ARTICLE IN PRESS

Quaternary International xxx (xxxx) xxx

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Dendro-anthracological tools applied to Scots type pine forests exploitation as fuel during the Mesolithic-Neolithic transition in the southern central pre-Pyrenees (Spain)

Marta Alcolea [a,b,c,*], Alexa Dufraisse [b], María Royo [d], Carlos Mazo [e], Martín de Luis [d], Luis A. Longares [d], Pilar Utrilla [f], Ramón Fábregas [a]

[a] GEPN-AAT Research Group, Universidade de Santiago de Compostela, Praza da Universidade 1, 15782, Santiago de Compostela, Spain
[b] CNRS/MNHN, UMR 7209 Archéozoologie, Archéobotanique: Sociétés, Pratiques et Environnements, Sorbonne Université, CP 56, 55 Rue Buffon, 75005 Paris, France
[c] ISEM, CNRS, IRD, EPHE, Université de Montpellier CC 065, Place Eugène Bataillon, 34095, Cedex 5 Montpellier, France
[d] Departamento de Geografía, IUCA, University of Zaragoza, C/ Pedro Cerbuna 12, 50009, Zaragoza, Spain
[e] Área de Prehistoria, P3A DGA Research Group, IUCA, University of Zaragoza, C/ Pedro Cerbuna 12, 50009, Zaragoza, Spain
[f] Área de Prehistoria, P3A DGA Research Group, IPH, University of Zaragoza, C/ Pedro Cerbuna 12, 50009, Zaragoza, Spain

A R T I C L E I N F O

Keywords:
Pinus sylvestris tp.
Early-Middle Holocene
Firewood procurement
Dendro-anthracology
Anthraco-typology
Charcoal analyses
Referential datasets
NE Iberia

A B S T R A C T

This work focuses on the reconstruction of fuelwood procurement during the Mesolithic-Neolithic transition in the southern central Pre-Pyrenees (Spain). The study combines wood charcoal identification with the application of dendro-anthracological approaches in the archaeological sequence of Esplugón (9.4–6.8 kyr cal BP) (Sabiñanigo, Huesca). Scots type pine (*Pinus sylvestris* tp.) reaches in this record around 90% of exploited firewood in line with its abundance in the inner Iberia mountainous areas during the onset of the Holocene. The classification of pine wood fragments in anthraco-groups is based on the combination of different dendro-anthracological tools: i) pith location tool and wood diameter estimation based on the trigonometric method tool (ADmodel), ii) the study of growth rate based on the annual tree-ring width measurements, and iii) a modern dendrological dataset. There are hardly any differences observed in firewood procurement between the last hunter-gatherers and the first farmers in the long sequences from rock-shelters with recurrent human occupations. First results from this site point to the exploitation of whole trees but a high use of small pine branches probably from the gathering of branch shedding.

1. Introduction

This work constitutes a holistic approach to Early-Middle Holocene archaeological wood charcoal assemblages from the southern central Pre-Pyrenees (Spain). Some of these assemblages are characterized by a very homogeneous composition, in which Scots type pine wood (*Pinus sylvestris* tp.) always reaches very high values, > 70%, despite the taxonomic diversity of the anthracological samples. Scots type pines (*Pinus sylvestris* tp.) have played an important role in Mediterranean vegetation since the Pleistocene which is reflected in their ubiquity presence in several wood charcoal assemblages of southern Europe (Alcolea, 2015; Alcolea et al., 2017a, 2017b; Allué et al., 2012, 2017a, 2017b; 2018; Allué and Mas, 2020; Aura et al., 2005; Badal et al., 2012a, 2012b; Badal and Martínez-Varea, 2018; Carrión et al., 2008, 2019; Mazo and Alcolea, 2020; Montes et al., 2016; Rubiales et al., 2010; Théry-Parisot, 2001, 2002; Théry-Parisot and Thiébault, 2005; Théry-Parisot et al., 2016, 2018; Vidal-Matutano, 2017; Vidal-Matutano et al., 2015, 2017, 2018).

Pinus sylvestris L. forests show a wider world distribution area nowadays although in the Iberian Peninsula they are now restricted to the highest elevations in mountain areas (Costa et al., 2001). They are accompanied by *Pinus nigra* subsp. *salzmannii* (Dunal) Franco in the lowlands and *Pinus mugo* subsp. *uncinata* (Ramond ex DC.) Domin, that dominates the highlands. Unfortunately, these species can hardly be distinguished on the basis of their microscopic wood anatomy, so they are grouped under the taxon *Pinus sylvestris* tp. Which refers to all these cryophillous pines that abound in the Mediterranean mountains.

The abundance of *Pinus sylvestris* tp. wood in certain archaeological

* Corresponding author.GEPN-AAT Research Group, Universidade de Santiago de Compostela, Praza da Universidade 1, 15782, Santiago de Compostela, Spain.
E-mail address: martaalcoleagracia@gmail.com (M. Alcolea).

https://doi.org/10.1016/j.quaint.2020.10.029
Received 7 July 2020; Received in revised form 11 October 2020; Accepted 12 October 2020
Available online 15 October 2020

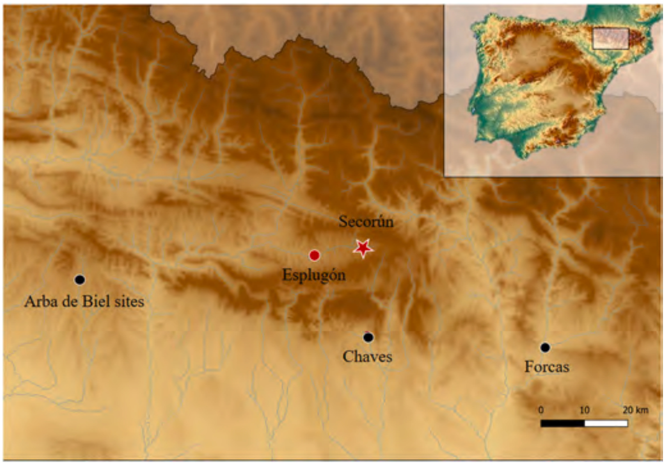

Fig. 1. Location of the Esplugón site (Huesca, Spain), the Station 1 sampled for modern dendrological reference (Secorún) and the main surrounding archaeological sites mentioned in the text. Base: MDT200 IGN (Spanish Government).

Fig. 2. Location of the rock-shelter in relation with their current biogeographical framework. Photographs: J.L. Peña and C. Mazo (University of Zaragoza).

records for thousands of years implies an evident limitation in the interpretation of the archaeological record from the point of view of standard wood charcoal analysis. However, the large amount of available fragments from the same taxon (Allué et al., 2009; Allué and Mas, 2020; Caruso-Fermé and Théry-Parisot, 2018; Dufraisse, 2006; Dufraisse and García-Martínez, 2011; Dufraisse et al., 2017, 2020; García-Martínez and Dufraisse, 2012; Henry and Théry-Parisot, 2014; Paradis-Grenouillet et al., 2013; Théry-Parisot et al., 2011; Théry-Parisot and Henry, 2012; Vidal-Matutano et al., 2017) also presents an opportunity to apply innovative anthracological and dendro-anthracological tools to the study of these anthracological contexts.

In this paper, the previously unpublished wood charcoal analysis of the entire archaeological sequence of the Esplugón site (Huesca, NE Iberia) is presented in its regional context. In addition, we introduce the quantitative study of the wood charcoal alterations, as well as the first results of the application of dendro-anthracological tools to wood charcoal fragments, which permit reconstructing which parts of the plants were exploited. For the latter, it has been necessary to create a specific modern dendrological dataset for Scots type pines (*Pinus sylvestris* tp.) in the south central Pre-Pyrenees. All these approaches enable a better global understanding of forest management by the human inhabitants of the site. The archaeological sequence of Esplugón, including succesive Mesolithic and Neolithic occupations, allows a comparison of fuelwood procurement between the last hunter-gatherers and the first farmers in this region. This work constitutes a starting point for future wood charcoal studies in Pleistocene and Holocene sequences from NE Iberia.

2. Regional setting and site description

The southern central Pre-Pyrenees represent a key region for understanding the Mesolithic-Neolithic transition in NE Iberia (Alcolea, 2018; Laborda, 2019). The Pyrenean foothills, or Pre-Pyrenees (450–950 m asl), comprise human occupations in rock-shelters and caves, some of them containing long sequences of prehistoric occupation, such as Esplugón, Forcas, Artusia, Aizpea and Arba de Biel sites (Utrilla et al., 2016, Obón et al., 2019; Utrilla and Mazo, 2014; García-Martínez de Lagrán et al., 2017; Barandiarán and Cava, 2002; Montes et al., 2016) (Fig. 1). All sites have many similarities as they contain recurrent and probably short-term occupations and they are strategically locatedover the valley, controlling both human and prey movements. Wood charcoal analysis has been recently performed in all of them (Zapata, 2001; Alcolea, 2015; Montes et al., 2016; García-Martínez de Lagrán et al., 2017 and current study).

Esplugón is the largest rock-shelter in the southern central Pyrenees known so far for this chrono-cultural period (Fig. 2). It is located in the middle transverse corridor of the Guarga valley (Huesca, NE Iberia) between the Pre-Pyrenees and the Pyrenees. The description of six Mesolithic and Neolithic archaeological layers makes it a reference site for understanding the Neolithisation process in the Ebro basin (NE Iberia) (Utrilla et al., 2012, 2016; Berdejo and Obón, 2013; Berdejo et al., 2018; Obón et al., 2019). Seven archaeological layers have been identified (numbered 1–7 from top to bottom) organized in 4 chrono-cultural stages of prehistoric occupation (Fig. 3):

- Stage 1. Layer 1. A partially disturbed Chalcolithic layer, which contained both Chalcolithic and historical materials.
- Stage 2. Layers 2 and 3 sup. An Early Neolithic (EN) occupation, in which geometric microliths with abrupt retouching was recovered, as well as occasional bone tools and pottery fragments with incised and cardial decorations.
- Stage 3. Layers 3 inf. And 4. A Late Mesolithic (LM) or Geometric Mesolithic occupation, in which a rich lithic assemblage of geometric microliths was recovered, with triangles in the earlier phases and later on trapezes.
- Stage 4. Layers 5 and 6. An Early Mesolithic (EM) occupation which still lacks an accurate chrono-cultural definition. Although the occasional lithic materials recovered seem to fit with a Notches and Denticulate Mesolithic (layer 5) and a Microblade Epipaleolithic (layer 6), the available radiocarbon dates do not support the Epipalaeolithic attribution.

14 radiocarbon dates (Table 1 and Fig. 4) place the occupation of the site (excluding Stage 1) between 9.4 and 6.8 kyr cal BP (Obón et al., 2019; Laborda, 2019). The Early Mesolithic (EM) stage occurs during the last millennium of the Early Holocene (9.4–8.5 kyr cal BP). The start of the Geometric Mesolithic or Late Mesolithic (LM) stage coincides with the 8.4 and 8.2 arid events that give rise to the Middle Holocene in the region (8.5–7.5 kyr cal BP). Finally, the Early Neolithic (EN) stage occurs during the Middle Holocene (7.3–6.8 kyr cal BP).

