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Mid-Holocene Palaeoenvironment, Plant Resources and Human Interaction in Northeast Iberia: An Archaeobotanical Approach

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Abstract: The role of the adoption of farming economies in the transformation of mid-Holocene landscapes in Northeast Iberia is under discussion given that the Neolithization coincides with the cold climatic phase dated ca. 7500–7000 cal BP. The main aim of this paper is to assess whether human activities or climate were the main driver of vegetation changes during the Middle Holocene through the study of the archaeobotanical data from three case studies: Cova del Sardo, La Draga, and Coves del Fem. The application of diverse archaeobotanical techniques to the different plant remains provides a complete picture of the vegetation composition and plant uses. During the early Neolithic, settlement surroundings were intensively exploited for firewood, wood raw material, timber, and plant fibers. The resources were obtained mainly from deciduous and pine forests, depending on the site localization, but also from riparian zones. The diversity of plants exploited was high, not only trees but shrubs and herbs. Evidence of deforestation has been identified in the settlement surroundings in La Draga and Cova del Sardo. The combination of plant exploitation with other agropastoral activities favored the expansion of colonizing species and enhanced biodiversity at a local scale.

Keywords: mid-Holocene; archaeobotany; Iberia; Neolithic; palaeoenvironment; plant resources

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1. Introduction

The establishment of a warmer humid climate during the Early Holocene in Europe [1] allowed the expansion of deciduous broadleaf forests in spaces previously occupied by pine forests and steppes [2,3]. In fact, in the most temperate Mediterranean areas, this process had already taken place at the end of the Pleistocene [3] and, following a south-north chronological gradient, progressively expanded towards the colder regions of Northern Europe [4]. This change was fundamental regarding the availability of novel raw materials that could potentially serve new uses. According to archaeobotanical investigations, these newly accessible taxa were immediately included in the economic system as raw materials for the production of all kinds of goods [5].

During the first half of the Holocene, profound changes at a socioeconomic level have been documented in Europe, involving innovations in food production (plant and animal domestication), management of resources, social organization, land use, and settlement patterns [5–11]. The new forms of subsistence involved the development of new technologies for obtaining and processing food, such as the adoption of agriculture [12,13] and animal domestication, as early as the Middle Holocene [14]. These new forms of subsistence also involved developing new types of tools and new ways of using vegetable raw materials. The importance of plant resources is reflected in the development of specific implements to obtain and transform them, especially in farming societies, as they substantially increased those societies' capacity to transform the environment. New technologies for forest resource exploitation and felling trees and shrubs and totally new tools specialized in woodwork (adzes, axes, planes and chisels) appeared and expanded.

Early evidence of farming societies in the northeast of the Iberian Peninsula are documented circa 7500–7400 cal BP [15–18]. According to the lack of ^{14}C dates corresponding to the first half of the eighth millennium cal BP and the very few corresponding to the second half of the ninth millennium cal BP it has been proposed that the first farmers colonized an empty or practically unoccupied area. The Neolithization in the region coincided with the cold climatic phase dated ca. 7500–7000 cal BP [19,20]. Therefore, the effect of the adoption of farming economies in the mid-Holocene landscapes in Northeast Iberia is under discussion, as it is difficult to identify whether human activity or climate was the main driver of vegetation change [5]. It has been proposed that agricultural practices had little impact on the environment because crops were grown in small plots [13,14,21]. The main question is whether the Neolithic communities' strategies of non-food plant exploitation in Northeast Iberia had greater impact on the landscape.

The establishment of open-air settlements in the Mediterranean area, for example at La Draga (Spain) or Dispilio (Greece), both dated to the eighth millennium cal BP, coincided with a significant decrease in arboreal pollen [22–24]. At such sites, these decreases were related to the felling of timber for the construction of dwellings, among other purposes. At these sites, the good preservation of organic materials has provided evidence of such felling of trees. However, most archaeological sites only provide a partial picture of non-food plant resource exploitation: charcoal remains resulting from firewood consumption are the only evidence of plant use. Yet firewood was only one of the resources needed by Neolithic communities. Although very few sites provide evidence of other forms of plant exploitation, when found, they display a great diversity of products made from plant raw material. In this paper, we analyze the role of human activity related to plant exploitation as a factor of landscape transformation during the Middle Holocene through the study of the archaeobotanical data from three case studies: Cova del Sardo, La Draga, and Coves del Fem (Figure 1). These sites are located in different biogeographical regions and are also characterized by different levels of preservation of plant remains. The main objectives of the research were: (i) to characterize past vegetal landscapes; (ii) to document the non-food plant exploitation strategies of Neolithic communities; and (iii) to identify the different intensities of human signals in the environment. The ultimate aim of the paper is to compare the impact that Neolithic societies exerted at a local and regional level through the three mentioned sites in Northeast Iberia. The application of diverse archaeobotanical techniques to the different plant remains preserved in the archaeological record provides a complete picture of vegetation composition and plant uses.

