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Marie Larrieu, Christophe Vaschalde, Jérôme Kotarba, Carole Puig, Jérôme Ros. Forest exploitation in the plains of early medieval northern Catalonia: Anthracological review. *Review of Palaeobotany and Palynology*, 2024, 320, pp.104993. 10.1016/j.revpalbo.2023.104993. halshs-04312626

**HAL Id: halshs-04312626**

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Submitted on 28 Nov 2023

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**To cite this paper:**

Larrieu M., Vaschalde C., Kotarba J., Puig C., Ros J., 2023. “Forest exploitation in the plains of early medieval northern Catalonia: anthracological review”, *Review of Palaeobotany and Palynology*. <https://doi.org/10.1016/j.revpalbo.2023.104993>

**“Forest exploitation in the plains of early medieval northern Catalonia:  
anthracological review”**

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## **Abstract**

In the north-western Mediterranean (Mediterranean France, Catalonia), the Early Middle Ages were a period of major change with a restructuration of rural settlements, that impacted both landscape management and how animal and plant resources were exploited. Recent bioarchaeological research has enabled us to understand the agropastoral changes associated with these new dynamics at a local scale, but their impact on the evolution of forest cover remains unevenly documented. The anthracological study of 8 rural archaeological sites located in the plains of early medieval northern Catalonia has made it possible to qualify the composition and state of the forests exploited by the local populations. The vegetation on the lower plains appears to be more open than in the hinterland, where human pressure on the environment appears to have been more moderate. Among the sites, Pujals seems to have drawn some of its fuel from the Pyrenees Mountain, raising the question of wood trading networks between the mountain and the plains at the time.

## **Keywords**

*charcoal analysis, woodland exploitation, wood fuel, wood trade, Middle Ages, regional review*

## **1. INTRODUCTION**

### *1.1. The Early Middle Ages: a turning point in rural landscape dynamics*

In the north-western Mediterranean (Mediterranean France, Catalonia), the Early Middle Ages were a period of major change, both regarding landscape structuration and how animal and plant resources were exploited. In fact, the 5<sup>th</sup>-6<sup>th</sup> centuries saw a restructuration of rural settlements around emerging centers of power, whether political or religious, around new agglomerations and around areas with particular agricultural potential (hills, terraces, wet depressions), favoring the emergence of new trade networks and new dynamics in land use (*e.g.* Wickham 2005; Schneider 2005, 2007, 2010; Ripart and Lauwers 2007; Ros *et al.* 2020). Over the last few decades, the boom in bioarchaeological research in the north-western Mediterranean made it possible to document these new dynamics, highlighting the continuities and breaks with the Roman era. For example, regarding breeding and meat consumption, this period saw a change in the frequency of exploited taxa, a global decrease in the bone dimensions of the main domestic species as well as changes in mortality patterns (*e.g.* Forest and Rodet-Belarbi 2002; Duval 2015; Colominas *et al.* 2019; Ros *et al.* 2020;

Mureau 2023), proving changes in livestock management. Regarding plant production, archaeobotanical research reveals that early medieval agriculture in the north-western Mediterranean was based on a greater diversity of plant species than in the Roman period, particularly in cereal production, with a boom in certain spring (millets) and acid/poor soils (rye) crops. The hypothesis is that early medieval peasants were looking for a certain form of food security, possibly linked to their greater autonomy and the preponderance of small and medium-sized farms (e.g. Ruas 2005; Ros *et al.* 2020; Ros *et al.* in press).

Changes in livestock farming practices, pastoralism and the opening up of new land for the development of new crops are all factors that can lead to important changes in woodland landscapes. Nonetheless, so far in this region, woodlands have been unevenly studied from a bioarchaeological point of view, despite their central role in the economy and daily practices of medieval rural populations.

### *1.2. Forest history in the plains of the medieval north-western Mediterranean: a brief review*

In the north-western Mediterranean, palynology provides relatively little information about the vegetation of the Early Middle Ages, as sediments associated with this period are very rarely preserved. Some insights have been gained from pollen sequences from the Marais des Baux in Provence (Andrieu-Ponel *et al.* 2000), Marsillargues (Planchais 1982), the lido of the Etang de Thau (Court-Picon *et al.* 2010) and the lower valleys of the Hérault and Aude rivers (Dolez 2018). More often than not, these studies provide information on local and regional vegetation at the scale of the Sub-Atlantic, without being able to detail the evolution of vegetation during the Early Middle Ages. The Sub-Atlantic was globally characterized by increasing human pressure, resulting in a decrease in forest taxa and an increase in cultivated taxa (most often *Olea* sp., sometimes *Juglans* sp.), with some exceptions. For example, at Sète and in the Marais des Baux, a period of resurgence of forest taxa (*Quercus pubescens* in particular) and a decline in taxa indicative of cultivation has been detected (Court-Picon *et al.* 2010).

Thanks to the precise dating of archaeological layers, anthracology can provide a more detailed analysis of the evolution of vegetation in the Early Middle Ages. In Languedoc and Provence, between the 5<sup>th</sup> and 7<sup>th</sup> c., vegetation seems to have evolved differently depending on the locality. Around Dassargues (Languedoc), on the Vidourle plain, L. Chabal (André *et al.* 1997; Chabal 1997, p. 132-133) hypothesized that the alluvial ash-hornbeam grove had regenerated, echoing a similar but slightly earlier dynamic identified around the pottery workshops at La Quintarié in Clermont-l'Hérault between the 4<sup>th</sup> and 6<sup>th</sup> c. (Fabre 2005).

Coastal and/or lagoon settlements appear to have opened the vegetal landscape during the same period. At Bourbou, the sclerophyllous oak woodland exploited for five centuries by potters saw pine trees develop around the 5<sup>th</sup>-6<sup>th</sup> c. (Chabal *et al.* 2012). In Camargue, where the landscape was much more wooded than it is today, pine trees began to decline in favor of tamarisk from the 4<sup>th</sup> to 5<sup>th</sup> c., possible result of greater human pressure combined with changes in the sedimentary environment and soil salinity (Chabal 2019). At Marignane, on the shores of the Etang de Berre, the most mesophilic taxa are a minority within a vegetation dominated by sclerophyllous oak, and disappear definitively after the 7<sup>th</sup> c. (Vaschalde 2022). In Catalonia, charcoal studies are pretty rare in rural contexts for this period (*e.g.* Euba Rementeria and Palet-Martinez 2010) and are only just beginning to take off in urban contexts (Vila Moreiras *et al.* 2012; Bianco *et al.* 2020, 2023). Around l'Esquerda, anthracological studies have identified a few cultivated taxa, in a mainly mesophilous woodland (Cubero i Corpas 2011).

In the north-western Mediterranean, anthracological data are rarer between the 8<sup>th</sup> and 10<sup>th</sup>-11<sup>th</sup> c. The few available sites in Camargue suggest that the process of replacing pine trees with tamarisk continued (Chabal 2019), attesting to a strong anthropisation of the environment, also documented in the 9<sup>th</sup>-10<sup>th</sup> c. at Augery de Corrège (Durand 1998). At Marignane, an abrupt but momentary opening of the sclerophyllous oak woodland gave way to Ericaceae scrub around the 10<sup>th</sup> c. (Vaschalde 2022), possibly linked to the development of agropastoral and/or craft activities (Durand *et al.* 2010). The end of the Marignane sequence is characterized by a regeneration of the sclerophyllous oak woodland tree which, given the persistence of the settlement, seems to be linked to a change in practices rather than to human abandonment. In Languedoc, signs of the opening up of the vegetation environment (cultivated taxa in particular) are evident as early as the 8<sup>th</sup>-9<sup>th</sup> c. (Figueiral 2016, 2018; Tarrou *et al.* 2020), which leads us to reconsider the extent of the changes observed in the vegetation in the 11<sup>th</sup> c. (Durand 1998; Durand *et al.* 2015).

