; Stevenson, 2000; Aranbarri et al., 2014) paleolake pollen sequences show the predominance of *Pinus*. Mesophilous taxa (*Betula* and *Corylus*) and both *Quercus* are documented in Early Holocene (ca. 9140e7780 cal yr BP) and a subsequent decline of the *Pinus* type *sylvestris* frequency (ca. 7780-5000 cal yr BP) shows an increase in thermophilous elements (Aranbarri et al., 2014).

In summary, discussed studies reveal a certain complexity of Lateglacial landscapes in the Middle Ebro Valley. Intense geographic and topographic gradients and climatic contrasts between the Pyrenees and the Iberian Range and central Ebro Depression have contributed to the marked physiographic heterogeneity of the region (Fig. 4). However, the new data presented in this work are consistent with the general framework described.

6.2. The presence of Aleppo pine in the central Ebro Basin Mesolithic contexts

According to the palaeoenvironmental information, geographic factors such as altitude and latitude seem to have a decisive impact in the availability of biomass resources. Analyzed pollen-records reflect open environments in the Middle Ebro Valley where pinewoods played a key role in the vegetation cover between the 10th and 8th millennium cal BP. We have documented the presence of two types of pines in studied charcoal assemblages: mountain pines (*Pinus* type *sylvestris*) in the Pyrenees and Iberian Ranges, and Mediterranean pines (*Pinus halepensis*) in the Central Ebro Depression and driest mid-mountain areas. The *Pinus* type *sylvestris* group comprises various mountain pine species, all well adapted to cold and continental climate features. *Pinus* type *sylvestris* dominates the Pleistocene and Tardiglaciar landscape except in southern Spain and specific exceptions in the north (Rubiales et al., 2010; Roiron et al., 2013). With Holocene environmental changes, this type of pines was restricted to mountainous areas, and sometimes survived in Mediterranean landscapes alongside Mediterranean pines in the northeast (Allué, 2002; Badal, 2004).

Fig. 2. Frequency of identified taxa in each site studied in this paper: Eplugón, Espantalobos and Ángel I.

Mediterranean pines are represented in the Middle Ebro Valley record by *Pinus halepensis*. Aleppo pine is a thermophilous taxon that tolerates a variety of climates throughout its range in the Iberian Peninsula, from the semiarid environment of the southeast basal areas to the sub-Mediterranean environments of the middle mountains of the Iberian Range and Pyrenees (Gil et al., 1996; Blanco et al., 1997; Cabanillas, 2010). Aleppo pine presence in Pleistocene and Tardiglaciar landscapes is limited to certain sites in the south and eastern coastal of the Iberian Peninsula (Badal, 1998; Badal and Carrión, 2001; Aura et al., 2005), but this type of pine abounded in these areas and other continental areas of the Iberian Peninsula and Ebro Valley during Holocene after 7500 cal BP sharing space with *Quercus* genera as revealed by anthracological sequences (Rodríguez-Ariza, 1992; Ros, 1992; Badal et al., 1994; Carrion, 2002, 2007, 2005; Duque, 2004; Martín y Piqué, 2008; Badal, 2009).

The presence of Pinus halepensis wood charcoal is still not very common in Mesolithic contexts of the Iberian Peninsula with exceptions such as La Cativera (Allué, 2002), La Falguera (Carrión, 2002; Carrión et al., 2006) or Cueva Blanca (Mingo et al., 2012; Uzquiano et al., 2015). In the central Ebro basin Aleppo pine is documented in Cabezo de la Cruz (Badal, 2013), Los Baños (Badal, 2004) and Espantalobos (Table 3). Their presence in Mesolithic settlements such are reflecting the last anthracological studies suggests that the Aleppo pine would be part of Holocene vegetation prior to the advent of agriculture and great Quercus spread in the Ebro Valley that occurred in the Middle Holocene, around 7000 cal BP (Pérez-Sanz, 2014). At this moment, archaeological charcoal records begin to reflect a significant increase in consumption of deciduous and evergreen oaks as fuel. This is perfectly visible in the long sequences such as Mendandia (Zapata and Peña-Chocarro, 2004), Kampanoste Goikoa (Zapata, 1998), Aizpea (Zapata, 1999, 2001) or Esplugón (unpublished data). Also an anthropic mark on the landscape begins to be seen in the pollen spectrum due to agricultural activities that bring the Neolithic (López-García et al., 1991; López-Garcia and López Saez, 2000; Montes et al., 2006; Rodanés et al., 1996).

Fig. 3. Images of vitrification on archaeological wood charcoal.