Archaeological materials recovered at the site as well as the preliminary archaeozoological results suggest that hunting was the main focus of the settlement throughout the excavated sequence. Recurrent short-term occupations are proposed for the Mesolithic while more or less stable, long-term occupations involving various activities (scraping, drilling, mowing) besides hunting, have been proposed for the Neolithic (Utrilla et al., 2016; Obón et al., 2019). In any case, the hunted species are characteristic of a forested environment dominated by red deer

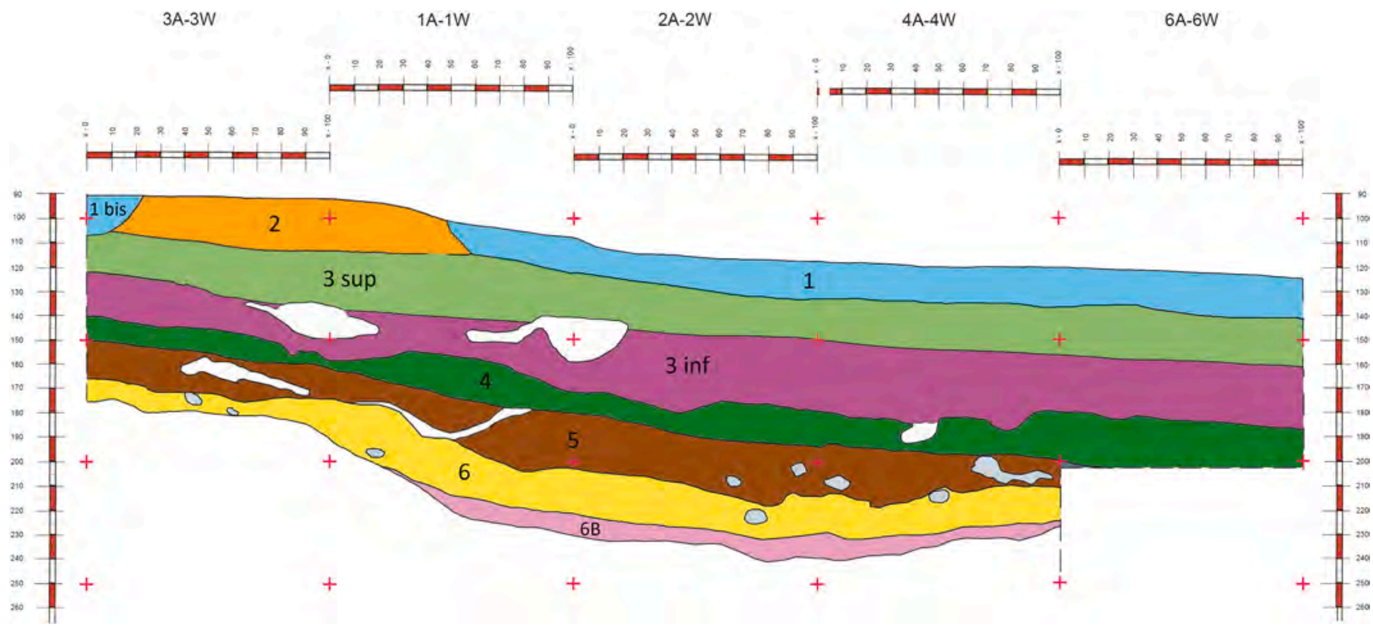

Fig. 3. West-east stratigraphic profile from the Esplugón site according to Laborda (2019).

Table 1
Radiocarbon dating from the Esplugón site in chronological order (OxCal v 4.3.2. IntCal13, Reimer et al., 2013; Bronk Ramsey, 2017). In italics, the dates which are not in agreement with its stratigraphic position, interpreted as intrusions due to bioturbations.

Sample type	Lab. Ref.	Date BP	Date 2s cal BP	Archaeological Layer	Phase
Bone	Beta 338,509	5970 ± 30	6893–6731	3 sup	EN
Bone	Beta 283,899	6120 ± 40	7159–6903	4	EN
Bone	MAMS 30169	6166 ± 23	7163–6997	6	EN
Bone	MAMS 30168	6282 ± 22	7259–7170	3 sup	LM
Bone	Beta 313,517	6730 ± 40	7668–7514	3 inf	LM
Bone	MAMS 30166	6781 ± 23	7670–7588	2	LM
Bone	Beta 306,723	6950 ± 50	7926–7681	3 inf	LM
Bone	MAMS 30167	7355 ± 23	8291–8044	4	LM
Charcoal	GrA 59,632	7620 ± 40	8519–8366	4	LM
Charcoal	GrA 59,634	7715 ± 45	8585–8419	6	LM
Bone	Beta 306,725	7860 ± 40	8934–8547	5	EM
Charcoal	GrA 59,633	8015 ± 45	9021–8717	5	EM
Bone	Beta 306,722	8380 ± 40	9486–9300	6	EM

(*Cervus elaphus*), roe deer (*Capreolus*), and wild boar (*Sus scrofa*) (Obón et al., 2019). Despite the presence of some domestic animals only in layer 2, neither traces related to livestock sheltering and feeding nor storage structures have been found so far at the site (Laborda, 2019).

Esolugón is located at 800 m asl. This area is currently characterized by a continental Mediterranean climate with long, dry summers, an average annual temperature between 12 °C and 14 °C, and 500 mm of annual precipitation. The vegetation is characteristic of the transitional zone between the meso-Mediterranean and the oro-Mediterranean biogeographic zones (Rivas Martínez, 1982). Present-day vegetation is influenced by the altitudinal gradient, relief, calcareous lithology and the high levels of human impact. Vegetation around the site is dominated by degraded forest of deciduous *Quercus* (*Quercus faginea* Lam. and *Quercus cerrioides* Wilk & Costa), Scots pine (*Pinus sylvestris* L.), and mainly extensive plantations of Austrian pine (*Pinus nigra* subsp. *laricio* Maire) growing throughout the valley. Boxwood (*Buxus sempervirens* L.), hawthorn (*Crataegus monogyna* Jacq.), dogwood (*Cornus sanguinea* L.), and brooms (*Echinospartum horridum* (Vahl) Rothm), grow abundantly in the scrubland and forest edges. The proximity of the Guarga river defines the ample presence of riparian vegetation dominated by black poplar (*Populus nigra* L.) and willow (*Salix eleagnos* Scop.).

3. Materials and methods

3.1. Materials

Archaeological works started in 2009. Specific strategies of sampling and recovery for archaeobotanical remains have been followed at Esplugón site during the 2012, 2013 and 2017 fieldwork seasons. Archaeological layers are characterized by high density and good preservation of charred wood remains. Hand-picking of visible charcoal remains found during fieldwork was accompanied by the wet sieving of all the excavated sediment through a 2-1 mm mesh. Also, flotation tests with a 0,5–0,25 mm mesh of 20 L of sediment per square meter and archaeological layer were performed by M. Alcolea in the Laboratory of Prehistory of the University of Zaragoza in 2018. No carpological remains have been found so far in the sampled archaeological deposit. Charred wood identified in this work corresponds to scattered charcoal in the sediment from samples recovered by hand-picking, wet sieving and flotation. Scattered charcoal is the result of consecutive combustion events reflecting successive collections of firewood (Chabal, 1997). It constitutes a valuable source of information about the surrounding vegetation of the site and the activities of human groups in the past (Chabal et al., 1999; Théry-Parisot et al., 2010).

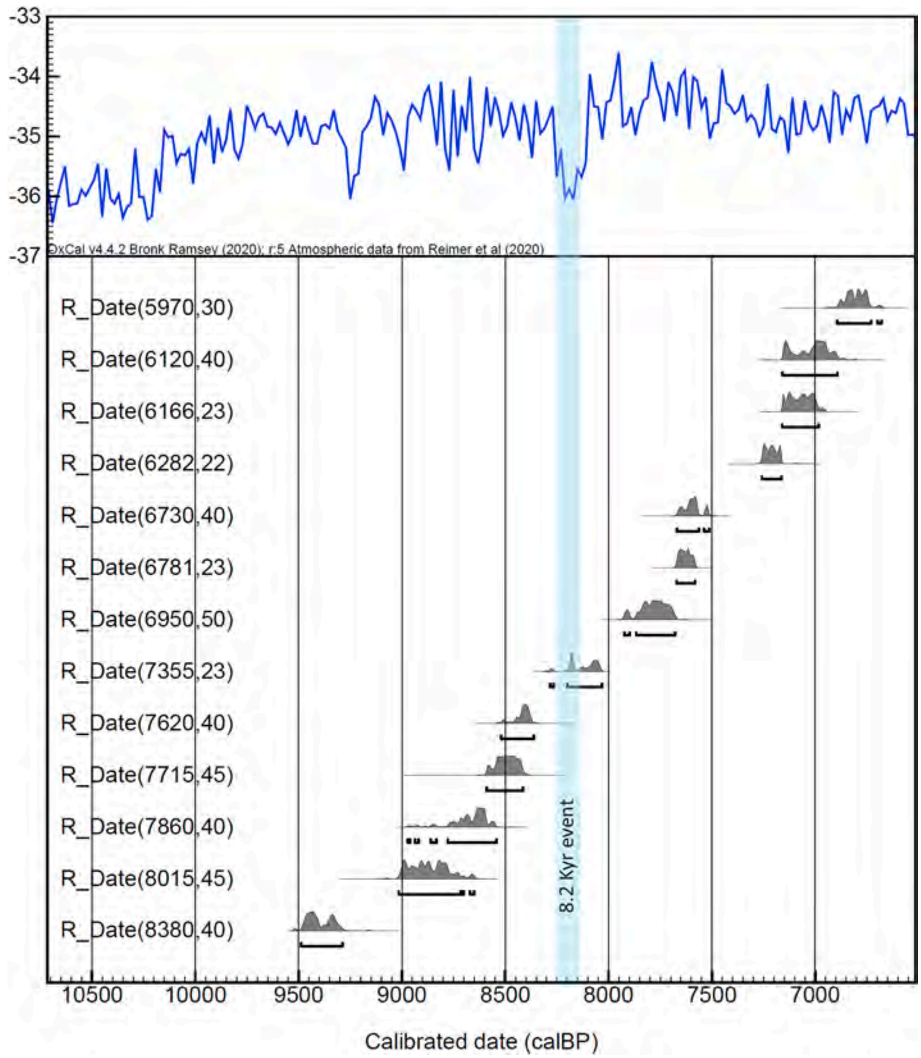

Fig. 4. Plotted dates 14C-AMS cal BP from the Esplugón site and GRIP climate curve prepared by the authors. Dates calibrated with OxCal v4.4 (Bronk Ramsey, 2017) and atmospheric curve IntCal20 (Reimer et al., 2020).

Table 2
Table summarizing applied dendrometric techniques according to Dufraisse et al., same volume.

Dendro-anthracological parameter	Morpho-anatomical criteria	Dendro-anthracological tools
Growth rate	Tree-ring width	Dendrometry by image analysis software
Minimum diameter	Convergence of ligneous rays	Pith location tool and wood diameter estimation Analysis Diameter model (ADmodel)

3.2. Methods

3.2.1. Wood charcoal analyses

Wood charcoal fragments were analysed following the standard methods in anthracology (Vernet, 1973). For the taxonomic identification the wood anatomical features of each fragment were observed along the three anatomical planes under magnifications between ×50 and ×600, using an incident light dark/bright field Leica DM2700M microscope at the University of Zaragoza (Spain). Botanical identifications were made by reference to wood anatomy atlases (Schweingruber, 1990; García Esteban et al., 2003) and modern carbonized wood reference specimens. Nomenclature follows the guidelines in *Tela Botanica* (https://www.tela-botanica.org/). No significant differences in the number of identified taxa have been documented from the screened and floated samples.

3.2.2. Charcoal preservation and condition of wood

Charcoal taphonomy in anthracological research provide additional information about plant growth, wood-gathering and combustion strategies, and post-deposition processes (Marguerie and Hunot, 2007; Théry-Parisot et al., 2010). In this study 4 relevant features were recorded as absent or present: cell collapse, compression wood, radial cracks and vitrification (Braadbaart and Poole, 2008; McParland et al., 2010; Moskal del Hoyo et al., 2010; Caruso-Fermé et al., 2013; Henry and Théry-Parisot, 2014; Vidal-Matutano et al., 2017; Caruso-Fermé and Théry-Parisot, 2018; Allué and Mas, 2020; Courty et al., 2020). These features in archaeological charcoals provide relevant information about the condition of the procured firewood as well as some conditions of the combustion process. Preservation factors also actually affects wood charcoal stucture preservation and therefore the possibilities in the application of dendro-anthracological techniques.