Across the area, the pace of research is uneven, and depends largely on local archaeological dynamism, the sensitivity to palaeoenvironmental issues, and the presence of dedicated bioarchaeologists. Over the last decade, the French department of Pyrénées-Orientales, which corresponds to the northern fringe of medieval Catalonia, has been the focus of significant bioarchaeological activity. Carpological and zooarchaeological studies have focused particularly on the medieval period, leading to the production of several reviews (*e.g.* Ros 2020; Ros *et al.* 2020), which confirm the rise of new agropastoral trends and the opening up

of new areas for agriculture. However, anthracological studies have long remained ad hoc, despite a corpus of sites that have yielded substantial quantities of charcoal. This significant potential prompted us to carry out the present study, aimed at documenting the composition and state of the early medieval forests in this region.

## **2. Material and method**

### *2.1. Regional setting*

This study focus on the coastal plains of the eastern Pyrénées (French department of the Pyrénées-Orientales), surrounded by the Corbières hills and the lagune of Salses (north), the Pyrenees mountains (west), the Albères hills (south) and the Mediterranean Sea (east) (Fig. 1). The plains are crossed by four west-east oriented coastal rivers: the Agly, the Têt, the Réart and the Tech. Archaeological and geomorphological surveys, as well as medieval written sources indicate that this hydrography has changed over the millennia, but that the valleys were pretty stable during the Roman and early medieval periods (Marichal *et al.* 1997; Calvet *et al.* 2002; Puig *et al.* 2007; Carozza *et al.* 2009). In the past, a greater quantity of wetland areas existed in the plains, drained between the end of the medieval and the beginning of the modern period (Puig *et al.* 2007). Among the sites we studied, some were located near these wetlands during the Early Middle Ages (Fig. 1).

In this region, the geological substrate is pretty much the same everywhere, but with dominant limestone in the north, and schists in the south (Servant 1970). The local vegetation includes elements from the thermo-, meso- and supramediterranean levels (Gausсен 1926, 1934), dominated by mixed evergreen (*Quercus ilex*) and pubescent (*Q. pubescens*) oak forest. According to the average annual rainfall, sub-sectors are distinguished, notably the drier coastal fringe (averages below 600 mm) and the inland area (subhumid type with higher rainfall). The drier coastal fringe is populated by evergreen oak formations, as well as Aleppo pine (*Pinus halepensis*), lentisk (*Pistacia lentiscus*) and kermes oak (*Quercus coccifera*) formations, and, mixed with pubescent and pedunculate oaks on deep soils, cork oak (*Q. suber*) forests. These species are absent in the inland area, where pubescent oak is more frequently mixed with evergreen oak.

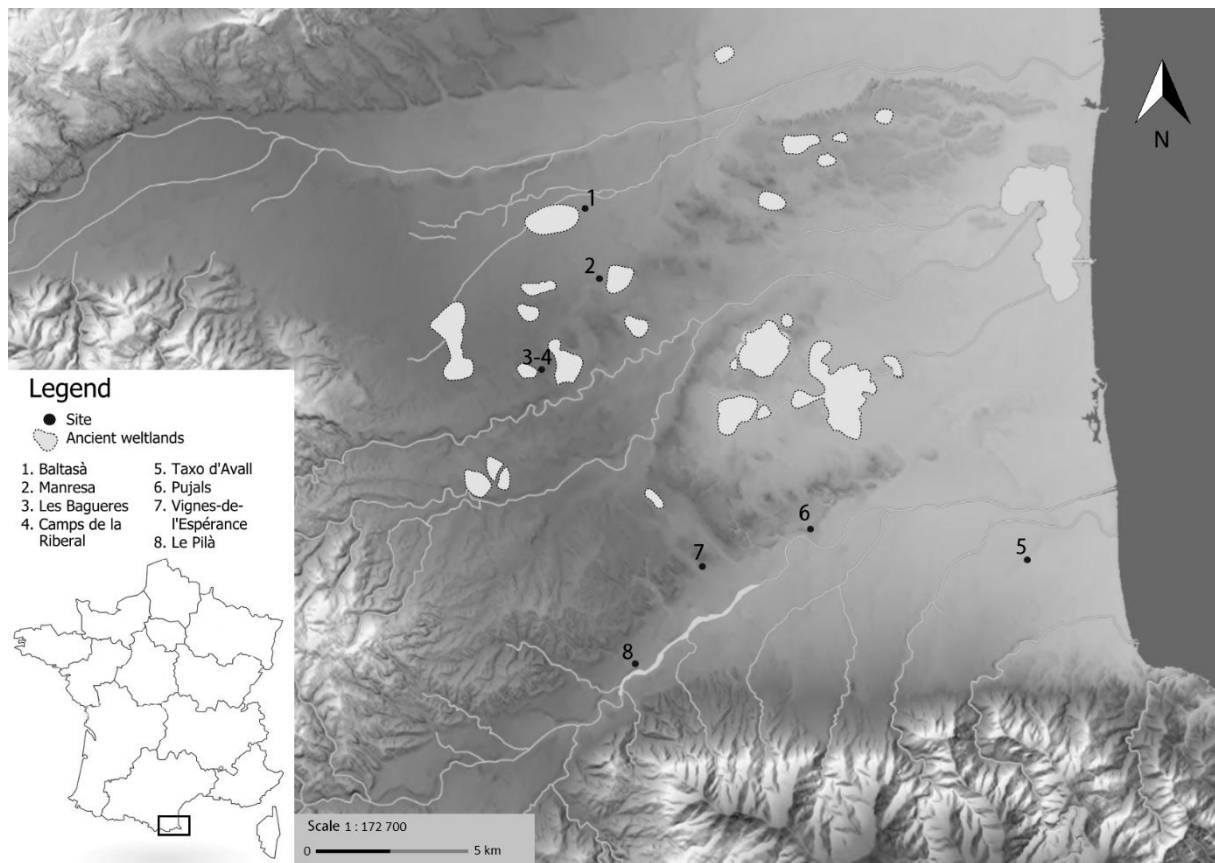


Fig. 1: Distribution of the archaeological sites of the corpus and restitution of disappeared wetlands (from Puig 2009).

## 2.2. *Corpus of archaeological sites*

Although their geographical position differs, all of the settlements have yielded archaeological structures testifying to medieval rural occupations, covering a chronology ranging from the 5<sup>th</sup> to the 10<sup>th</sup> c. AD. (Tab. 1). These settlements were uncovered within the framework of preventive archaeology operations, following various land development projects such as the construction of a TGV line, a high school, and the installation of photovoltaic panels in the field. As a result of these operations, various structures were uncovered (Fig. 2) (Kotarba *et al.* 2011, 2012, 2015; Jandot *et al.* 2007; Puig *et al.* 2020). No evidence of habitation as such was found, but numerous silage areas and planting pits were discovered, notably at sites 1, 2, 5 and 6 (Fig. 1). The numerous storage structures, associated with ovens and hearths, indicate that the settlements correspond to farms with areas of domestic activity. The excavated contexts mainly correspond to accumulation contexts: pits, shafts and silos filled with domestic waste. Sites 4, 5 and 8 have the particularity of having yielded domestic ovens and oven reject pits, some of whose levels were rich in concentrated charcoal fragments.