7. Mesolithic fuel use in the Middle Ebro Valley

The Mesolithic groups would be influenced by the context of seasonality and mobility (Barandiarán and Cava, 2000; Alday, 2002; Utrilla, 2002; Cava, 2004). Its fuel needs would therefore be covered by biomass resource available in the vicinity of the campsite. Previous anthracological studies in the northeast of the Iberian Peninsula indicate that opportunistic management of fuel is the paleoeconomical strategy that has prevailed among mobile Holocene hunter-gatherers (Carbonell et al., 1985; Garcia- Arguelles, 1990; Uzquiano, 1990; Jordá et al., 1992; Mir and Freixas, 1993; Piqué, 1995; Ros, 1995; Berguedá, 1998; Allué, 2002; Carrión, 2002; Aura et al., 2005; Allué et al., 2012). Regardless of the type of pine present in the environment, these are the most consumed taxon as fuel (100-25%) by Mesolithic populations of the Middle Ebro Valley (Table 3). Only in the charcoal records from Espantalobos does this taxon share prominence with juniper and maple. Almost all records discussed reveal very high percentages of pine in some cases over 90%. Especially at higher altitudes, we find reduced biodiversity in charcoal assemblages. The paleoenvironmental framework in which Mesolithic populations of the Middle Ebro Valley are developed was defined in the previous section. As we have seen, factors such as topography and climate have a decisive impact on the vegetation cover and hence in the availability of biomass resources, so analyzed records reflect open environments where pinewoods played a key role in the Early Holocene vegetation cover. This poorly diversified landscape appears as the main cause of the low diversity of taxa exploited in certain areas. However, the ubiquity of pine in the paleoenvironmental records does not mean that this taxon does not appear over-represented in some of the archaeological levels discussed in this paper. A cause of this over-representation of pinewood could be due to this species producing ample quantities of deadwood. Despite being sporadic, the presence of deciduous and shrubby taxa in all assemblages indicates that these were consumed when available (Fig. 5). As already noted the high percentages of pinewood at the Ángel I, Forcas II (Alcolea, 2014), and Rambla de Legunova (Montes et al., 2015b) assemblages may be due to an insufficient sampling. It is not the case of the Esplugón site where rigorous sampling has extracted all the available anthracological information.

Fig. 4. Biogeographical profile showing hypothetical reconstruction of wooded formations (9500-7500 cal BP) in the Middle Ebro Valley in the north-south length.

Table 3. Absence/presence of woody taxa in Mesolithic contexts from Middle Ebro Valley based on wood charcoal analysis after Badal, 2004, 2013; Alcolea, 2014; Montes et al., 2015b and archaeological sites studied in this paper. (***) <50%; (**) 50-10%; (*) 10% or unknown.

The high frequencies of Pinus type sylvestris wood are observed in mentioned settlements e as occurs at other archaeological sites from this chronology in the Upper Ebro Basin such as Mendandia (Zapata and Peña-Chocarro, 2004) or Kampanoste Goikoa (Zapata, 1998). In several of these sites high percentages of pine are also associated with very high percentages of charcoal vitrification (Fig. 6). As we said, this is a phenomenon of fusion and homogeneisation of the charcoal cellular walls and the causes of this phenomenon are unknown e although it has generally been considered as a result of high temperature burning or humidity rate of wood among other possible causes (Fabre, 1996; Scheel-Ybert, 1998; Braadbaart and Poole, 2008; McParland et al., 2010; Henry, 2011). In any case, this phenomenon suggest similar burning conditions of the assemblages. Factors such as the state of the wood and certain characteristics of the combustion process seem to have a decisive role in the onset of this phenomenon. We know that in non-permanent habitation sites the preferred firewood has a strong relationship with the functions of hearths (Théry-Parisot, 2002). Ethnographic and archaeological research reveals that firewood selection considered the raw physiological state (green/dead) and the phenological characteristics (altered/non-altered) of wood over the species factor (Heizer, 1963; Ford, 1979; Scheel-Ybert, 2001; Henry, 2011). In this manner other characteristics of the wood (humidity rate, diameter, altered or not state) would also further condition their suitability for use as fuel (Chabal et al., 1999; Théry-Parisot, 2001, 2006; Badal and Carrión, 2004). Certain hearts functions, such as food smoking (Alday, 2007), require considerable smoke to be produced and this would favor the collection of wood in a green state. An interesting hypothesis about vitrification of charcoal is that this occurs in green wood (Zapata and Peña-Chocarro, 2004) in relationship with certain hearts functions. This could be one of the causes of pinewood over-representation in some deposits in relation to vitrification of wood charcoal. However, these relevant factors in fuel management are very difficult to find in archaeological contexts despite the proliferation of recent research (Théry-Parisot, 2001; Badal and Carrión, 2004; Allué et al., 2009; Moskal et al., 2010; Théry-Parisot et al., 2010; Henry, 2011; Chrzazvez et al., 2014; Duffraisse, 2014; Henry and Théry-Parisot, 2014).

Fig. 5. Histogram showing the number of taxa by ecological groups (conifers, mesothermophytes and shrubby taxa) documented of each archaeological site discussed in this paper ordered north-south length in relation to schematic geographical profile of the Middle Ebro Valley. HC Hearth or combustion area; SC Scattered charcoal.

Fig. 6. Diagram showing vitrification values in some Mesolithic contexts from Upper and Middle Ebro Valley after Zapata (1998, 1999) and archaeological sites studied in this paper.