3.2.3. Dendro-anthracological techniques

Dendro-anthracological tools allow measuring dendro-anthracological parameters based on morpho-anatomical criteria

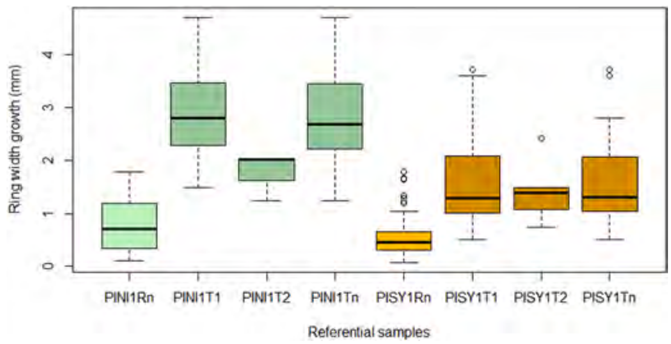

Fig. 5. Boxplot showing tree-ring width analysis results in the modern dendrological reference dataset Secorún. (PINI) *Pinus nigra*, (PISY) *Pinus sylvestris*. (Rn) Total values from branches, (T1) Values from 1.30 height trunks, (T2) Values from apical trunks, (Tn) Total values from trunks.

(Table 2). Dendro-anthracological techniques have been applied on selected *Pinus sylvestris* tp. wood charcoal fragments with the aid of a multizoom microscope (Nikon AZ100) that allows magnification factors from ×4 to ×500 and the NIS Element image analysis software at the National Museum of Natural History (France). The measurements are based on the distance and the angle between two ligneous rays. They were obtained by using a semi-automatic system based on 4 landmarks integrated in the Nikon NIS Elements software. All measurements are taken in transverse (or cross) plane. The selection of fragments was based on two criteria: size and preservation status. In terms of size, a minimum of 4 mm^2 is required in transverse (or cross) plane. Regarding the preservation status, the microscopic wood anatomical features must not be deformed, particularly the ligneous rays and the growth ring boundaries.

3.2.3.1. The pith location tool and wood diameter estimation. *Pinus sylvestris* tp. is an appropriate taxon to apply dendro-anthracological techniques. Regarding microscopic wood anatomy features, the presence of visible ligneous rays allow measuring the charcoal pith distance by applying the trigonometric method (Dufraisse and García-Martínez, 2011; Paradis-Grenouillet et al., 2013). It is also important that a modern reference dataset is available for measuring the caliber of pines in the framework of the DENDRAC project (http://dendrac.mnhn.fr/) (Dufraisse et al., 2020). The pith location tool is used to measure the distance between the charcoal fragment and the theoretical location of the missing pith. This tool is based on measurements of the angle and the distance between two ligneous rays and the application of correction factors (Dufraisse and García-Martínez, 2011; Dufraisse et al., 2020). The angle must be >2° and the distance >2 mm for reducing the margin of error and improving results in dendro-anthracological applications (Dufraisse et al., 2017, 2020). The values were ordered into diameter classes chosen to be compatible with the standards used in dendrometrical plans by foresters: 4 cm, 7 cm and 20 cm but adding some wood cuts. For conifers diameter classes chosen are [0–2] cm, [2–4] cm, [4–7] cm, [7–10] cm, [10–14] cm, [14–20] cm and [>20] cm (Dufraisse et al., 2017).

3.2.3.2. The Analysis Diameter model (ADmodel). The Analysis Diameter model has been developed as a tool dedicated to recompose unburnt wood diameter (UWD) in terms of volume based on the distribution of diameter classes obtained with the pith estimation tool (Dufraisse et al., 2017). It was developed, based on the fact (i) burnt wood undergoes both mass loss and charcoal fragmentation, and (ii) a trunk is biologically considered to be a stack of hollow cones whose thickness corresponds to the amplitude of the diameter classes (Dufraisse, 2006; Dufraisse and García-Martínez, 2011). A calculation table provides the respective distribution of these cones in terms of volume (Dufraisse et al., 2020). This model does not reconstruct the original quantity or volume of burnt wood (Dufraisse and García-Martínez, 2011; Dufraisse et al., 2017).

3.2.3.3. Tree-ring analysis and growth rate. *Pinus sylvestris* tp. wood is characterized in the transverse (or cross) plane by distinct growth ring boundaries (occasionally generating false growth rings in samples from lowlands) and generally abrupt transition from early (EW) to latewood (LW) (Schweingruber, 1990; Schoch et al., 2004). It makes *Pinus sylvestris* tp. an appropriate taxon for measuring tree-ring and EW width. Both has been measured in mm with the NIS Element image analysis software (Nikon AZ100). Correction factors have been applied to reverse shrinkage effect in the tree-ring width during charring (García-Martínez and Dufraisse, 2012). The results were plotted by R software (R Core Team, 2017).

In order to establish a discriminating threshold between slow growth rate and fast growth rate we have built a modern dendrological reference dataset in the southern central Pre-Pyrenees. Trunks and branches of three *Pinus sylvestris* L. and three *Pinus nigra* subsp. *laricio* Maire adult trees between 40 and 50 years old were sampled from the Station 1, called Secorún (UTM 30T 734715 4698130, 1047 m asl), very close to Esplugón (Fig. 1). Our goal was to know the intra-individual and intra-stational variability to establish the existence of different growth patterns between trunk and branches within the same trees and populations. Trunk core discs were sampled at breast height, 1.30 m above ground, as is standard in dendrochronology. Apical trunks are sampled at an average height of 10.5 m at which they have a similar diameter to the sampled branches. Four primary branches regularly located along the trunk height have been sampled and measured for each tree. The samples have been measured to the nearest 0.01 mm with the TSAP-Win program and LINTAB™ (Rinntech, Heidelberg, Germany) (Rinn, 2011).

3.2.4. Anthraco-typological classification

The combination of these dendro-anthracological parameters permits the classification of fragments in four anthraco-groups based on the relationship between the estimated minimum diameter and the growth rate (Dufraisse et al., 2017). Following the foresters' diameter ranking, values < 7 cm were considered to represent branches, and values > 7 cm were considered mature or young trunks. This is the threshold used in this work even though in the case of archaeological charcoal fragments, projected diameters <7 cm could correspond to both branches and young individuals (Picornell-Gelabert and Dufraisse, 2018). Regarding growth rate, the threshold between slow growth and fast growth in this work has been established in 1 mm based on the modern dendrological reference dataset created at the Station 1 Secorún (Fig. 5). An anthraco-typological key to sort *Pinus sylvestris* tp. archaeological charcoal fragments into 4 anthraco-groups is proposed (Fig. 6) following Dufraisse et al. (2017) for deciduous oak. Following these assumptions, the anthraco-group 1 corresponds theoretically to the exploitation of branches while anthraco-groups 2, 3 and 4 represent to the exploitation of trunks. The group 2 would correspond to the inner part of the trunk while groups 3 and 4 to the outer part (see also Picornell-Gelabert et al., same volume).

4. Results

4.1. Taxonomic diversity

We have studied 1480 wood charcoal fragments from 6 archaeological layers (Table 3). The presence of 7 taxa has been documented: ash (*Fraxinus* sp.), juniper (*Juniperus* sp.), Scots type pine (*Pinus sylvestris* tp.), deciduous oak (*Quercus* sp. deciduous), holm oak (*Quercus* sp. evergreen), and thorny shrubs belonging to the Rosaceae family (Rosaceae/Maloideae and *Prunus* sp.). The reported percentages of Scots type pine wood vary between 75 and 100% of the identified fragments in the different archaeological layers (Fig. 7). Based on the total number of

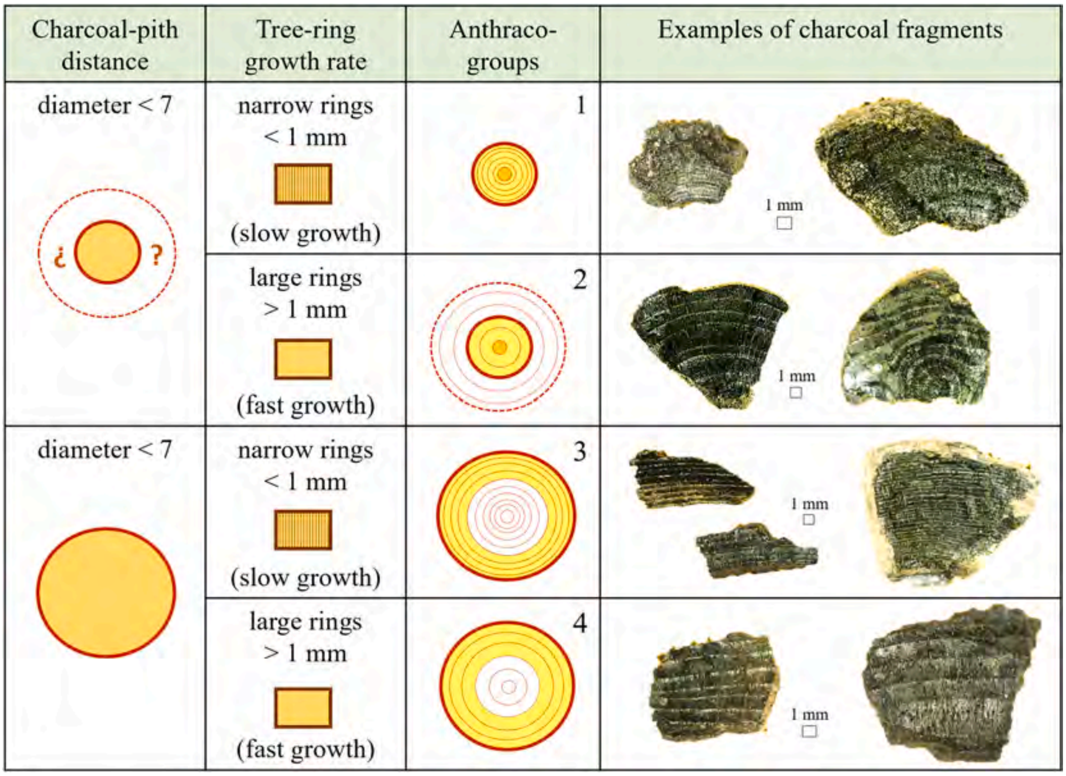

Fig. 6. Anthraco-typological key to sort *Pinus sylvestris* tp. archaeological charcoal fragments into 4 anthraco-groups. Based in Dufraisse et al. (2017) for deciduous oaks.

Table 3
Absolute and relative frequencies of the taxa identified in the Esplugón site. (EM) Early Mesolithic, (LM) Late Mesolithic, (EN) Early Neolithic.

Layer	6		5		4		3 inf		3 sup		2	
Chronology	EM		EM		LM		LM		EN		EN	
Taxa	n	%	n	%	n	%	n	%	n	%	n	%
Fraxinus sp.	–	–	–	–	1	0.5	–	–	–	–	4	1.7
Juniperus sp.	3	1.3	–	–	–	–	–	–	–	–	1	0.4
Pinus sylvestris tp.	222	93.7	193	92.7	194	99	216	96.9	220	90.5	183	76.6
Prunus sp.	2	0.8	–	–	1	0.5	–	–	–	–	2	0.8
Quercus sp. deciduous	4	1.7	13	5.7	–	–	6	2.7	23	9.5	44	18.4
Quercus sp. evergreen	3	1.3	3	1.4	–	–	–	–	–	–	2	0.8
Rosaceae/Maloideae	3	1.3	–	–	–	–	1	0.4	–	–	3	1.3
Total determinable	**237**		**208**		**196**		**223**		**243**		**239**	
Undeterminable	7	2.9	28	11.9	54	21.6	27	10.8	7	2.8	11	4.4
Total	**244**		**236**		**250**		**250**		**250**		**250**	

determined fragments at the site, pine reaches 91%, followed by oak that reaches 6.7% while the remaining taxa comprise c. 2.3%. The high frequency of pine is common in anthracological assemblages from rockshelters in the region during the entire timespan covered by the Esplugón sampled stratigraphy.

4.2. Condition of wood

Relevant features recorded in this study: cell collapse, compression wood, radial cracks and vitrification, entail high percentages in the anthracological assemblage of Esplugón (Table 4 and Fig. 8). They are common alterations in archaeological charcoals.

Cell collapse is commonly associated with decayed or rotten wood caused by fungi and xylophagous insects (Moskal del Hoyo et al., 2010; Henry and Théry-Parisot, 2014; Vidal-Matutano et al., 2017) or chemical and physical alterations that affect deadwood (Allué and Mas, 2020). A high number of fragments shows signs of fungal degradation, affecting 34.9–58.6% of pine charcoal fragments. This alteration inhibits the application of dendro-anthracological techniques to fragments in which an important part of the transverse surface is affected by this parameter.