N°	Settlement	Locality	Studied area	Dating	Number of sample	Sample volume (L)	Number of context	Context type	Type of studies and references		
									Archeozoology	Carpology	Anthracology
1	Baltasà	Toulouges	6 hectares	6th-7th c. A.D.	1	700	1	1 well	Ros et al. 2020	-	Machado & Fabre 2011
2	Manresa	Canohès	7000 m²	6th-8th c. A.D.	7	830	6	4 silos, 1 oven, 1 pit	Ros et al. 2020	Ros et al. 2020	Machado & Fabre 2011
3	Les Bagueres 56	Ponteilla	-	6th-8th c. A.D.	2	700	2	2 pits	Ros et al. 2020	Ros et al. 2020	Machado & Fabre 2011
4	Camps de la Ribera	Ponteilla	-	8th-9th c. A.D.	3	30	2	1 oven, 1 oven discharge pit	-	Ruas in Ros 2020	Machado & Fabre 2009
5	Taxo les Gavarettes	Argelès-sur-Mer	-	5th-10th c. A.D.	11	110	8	2 hearths, 3 silos, 2 ovens, 1 circulation level	-	Ros 2020	Vaschalde unpub
6	Pujals	Ortaffa	6 hectares	5th-8th c. A.D.	4	49	4	4 pits	Ros et al. 2020	Ros et al. 2020	-
7	Vignes-de-l'Espérance	Banyuls-deis-Aspres	-	Early Middle Ages	4	40	2	2 pits	-	Ruas in Ros 2020	Fabre unpub
8	Le Pilà	Le Boulou	800 m²	Early Middle Ages	3	128	2	1 oven, 1 oven discharge pit	-	Ros 2020	Poirier 2009

Tab. 1: Corpus of archaeological sites including an anthracological study. "L" = liter, "-" = no data.

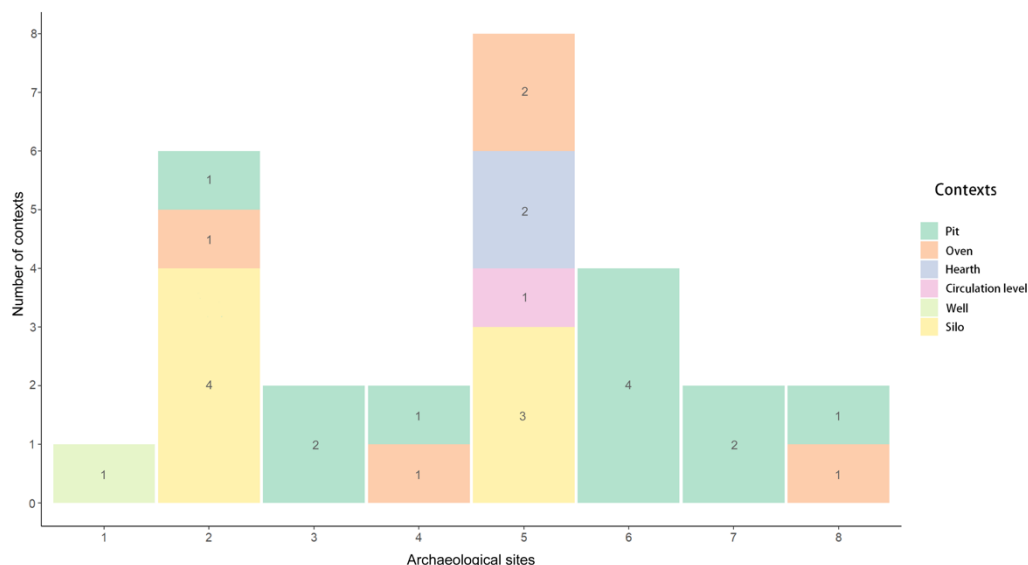


Fig. 2: Types of contexts that provided anthracological remains in the archaeological sites (site number refers to table 1).

The interpretation of this corpus requires precautions, due to its heterogeneous nature. The sites were not excavated by the same teams, and the studied area and the quantity of studied samples also vary (Tab. 1). These differences in sampling can lead to biases, which must be taken into account for any subsequent analysis.

### 2.3. Sampling and sieving protocol

For all sites, sediment samples were taken for archaeobotanical analysis, in volumes ranging from 3 to 100 liters per sample. Water sieving and/or manual flotation on fine mesh (0,5 mm) were carried out, in order to recover bioarchaeological remains. Some samples, intended solely for charcoal study, were sieved on mesh sizes ranging from 2 mm to 4 mm, avoiding the collection of small-sized charcoal fragments that are difficult to identify (Kabukcu and Chabal 2021).



#### 2.4. Identification

The anthracological study was carried out by different specialists on 32 samples. The charcoal fragments were identified on the basis of the observation of the anatomical structure of the wood in three observation planes (transverse, longitudinal tangential and longitudinal radial). Identification was carried out using a reflection microscope with dark-bright field and x100, x200 and x500 magnification, with the help of reference atlases (Jacquiot 1955; Jacquiot *et al.* 1973; Schweingruber 1990; Vernet *et al.* 2001) and the reference collection of the bioindicator platform of the Institut des Sciences de l'Évolution de Montpellier (UMR 5554). The final matrix shows 5,910 observed charcoal fragments.

### 3. Results

#### 3.1. Representativeness of the results

The results as a whole form a picture of past vegetation that needs to be interpreted taking into account the limitations of the material. The contexts of wood deposits among the studied sites are diverse, some coming from pits, others from ovens. These concentrated deposits are linked to domestic activity: they provide partial palaeoenvironmental information, complementing the interpretations from material issued from scattered deposits. The anthracological information between the different sites is uneven: some sites provided less than 200 identified fragments (site 4), while others have more than 1,000 (sites 5, 7). Taking these limitations into account allows us to provide the most reliable and accurate palaeoenvironmental interpretation possible. The total anthracological corpus (Appendix 1) is based on 5,910 observed charcoals, allowing the identification of 44 taxa, including 40 Angiosperms and 4 Gymnosperms. The presence of stage 1 to 5 vitrification (McParland *et al.* 2010; Vaschalde 2018), of nodes, and pieces of bark prevented or limited identification. In the corpus, this represents 9,2% of the observed fragments, with 0,4% undetermined gymnosperms, 8,2% undeterminable, 0,1% undetermined, 0,2% knots and 0,3% pieces of bark.