To conclude, this study suggests that the Mesolithic inhabitants of the Middle Ebro Valley were well-adapted to their local context and exploited firewood in the vicinity of settlements according to the principle of least effort (Shackleton and Prins, 1992; Chabal, 1997). Palaeobotanical data have shown that Mesolithic landscapes were dominated by conifer forests that produce ample quantities of deadwood. Firewood collection is local and opportunistic and occurred in proximity to the site e although factors such as the state of the wood may have had a significant impact on fuel management strategies for these populations, being more important than the species factor, and may condition the overrepresentation of certain taxa.

8. Conclusions

Currently, the number of archaeobotanical studies of the Mesolithic helps to define the environmental conditions in which these human groups developed. The synthesis of anthracological data presented in this paper contributes to characterize the ecological and cultural context of firewood exploitation during 10th to 8th millennium cal BP in the Middle Ebro Valley. The Mesolithic period is the last stage of an exclusively predatory economy based on hunting and gathering and is also a period ofenvironmental change. In this context, charcoal analysis is a profitable tool for reconstructing local vegetation. The pollen records discussed reveal open environments and support the well-known importance of pine forests, regardless of altitude and latitude. Preliminary data concerning plant use provided in this work reveals that different pine species, either Mediterranean or mountain pines, have played a fundamental role in firewood exploitation in all the assemblages. This work also suggests the expanding consumption in lowlands of woody taxa during Lateglacial and Early Holocene climatic ameliorations by Mesolithic inhabitants of the Middle Ebro Valley. Typical species of the Mediterranean area are documented at Espantalobos and previously at Cabezo de la Cruz (Badal, 2013). Both are located in the Central Ebro Depression outside the mountainous influence of the Pyrenees and the Iberian Range. Latitudinal and altitudinal variables are very important for understanding taxonomic distribution in the analyzed samples. In summary, mobile hunter-gatherer populations seem to have exploited local areas and used opportunistic firewood collection strategies. However, taphonomic alterations observed in some of the charcoal studied in this paper suggest that other factors such as the state of the wood would be taken into account by these populations for fuel selection even more than the species factor. Fieldwork at Espantalobos and Esplugón is ongoing, and wood charcoal remains will provide new data about Mesolithic firewood management patterns and landscape.

Acknowledgements

This work was funded by a fellowship from Ministerio de Economía y Competitividad (Spain) (BES 2012-0553828) in contribution to the research project Repensando viejos yacimientos. Ampliando nuevos horizontes en la Prehistoria del Valle Medio del Ebro (HAR 2011-27197). I would like to express my gratitude to P. Utrilla, L. Montes, R. Domingo, A. Berdejo and A. Obón for their confidence and their effort in the fieldwork. I would like to specially thank the session organizers E. Allué, M.A. Courty and Ll. Picornell for inviting me to participate in this special volume. Finally, I thank the anonymous reviewers who helped to improve the manuscript.