Compression wood is associated with a loss of verticality in stem growth. In mountain environments, it can affect both branches and trunks growing on acute slopes, thus it cannot be used as a discriminating factor. Reaction wood reaches from 25.2 to 69.6% of the pine charcoal fragments. These fragments have been ommited from dendro-anthracological analysis even though correction factors may reduce the influence of off-centred piths (Dufraisse et al., 2017, 2020).

The presence of radial cracks on the transverse plane affects 5.6–20% of pine charcoal fragments. They are very common in charred wood because of the loss of volatile compounds during the combustion process. Proposed as evidence of the use of green wood as fuel, it has been demonstrated that the occurrence of radial cracks is not correlated with moisture content (Thèry-Parisot and Henry, 2012; Caruso-Fermé and Thèry-Parisot, 2018) being probably important other volatile compounds, e.g. resins, which are common in Scots pines type. Its presence

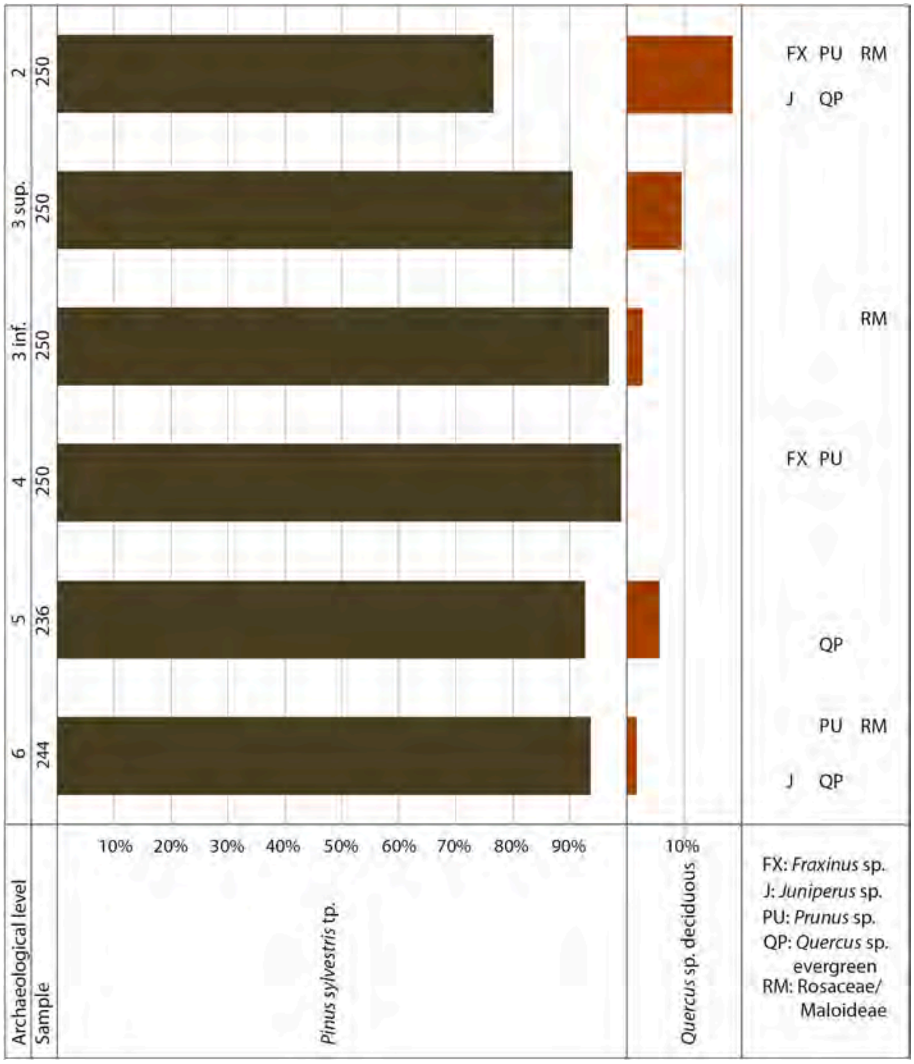

Fig. 7. Anthracological diagram from the Esplugón site (Huesca, NE Iberia).

Table 4
Relevant features recorded in the Esplugón charcoal assemblage. The count is based in a binomial system (presence/absence). The percentages are calculated in relation to the number of charcoal fragments identified as *Pinus sylvestris* tp. except in the case of vitrification, calculated in relation to the total number of studied fragments. (EM) Early Mesolithic, (LM) Late Mesolithic, (EN) Early Nolithic.

Layer	6		5		4		3 inf		3 sup		2	
Chronology	EM		EM		LM		LM		EN		EN	
Alterations	n	%	n	%	n	%	n	%	n	%	n	%
Cells collapse	117	52.7	81	41.9	79	40.7	104	48.1	129	58.6	64	34.9
Compassion wood	111	50	83	59.7	135	69.6	146	67.6	88	40	46	25.2
Radial cracks	44	19.8	21	10.8	34	17.5	26	5.6	44	20	18	9.8
Total *Pinus*	**222**	**100**	**193**	**100**	**194**	**100**	**216**	**100**	**220**	**100**	**183**	**100**
Vitrification	14	5.7	28	11.9	61	24.4	31	12.4	8	3.2	14	5.6
Total fragments	**244**	100	**236**	100	**250**	100	**250**	100	**250**	100	**250**	100

could affect and deform ray distance and angle. Heavily affected pine charcoal fragments have been also omitted from dendro-anthracological analysis.

Finally, vitrification affects 3.2–24.4% of charcoal fragments. This feature often does not allow the taxonomic ascription of the affected charcoal fragments. It is the main cause of the high number of fragments that could not be determined (classified as undeterminable; see Table 3). Although in the current state of the research the causes of this feature are not known (Braadbaart and Poole, 2008; McParland et al., 2010; Courty et al., 2020), it is related to the combustion process. It is especially usual in conifers, probably associated with some specific compounds as resins. The high presence of reaction wood, which increases the lignin in tracheid cell walls, a thermoplastic compound, could also favour the vitrification of wood (Alcolea, 2017).

4.3. Minimum calibres of exploited stems

Charcoal preservation and condition of wood have strongly conditioned the application of dendrometric tools. Although only 199 pine wood charcoal fragments met special requirements of size and

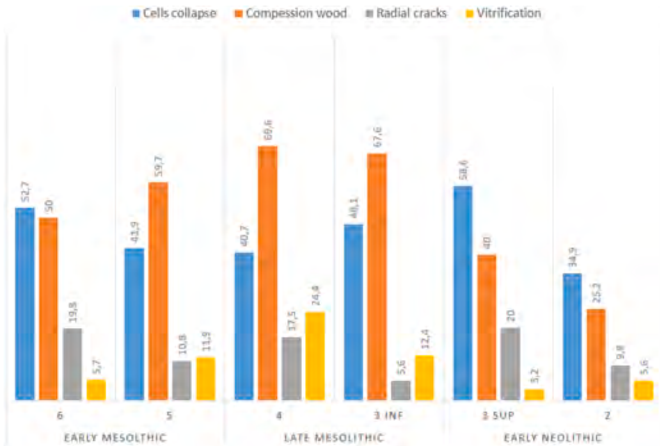

Fig. 8. Condition of wood at the charcoal assemblage from Esplugón by a binomial system based on presence or absence. The percentages of alteration are calculated in relation to the total number of studied fragments. (EM) Early Mesolithic, (LM) Late Mesolithic, (EN) Early Nolithic.

preservation status, there are evenly spread across the different phases (Table 5). Both 2 Mesolithic (n = 155) and Neolithic (n = 44) stages are well-represented in the subsample. Trigonometric method has been applied to estimate minimum calibres of exploited firewood. Diameter classes for each stage have been established on the base of minimum diameters of each fragment using pith location tool and wood diameter estimation (Table 5). The UDW has been recomposed using the Analysis Diameter model (ADmodel) (available in https://dendrac.mnhn.fr/spip.php?article237) (Dufraisse et al., 2020).

At the Esplugón site, the exploitation of small calibres predominates throughout the entire archaeological sequence. Minimum diameter classes between 4 and 7 cm predominate during the 2 Mesolithic stages (EM and LM). During the Early Neolithic (EN) this diameter class diminishes while the diameter classes between 2 and 4 cm and 7 and 10 cm gain importance. Above 10 cm of diameter few fragments have been documented (Table 5). Recomposed percentages (AD%) reinforce the observed tendency.

Usually, the diameter classes <7 cm correspond to branches and/or the inner part of the trunks, and the diameter classes >7 cm correspond to the outer part of the trunks (Deleuze et al., 2014). This assertion was tested and confirmed on *Pinus halepensis* (Picornell et al., same volume). However, the class between 7 and 10 cm of diameter, considered as a transition, is difficult to classify in this scheme. To discriminate the parts of the exploited stems it is necessary to combine minimum calibres with the growth rate of tree-rings.

4.4. Growth rate

Growth rate has been calculated in 199 pine charcoal fragments by measuring growth ring width. A total of 1788 growth ring width has been measured and the average value has been calculated to obtain growth rate of each charcoal fragment. Results show calibrated values after applying correction factors (García-Martínez and Dufraisse, 2012).

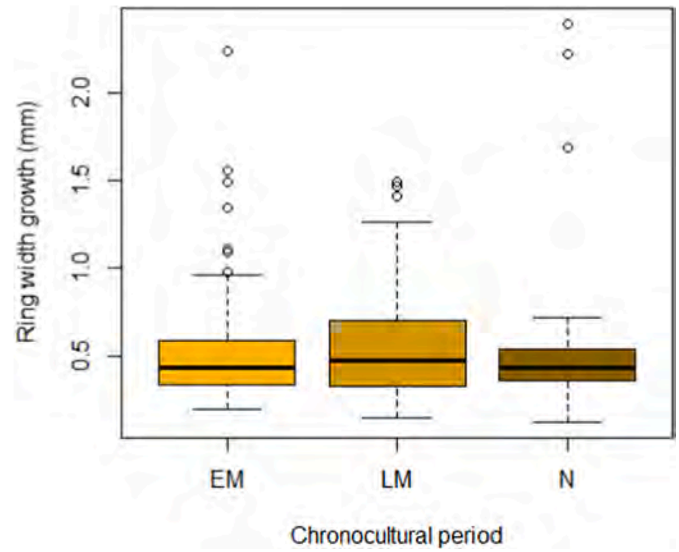

Fig. 9. Boxplots showing tree-ring width analysis results in the Esplugón site. Results organized by chronological periods: (EM) Early Mesolithic, (LM) Late Mesolithic, (N) Early Neolithic.

No major differences in growth rate have been documented among the different stages (Fig. 9). Organizing growth ring width by diameter classes it can be observed that average values are higher in the diametrer classes >10 cm. Wider growth rings are documented in the 2–4 cm and 4–7 cm diameter classes but they always constitute outlier values (Fig. 10).

The results of dendrological analysis of the modern dendrological reference dataset from Secorún show clear intra-individual differences in growth rate between trunks and branches from the same tree and they are reproduced in all sampled individuals (Fig. 5). According to these data, the threshold between slow and fast growth rate has been established in 1 mm. Archaeological pine charcoal fragments that present average growth ring width values < 1 mm are considered as slow growth rate and those that present values > 1 mm are considered as fast growth rate.

4.5. Anthraco-typological classification: the exploited parts of plants

Anthraco-typological classification of the studied anthracological assemblage combines the estimation of the minimum calibres and the growth rate (Dufraisse et al., 2017). The 199 pine wood charcoal fragments have been classified in 4 groups (Table 6). The anthraco-type 1, that theoretically correspond to branches, has the largest number of fragments in the 3 studied stages, reaching almost 80% during the Early

Table 5
Diameter classes of charcoal fragments analysed by dendrometric techniques at the Esplugón site. AD% = % corrected recomposed. (EM) Early Mesolithic, (LM) Late Mesolithic, (EN) Early Neolithic.