#### 3.2. Composition of the assemblages and woodland identification

The presented diagram (Fig. 3) is synchronic, providing information on the plant assemblages identified over the Early Medieval period (5<sup>th</sup>-10<sup>th</sup> c.). Oak woodland species dominate for sites 1 to 4, 7 and 8. Deciduous oaks dominate at site 1 with 21%, and at site 3 with 42%. Conversely, evergreen oaks (*Quercus suber*, *Q. coccifera/ilex*) dominate in sites 2 and 4: 36,2% and 66% of identified fragments. The predominance of deciduous and evergreen oaks

is characteristic of the Mediterranean mixed oak forest (Braun-Blanquet 1936; Quézel and Médail 2003 a, b). This mixed oak woodland has different facies depending on the associated species. The holm oak can form, with *Acer campestre*, *A. monspessulanum*, *Fraxinus* sp., *Corylus avellana* and *Tilia platyphyllos*, a supramediterranean, thermophilic, mesoxerophilic and acidiline linden-ash-maple forest. In a more humid bioclimate, on deep draining soils, deciduous oak forests (probably *Quercus pubescens*) develop (Quézel and Médail 2003 a, b). The deciduous oaks associated with *Buxus sempervirens* found in sites 2 and 3 form boxwood oak forests, often in the form of coppice, or coppice under forest (Rameau *et al.* 2008). The dominant taxa in sites 5 and 6 are *Arbutus unedo* and *Erica* sp. In site 5, 62% of fragments were identified as *Erica* sp. and 10% as *Arbutus unedo*, and at site 6, 21% were *Arbutus unedo* and 12% *Erica* sp. These taxa, together with *Juniperus* sp., Lamiaceae, Fabaceae, Cistaceae, *Cistus* sp., and *Pistacia* sp. form a matorral. *Erica arborea* and *Arbutus unedo* are pioneer taxa, characteristic of the maquis, which is the siliceous facies of the matorral, whereas the garrigue (*Juniperus* sp, *Cistus* sp, *Pistacia lentiscus*, *Rhamnus alaternus*, *Quercus coccifera*, Fabaceae, Lamiaceae, *Buxus sempervirens*) develops in calcareous conditions (Rameau *et al.* 2008).

Many fruit trees are found in the assemblage: *Ficus carica*, *Vitis vinifera*, *Olea europaea*, *Juglans regia*, Rosaceae t. *Rubus fruticosus*, Rosaceae t. *Crataegus*, Rosaceae Prunoideae, Rosaceae Maloideae. These taxa can be found in the wild in the above-mentioned groups (edge, matorral, shrub formation, riparian), as well as being cultivated.

A group of alluvial forest taxa is identified, composed of *Ulmus* sp., *Fraxinus* sp., *Corylus* sp. and *Tilia* sp. This assemblage can be found in major riverbeds and is distinct from the *Salix* sp., *Populus* sp. and *Alnus* sp. assemblages found in minor riverbeds. *Pinus* t. *sylvestris*, *Fagus sylvatica* and *Abies alba* are species with a mountain affinity. Their discovery in the plains may be evidence of the occasional presence of a few individuals (residual pine colonies, beech trees descending under mesophilic conditions) (Quézel and Médail 2003b).

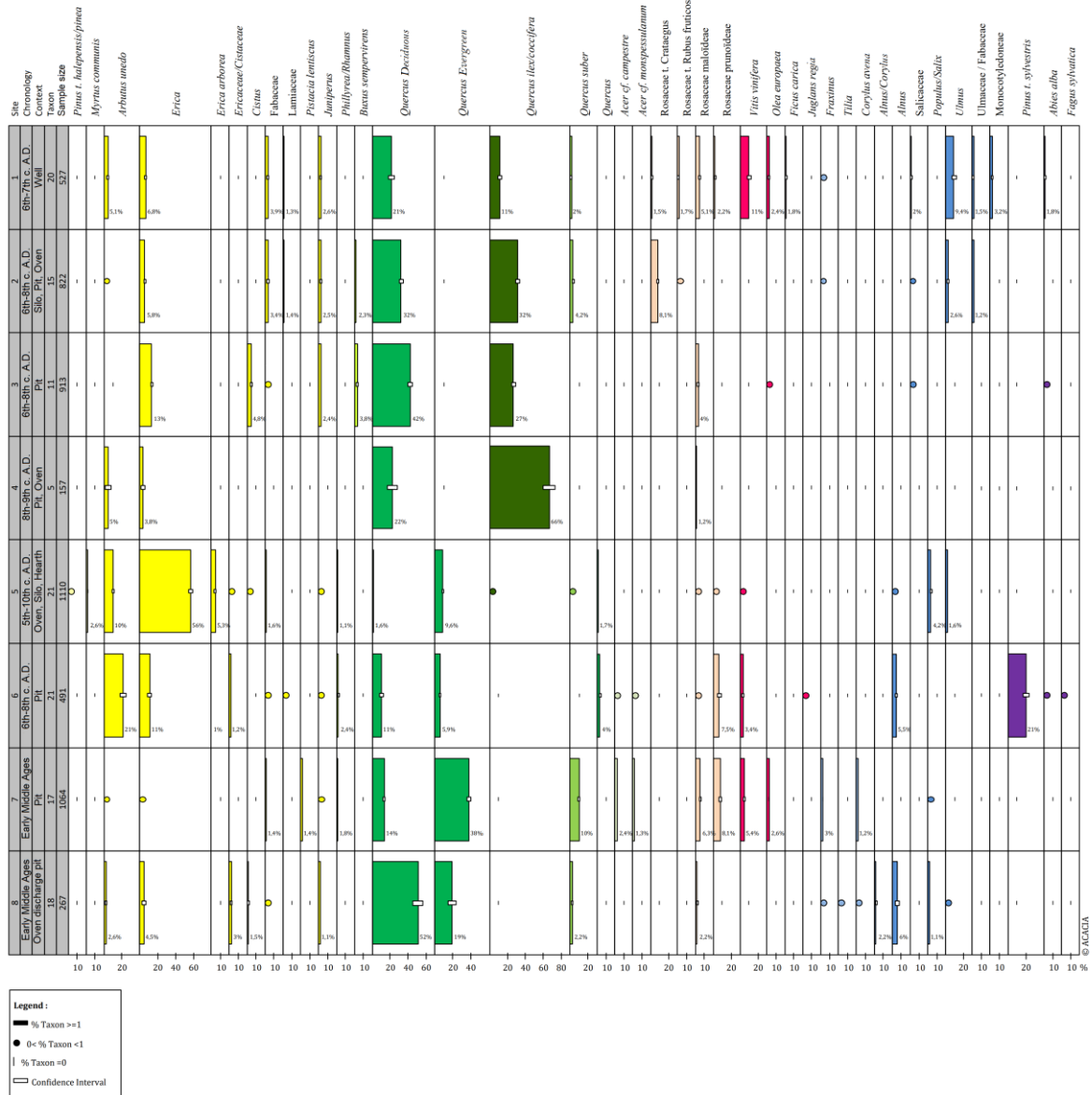


Fig. 3: Synchronic anthracological diagram produced in Excel 2003 ACACIA macro (Nourissier *et al.* 2016). The species proportions are colored according to the vegetation assemblage to which they are assimilated: yellow=matorral, green=oak forest, orange=pre-forest/hedgerow boundary, pink=potentially cultivated taxa, blue=alluvial/riparian forest, purple=mountain taxa. Site number refers to table 1.

### 3.3. Structuring the corpus

The two dimensions of the "Correspondence Factor Analysis" (Fig. 4) are defined by axis 1 (37,8% inertia) and axis 2 (23% inertia). A third dimension is taken into account, whose axis has an inertia of 18% (Appendix 2). Only the two dimensions that explain a maximum of variance are described here.