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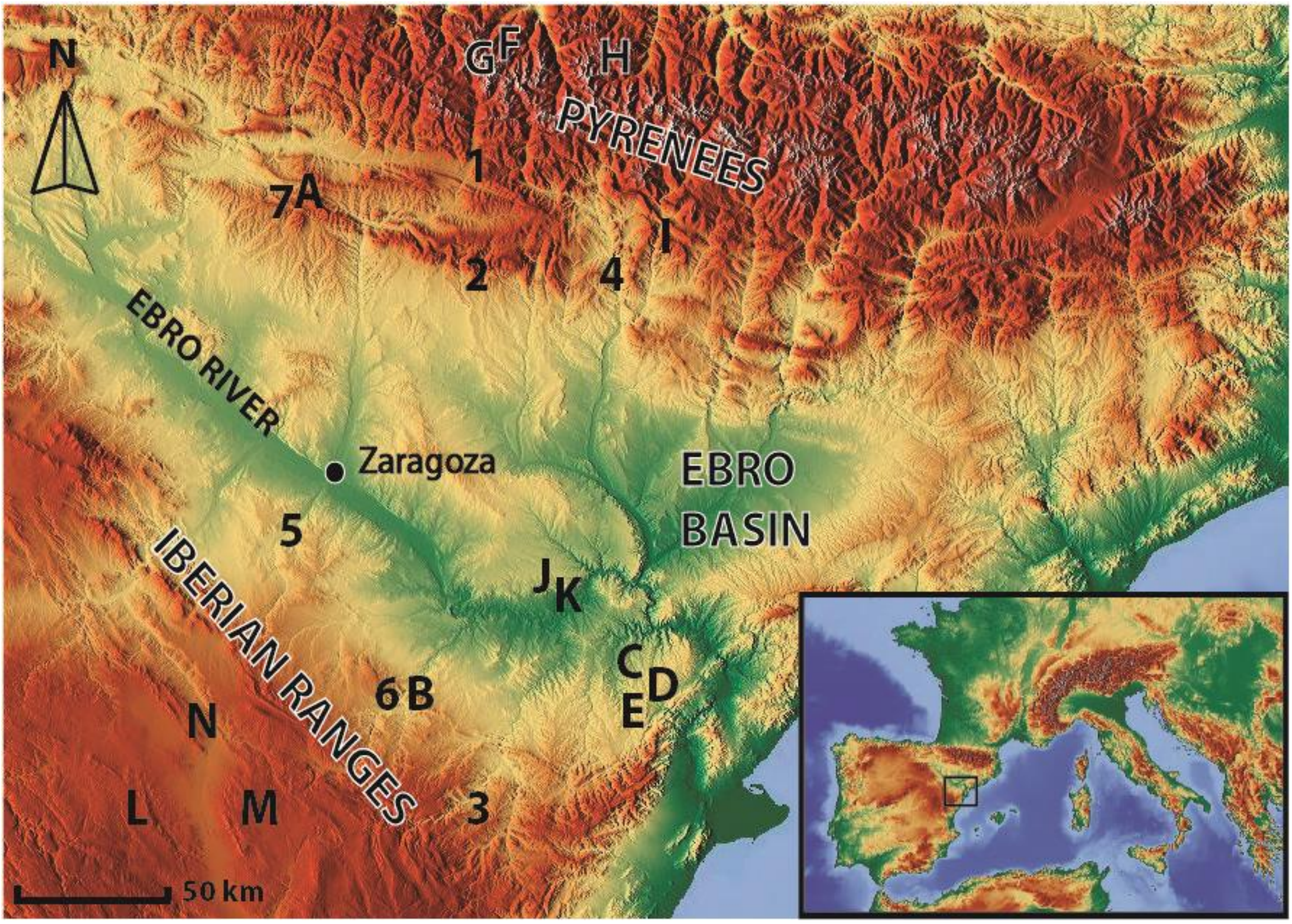
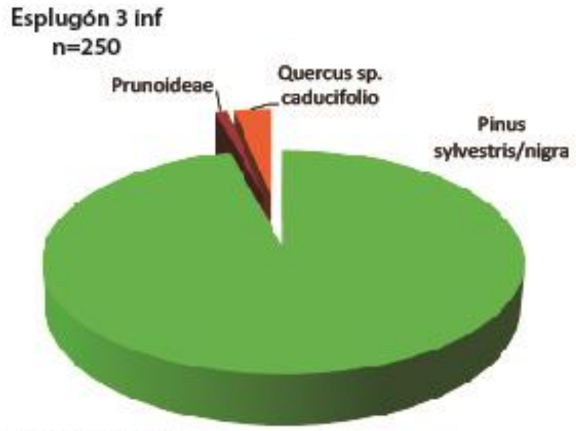
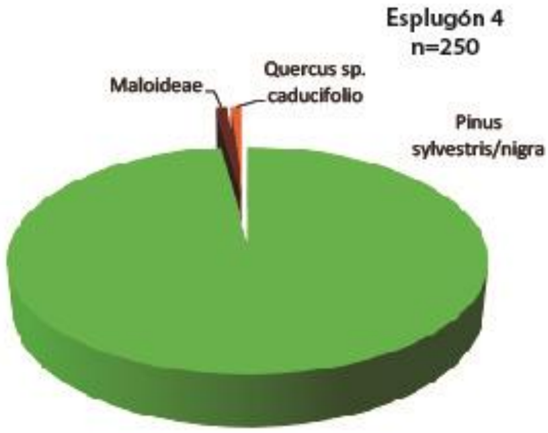
Settlement	Estratigraphic unit	Lab. reference	Sample type	Date BP	Date cal BP	Date cal BC	Cultural unit
Ángel I	8d	GrA-22826 GrN-15220	Unidentified charcoal	8390±60 8150±170	9402 ± 71 9064±251	7452±71 7114±251	MD
Espantalobos	e	Beta 361625	Charcoal *Juniperus* sp.	7900±50	8771±123	6821±123	MG/MD
Los Baños	2b1	GrN-24299	Unidentified charcoal	7840±100	8709±164	6759±164	MG/MD
Ángel I	8c	GrA-27278 GrA-27274	Unidentified charcoal	7955±45 7435±45	8830 ± 113 8269±54	6880±113 6319±54	MG
Esplugón	4	GrA-59632	Charcoal *Pinus sylvestris*	7620±40	8428±26	6474±26	MG
Espantalobos	c	Beta 361624	Charcoal *Juniperus* sp.	7390±40	8242±54	6292±54	MG
Los Baños	2b3	GrA-21551 GrA-21550	Unidentified charcoal	7550±50 7350±50	8366±34 8171 ± 92	6416±34 6221 ± 92	MG
Rambla de Legunova	2	GrA-61768 GrA-47886	Bone/ Unident. charcoal	7260±45 7235±45	8088±57 8072±60	6138 ± 57 6122 ± 63	MG
Forcas II	II	GrN-22686 Beta 250944	Unidentified charcoal	7240±40 7150±40	8077±60 7979 ± 25	6127±60 6029±25	MG
Cabezo de la Cruz	1351	GrN-29134	Charcoal *Pinus halepensis*	7130±130	7965±139	6015±139	MG
Forcas II	IV	Beta 59995 Beta 290932	Unidentified charcoal	7090±340 7000±40	7953 ± 313 7853±58	6003±313 5903±58	MG
Cabezo de la Cruz	1450	GrN-29861	Unidentified charcoal	6970±40	7803±53	5853±53	MG
Esplugón	3 inf	Beta 306723	Bone	6950±50	7784±59	5834±59	MG