Chronology	EM			LM			EN		
Diameter class	n	%	AD%	n	%	AD%	N	%	AD%
0–2 cm	3	4.5	0	7	8.0	0	2	4.5	0
2–4 cm	27	40.3	32.3	32	36.4	31.3	21	47.7	46.6
4–7 cm	26	38.8	42.4	33	37.5	47.4	11	25	20.0
7–10 cm	8	12.0	19.8	9	10.2	14.6	7	15.9	25.8
10–14 cm	1	1.5	1.8	5	5.7	2.1	1	2.8	1.8
14–20 cm	1	1.5	2.3	2	2.8	4.7	1	2.8	3.2
>20 cm	1	1.5	1.4	0	0	0	1	2.8	2.7
Total	**67**	**100**	**100**	**88**	**100**	**100**	**44**	**100**	**100**

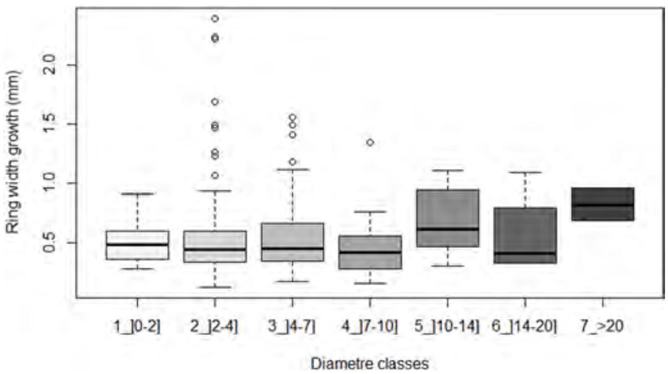

Fig. 10. Boxplots showing tree-ring width analysis results in the Esplugón site. Results organized by diametre classes.

Mesolithic (EM) and 70% during the Late Mesolithic (LM) and Early Neolithic (EN). The anthraco-types 2, 3 and 4, that theoretically correspond to different parts of the trunk, represent lower percentages, reaching 20% during the Early Mesolithic (EM) and almost 30% during the Late Mesolithic (LM) and Early Neolithic (EN).

5. Firewood procurement in the southern central Pre-Pyrenees during the Early-Middle Holocene

5.1. Floristic composition of the forest: taxonomic analyses

5.1.1. Early Mesolithic (9.4–8.5 kyr cal BP)

During the Early Mesolithic occupation in Esplugón, the *Pinus sylvestris* tp. is the preferred wood for fuel with values reaching up to 90%. Even though extremely high values of conifers persist at the onset of the Holocene in the southern central Pre-Pyrenees in both lowland and high altitudes, pollen lake records suggest the rapid spread of mesophytes in the low montane bioclimatic zone, mainly deciduous *Quercus*, after ca. 9.5 kyr cal BP due to increases in temperature and water availability, and warmer summers (Pérez-Sanz, 2014; González-Sampériz et al., 2017). These are present in the anthracological record of Esplugón in low frequencies. Deciduous and evergreen *Quercus* hardly represent 3% of identified wood charcoal fragments in layer 6 and 7% in layer 5. Shrubby taxa typical of forest edges (*Juniperus* sp., *Prunus* sp., Rosaceae/Maloideae) complete the list also reaching low values in the layer 6 and disappearing in layer 5.

Other Pre-Pyrenean anthracological sequences show similar patterns: *Pinus sylvestris* tp. prevails in low montane assemblages until ca. 8.5 kyr cal BP as indicated by the anthracological assemblages from Forcas (Alcolea, 2015), Artusia (García-Martínez de Lagrán, 2017) and the Arba de Biel sites (Montes et al., 2016). At the lowlands, Scots type pine forests are replaced by thermophilous Mediterranean pines (*Pinus halepensis*) from ca. 8.7 kyr cal BP (Alcolea et al., 2017a; Alcolea, 2018; Aranbarri et al., 2020).

Table 6
Anthraco-groups to which charcoal fragments analysed at the Esplugón site belong according Dufraisse et al. (2017). (1) Diameter <7 and growth rate <1 mm, (2) diameter <7 and growth rate >1 mm, (3) diameter >7 and growth rate >1 mm, (4) diameter >7 and growth rate >1 mm. (EM) Early Mesolithic, (LM) Late Mesolithic, (EN) Early Neolithic.

Chronology	EM		LM		EN	
Anthraco-type	*n*	%	*n*	%	*n*	%
1	53	79.1	62	70.5	31	70.5
2	3	4.5	10	11.4	3	6.8
3	8	11.9	16	18.2	10	22.7
4	3	4.5	0	0	0	0
Total	**67**	**100**	**88**	**100**	**44**	**100**

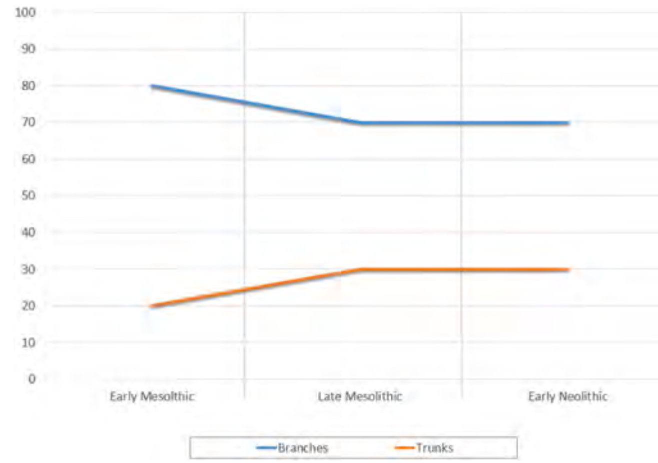

Fig. 11. Evolution of the parts of plants exploited at the Esplugón site.

5.1.2. Late Mesolithic (8.5–7.5 kyr cal BP)

After 8.2 kyr cal BP pollen lake records indicate that semi-deciduous and evergreen *Quercus* replaced mesophytes in the lowlands and low montane bioclimatic zone (González-Sampériz et al., 2017). Simultaneously, these deciduous forests replaced pinewoods also in the high montane and subalpine (Plà and Catalán, 2005; González-Sampériz et al., 2005; Pérez-Sanz et al., 2013) indicating a relevant increase in winter temperatures and a shift in the precipitation regime with a more evenly distributed rainfall (Magny et al., 2002; Morellón et al., 2009).

Pinus sylvestris tp. persists as the most consumed wood for fuel in Esplugón during its Late Mesolithic occupation in layers 4 and 3 inf. between 8.5 and 7.5 kyr cal BP. Accompanying taxa are basically the same as in the previous period and they do not reach 10% of wood

Fig. 12. Architecture of *Pinus sylvestris* L. depending on whether it grew isolated (left) or in population (right) according to Riou-Nivert (2001), 107.

Fig. 13. Current vegetation around Esplugón. A. Map based on Forest Map MFE50 (Spanish Government) , black star marks the site location. B. Deadwood accumulated in the Guarga riverbanks because of the presence of large blocks of limestone. July of 2013. C. *Pinus sylvestris* L. currently growing next to the site. Photographs: M. Alcolea.

charcoal fragments. The only novelty is the presence of riparian vegetation represented by a single charcoal fragment of ash (*Fraxinus* sp.). This resilient tendency of low montane pine forests in the southern central Pyrenees is also supported by the anthracological records of Forcas (Alcolea, 2015) and Arba de Biel sites (Montes et al., 2016). On the contrary, the human use of widespread deciduous forest is well-documented in south eastern Pyrenean deposits (Zapata and Peña-Chocarro, 2005; Ruíz-Alonso and Zapata, 2017).

5.1.3. Early Neolithic (7.3–6.8 kyr cal BP)

Despite the chronological gap in the sequence suggested by radiocarbon dating (7.5–7.3 kyr cal BP) *Pinus sylvestris* tp. continues being the most consumed wood for fuel in Esplugón, reaching up to 90% in layer 3 sup., and 75% in layer 2. On the contrary, *Pinus sylvestris* tp. has completely disappeared in the eastern Pre-Pyrenean sequences at 7.3 kyr cal BP, mainly replaced by deciduous *Quercus* and yew (*Taxus baccata*) accompanied by shrubby taxa (Ruíz-Alonso and Zapata, 2017). The Neolithic deposit of Esplugón just start showing a trend towards the use of deciduous taxa in layer 2, dated to 6.8 kyr cal BP, where deciduous *Quercus* reaches almost 20% accompanied by all the aforementioned taxa. Resilience of Scots type pinewoods at Esplugón is supported by other wood charcoal analyses in southern central Pre-Pyrenees from the low montane (Alcolea, 2015; Montes et al., 2016; Alcolea et al., 2017b) to the subalpine bioclimatic zones (Heinz and Vernet, 1995; Obea et al., 2011; Obea, 2014) at least until 6 kyr cal BP. The limited presence of other taxa in the anthracological record could be related to the structure of pine forests with low shrubby undergrowth (Allué et al., 2018).

5.2. Structure of the forest: dendro-anthracological insights

5.2.1. The exploited parts of plants

Pinus sylvestris tp. is the main taxon exploited for fuel throughout the archaeological sequence of Esplugón and also in other short-term human occupations in rock-shelters, like Forcas (Alcolea, 2016) and the Arba de Biel sites (Montes et al., 2016) suggesting that this woody taxon is the most available in the immediate vicinity of the sites. Even though the resilience of Scots type pine forests has been proposed in some inland regions of Mediterranean Iberia until ca. 7.7 kyr cal BP (Rubiales et al., 2010; Aranbarri et al., 2014) or even during the whole Middle Holocene (8.2–4.2 kyr cal BP) (Franco Múgica et al., 2001, 2005) due to the delayed onset of the interglacial conditions based on high continentality, water shortage and absence of well-developed soil (Carrión et al., 2010), regional pollen data in the southern central Pyrenees and Pre-Pyrenees point to a retreat of Scots type pine forests from 9.5 kyr cal BP, more evident after 7.3 kyr cal BP (González-Sampériz et al., 2017). Wood charcoal analysis at Chaves (7.6–7.0 kyr cal BP) reveals the use of a broad spectrum of woody taxa (Alcolea et al., 2017b) as expected in a long-term settlement where diversified human activities took place (Utrilla and Laborda, 2018). Although Scots type pine is the most consumed taxon it only reaches 30% at level Ib (7.6–7.3 kyr cal BP) (Alcolea et al., 2017b).

Regarding the parts of exploited plants, no big differences have been documented between the different stages of human occupation. The use of branches, between 70 and 80%, prevails over the use of trunks, between 20 and 30% throughout the entire archaeological sequence (Fig. 11). The arrival of the Neolithic does not introduce a change in forest management strategies. This is consistent with the documented uses of the rock-shelter. The main human activity is always the hunting of the forest wild species like roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*) and wild boar (*Sus scrofa*) (Obón et al., 2019). Domestic animals are restricted to layer 2 and neither storage structures nor stabling layers implying chages in the site function have been found (Laborda, 2019).