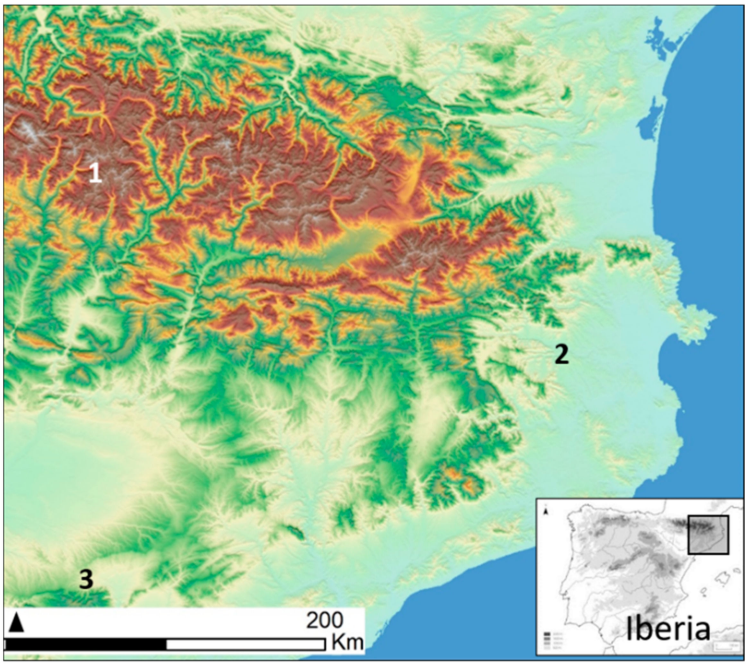

Figure 1. Location of the sites in the northeast of the Iberian Peninsula: 1. Cova del Sardo, 2. La Draga, 3. Coves del Fem.

2. Geographical Settings

The landscape in the northeast of the Iberian Peninsula is extremely diverse due to the heterogeneous orography and climate in the territory. Altitude and distance from the coast strongly influence the climate in this broad region and different sub-climates have been defined: littoral Mediterranean with low and irregular precipitation, in a limited area due to the presence of mountain ranges near and parallel to the coast; humid Mediterranean or sub-Mediterranean, characterized by higher precipitation and colder temperatures in inland regions close to the pre-Pyrenean slopes (500/1000–1600/1800 m asl); and continental Mediterranean, with low precipitation and contrasting temperatures; very warm in summer and cold in winter. The high-mountain or axial Pyrenees have a continental Atlantic-influenced climate with different mountain sub-types.

The vegetation is characterized by the presence of Meso/Thermo-Mediterranean vegetation on the Mediterranean coast and inland, with the dominance of evergreen sclerophyllous forests (*Quercus ilex* L., *Quercus coccifera* L., *Pinus halepensis* Mill.) and shrublands (maquia and garrigue). In the sub-Mediterranean area, humid Mediterranean forests (mixture of pines and deciduous *Quercus*, *Corylus avellana* L. and *Fagus sylvatica* L.) dominate in the landscape. Finally, boreal conifer forests (*Pinus uncinata* and *Abies alba* Mill.) are present in the subalpine zone (1600–2300 m asl) in the Pyrenees.

In this study, we focus on three different Northeast Iberian areas: high-mountain Pyrenees (Cova del Sardo), the northern inner plain (La Draga) and the southern Montsant mountainous area in the Ebro Valley (Coves del Fem) (Figure 1). These areas allow us to conduct landscape reconstruction and to study human management of vegetal resources during the Neolithic in Euro-Siberian conifer forests, in sub-Mediterranean broadleaf deciduous forests and in Mediterranean sclerophyllous forests.

Cova del Sardo is situated in the central part of the Aiguestortes i Estany de Sant Maurici National Park (PNAESM). The park covers an area of 14,119 ha around the heads of the Sant Nicolau and Espot valleys, in a high montane environment with glacial landforms and granite substrate. The PNAESM ranges in altitude from 1300 to 3000 m asl and contains four vegetation belts: upper montane, subalpine, alpine and subnival [25]. The climate is defined as mountain Atlantic-influenced; predominantly temperate in the valleys and colder in the peaks. The mean temperature is around 4–5 °C in Sant Nicolau upper valley.