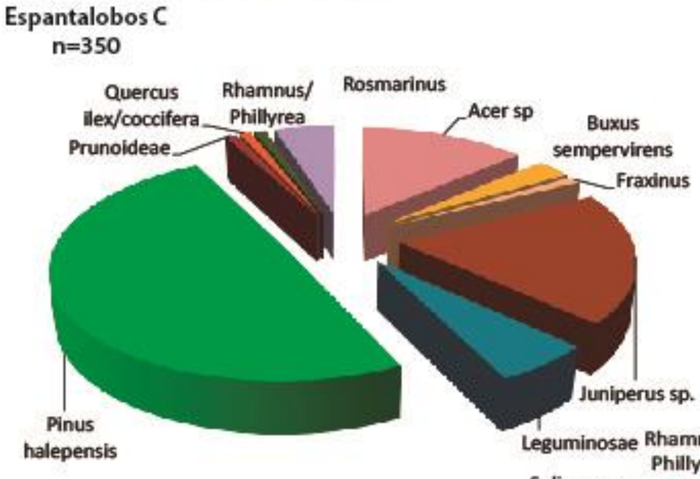
Archaeological site	Esplugón				Espantalobos				Ángel I			
Archaeological layer	3 inf		4		c		e		8c		8d	
Taxa	n	%	n	%	n	%	n	%	n	%	n	%
Acer sp.					43	13.9	58	22.5				
Buxus sempervirens					8	2.6	7	2.7				
Fraxinus sp.					1	0.4						
Juniperus sp.					61	19.8	87	33.6			15	23.1
Leguminosae					18	5.8	7	2.7				
Monocotiledoneae							2	0.8				
Pinus halepensis					157	51.0	73	28.3				
Pinus sylvestris/nigra	216	96.9	194	99.0					62	100	50	76.9
Pistacia sp.							3	1.2				
Prunoideae	1	0.4			1	0.4						
Quercus ilex/coccifera					2	0.6						
Quercus sp. deciduous	6	2.7	1	0.5								
Rhamnus/Phillyrea					3	1.0	9	3.5				
Rosaceae/Maloideae			1	0.5								
Rosmarinus officinalis					14	4.5	9	3.5				
Salix/Populus							3	1.2				
Indeterminable	27	10.8	54	21.6	42	12	42	14	17	21.5	44	40.4
Total determinable	223	100	196	100	308	100	258	100	62	100	65	100
Total fragments	**250**		**250**		**350**		**300**		**79**		**109**	
Total taxa	**3**		**3**		**10**		**10**		**1**		**2**	

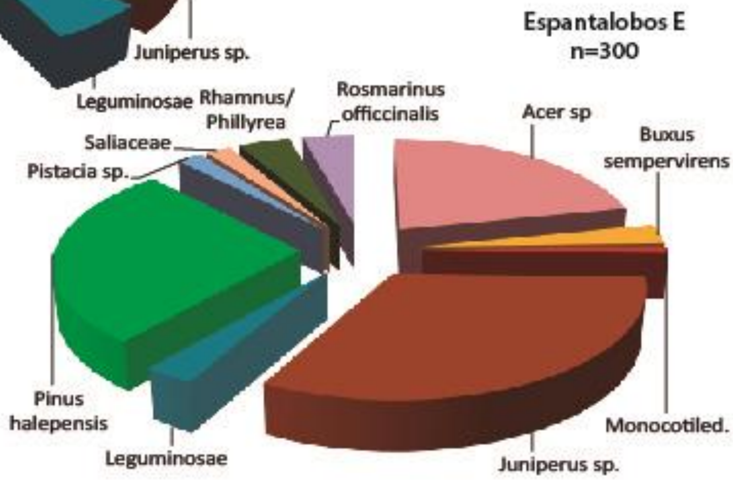
Archaeological site	Esplugón		Rambla	Forcas II		Espantalobos		Cabezo de la Cruz			Los Baños		Ángel I	
Altitude (m.a.s.l.)	800		760	480		500		428			515		735	
Archaeological layer	3 inf	4	2	II	IV	c	e	1450	1398	1351	2b3	2b1	8c	8d
Radiocarbon date cal BP	5834±59	8428±26	8088±57	7953 ± 313	8077±60	8242±54	8771±123	5853±53		7965±139	8366±34	8709±164	8830 ± 113	9064±251
Pinus type *sylvestris*	***	***	***	***	***						*	*	***	***
Pinus halepensis						***	**	***	***	***	*	*		
Pinus sp.								*	**	*	*	*		
Juniperus sp.						**	**	*	*	*	*			**
Quercus sp. deciduous	*	*			*					*				
Quercus coccifera/ilex						*				*		*		
Quercus sp.										*		*		
Acer sp.						**	**							
Buxux sempervirens						*	*							
Fraxinus sp.						*								
Labietae cf. *Lavandula*									*			*		
Leguminosae						*	*							
Pistacia sp.							*							
Prunoideae	*					*			*	*				
Rhamnus/Phillyrea						*	*			*				
Rosaceae/Maloideae		*												
Rosmarinus officinalis						*	*							
Salix/Populus							*							
Monocotiledónea							*		*	*				