5.2.2. Scots type pine forests exploitation as fuel

The three native species of cryophillous montane pines growing in NE Iberia are normally grouped in the taxon *Pinus sylvestris* tp. Montane Iberian pines include *Pinus sylvestris* L., *Pinus mugo* subsp. *uncinata* (Ramond ex DC.) Domin, *Pinus nigra* subsp. *salzmannii* (Dunal) Franco. Theoretically they grow nowadays at different altitudes in NE Iberia: *Pinus nigra* between 500 and 800 m asl, *Pinus sylvestris* between 800 and 1700 m asl, and *Pinus uncinata* above 1800 m asl (Costa et al., 2001), but usually they overlap biogeographically and can interbreed (Quézel and Médail, 2003). These trees do not show differences in wood anatomy allowing to identify each of them (Greguss, 1955; Schweingruber, 1990) so its past distribution at species level is not well-known (Roiron et al.,

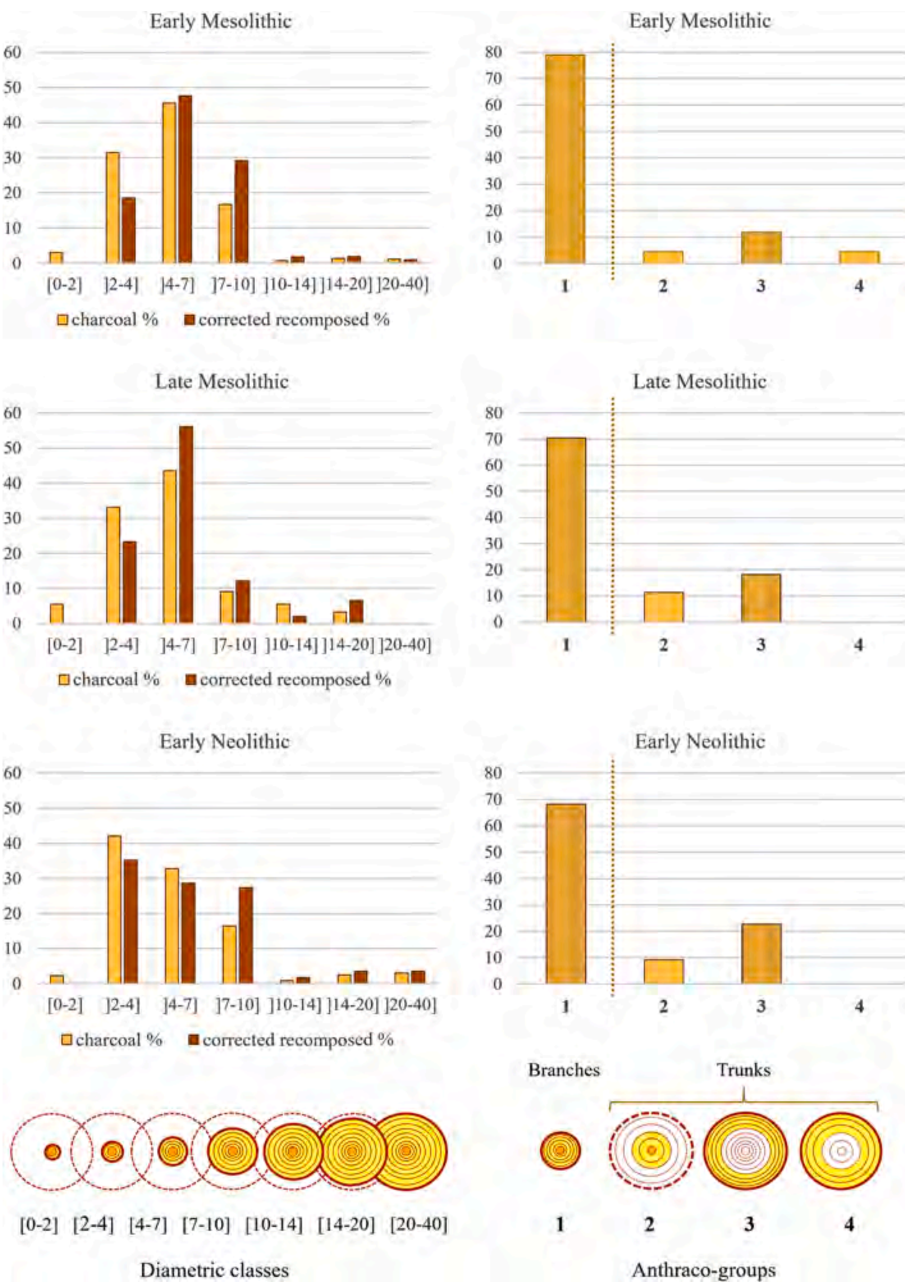

Fig. 14. Diagrams summarizing the results of the application of dendro-anthracological tools to wood charcoal fragments in the Esplugón site. At left, diametric classes obtained by trigonometric method expressed in percentages by fragments and corrected recomposed percentages by ADmodel (available in https://dendrac.mnhn.fr/spip.php?article237). At right, measured fragments grouped in anthraco-groups based in anthraco-typological key showed in Fig. 6. The results are grouped in chrono-cultural periods.

2013 Allué et al., 2018). Likewise, is not possible to know if our deposits contain more than one species of Scots type pine. In any case, they share biogeographical parameters and tree architecture.

We propose that the architecture of Scots type pines strongly influences their use as firewood. The architecture of the tree is characteristic of each species and allows to understand its growth strategy and occupation of the space. Scots type pine trees present a monopodial structure composed of a single stem or trunk that reaches up to 30 m. The trunk is generally straight but it can present alterations due to the ecological conditions of its growth (strong winds, the weight of the snow, the extreme dryness or slope angle). The primary branches grow in polycyclic crowns, formed annually at the same level around the trunk parallel to each other and displaying similar calibres. These trees are characterized by a strong apical dominance, meaning that the branches develop more slowly than the trunk (Riou-Nivert, 2001).

Scots type pine forests have a pyramidal or conical shape when young, which nevertheless changes with age. The silouette of adult trees can vary depending on whether they grow isolated or in groups (Fig. 12). When they grow isolated generally green branches reach the foot of the tree. When they grow in groups, these trees exert competition over each other at two levels: (i) in the soil, which affects their radical underground system, and (ii) in the air, which affects their air system, that is, the branches. In the first case, they “run away” from each other, moving as far as possible to take advantage of soil moisture, giving rise in general to open forests. In the second case, they “run away” seeking to reach a greater height to have more access to light. The growth in population also provides a lateral shelter, that results in thinner branches and a reduced growth in diameter of the trunk (Riou-Nivert, 2001). In this case, the lower branches under cover usually die due to lack of light. There is very little physiological connection between branches and trunk (Shigo et al., 1987). When they are no longer functional, a resinous partition isolates them to protect the trunk from infections. The branch becomes parasitic and stops participating in the life of the tree. When the process of decomposition by microorganisms is advanced the branch falls according to the phenomenon known as branch shedding (or natural pruning) (Riou-Nivert, 2001). This observation is supported by the high percentages of decayed wood documented in the record (Fig. 8), which are associated with the use of deadwood as fuel (Allué et al., 2009; Henry and Théry-Parisot, 2014; Vidal Matutano et al., 2017).

Different palaeoenvironmental and cultural factors has been previosly proposed in the preferential use of *Pinus sylvestris* tp. as fuelwood by European hunter-gatherer groups. The significant mobility of human groups, resulting in seasonal occupations of the sites, and a relatively limited lithic tool kit would undoubtedly have had an impact on firewood procurement. A marked preference for deadwood procurement optimally ensures the supply during short-term occupations while green wood, which must be cut and dried over several months, is more suited to long-term occupations. Also combustion properties largely depend on the condition (dead or living, dry or green) and morphological (size and diameter) state of wood more than species (Allué et al., 2009; Henry and Théry-Parisot, 2014; Théry-Parisot et al., 2016; Vidal Matutano et al., 2017). Also, specific functions of the sites could influence choices underlying the collection of wood, as is the case of Chauvet-Pont d'Arc, where Scots pine type is selected to provide light and produce charcoal for its use in rockart motifs painting (Théry-Parisot and Thiébault, 2005; Théry-Parisot et al., 2018).

Our hypothesis is that the selection of Scots type pine wood in Mesolithic-Neolithic transition Pre-Pyrenean sequences could be related to its capacity to produce a large amount of dead biomass, almost dry, easy to gather, and more or less regular in size and diameter, resulting in a certain overrepresentation of this taxon in seasonal or temporary settlements in rock-shelters located in the southern central Pre-Pyrenees and Pyrenees (Fig. 13). Apart from small calibre branches, probably related to the branch shedding of defunct branches, the discrete presence of the largest diameter classes suggests the consumption of trunks as well (Fig. 14). This does not necessarily imply that live trees were felled for firewood use. Scots type pine forests tend to alternate live trees with dead trees (Costa et al., 2001), so dry trunks that remain standing for years could be easily cut down by prehistoric groups. Forest expansion attested from ca. 9.5 kyr cal BP and changes in fire regimes (González-Sampériz, 2004; Gil-Romera et al., 2014) could have resulted in a higher biomass availability.

6. Conclusions and perspectives

Summing up, wood charcoal analysis at Esplugón reveals that Scots type pine (*Pinus sylvestris* tp.) is the most consumed firewood along the entire archaeological sequence. Although deciduous *Quercus* appears from the base of the sequence, its use as fuel is always secondary. These results match those from other studies in low montane rock-shelters containing long sequences of human occupation during the Mesolithic-Neolithic in the southern central Pre-Pyrenees.

The recurrent observation of anatomical wood decay features suggests the main use of deadwood as fuel. First dendro-anthracological results suggest the large use of branches and sometime trunks along the whole archaeological sequence. Small calibre branches are more abundant in the record, probably related to branch shedding of defunct branches. The discrete presence of the largest diameter classes points to the consumption of trunks, possibly taking advantage of the fact that *Pinus sylvestris* L. forests frequently alternate live and dead trees.

No important changes in forest management have been documented between the last hunther-gatherers and the first farmers at Esplugón, neither in terms of species nor of the exploited parts of plants. So, we propose that there was continuity in the patterns of firewood gathering as domestic fuel across the successive short-term occupations of the rock-shelter mainly dedicated to the hunting of forest species despite the appearance of the first domesticated elements with the arrival of the Neolithic.

Finally, the application of dendro-anthracological tools to NE Iberia is novel. The development of this research line applied to Mesolithic-Neolithic transition and more recent archaeological contexts as well as to different taxa could be key for understanding different uses of wood, fuelwood procurement and forest management in the past.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This study agrees with the objectives to the project *Luz e calor na cova. Uso y aprovechamiento del combustible vegetal por parte de las sociedades cazadoras-recolectoras y primeras productoras del norte de Iberia.* M. Alcolea is funded by a Post-Doc Grant from Xunta de Galicia mod. A (Ref. ED481B 2018/016). The funding of the research has been possible thanks to the R + D Project HAR 2017-85023-P *Gaps and sites. Vacíos y ocupaciones en la Prehistoria de la Cuenca del Ebro* funded by the Ministry of Science and Innovation (Spain) and the research group PRESAGE, CNRS UMR 7209 *Archéozoologie, Archéobotanique: Sociétés, Pratiques et Environnements* (National Museum of Natural History, France). The authors acknowledge the heads of the archaeological excavation P. Utrilla (University of Zaragoza), A. Berdejo and A. Obón (*De la Roca al Metal* independent research Group), the access to archaeobotanical materials. The authors acknowledge M. Lemoine (MNHN) their assistance in dendro-anthracological data curation. We also would like to specially thank the guest editor, Eleni Asouti, the invitation to participate in this special issue.

References

Alcolea, M., 2015. La secuencia antracológica de Forcas II (Graus, Huesca) y su contribución al conocimiento de la evolución paleoambiental holocena del Prepirineo central. Saldvie 15, 53–63.

Alcolea, M., 2017. Mesolithic fuel use and woodland in the Middle Ebro Valley (NE Spain) through wood charcoal analysis. Quat. Int. 431, 39–51.

Alcolea, M., Domingo, R., Piqué, R., Montes, L., 2017. Landscape and firewood at Espantalobos mesolithic site (Huesca, Spain). first results. Quat. Int. 457, 198–210.

Alcolea, M., 2018. Donde hubo fuego: estudio de la gestión humana de la madera como recurso en el valle del Ebro entre el Tardiglaciar y el Holoceno Medio, vol. 53. Prensas Universitarias. University of Zaragoza.

Alcolea, M., Utrilla, P., Piqué, R., Laborda, R., Mazo, C., 2017. Fuel and acorns: early neolithic plant use from cueva de Chaves (NE Spain). Quat. Int. 457, 228–239.

Allué, E., Euba, I., Solé, A., 2009. Charcoal taphonomy: the study of the cell structure and surface deformations of pinus sylvestris type for the understanding of formation processes of archaeological charcoal assemblages. Journal of Taphonomy 7 (2–3), 57–72.

Allué, E., Martínez-Moreno, J., Alonso, N., Mora, R., 2012. Changes in the vegetation and human management of forest resources in mountain ecosystems at the beginning of MIS 1 (14.7–8 ka cal BP) in Balma Guilanyà (Southeastern Pre-Pyrenees, Spain). C.R. Palevol 11, 507–518.

Allué, E., Solé, A., Burguet-Coca, A., 2017a. Fuel exploitation among Neanderthals based on the anthracological record from Abric Romaní (Capellades, NE Spain). Quat. Int. 431, 6–15.

Allué, E., Picornell-Gelabert, L., Daura, J., Sanz, M., 2017b. Reconstruction of the palaeoenvironment and anthropogenic activity from the upper pleistocene/holocene anthracological records of the NE iberian Peninsula (barcelona, Spain). Quat. Int. 457, 172–189.