Over 1800 m asl, temperatures hardly reach above 0 °C during winter and 10–13 °C in summer, with an annual precipitation of 1200 mm, mostly as snow.

The site of La Draga is located in the Pla de l'Estany, which consists of a plain around Lake Banyoles (173 m asl) surrounded by medium-height mountains (600–985 m asl). The climate in Banyoles is defined as humid Mediterranean or sub-Mediterranean, with an annual precipitation of 750 mm and a mean annual temperature of 15 °C.

Finally, Coves del Fem is located in the Parc Natural de la Serra del Montsant. It belongs to the Catalan Pre-Coastal Range, with steep valleys over the course of Montsant river, a tributary to the Ebro River, and reaching maximum heights of 1063–1163 m asl. The climate is defined as Mediterranean, with an annual precipitation of 525 mm and a mean annual temperature of 13.2 °C in Ulldemolins.

3. Archaeological Settings: Case Studies

Cova del Sardo (code VB-014) is a 19.3 m^2 natural rock shelter, with an exterior terrace of 110 m^2 with evidence of occupation. The site is located at 1774 m asl in a small alluvial semi-plain in the middle Sant Nicolau valley, in the lower subalpine belt, facing south and 60 m above the modern river bed (Figures 1 and 2). The first evidence of human presence in Cova del Sardo was dated in 8th millennium BP, at 7513–7326 cal BP, from an excavated hearth structure under the rock shelter cornice (Phase 9) [26]. Nevertheless, the lack of pottery does not allow a cultural attribution of this occupation. The first Neolithic occupation of the site took place during the 7th millennium BP, between 6776–6325 cal BP (Phase 8). This occupation was located both under the cornice and on the terrace surface, where different hearth structures and walls were built and used [27,28]. Afterwards, the site was reoccupied, especially under the rock shelter between 6179–5325 cal BP (Phase 7). During the late 6th millennium BP, in the Late Neolithic (Phase 6), a pine wood palisade was identified under the cornice and over the terrace. Finally, in the 5th millennium BP from 4851 to 4445 cal BP, during the Chalcolithic period, the rock shelter was occupied for the last time in Prehistory (Phase 5). Widespread occupation of different rock shelters is documented in the area of PNAESM in this last period [29], some of them very close to Cova del Sardo: for instance, the sites of Cova de Sarrade and Abric de les Covetes (4521–4296 cal BC) are located in the 1 km^2 surrounding area. All these occupations ended abruptly at a time dated in most sites to 4250 cal BP, around the 4.2 cold/arid event [30]. The present paper discusses the results of the study of plant macro-remains found in the excavation of one of these rock shelters (Cova del Sardo) and its outer terrace, together with pollen and phytolith analyses [31–33]. The results are then contextualized with a geological core that was taken 530 m from the site, in a river terrace in the valley bottom (Forcall de Sant Esperit-AS 2), which provides environmental information about the occupation area outside the rock shelters but is contemporary with it.

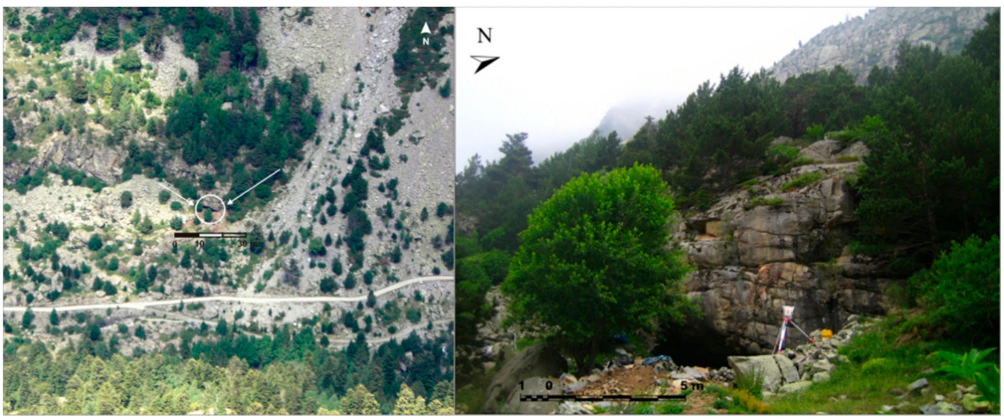

Figure 2. (**Left**) General view of the location of Cova del Sardo, the white circle indicates the rock shelter. (**Right**) Detail of the entry of the rock shelter. Photographs by Grup d'Arqueologia de l'Alta Muntanya UAB-CSIC.