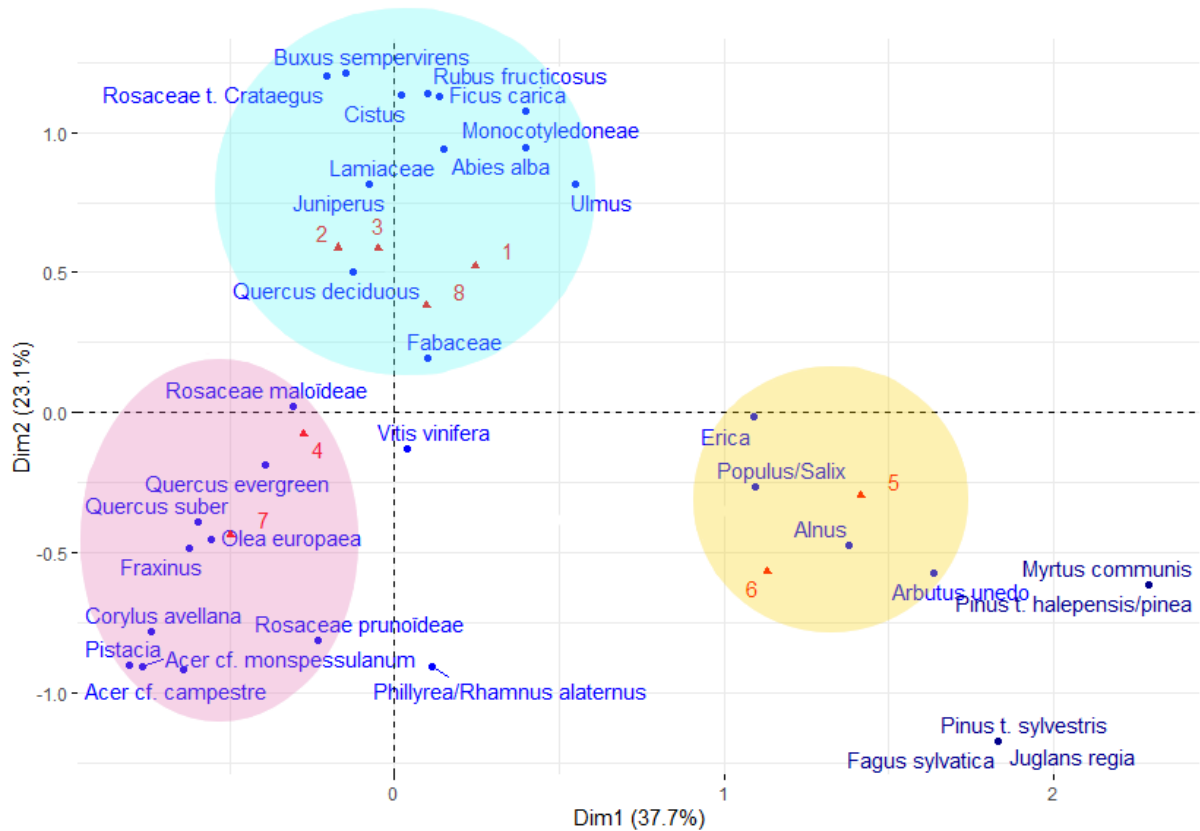


Fig. 4: Correspondence Factor Analysis (CFA) (60.8% variance) of species occurrences identified from charcoal fragments (blue dots) for each site (red dots). Dark blue taxa are represented, but are not included in the CFA to maintain clarity of representation. Site number refers to table 1.

Axis 1 represents the largest deviation from independence. The variables (Appendix 3) that contribute most to its inertia are: *Erica* sp. (31%), *Arbutus unedo* (32,7%), *Populus/Salix* (4,5%), *Alnus* sp. (4,5%), which cluster in the positive pole, and *Quercus evergreen* (13,2%), *Quercus suber* (3,4%) in the negative pole. This axis thus allows us to oppose the taxa of sclerophyllous oak forests to the taxa characteristic of maquis and riparian vegetation. For axis 2, the contributing variables are *Quercus deciduous* (23,8%), *Buxus sempervirens* (5,5%), *Ulmus* sp. (5,5%) and *Rosaceae t. Crataegus* (8,2%) for the positive pole, and *Acer cf. campestre* (3,8%), *Acer cf. monspessulanum* (3,6%), *Arbutus unedo* (7%), *Rosaceae Prunoideae* (10,6%), *Quercus evergreen* (4,7%), *Phillyrea/Rhamnus alaternus* (4%) for the negative pole. The mixed sclerophyllous oak woodland taxa (*Acer* sp., *Quercus deciduous*) and pre-forest taxa (*Phillyrea/Rhamnus alaternus*, *Arbutus unedo*, *Rosaceae Prunoideae*) are found in opposition to the taxa of boxwood deciduous oak, edges (*Rosaceae t. Crataegus*) and mesophilic (*Ulmus* sp.) woodlands.

The spatial representation of the variable points makes it possible to draw a cloud of points divided into three sub-clouds. The first group is located in the positive pole of axis 1 and negative pole of axis 2. It consists of sites 5 and 6, whose assemblages are mainly based on the taxa *Erica* sp. and *Arbutus unedo*. They are accompanied by *Populus/Salix* towards site 5, and *Alnus* towards site 6. Two of the taxa have a littoral affinity, namely *Myrtus communis* and *Pinus t. halepensis/pinea*, and *Myrtus* may belong to scrubland vegetation. For site 6, the taxa *Juglans regia*, *Fagus sylvatica*, and *Pinus t. sylvestris* are added to the assemblage. These taxa are classified as additional variables, so that their rarity does not distort the CFA to the point of rendering it unreadable. The second group is drawn in the negative pole of axis 2. It represents the assemblage of site 7, which is similar to site 4 due to the strong contribution of *Quercus* evergreen. The dominant variables in this assemblage are *Quercus* evergreen, Rosaceae Prunoideae, *Acer* cf. *campestre*, *Phillyrea/Rhamnus alaternus*. This group is structured around sclerophyllous oak and maple taxa, which is supported by the less contributing variable *Acer* cf. *monspessulanum*. In the third group are the positive poles of axis 1 and 2. Sites 1 to 3 and 8, structured around the variables *Quercus* deciduous, *Buxus sempervirens*, Rosaceae t. *Crataegus* and *Ulmus* sp. The assemblages of these sites are thus characterized by mesophilic oak woodland and pre-forest edge species.

#### 4. DISCUSSION

This anthracological review provides a micro-regional overview of shrub and tree cover during the Early Middle Ages in the plains of northern Catalonia. It allows proposing a model, in the form of an east-west transect, the diagram and the CFA showing different states of vegetation. A gradient of vegetation is observed from the coast to the foothills, with a transition from Ericaceous scrub to sclerophyllous oak forest, then to deciduous oak forest (Fig. 5).