Allué, E., Martínez-Moreno, J., Roy, M., Benito-Calvo, A., Mora, R., 2018. Montane pine forests in NE Iberia during MIS 3 and MIS 2. a study based on new anthracological evidence from cova gran (santa linya, iberian pre-pyrenees). Rev. Palaeobot. Palynol. 258, 62–72.

Allué, E., Mas, B., 2020. The meaning of Pinus sylvestris-type charcoal taphonomic markers in Palaeolithic sites in NE Iberia. J. Archaeol. Sci. Rep. 30, 102231.

Aranbarri, J., Alcolea, M., Badal, E., Vila, S., Allué, E., Iriarte-Chiapusso, M.J., Sebastian, M., Magri, D., González-Sampériz, P., 2020. Holocene history of Aleppo pine (*Pinus halepensis* Mill.) woodlands in the Ebro Basin (NE Spain): climate-biased or human-induced? Rev. Palaeobot. Palynol. 279, 104240.

Aranbarri, J., González-Sampériz, P., Valero-Garcés, B., Moreno, A., Gil-Romera, G., Sevilla-Callejo, M., García-Prieto, E., Di Rita, Mata, M.P., Morellóne, M., Magri, D., Rodríguez-Lázaro, J., Carrión, J.S., 2014. Rapid climatic changes and resilient vegetation during the Lateglacial and Holocene in a continental region of south-western Europe. Global Planet. Change 114, 50–65.

Aura, J.E., Carrión, Y., Estrelles, E., Jorda, G.P., 2005. Plant economy of hunter-gatherer groups at the end of the last Ice Age: plant macroremains from the cave of Santa Maira (Alacant, Spain) ca. 12000–9000 BP. Veg. Hist. Archaeobotany 14 (4), 542–550.

Badal, E., Carrión, Y., Figueiral, I., Rodríguez-Ariza, M.O., 2012a. Pinares y enebrales. El paisaje solutrense en Iberia. Espacio Tiempo y Forma. Serie I. Prehistoria y Arqueología 1 (5).
Badal, E., Villaverde, V., Zilhao, J., 2012b. Middle Palaeolithic wood charcoal from three sites in south and West Iberia. Biogeographical implication. Sagvntvm Extra 13, 13–24.
Badal, E., Martínez-Varea, C., 2018. Different parts of the same plants. Charcoals and seeds from Cova de les Cendres (Alicante, Spain). Quat. Int. 463, 391–400.
Barandiarán, I., Cava, A., 2002. Cazadores-recolectores en el Pirineo navarro. El sitio de Aizpea entre 8000 y el 6000 años antes de ahora. Veleia, vol. 10.
Berdejo, A., Obón, A., 2013. Un nuevo yacimiento neolítico en las sierras exteriores del Pirineo central: el Esplugón (Villobas). Bolskan 2, 139–144.
Berdejo, A., Obón, A., Utrilla, P., Laborda, R., Sierra, A., Alcolea, M., Bea, M., Domingo, R., 2018. El abrigo de El Esplugón (Molino de Billobas-Sabiñánigo, Huesca). Un ejemplo de la transición Mesolítico/Neolítico en el prepirineo oscense. In: Rodanés, J.M., Lorenzo, J.I. (Eds.), Actas del II Congreso de Arqueología y Patrimonio Aragonés, pp. 29–40.
Braadbaart, F., Poole, I., 2008. Morphological, chemical and physical changes during charcoalification of wood and its relevance to archaeological contexts. J. Archaeol. Sci. 35, 2434–2445.
Bronk Ramsey, C., 2017. OxCal Program, Version 4.3. Oxford Radiocarbon Accelerator Unit. University of, Oxford.
Carrión, J.S., Finlayson, C., Fernandez, S., Finlayson, G., Allué, E., López-Sáez, J.A., López-Garcia, P., Gil-Romera, G., Bailey, G., González-Sampériz, P., 2008. A coastal reservoir of biodiversity for Upper Pleistocene human populations: palaeoecological investigations in Gorham's Cave (Gibraltar) in the context of the Iberian Peninsula. Quat. Sci. Rev. 27, 2118–2135.
Carrión, J.S., Fernández, S., González-Sampériz, P., Gil-Romera, G., Badal, E., Carrión, Y., López-Merino, L., López-Sáez, J.A., Fierro, E., Burjachs, F., 2010. Expected trends and surprises in the lateglacial and Holocene vegetation history of the iberian Peninsula and balearic islands. Rev. Palaeobot. Palynol. 162, 458–475.
Carrión, Y., Calatayud, P.G., Eixea, A., Martínez-Varea, C.M., Tormo, C., Badal, E., Zilhao, J., Villaverde, V., 2019. Climate, environment and human behaviour in the Middle Palaeolithic of Abrigo de la Quebrada (Valencia, Spain): the evidence from charred plant and micromammal remains. Quat. Sci. Rev. 217, 152–168.
Caruso-Fermé, L., Huerta, R., Théry-Parisot, I., 2013. ¿Recolectar o cortar?: modalidades de adquisición del material leñoso en cazadores-recolectores de Patagonia. In: Zangrando, A., Barberena, R., Gil, A., Neme, G., Giardina, M., Luna, L., Otaola, C., Paulides, S., Salgán, L., Tívoli, A. (Eds.), Tendencias teórico-metodológicas y casos de estudio en la arqueología de la Patagonia. Museo de Historia Natural de San Rafael and INAPL, pp. 281–287.
Caruso-Fermé, L., Théry-Parisot, I., 2018. The shrinkage cracks and the diameter of the log: an experimental approach towards fuel management by patagonian hunter-gatherer (Paredón Lanfré site Río Negro Province, Argentina). Archaeol. Anthropol. Sci. 10 (7), 1821–1829.
Chabal, L., 1997. Forêts et sociétés en Languedoc (Néolithique final, Antiquité tardive): l'anthracologie, méthode et paléoécologie. Documents d'Archéologie Française, vol. 63. Maison des Sciences de l'Homme, Paris.
Chabal, L., Fabre, L., Terral, J.F., Théry-Parisot, I., 1999. L'Anthracologie. La Botanique. Errance, París, pp. 43–104.
Costa, M., Morla, C., Sainz, H., 2001. Los Bosques Ibéricos. Una Interpretación Geobotánica. Planeta, Madrid.
Courty, M.A., Allué, E., Henry, A., 2020. Forming mechanisms of vitrified charcoals in archaeological firing- assemblages. J. Archaeolog. Sci. Rep. 30, 102215.
Deleuze, C., Monreau, F., Renaud, J.P., Vivien, Y., Rivoire, M., Santenoise, Ph, Longuetaud, F., Mothe, F., Hervé, J.C., Vallet, P., 2014. Estimer le volume total d'un arbre, quelles que soient l'essence, la taille, la sylviculture, la station. RDV Tech. ONF 44, 22–32.
Dufraisse, A., 2006. Charcoal anatomy potential, wood diameter and radial growth. In: Dufraisse, A. (Ed.), Charcoal Analysis: New Analytical Tools and Methods for Archaeology. Papers from the Table Ronde Held in Basel 2004, vol. 1483. BAR International Series, pp. 47–59.
Dufraisse, A., García-Martínez, M.S., 2011. Mesurer les diamètres du bois de feu en anthracologie. Anthropobotanica 1, 1–18.
Dufraisse, A., Coubray, S., Girardclos, O., Nocus, N., Lemoine, M., Dupouey, J.L., Marguerie, D., 2017. Anthraco-typology as a key approach to past firewood exploitation and woodland management reconstructions. Dendrological reference dataset modelling with dendro-anthracological tools. Quat. Int. 463, 232–249.
Dufraisse, A., Bardin, J., Picornell-Gelabert, L., Coubray, S., García-Martínez, M.S., Lemoine, M., Vila, S., 2020. Pith location tool and wood diameter estimation: validity and limits tested on seven taxa to approach the length of the missing radius on archaeological wood and charcoal fragments. J. Archaeol. Sci. Rep. 29, 102166.
Franco-Múgica, F., Gómez-Manzaneque, F., Maldonado, J., Morla, C., Sainz-Ollero, H., 2001. The holocene history of Pinnus forests in the Spanish northern meseta. Holocene 11 (3), 343–358.
Franco-Múgica, F., García-Antón, M., Maldonado-Ruiz, J., Morla, C., Sainz, H., 2005. Ancient pine forest on inland dunes in the Spanish northern meseta. Quat. Res. 63 (1), 1–14.
García-Esteban, L., Guindeo-Casasus, A., Peraza-Oramas, C., de Palacios, P., 2003. La madera y su anatomía. Anomalías y defectos, estructura microscópica de coníferas y frondosas, identificación de maderas, descripción de especies y pared celular. Mundi-Prensa, Madrid.
García-Martínez, M.S., Dufraisse, A., 2012. Correction factors on archaeological Wood diameter estimation. Sagvntvm Extra 13, 283–290.
García-Martínez de Lagrán, I., Iriarte, E., García-Gazólaz, J., Tejedor, C., Gibaja, J.F., Moreno-García, M., Pérez-Jordá, G., Ruíz-Alonso, M., Sesma, J., Garrido-Pena, R., Carrancho, A., Peña-Chocarro, L., Rojo, M., 2016. 8.2 ka BP paleoclimatic event and the Ebro valley mesolithic groups: preliminary data from Artusia rock shelter (Unzué, Navarra, Spain). Quat. Int. 403, 151–173.
Gil-Romera, G., González-Sampériz, P., Lasheras, L., Sevilla-Callejo, M., Moreno, A., Valero-Garcés, B., López-Merino, L., Carrión, J.S., Pérez-Sanz, A., Aranbarri, J., García-Prieto, E., 2014. Biomass-modulated fire dynamics during the last glacial–interglacial transition at the cntral pyrenees (Spain). Paleogeogr. Paleoclimatol. Paleoecol. 402, 113–124.
González-Sampériz, P., 2004. Evolución paleoambiental del sector central de la cuenca del Ebro durante el Pleistoceno superior y Holoceno. Instituto Pirenaico de Ecología, Zaragoza.
González-Sampériz, P., Valero-Garcés, B., Carrión, J.S., Peña-Monné, J.L., García-Ruiz, J. M., Martí Bono, C., 2005. Glacial and Lateglacial vegetation in northeastern Spain: new data and a review. Quat. Int. 140, 4–20.
González-Sampériz, P., Aranbarri, J., Pérez-Sanz, A., Gil-Romera, G., Moreno, A., Leunda, M., Sevilla-Callejo, M., Corella, J.P., Morellón, M., Oliva, B., Valero-Garcés, B., 2017. Environmental and climate change in the southern Central Pyrenees since the last glacial maximum: a view from the lake records. Catena 149, 668–688.
Greguss, P., 1955. Identification of Living Gymnosperms on the Basis of Xylotomy. Akadémiai Kiado, Budapest.
Heinz, C., Vernet, J.L., 1995. Analisi antracologica dels nivells mesolítics i del neolític antic de la Balma de la Margineda. Paleoecologia i relacions home-vegetació. In: Guilaine, En J., Martzluff, M. (Eds.), Les excavacions a la Balma de la Margineda (1979-1991). Serie Prehistoria d'Andorra 3. Govern d'Andorra, pp. 26–64.
Henry, A., Théry-Parisot, I., 2014. From Evenk campfires to prehistoric hearths: charcoal analysis as a tool for identifying the use of rotten wood as fuel. J. Archaeol. Sci. 52, 321–336, 2014.
Laborda, R., 2019. El Neolítico antiguo en el Valle Medio del Ebro. Una visión desde la cerámica y las dataciones radiocarbónicas. Prensas Universitarias. University of Zaragoza.
Magny, M., Miramont, C., Sivan, O., 2002. Assessment of the impact of climate and anthropogenic factors on Holocene Mediterranean vegetation in Europe on the basis of palaeohydrological records. Paleogeogr. Paleoclimatol. Paleoecol 186 (1–2), 47–59.
Marguerie, D., Hunot, J.Y., 2007. Charcoal analysis and dendrology: data from archaeological sites in north-western France. J. Archaeol. Sci. 34 (9), 1417–1433.
Mazo, C., Alcolea, M., 2020. New data concerning neanderthal occupation in the iberian system: first results from the late Pleistocene (MIS 3) aguilón P5 cave site (NE Iberia). Quat. Int. 551, 105–122.
McParland, L., Collinson, M.E., Scott, A.C., Campbell, G., Veal, R., 2010. Is vitrification in charcoal a result of high temperature burning of wood? J. Archaeol. Sci. 37 (10), 2679–2687.
Montes, L., Domingo, R., González-Sampériz, P., Sebastián, M., Aranbarri, J., Castaños, P., Alcolea, M., García-Simón, L.M., Laborda, R., 2016. Landscape, resources and people during the mesolithic and neolithic times in NE Iberia: the Arba de Biel basin. Quat. Int. 403, 133–150.
Moskal-del Hoyo, M., Wachowiak, M., Blanchette, R.A., 2010. Preservation of fungi in archaeological charcoal. J. Archaeol. Sci. 37 (9), 2106–2116.
Morellón, M., Valero-Garcés, B., Vegas-Vilarrúbia, T., González-Sampériz, P., Romero, O., Delgado-Huertas, A., Mata, P., Moreno, A., Rico, M., Corella, J.P., 2009. Lateglacial and Holocene palaeohydrology in the western mediterranean region: the lake estanya record (NE Spain). Quat. Sci. Rev. 28 (25–26), 2582–2599.
Obea, L., 2014. El paisaje neolítico: un estudio preliminar de los restos antracológicos de Coro Trasito (Tella). In: Clemente, I., Gassiot, E., Rey, J. (Eds.), Sobrarbe antes de Sobrarbe. Pinceladas de historia de los Pirineos. Centro de estudios de Sobrarbe, pp. 43–54.
Obea, L., Piqué, R., Martin, M., Gassiot, E., 2011. The exploitation of forest resources in mountain areas during the Neolithic in the northeast of the Iberian Peninsula. Sagvntvm Extra 11, 129–130.
Obón, A., Berdejo, A., Laborda, R., Sierra, A., Alcolea, A., Bea, M., Domingo, R., Utrilla, P., 2019. L'abri de L'Esplugón (Villobas-Sabiñánigo, Huesca, Espagne): apports des données à la question de la transition Mésolithique-Néolithique dans les Pré-Pyrénées centrales. In: Deschamps, M., Costamagno, S., Milcent, P.Y., Pétillon, J.-M., Renard, C., Valdeyron, N., dirs (Eds.), La conquête de la montagne: des premières occupations humaines à l'anthropisation du milieu. Éditions du Comité des travaux historiques et scientifiques, pp. 1–24.
Paradis-Grenouillet, S., Dufraisse, A., Allée, P., 2013. Tree ring curvature measures and wood diameter: comparison of different imaging techniques. In: Damblon, F. (Ed.), IVe International Meeting of Anthracology (Bruxelles, Septembre 2008). BAR International Series, pp. 173–182.
Plà, S., Catalán, J., 2005. Chrysophyte cysts from lake sediments reveal the submillennial winter/spring climate variability in the northwestern Mediterranean region throughout the Holocene. Clim. Dynam. 24, 263–278.
Pérez-Sanz, A., 2014. Holocene Climate, Vegetation and Human Impact in the Western Mediterranean Inferred from Pyrenean Lake Records and Climate Models. University of Zaragoza. Unpublished PhD.
Pérez-Sanz, A., González-Sampériz, P., Moreno, A., Valero, B., Gil-Romera, G., Rieradevall, M., Tarrats, P., Lasheras, L., Morellón, M., Belmonte, A., Sancho, C., 2013. Holocene climate variability, vegetation dynamics and fire regime in the central Pyrenees: the Basa de la Mora sequence (NE Spain). Quat. Sci. Rev. 73, 149–169.
Picornell-Gelabert, L., Dufraisse, A., 2018. Wood for building: woodland exploitation for timber procurement in the prehistoric and protohistoric balearic islands (mallorca and menorca; western mediterranean). Environ. Archaeol. https://doi.org/10.1080/14614103.2018.1521086.