La Draga is located on the eastern shore of Lake Banyoles (Girona, Spain) at 170 m asl (Figures 1 and 3). The lake, located in a natural tectonic depression, is approximately 2100 m by 750 m in size. The archaeological site covers a surface area of over 15,000 m^2, of which near 1000 m^2 have already been excavated, including 400 m^2 that are waterlogged. Several sectors have been differentiated: in Sector A, the archaeological level is above the water table. In Sector B, the archaeological level is below the water table, and Sector C is currently under water. In Sectors B and C, the waterlogged conditions have favored the preservation of organic remains, including wooden tools and plant crafts (bows, handles, baskets, cords, combs, digging sticks, vessels, spindles, and sickle handles), wooden architectonical elements, fungi and leaves, from the earliest occupation [34–42]. The available radiocarbon dates have determined an occupation from 7274 to 6927 cal BP (Phase I), and a more recent occupation from 7160 to 6746 cal BP (Phase II) [40,43], both corresponding to the early Neolithic farmers who settled in the region. According to the dendrochronological data, the first settlement had a minimum duration of 29 years [43]; later the site was reoccupied several times. Here the results of the study of wood, charcoal, seeds, fibers and pollen from the archaeological layers are discussed and then contextualized with the results of pollen analysis performed off-site.

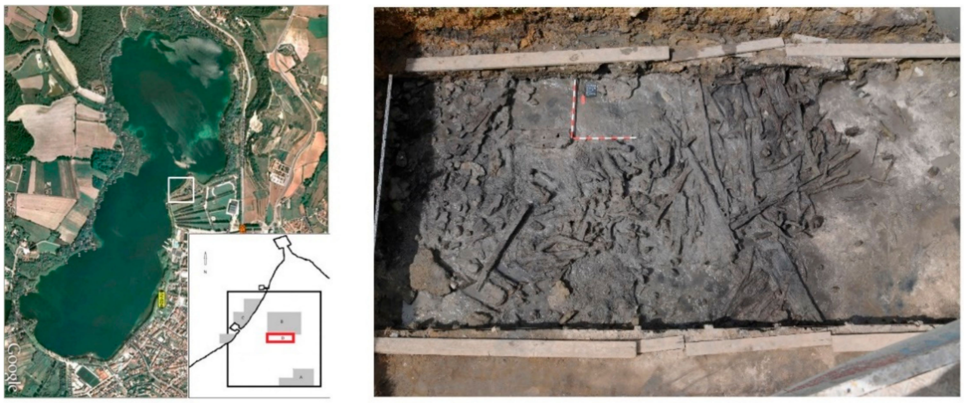

Figure 3. (**Left**) Details of the location of La Draga site, indicated with a white square, on the shore of the Banyoles Lake. (**Right**) Wooden layer of sector D corresponding to Phase I (red rectangle in the left picture). Photographs by La Draga team.

The site of Coves del Fem (Ulldemolins) is located in the Natural Park of Serra del Montsant in Southern Catalonia (Figures 1 and 4). Today the site is a rock shelter 10 meters above the current level of the Montsant River, with a surface area of 300 m^2. The first fieldwork season at the site has revealed a stratigraphy almost 135 cm thick, which covers the transitional period from the last hunter–gatherers to the first farming occupations in the area [44–46]. The excavated surface in the upper layers covers 9 m^2 whilst from Layer 1008 to Layer 1014 the excavated surface is limited to 5 m^2. The upper layers documented at Coves del Fem are ascribed to the Early Neolithic Epicardial (6891–6495 cal BP), the last Early Neolithic phase in the region. In these layers, pollen is well preserved and carbonized archaeobotanical remains are abundant, including basketry, charcoal, fruits, and seeds. Wooden remains have also been preserved desiccated, displaying woodworking traces. These layers have also provided evidence of cereal cultivation. The layers attributed to the Early Neolithic Cardial, the first Neolithic phase in the region, are dated between 7617–7427 cal BP. Finally, the lower layers correspond to the Mesolithic occupations of the last hunter–gatherers (8005–7668 cal BP). Abundant macrobotanical remains have been recovered in both the Cardial Neolithic and the Mesolithic layers.