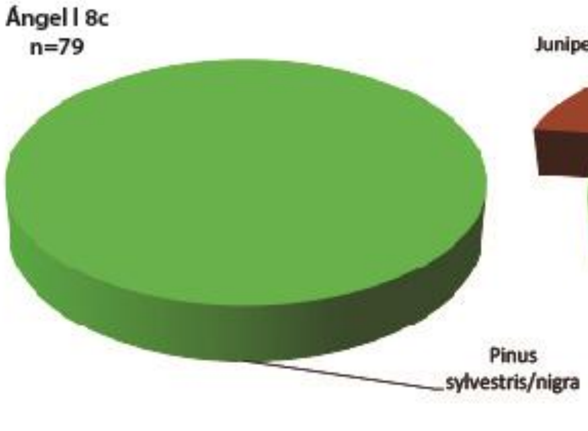

N
G
F
H
PYRENEES
1
7
A
I
2
4
EBRO RIVER
Zaragoza
EBRO
BASIN
5
IBERIAN RANGES
J
K
C
D
E
6
B
N
L
M
3
50 km

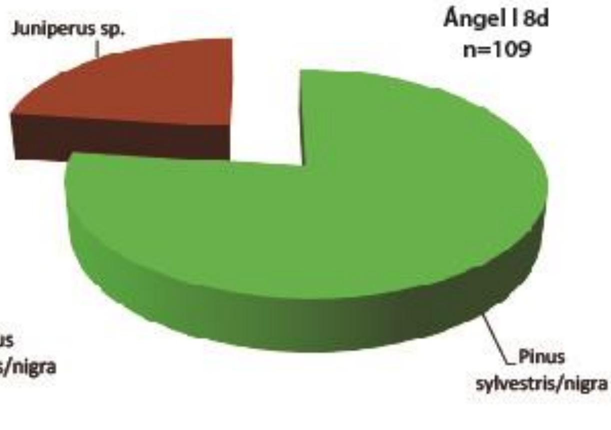

Esplugón 3 inf
n=250
Prunoideae
Quercus sp. caducifolio
Pinus sylvestris/nigra


Esplugón 4
n=250
Maloideae
Quercus sp. caducifolio
Pinus sylvestris/nigra

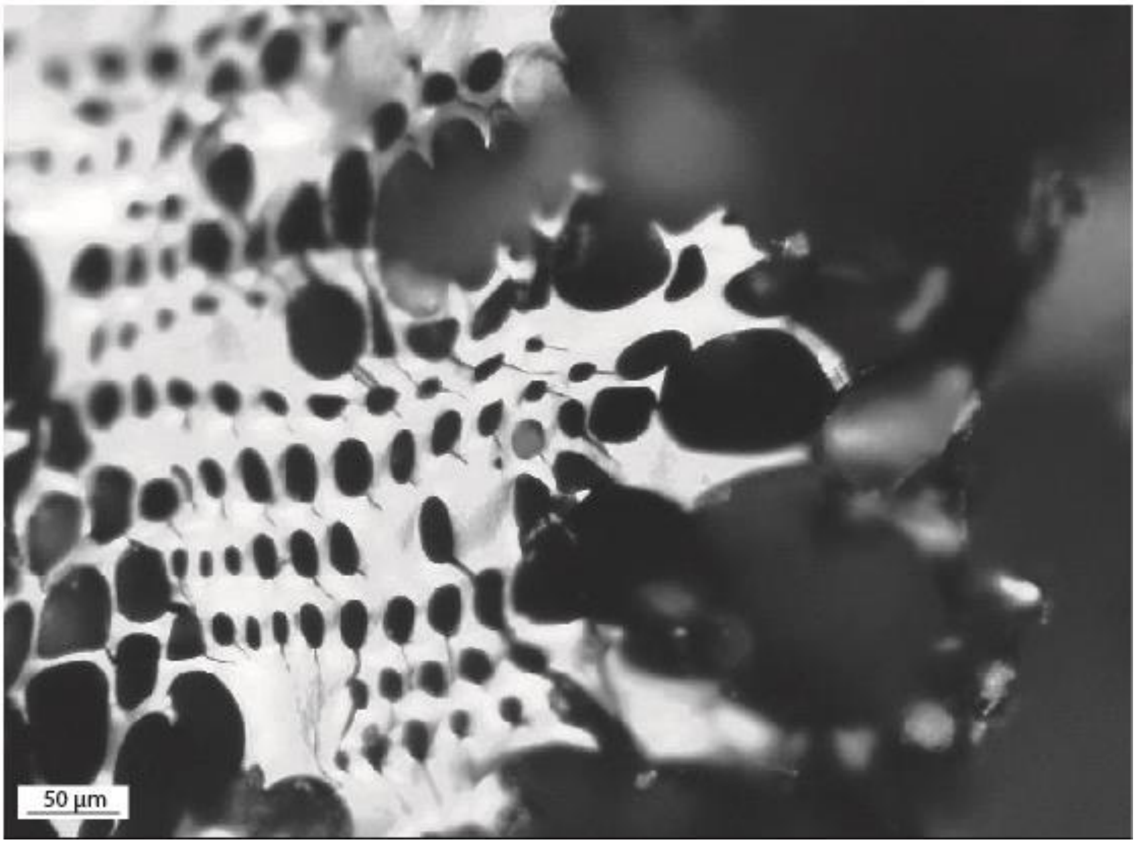

Espantalobos C
n=350
Quercus ilex/coccifera
Rhamnus/ Phillyrea
Rosmarinus
Acer sp
Buxus sempervirens
Fraxinus
Prunoideae
Juniperus sp.
Leguminosae
Pinus halepensis