Quézel, P., Médail, F., 2003. Ecology and Biogeography of Mediterranean Basin Forests. Elsevier, Paris.
R Core Team, 2017. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.
Reimer, P.J., Austin, W.E., Bard, E., Bayliss, A., Blackwell, P.G., Ramsey, B.C., Butzin, M., Cheng, H., Edwards, R.L., Friedrich, M., Groots, P.M., Guilderson, T.P., Hadjas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kromer, B., Manning, S.W., Muscheler, R., Palmer, J.G., Pearson, C., van der Plicht, J., Reimer, R.W., Richards, D.A., Scott, E. M., Southon, J.R., Turney, C.S.M., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S.M., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reining, F., Sakamoto, M., Sookdeo, A., Talamo, S., 2020. The IntCal20 northern hemisphere radiocarbon age calibration curve (0–55 cal kBP). Radiocarbon 62 (4), 725–757.
Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Ramsey, C.B., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guidelson, T.P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Hoffmann, D.L., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Staff, R.A., Turney, C.S.M., van del Plicht, J., 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0-50,000 years cal BP. Radiocarbon 55 (4), 1869–1887.
Rinn, F., 2011. TSAP-win. Time series analysis and presentation for dendrochronology and related applications. User ref. 110. www.rinntech.com.
Riou-Nivert, P., 2001. Les Résineux. Institut pour le dévelopement forestier, Paris.
Rivas-Martínez, S., 1982. Étages bioclimatiques, secteurs chorologiques et séries de végetation de l"Espagne méditerranéenne. Ecol. Mediterr. VIII (1/2), 275–288.
Roiron, P., Chabal, L., Figueiral, I., Terral, J.F., Ali, A., 2013. Palaeobiogeography of Pinus nigra Arn. subsp. salzmannii (Dunal) Franco in the north-western Mediterranean Basin: a review based on macroremains. Rev. Palaeobot. Palynol. 194, 1–11.
Rubiales, J.M., García-Amorena, I., Hernández, L., Génova, M., Martínez, F., Manzaneque, F.G., Morla, C., 2010. Late quaternary dynamics of pinewoods in the iberian mountains. Rev. Palaeobot. Palynol. 162, 476–491.
Ruíz-Alonso, M., Zapata, L., 2017. Transformation and human use of forests in the Western Pyrenees during the Holocene based on archaeological wood charcoal. Quat. Int. 364, 86–93.
Schoch, W., Heller, I., Schweingruber, F.H., Kienast, F., 2004. Wood anatomy of central European Species. Online version: www.woodanatomy.ch.
Schweingruber, F.H., 1990. Anatomie Europäischer Hölzer. Haupt, Stuttgart.
Shigo, A.L., Vollbrecht, K., Hvass, N., 1987. Biologie et soins de l'arbre: guide photographique. IDF, Paris.
Théry-Parisot, I., 2001. Economie des combustibles au paléolithique: expérimentation, taphonomie, anthracologie. Dossiers de documentation archéologique 20. CNRS Editions, Paris.
Théry-Parisot, I., 2002. Gathering of firewood during the palaeolithic. In: Thiébault, S. (Ed.), Charcoal Analysis, Methodological Approaches, Palaeoecological Results and Wood Uses, vol. 1063. BAR International Series, pp. 242–249.
Théry-Parisot, I., Henry, A., 2012. Seasoned or green? Radial cracks analysis as a method for identifying the use of green wood as fuel in archaeological charcoal. J. Archaeol. Sci. 39 (2), 381–388.
Théry-Parisot, I., Thiébault, S., 2005. Le pin (Pinus sylvestris): préférence d'un taxon ou contrainte de l'environnement? Etude des charbons de bois de la Grotte Chauvet. Bull. Soc. Prehist. Fr. 102 (1), 69–75.
Théry-Parisot, I., Chabal, L., Chrzavzez, J., 2010. Anthracology and taphonomy, from wood gathering to charcoal analysis. a review of the taphonomic processes modifying charcoal assemblages, in archaeological contexts Palaeogeogr. Palaeoclimatol. Palaeoecol. 291 (1–2), 142–153.
Théry-Parisot, I., Dufraisse, A., Chzrazvzez, J., Henry, A., Paradis-Grenouillet, S., 2011. Charcoal analysis and wood diameter: inductive and deductive methodological approaches for the study of firewood collecting practices. Sagvntvm Extra 11, 31–32.
Théry-Parisot, I., Henry, A., Chrzazvez, J., 2016. Apport de l'expérimentation à la compréhension des pratiques en anthracologie: gestion et utilisation du bois de feu dans les sociétés préhistoriques. Cadernos do LEPAARQ 13 (25), 511–536.
Théry-Parisot, I., Thiébault, S., Delannoy, J.J., Ferrier, C., Feruglio, V., Fritz, C., Gely, B., Guibert, P., Monney, J., Tosello, G., Clottes, J., Geneste, J.M., 2018. Illuminating the cave, drawing in black: wood charcoal analysis at Chauvet-Pont d'Arc. Antiquity 92 (362), 320–333.
Utrilla, P., Laborda, R., 2018. La Cueva de Chaves (Bastarás, Huesca): 15000 años de ocupación prehistórica. Trab. Prehist. 75 (2), 248–269.
Utrilla, P., Mazo, C., 2014. La Peña de las Forcas (Graus, Huesca): Un asentamiento estratégico en la confluencia del Ésera y el Isábena. Prensas Universitarias. University of Zaragoza.
Utrilla, P., Berdejo, A., Obón, A., 2012. El Esplugón: un gran abrigo mesolítico en el valle del Guarga (Huesca). In: Muñiz-älvarez, J.R., coord (Eds.), Ad Orientem. Del final del Paleolítico en el norte de España a las primeras civilizacions del Oriente Próxim: Estudios En Homenaje A Juan Antonio Fernández-Tresguerres. University of Oviedo, pp. 235–251.
Utrilla, P., Berdejo, A., Obón, A., Laborda, R., Domingo, R., Alcolea, M., 2016. El abrigo de El Esplugón (Billobas-Sabiñánigo, Huesca). Un ejemplo de transición Mesolítico-Neolítico en el Prepirineo central. In: Bonet, H., coord (Eds.), Del Neolític a l'Edat del Bronze en el Mediterrani Occidental. Estudis en homenatge a Bernat Martí Oliver. Museu de Prehistòria de València, pp. 75–96.
Vernet, J.L., 1973. Étude sur l'histoire de la végétation du Sud-Est de la France au Quaternaire d'après l'étude des charbons de bois principalement. Paleobiol. Cont. 4, 1–90.
Vidal-Matutano, P., 2017. Firewood and hearths: middle palaeolithic woody taxa distribution from el salt, stratigraphic unit xb (eastern Iberia). Quat. Int. 457, 74–84.
Vidal-Matutano, P., Hernández, C.M., Galván, B., Mallol, C., 2015. Neanderthal firewood management: evidence from stratigraphic unit IV of abric del pastor (eastern Iberia). Quat. Sci. Rev. 111, 81–93.
Vidal-Matutano, P., Henry, A., Théry-Parisot, I., 2017. Dead wood gathering among Neanderthal groups: charcoal evidence from Abric del Pastor and El Salt (Eastern Iberia). J. Archaeol. Sci. 80, 109–121.
Vidal-Matutano, P., Pérez-Jordà, G., Hernández, C.M., Galván, B., 2018. Macrobotanical evidence (wood charcoal and seeds) from the Middle Palaeolithic site of El Salt, Eastern Iberia: palaeoenvironmental data and plant resources catchment areas. J. Archaeolog. Sci. Rep. 19, 454–464.
Zapata, L., 2001. El uso de los recursos vegetales en Aizpea (Navarra, Pirineo Occidental): la alimentación, el combustible y el bosque. In: Barandiarán, I., Cava, A. (Eds.), Cazadores-recolectores en el Pirineo navarro: el sitio de Aizpea entre 8.000 y 6.000 BP. Veleia, vol. 10, pp. 325–359.
Zapata, L., Peña-Chocarro, L., 2005. Los macrorrestos vegetales del yacimiento de Mendandia. In: Alday, A. (Ed.), El campamento prehistórico de Mendandia: ocupaciones mesolíticas y neolíticas entre el 8500 y el 6400 B.P. Diputación Foral de Álava. Vitoria, pp. 411–425.