Figure 4. General view of Coves del Fem. Photograph by Coves del Fem team.

4. Methods

The different parts of plants were used in diverse ways in Prehistory. The repeated use and even the discarding of particular parts have greatly conditioned their integration in the archaeological record. In addition, it is known that not all the parts of a plant are preserved in the same way in the record. Factors such as their fragility, as in the case of fibers or the pollen of certain species that are under-represented in the archaeological record, or whether or not they have been exposed to fire in the case of wood, fruit, and seeds, condition our awareness of their presence at a site. The holistic approach applied in this paper, combining different archaeobotanical disciplines, each one specializing in different remains of the same element, can achieve a much wider and precise picture of the palaeovegetation and how prehistoric human societies interacted with it. Thus, wood, charcoal, phytoliths, and pollen have been analyzed in order to reconstruct the vegetation history, resources exploited, and the human signal in the environment. Here, we briefly explain the methods used for sampling and identifying the plant remains.

The sediment sampling and processing strategies applied at each site are slightly different, but always of a systematic nature, combining hand-picking of large objects (mainly wood and charcoal fragments) with sediment processing with water for the recovery of smaller organic remains. At Cova del Sardo, the type of sampling was probabilistic (20% of all stratigraphic units were sieved) and the sediment was processed in a flotation tank [21]. At La Draga, several sampling and sieving strategies have been applied over the years [47], but, since 2010, a combination of samples taken per grid quadrant (50 × 50 cm) and from profiles and sieved with the wash-over technique and samples water-screened for the recovery of larger items (>2 mm) was applied [21,48]. At Coves del Fem, sediment was processed in a flotation tank to recover charcoal and seed remains, while charcoal was also recovered by hand and dry screening. The mesh sizes that were used to collect the heavy fraction (non-organic material) and the light fraction (of organic remains) were 4, 2, 1, 0.5 and 0.3 mm.

Seed identification was based on morphometrical criteria and the observation of the seed surface in comparison with reference collection material at the Museu d'Arqueologia de Catalunya-Girona and the IPAS at the University of Basel, as well as identification atlases for wild plants [49] and cultivated plants [50]. A stereomicroscope with a 6.5−50× magnification range was used for this purpose.

The determination of wood and charcoal followed standard procedures. The anatomical patterns of each wood species were observed along three anatomical sections (transversal, longitudinal tangential, and longitudinal radial) using a reflected light microscope equipped with bright/dark field (BF-DF), in the case of charcoal, and transmitted light, in the case of wood samples [51,52], at magnification factors between 40× and 400×. Archaeological samples were compared with modern wood, as well as with wood anatomy atlases [53].

The study of wooden artifacts consists of the identification of the raw material from its anatomical features and the characterization of the technological processes based on the marks observed on the artifact surface [34,41,42]. In addition, the age and diameters of piles and planks were recorded in order to characterize the forest exploited [41,54]. The study of dendro-anthracological factors is vital to understand forest management by past societies. Among these, the minimum diameter of the wood has been one of the most frequently used factors. Qualitative analysis, based on the curvature of the growth rings [55], has been replaced by more precise quantitative approaches that use new image analysis tools [56]. The calculation of the minimum diameters, whether it is based on the morphology of the growth rings (circle method) [57] or on trigonometrical methods of the convergence of the radiuses of the wood [58–60], enables hypotheses to be proposed about the parts of the plants that were obtained and the practices of forest management.

Vegetal fiber identification is usually performed using both optical microscopy (OM) and scanning electronic microscopy (SEM). The samples needed are minimum-sized and are usually fragments broken during the excavation and restoration processes. As in charcoal analysis, transversal sections are observed using a reflected BF-DF optical microscope. SEM analysis allows the observation of both transversal and paradermal surfaces. The method needs samples to be mounted on stubs with carbon tapes and sputter-coated with a thin layer of gold (10–15 nm). In both cases, archaeological sample descriptions are based on microanatomical observation and compared with modern materials and specialized technical literature [53,61].

Underground storage organs (USOs) are plant structures that store energy (mostly carbohydrates) and water, and include roots, tubers, or bulbs. The identification of USOs is based on the detailed description of the observable anatomical structures [62]. In the case of small-sized tubers that are complete, the outer features, such as shape or detachment scars, may be the key, whereas it is necessary to examine the internal anatomy of fragmented storage organs, especially the organization of vascular tissue and anatomy of parenchyma cells, for which SEM is required.