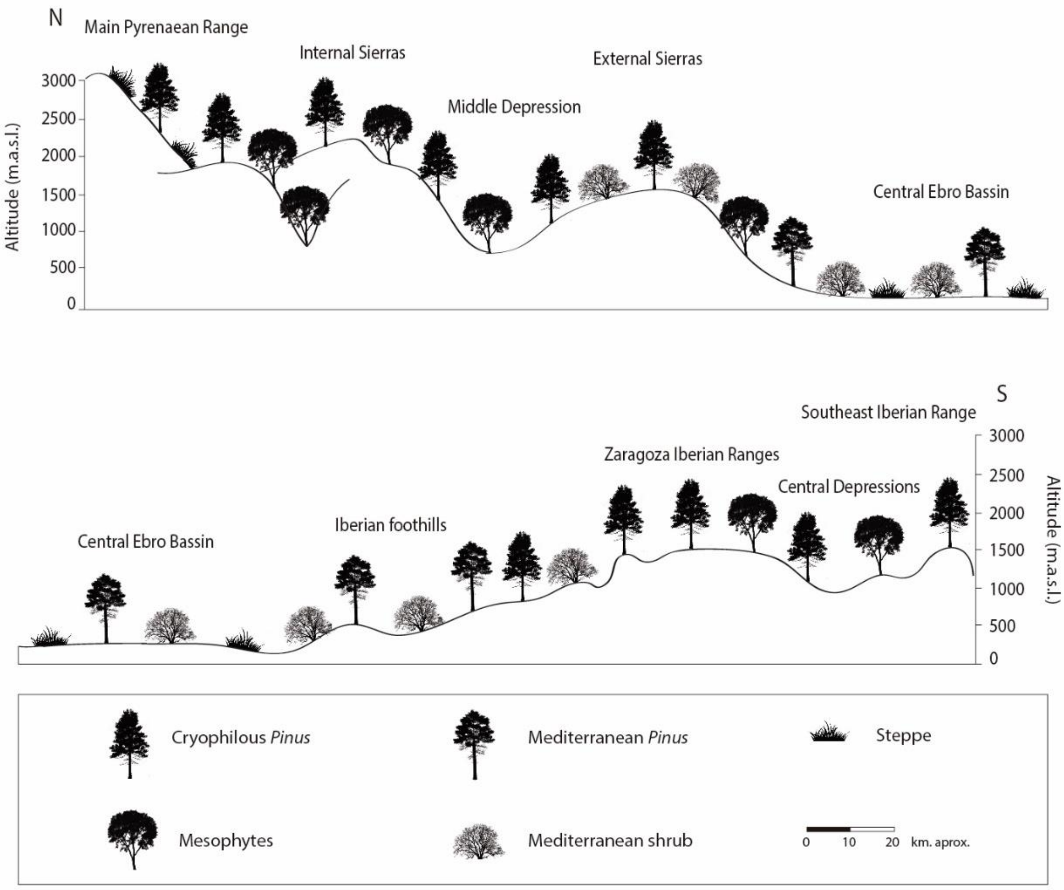

Espantalobos E
n=300
Rhamnus/ Phillyrea
Rosmarinus officcinalis
Acer sp
Buxus sempervirens
Saliaceae
Pistacia sp.
Pinus halepensis
Leguminosae
Juniperus sp.
Monocotiled.