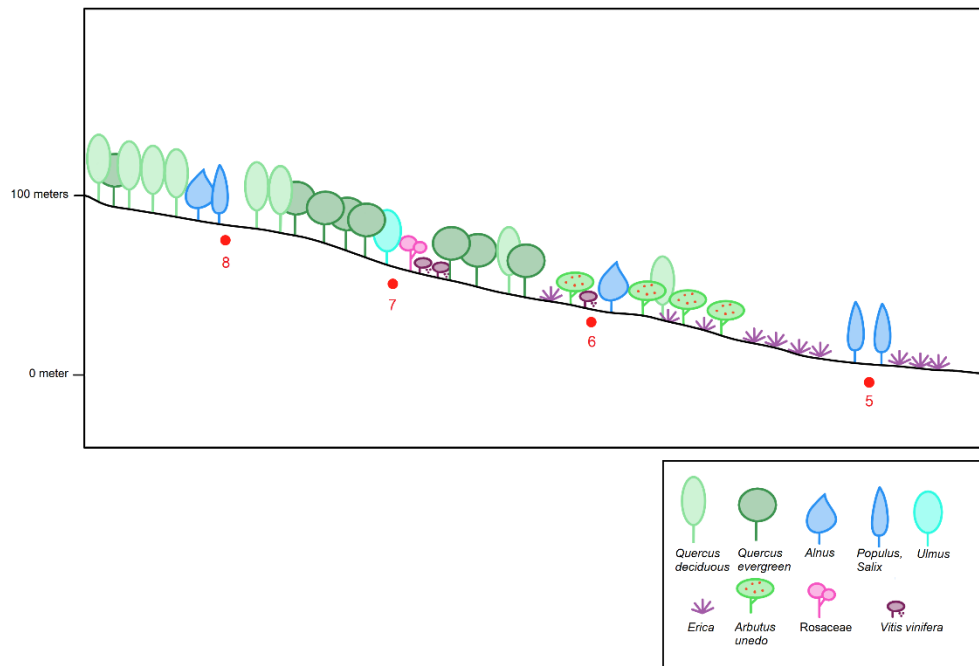


Fig. 5: Restitution of the gradient of vegetation observed from the coast to the foothills. Site number refers to table 1.

This gradient could be explained by: 1) natural factors (different edaphic conditions, altitude) favoring a layering of vegetation, or 2) the strong role of anthropic pressure, with different modes of exploitation depending on the location. The current distribution of potential vegetation and the geography of this area invalidate the first hypothesis: all the sites are located at an altitude of between 10 and 100m, which is too low to explain a bioclimatic layering of vegetation (Ozenda 1975; Quézel 1976). The hypothesis of a strong anthropic influence is supported by palynological data, documenting clearings on the plains around 3000 BC, prior to those on the mountains (Planchais 1985). For the same period, a greater exploitation of the coastal plains that gradually extended inland has also been documented in the Languedoc (Durand and Ruas 2004) and the Camargue (Chabal 2019).

To interpret these differences in the composition and state of the forest cover, we therefore need to carry out a detailed analysis, following the groups highlighted by the CFA (Fig. 4). For ease of reading, we propose a spatial reconstruction of the vegetation cover documented by the anthracological analysis (Fig. 6).

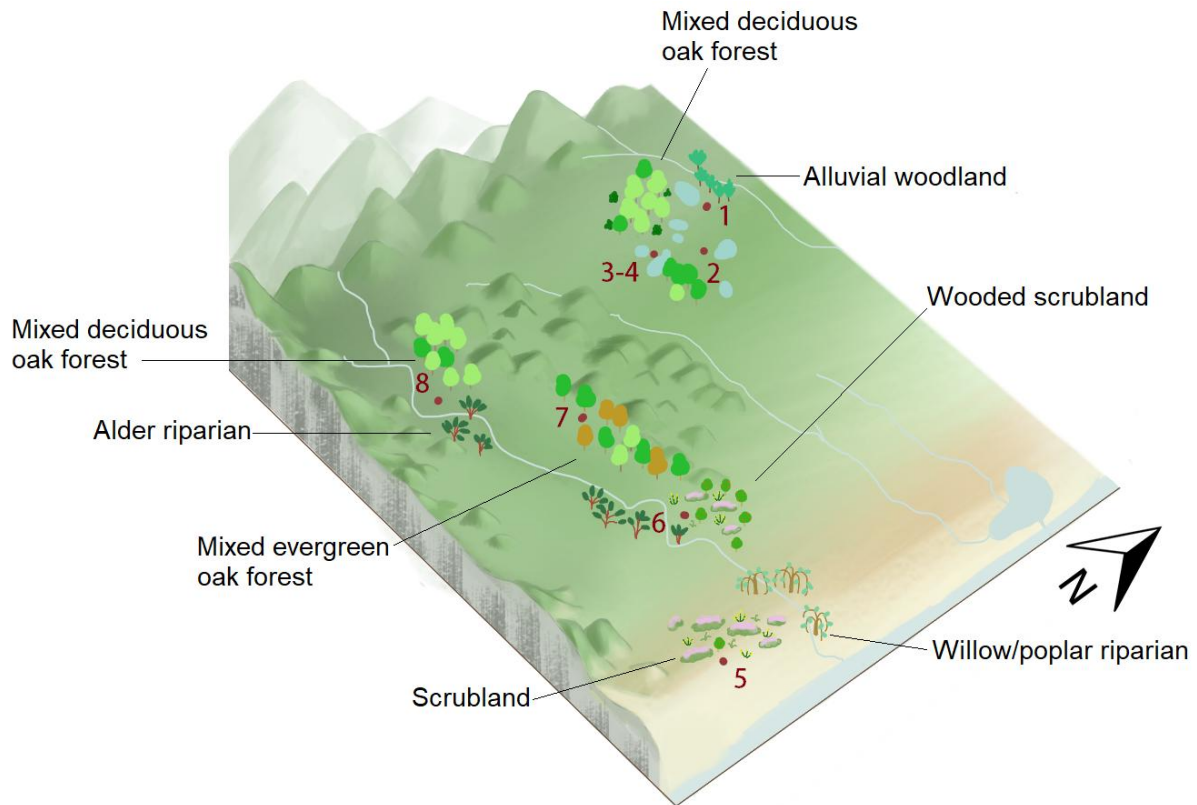


Fig. 6: Spatial reconstruction of forest cover in the plains of northern Catalonia during the Early Middle Ages.

#### 4.1. Role of human pressures in lowland areas: the opening of the matorral and riparian zones

Although the vegetation exploited by the inhabitants of Pujals and Taxo les Gavarettes appear similar, they seem to be in a different state (Fig. 3, 4) that may be explained by differences in landscape management and, more generally, by differences in human pressure on the surrounding land. Pujals inhabitants exploit a relatively dense Ericaceous scrub, with a high proportion of *Arbutus unedo* (Mesléard and Lepart 1989, 1991), and a well-preserved riparian forest, as shown by the presence of alder (Gausson 1934). The documented woodland, beyond being denser and better preserved, could have even been in the process of being closed. Recolonization of woody species is indeed possible when pastoral pressure decreases, favoring young shoots (and Fabre 2011). Between the Gallo-Roman period and the Middle Ages, this type of dynamic caused by pastoral abandonment was identified at the site of Lunel-Viel in Languedoc, and between the 3<sup>rd</sup> and 5<sup>th</sup> c., a decrease in agricultural and grazing land (Devroey 2009) is thought to have led to the regeneration of oak woodland in certain regions of Gaul (Durand and Leveau 2004). At Pujals, the woodland composition suggests little anthropogenic impact or a potential decline in agro-pastoral activity, but data from earlier phases would be needed to confirm this dynamic.