Palynological studies provide data to reconstruct vegetation history at local (archaeological sites) and regional (lacustrine deposits) scales and environmental conditions at the local scale (pollen from hygrophytes and aquatic plants and non-pollen palynomorphs-NPP) [63,64]. Samples were processed following standard methods [65,66] and 300–400 pollen grains of terrestrial taxa per sample were identified according to pollen atlas [67,68] and specialized literature [63,64,69]. Pollen analysis is also a source of information about plant uses in archaeological sites, given the overrepresentation of herbaceous pollen in this type of context, enabling the identification of crops and gathered species.

Phytolith studies have been approached using different methods and objectives in archaeology [70]. In our case study, phytolith analyses have been applied as an archaeobotanical tool, complementary to vegetal macro-remains studies and other microscopical proxies, and used to reconstruct intra-site and off-site plant management, including shepherds' practices [71]. Phytolith proxies have also provided local data to reconstruct vegetation changes and past landscapes in human-impacted or occupied areas, using test pits and soil profiles in the surrounding area of main settlements [28,72]. The samples were processed using the sodium polytungstate (SPT) method for phytolith extraction [73]. Here, 200–400 phtytolith per sample were identified according to the International Code for Phytolith Nomenclature (ICPN 2.0) [74] using a transmitted light optical microscope (OM) at 400x magnification.

5. Results

5.1. Cova del Sardo and Forcall de Sant Esperit (AS 2)

A total of 136 seed/fruit remains were recovered at Cova del Sardo, from all four Neolithic occupation phases (Phases 8 to 4). The low number of finds and the similarity in the results obtained does not allow the observation of any trends or changes in plant use between the different phases. Fifteen taxa were identified. The edible plants include cereals: barley (*Hordeum vulgare* L. var. *nudum*) and naked wheat (*Triticum aestivum* s.l./*durum*, as well as some fleshy fruits, nuts and berries: *Rubus fruticosus* L. agg., *Rubus idaeus* L., *Corylus avellana* L., *Prunus padus* L., and *Pinus sylvestris* L. Among non-edible plants, several other taxa were encountered, including potential weeds or ruderals (*Galium aparine* L. subsp. *aparine* and *Galium aparine* L. subsp. *spurium*), plants from woodland edges and clearings (*Sambucus* cf. *racemosa* L.) and woodland taxa like *Cornus sanguinea* L. and *Abies alba* Mill., as well as taxa that were not identified at the species level and could have had several uses: cf. Asteraceae, *Potentilla* sp., *Vicia* sp. and *Vicia/Lathyrus.* Some of the fruits probably reached the site together with wood gathered for fuel, such as *Prunus padus*, which is edible but not normally eaten without previous processing, or *Abies* needles and cone fragments of *Pinus sylvestris*. Other taxa may have a more accidental presence at the site, such as *Galium aparine* fruits, which could have arrived attached to animal fur and been charred by accident [21].

A large number of charcoal samples were taken for a taxonomic study from all the studied levels, both in Cova del Sardo and in its outer areas. The study of 963 charcoal fragments from the 16 stratigraphic units in Cova del Sardo (Figure 5) documented the dynamics of forest management by the agropastoral societies that occupied the valley in the Neolithic [33]. The results showed the predominance of Scots/mountain pine (*Pinus* type *sylvestris/uncinata*) in the whole sequence, in which they made up 79.83% of the remains, accompanied by other conifers like *Juniperus* and *Abies*, which were quantitatively important in some levels (Figure 5). Deciduous species were less common, but included *Quercus* sp. deciduous and *Betula* sp., as well as riparian taxa like *Fraxinus* sp., *Corylus avellana* and willows (*Salix/Populus*). The relative abundance of *Juniperus* in Phases 7 and 5 is especially interesting because this taxon grows in open spaces, which may indicate a use of the shrubs that colonized forest clearings.