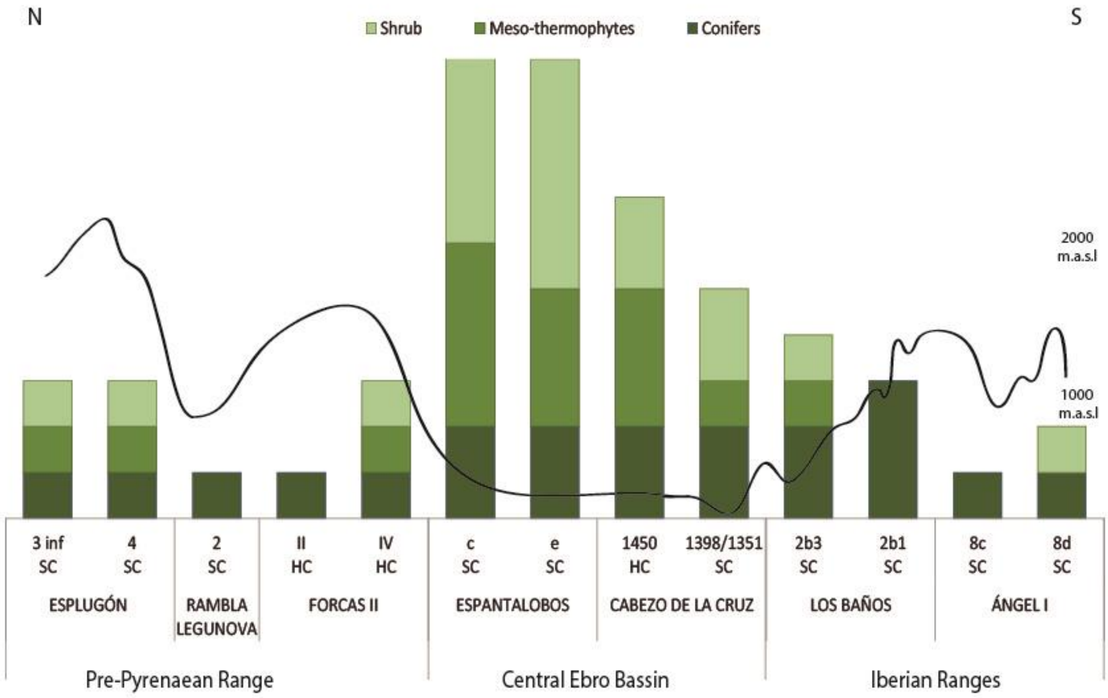

Ángel I 8c
n=79
Pinus sylvestris/nigra


Ángel I 8d
n=109
Juniperus sp.
Pinus sylvestris/nigra

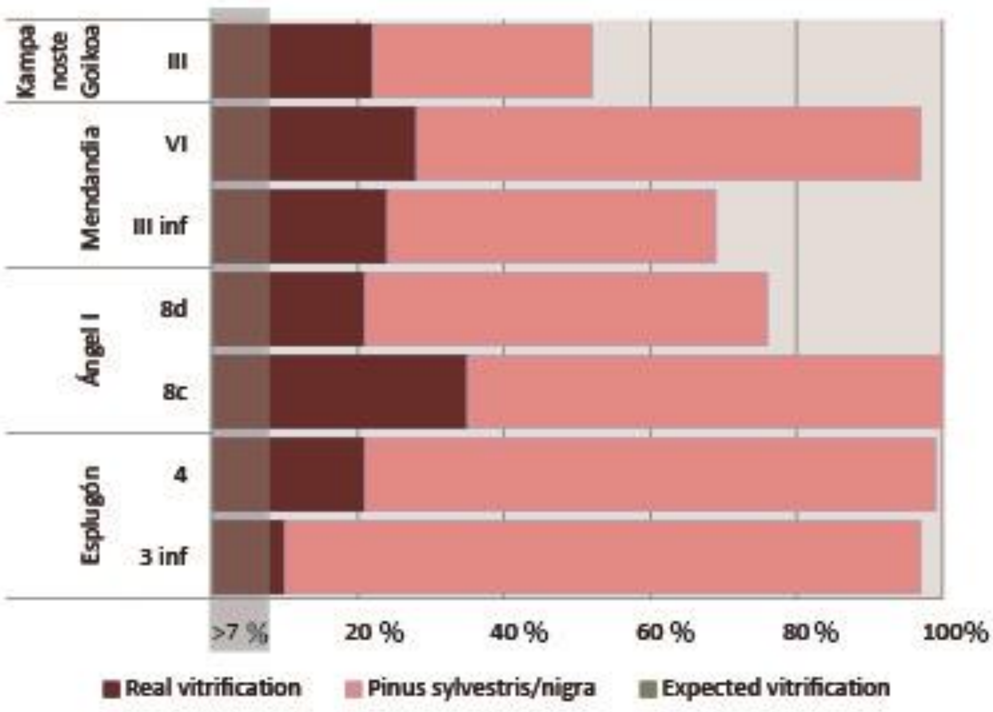

50 µm


50 µm


N
Main Pyrenaean Range
Internal Sierras
External Sierras
Middle Depression
Central Ebro Bassin
Altitude (m.a.s.l.)
3000
2500
2000
1500
1000
500
0
S
Southeast Iberian Range
Zaragoza Iberian Ranges
Central Depressions
Iberian foothills
Central Ebro Bassin
Cryophilous Pinus
Mediterranean Pinus
Steppe
Mesophytes
Mediterranean shrub
0 10 20 km. aprox.



N
S
Shrub
Meso-thermophytes
Conifers
2000
m.a.s.l
1000
m.a.s.l
3 inf
SC
4
SC
2
SC
II
HC
IV
HC
c
SC
e
SC
1450
HC
1398/1351
SC
2b3
SC
2b1
SC
8c
SC
8d
SC
ESPLUGÓN
RAMBLA LEGUNOVA
FORCAS II
ESPANTALOBOS
CABEZO DE LA CRUZ
LOS BAÑOS
ÁNGEL I
Pre-Pyrenaean Range
Central Ebro Bassin
Iberian Ranges



Kampa noste Goikoa
III
Mendandia
VI
III inf
Ángel I
8d
8c
Esplugón
4
3 inf
>7 %
20 %
40 %
60 %
80 %
100%
Real vitrification
Pinus sylvestris/nigra
Expected vitrification