On the other hand, at Taxo les Gavarettes, the scrubland appears to be less dense (higher proportion of *Erica*) and the presence of willow and poplar, more heliophilous, indicates an open riparian zone (Rameau *et al.* 2008). This open wooded landscape dominated by *Erica* scrub is echoing the pollen sequence of Marsillargues in Languedoc, where a peak of *Erica arborea* associated with a decline in the sclerophyllous oak forest indicates an opening of the environment around the 9<sup>th</sup> century (Durand 1998). At Taxo, *Quercus coccifera/ilex* and *Q. suber* (Fig. 3) are evidence of a sclerophyllous oak woodland and a cork oak forest in a vestigial state following a major opening up (Molinier and Molinier 1974). This opening up can be explained by repeated cutting to obtain fuel and/or of burning to open up agro-pastoral areas (Durand and Ruas 2004), which favours *Erica* sp. (Mesléard and Lepar 1989, 1991). The significant anthropic pressure exerted on the wooded environment can be explained by the site's agricultural and/or craft vocation, as evidenced by the huge silage area (2,000 silos) and the discovered ovens, the function of which has yet to be documented (Puig *et al.* 2020). In the Mediterranean, the *Erica* genus has been exploited, maintained and perhaps even cultivated for charcoal-making since protohistoric times (Durand *et al.* 2010; Durand and Vaschalde 2018). Prized by blacksmiths, this charcoal was also used in domestic contexts (Gaucher and Vaschalde 2021). Although there is no evidence of charcoal-making at Taxo les Gavarettes, it seems clear that Ericaceae had a special status there.

#### 4.2. Variable human pressure in inland areas: on oak woods and alluvial forests

Some of the sites, located further inland, appear to have developed a fuel economy based on the exploitation of oak woods and alluvial forests. Although these sites all correspond to modest scale rural occupations, whose economy is centered on farming and livestock rearing, their impact on the forest landscape seems to vary, suggesting differences in pressure on the surrounding environment.

Among these sites, Camps de la Ribera (site 4) and Vignes de l'Espérance (7) are structured around *Quercus coccifera/ilex* (most probably *Q. ilex*) (Fig. 4). At Camps de la Ribera, the results are issued from a single kiln (Appendix 1). Given the nature of the only studied context, the large proportion of evergreen oak certainly reveals a strong human selection, and therefore results have scarce paleoenvironmental value (Kabucku and Chabal 2021). At Vignes de l'Espérance, sclerophyllous oaks are accompanied by *Quercus* deciduous, *Acer* sp. and *Phillyrea/Rhamnus alaternus* (Fig. 3). This composition bears witness to a stage in the dynamics of competition between holm oak and white oak, already documented in Protohistoric and Ancient Languedoc (Thiébault and Heinz 1998; Chabal 2001). In the north-



western Mediterranean, human pressure (e.g. repeated clear-cutting) tends to favor the holm oak, which grows back more vigorously thanks to its permanent foliage (Espelta *et al.* 1999). This phenomenon is reflected anthracologically by an increase in the frequency and dominance of holm oak in the studied assemblages (Chabal 2001), as at Vignes de l'Espérance. This anthropogenic pressure is confirmed by the presence of other taxa (e.g. *Erica* sp., *Cistus* sp.), identified by both anthracological and carpological remains (Ros 2020). At Vignes de l'Espérance, the opening of the environment is thought to have been favored by pastoral pressure and the exploitation of wood for fuel (Machado and Fabre 2011). The presence of *Corylus* sp. and *Fraxinus* sp. also testifies to the existence of a sparse alluvial woodland, benefiting from the moisture of the streams flowing into the Tech (Leroyer *et al.* 2012).

In sites 1 to 3 (Baltasà, Manresa, Les Baguères 56) and 8 (Le Pilà), the forest landscape is dominated by *Quercus* deciduous, probably *Q. pubescens* (Fig. 4), in mixed woodlands also populated by *Q. coccifera/ilex*, as well as *Buxus sempervirens* for sites 2 and 3 (Fig. 3). *Ulmus* sp., in association with *Fraxinus* sp., forms a mesophilic alluvial plain forest (Chabal 1997; Dufour and Piégay 2006). The wooded landscape is therefore little degraded, but the ratio between evergreen and deciduous oaks suggests that the oak forest is beginning to be exploited. The deciduous oak forest has been exploited (coppiced?) for a sufficiently short period of time and/or not intensively enough for *Quercus ilex* to be dominant, and the alluvial forest is maintained and provides fuel. This type of forest, richer in elm than ash, is similar to the dense alluvial forests identified in the medieval Camargue (Chabal 2019).

Despite the numerous wetlands that existed in the vicinity of sites 1 to 3 in the Middle Ages, the anthracological samples reveal little trace of riparian tree strata. This is a cause for concern, as it has been suggested that lands along the water's edge were exploited for local agricultural production (millets, flax cultivation and retting) and livestock rearing (production of bedding and fodder) (Ros *et al.* 2020). The exploitation of the riparian forest, prior to total clearing, leads to a vegetation dominated by *Salix* sp. (Dufour and Piégay 2006). In these sites, the total absence of willow and the presence of monocotyledonous charcoal (perhaps reed or cane), and seeds and stems of seasonal to permanent amphibian taxa suggest the existence of a very open wetland (Ros 2020), raising the question of how long these areas had been exploited, and potentially cleared before the medieval period. In contrast, site 8, located

on the banks of the Tech river, delivered a wide variety of riparian taxa, indicating the existence of substantial woodland near the river.

Finally, the presence of fruit taxa (e.g. Rosaceae, *Olea europaea*, *Vitis vinifera*) in various sites raises the question of their status, as evidence of the openness of the area (pre-forest edges and/or hedgerows) or the existence of local arboriculture.

#### 4.3. Exchange networks between the plains and mountains

While most of the sites used local species, Pujals stands out for its exceptional proportion of *Pinus t. sylvestris* (20% of the studied fragments), making it the second most important taxon of the site (Fig. 3). Other taxa with mountain affinities, such as *Fagus sylvatica* and *Abies alba*, were also identified in the same samples, raising the question of their origin.

The presence of these taxa in lowland sites, particularly in Languedoc, has sometimes been interpreted as a sign of their presence at low altitude (Chabal 1997; Durand 1998; Puertas 1998), mountain species being able to exceed their range in cooler/humid conditions (Quézel et Médail 2003b). However, Pujals stands out from these sites: the very high quantity of *Pinus t. sylvestris* charcoal fragments is an anomaly compared with the other medieval sites of the region. If this is a mountain import, the question arises as to the form and role of the imported elements. *Pinus sylvestris* can be used as timber (Davasse 1992; Chabal 1994), then be reused as fuel, as well as the waste from its manufacture. However, no elements of this type (posts, beams) were identified during the excavations. The initial nature (e.g. green wood, dead wood, architectural wood) of the Pujals pine charcoal could be revealed through entomo-anthracological analyses, as certain insects only thrive in certain types of wood (Toriti *et al.* 2021). Although we cannot confirm that pine was imported from the mountains, it is known by textual archives that during the Late Middle Ages, the Tech river had a role in transporting mountain wood to the plains, for dyeing factories (Verna 2017).

At Pujals, other resources are likely to have been imported from the mountain hinterland, in particular rye (*Secale cereale*). This cereal, which flourished in the eastern Pyrenees from the Late Imperial period onwards, was extremely sporadic and discreet on the early medieval plain, whereas it was systematic in the high-altitude sites (Ros 2020; Ros *et al.* in press). At Pujals, the discovery of samples made up of thousands of rye caryopsis, with no other evidence of local harvesting or processing (straw waste, crop weeds), is another anomaly, reinforcing the idea that the consumed plant resources were of allochthonous origin. Zooarchaeological data does not allow us to confirm or refute this hypothesis, due to the lack of strontium analyses to characterize the local nature of the consumed meat resources. To

date, Pujals faunal remains provide evidence of a trade with the coast, notably through the discovery of marine shellfish (cockles, mussels and oysters) (Ros *et al.* 2020). Pujals subsistence economy is therefore based on different supply networks, stretching from the mountains to the coast. This raises questions about the site status: is it a site with a particular socio-economic status because of its activities, or the origin of its inhabitants? Or was it a trading site, precursor of a trading economy that did not really take off in Roussillon until the 10<sup>th</sup>-12<sup>th</sup> c.?