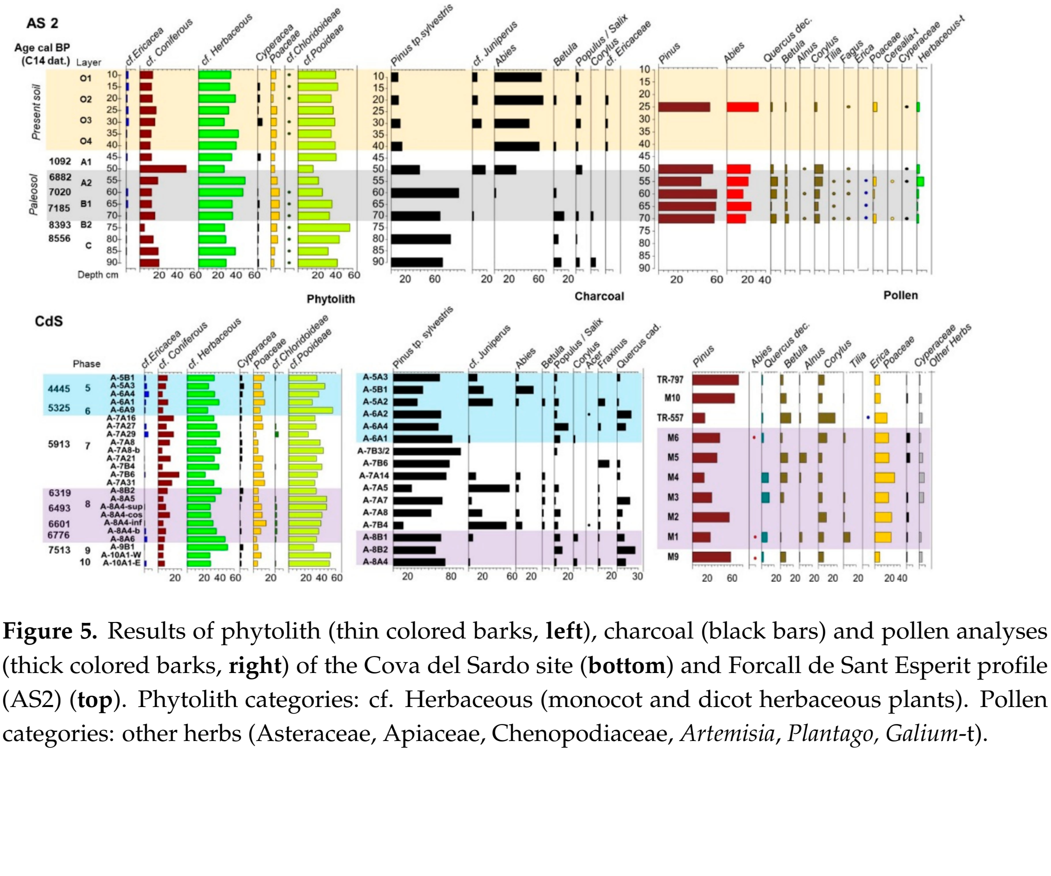

Figure 5. Results of phytolith (thin colored barks, **left**), charcoal (black bars) and pollen analyses (thick colored barks, **right**) of the Cova del Sardo site (**bottom**) and Forcall de Sant Esperit profile (AS2) (**top**). Phytolith categories: cf. Herbaceous (monocot and dicot herbaceous plants). Pollen categories: other herbs (Asteraceae, Apiaceae, Chenopodiaceae, *Artemisia*, *Plantago*, *Galium*-t).

Pollen analyses show that the forest was most affected in the proximities of the site (Figure 5), especially during Phase 8, when a more intense occupation of the outer terrace has been documented (6800–6400 cal BP) [31]. However, when these results are compared with those from a test pit 530 m to the southeast of Cova del Sardo in Forcall de Sant Esperit (AS2), an earlier low-intensity stage of human impact is detected, at a time of a mixed forest of conifers (*Pinus* and *Abies*) and broadleaf taxa (*Quercus*, *Corylus*, *Tilia* and *Fagus*). In climate terms, this period (7250–6350 cal BP) seems to correspond to a period with a greater relative frequency of thermo-mesophile species and is interpreted as a more temperate phase. The presence of *Abies* pollen is very significant in this period, in relative percentages of 16–25%, as this species was thought to have reached the valley in a more recent chronology. The marginal frequency of *Fagus* is also quite significant. A phase of erosive degradation and increase in ruderal species (Apiaceae, Amaranthaceae-Chenopodioideae) and shrubs (Ericaceae, *Juniperus*) later than 6882 cal BP was identified at the base of this level. In addition, Cerealia-t pollen and spores of coprophilous fungi (*Cercaphora*-t) were detected in association with a decrease in arboreal pollen, especially of *Pinus*. These results are coherent with the 10 pollen samples studied for the interior of Cova del Sardo, but in a chronology that is one or two centuries earlier, which suggests that opening up of the valley bottom must have preceded the occupation of the site [28].