## 5. CONCLUSION

This regional compilation has revealed a variable use and state of forest landscapes, depending on the location of the sites. On the coastal fringe, the woodland is very open, in the form of Ericaceae scrub, certainly due to the intensity of local anthropic pressure, whether agricultural, pastoral or artisanal. It remains to be determined whether the Roman occupations on the plains, and in particular the nearby urban agglomeration of Ruscino, played a role in the state of the forests inherited by the early medieval populations or if the opening were caused by the restructuration of rural settlements between the 5<sup>th</sup> and the 7<sup>th</sup> c. Inland, we observe contrasting situations, with mixed oak woodland and alluvial forest providing most of the fuel used at the various sites. Globally, the local populations did not appear to be evolving in a completely open, deforested landscape, inheriting relatively unspoilt woodland landscapes, although there were signs at several sites that the environment was opening up. At Pujals, the evidence of a network of exchanges with the mountains and the coast is a unique feature that needs to be studied in greater depth. Isotope analyses of domestic faunal remains would reveal whether these plain-mountain relationships were also expressed through transhumance.

Among the research prospects, two will be explored in the coming years. The first will be to study earlier phases (Roman period, Second Iron Age) to determine the origin of the forest opening identified on the coastal fringe. The aim will be to determine whether these open Ericaceae formations and degraded riparian zones are a consequence of protohistoric human activity, the expansion of the *villae* model during the High Empire, or the new rural dynamics of the Early Middle Ages. A second area of research will be to determine how the forest environment changed over the course of the Middle Ages in this region. During the 10<sup>th</sup> c., the city of Perpignan took on a central role in northern Catalonia, and experienced a dazzling demographic boom, the consequences of which on the landscape have been little explored. Preliminary anthracological analyses have revealed that in the oldest urban contexts, the fuel

mainly consisted of Ericaceae (Dimanche 2022). It now remains to be seen whether fuel management for the growing population was carried out in a reasoned way over the long term, or whether it led to total deforestation of the plain, leading to the establishment of commercial networks enabling the city to be supplied regularly and adequately.

## **ACKNOWLEDGEMENTS**

This research could not have been possible without the work carried out over many years by various institutions, companies and colleagues working in Roussillon, in particular the Departmental Archaeological Service of Pyrénées-Orientales, Inrap, Acter, as well as the many archaeologists whose implication was essential to constitute the archaeobotanical corpus. We would also like to thank Allowen Evin (ISEM), whose support made it possible to carry out this work and produce this paper.

**Funding:** This project received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 852573, PI: A. Evin).

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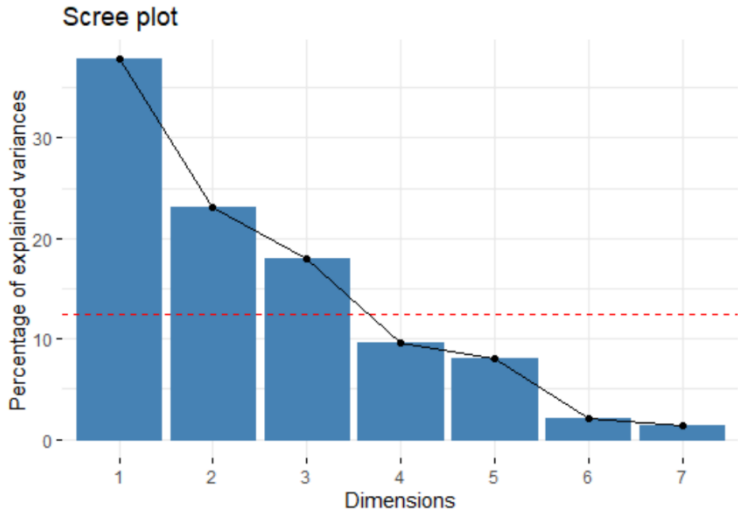
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Appendix 1: Anthracological spectrum of the corpus. Total number of 5,910 charcoal identified fragments.

Taxon	Buisson					Moyennes Coteaux					Les Rigoles III					Coteau de la Motte					Tous les sites					Région					Sud de Tignes					Le Puy					Total									
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5										
Alnus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					
Betula	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					
... (many more rows) ...																																																		

Appendix 2: Graphical representation of the percentage of variance explained for each of the dimensions of the CFA. The red limit represents the dimensions taken into account in the CFA.





Appendix 3: Contribution of the row variables to each dimension of the factorial space of the (without taking into account the additional variables).

	Dim 1	Dim 2	Dim 3	Dim 4
Buxus sempervirens	0.040555561	5.516042864	3.585243150	0.014758787
Quercus deciduous	0.826880072	23.798455804	6.567247338	12.511272611
Quercus evergreen	13.422688396	4.704225454	1.766104310	3.178268362
Quercus suber	3.381413541	2.153150242	0.692127195	0.477547774
Acer cf. campestre	1.201659067	3.857599710	0.070859814	0.004288347
Acer cf. monspessulanum	1.672333598	3.669850781	0.073139783	0.172656546
Corylus avellana	0.345192554	0.605843064	0.002371347	0.001414935
Ficus carica	0.068395747	0.939885624	7.088930799	0.001177924
Fraxinus	0.939476545	0.838421105	0.526287271	0.118985537
Rosaceae t. Crataegus	0.139737212	8.235397399	0.375591269	0.219024653
Rosaceae maloideae	0.649514868	0.005504968	0.505436704	0.013579160
Rosaceae prunoideae	0.576998952	10.655808976	1.123630110	5.219055319
Rosaceae t. Rubus fruticosus	0.007096521	1.625296318	3.448827670	0.007007391
Olea europaea	0.994478058	0.964750636	1.920282025	0.208499367
Vitis vinifera	0.006213268	0.111141926	18.308196796	1.607235619
Arbutus unedo	32.753304691	6.999100110	0.239212357	8.662773270
Cistaceae	0.097464105	3.042991122	6.092038383	0.341615201
Erica	31.332514439	0.043653264	4.389766668	17.924406609
Fabaceae	0.048282270	0.361316899	1.500395126	1.331127201
Juniperus	0.015357194	3.507581377	0.073675359	0.020255807
Lamiaceae	0.020001339	1.440390551	1.532173288	0.151760889
Monocotyledoneae	0.116272770	1.597805560	12.051182358	0.002002471
Phillyrea/Rhamnus alaternus	0.032688020	4.089174695	0.006340019	0.226407678
Pistacia	1.061851949	2.072543965	0.042463530	0.191626619
Alnus	4.259805321	0.940757125	0.427126858	31.480003711
Populus/salix	4.524146921	0.425298899	0.115872443	14.000587988
Ulmus	1.355872200	5.526725848	20.310682117	1.777141187
Ulmaceae / Fabaceae	0.010567687	1.308418578	3.380363971	0.003795068
Abies alba	0.099237137	0.962867137	3.784431943	0.131723968