A total of 41 sedimentary samples of phytoliths have been studied for Cova del Sardo and its immediate surroundings [28]. For the Middle Holocene occupation phases, 12 phytolith samples came from the occupation levels inside the rock shelter, 12 from the outer terrace and 17 from AS2. In this test pit, a geomorphological study identified a pozsol-type palaeosoil, rich in charcoal, organic matter and phosphorus, with an anthropic origin, and dated between 7243 and 6882 cal BP. An earlier geological level was dated to the end of the Early Holocene, in 8556–8393 cal BP. In AS2, the sedimentary anthracomass was calculated and the micro-charcoal of different sizes was studied to observe the dynamic of palaeo-fires. These corroborated the frequent iteration of fires in the valley following the first Neolithic occupation, between 7243 and 6882 cal BP.

The phytoliths associated with this first anthropic occupation level in the valley (Figure 5), dated 7200–6800 cal BP, indicate the proliferation of different herbaceous plants types and Gramineae that does not correspond to the typical natural sub-Alpine meadows, these normally develop in sunny open environments and are formed by grasses of the C_3 Pooideae photosynthetic pattern usually dominated by *Festuca eskia* [28]. The increase in ruderals herbs in these burnt palaeosoils in the valley bottom may reflect a typical pattern of hygrophile meadows, very acidic and rich in organic matter, characteristic of areas that flood seasonally or are very humid, where monocotyledons of shaded areas proliferate, like *Nardus stricta* and *Carex* sp., together with other herbaceous plants rich in nutrients for livestock (*Trifolium alpinum, Plantago alpina, Poa supina, Chenopodium sp., Galium aparine,* etc.) [75]. The formation of these palaeosoils would be due to a reiterated use of fire to clear them and the introduction of domestic animals, but without completely deforesting the area [72].

5.2. La Draga

Seed and fruit remains were found in extremely high numbers at La Draga (well over 300,000) [21,47]. A large part of the recorded remains consists of charred cereal remains (Figure 6) including naked wheat (*Triticum durum/turgidum* type), 2-row barley (*Hordeum distichum*, possibly naked) and small amounts of emmer (*Triticum dicoccum*), einkorn (*Triticum monococcum*) and Timopheev's wheat (*Triticum timopheevi*). Among other quantitatively well represented plants, opium poppy (*Papaver somniferum*) was probably a cultivated plant at the site. Significant amounts of gathered plants with alimentary uses were also detected; for instance, acorns (*Quercus* sp.), hazelnuts (*Corylus avellana*), crab apple (*Malus sylvestris*), sloe (*Prunus spinosa*), bramble (*Rubus fruticosus*) and wild grape (*Vitis vinifera* subsp. *sylvestris*). Most remains were found in an uncharred state. No major differences have been observed so far between the two occupation phases in terms of the main plants consumed as food. Differences were mainly due to taphonomic reasons, since the youngest phase at the site is not preserved under permanently waterlogged conditions and therefore uncharred plant remains are absent. Our results for non-food plants consequently focus on the first and oldest occupation phase. Plants from aquatic/shoreland environments are prominent: *Alisma plantago-aquatica*, *Apium nodiflorum*, *Chara* sp., *Cladium mariscus*, *Cyperus fuscus*, *Iris pseudacorus*, *Lycopus europaeus*, *Mentha aquatica*, *Najas marina/intermedia*, *Nymphaea alba*, *Phragmites australis*, *Polygonum lapathifolium*, *Potamogeton* sp., *Ranunculus aquatilis*, *Ranunculus sceleratus*, *Scirpus lacustris*, *Typha angustifolia* and *Typha latifolia*. Some ruderals or potential weeds may also be listed, such as *Eupatorium cannabinum*, *Plantago major*, *Urtica dioica* or *Verbena officinalis*, among others. Among plants from woodland areas, abundant remains of *Alnus glutinosa*, fruit stones of *Cornus sanguinea*, *Crataegus monogyna*, *Taxus baccata* and *Tilia platyphyllos* have been recovered. As in other pile-dwelling sites, it was found that some uncharred fruit stones (probably *Prunus avium*) were transformed into beads, which is a type of use of plant material that is not often documented in dry sites. Despite the extraordinary preservation of organic material at the site, only a single USO remain has been found at La Draga, in Square JJ78, excavated during the 2010 field season. It was studied in 2012 in the BIAX Consult laboratory (Zaamdam, The Netherlands) in collaboration with L. Kubiak-Martens. It seems to be a fragment of a dicot, probably from the *Cyperus* genus.

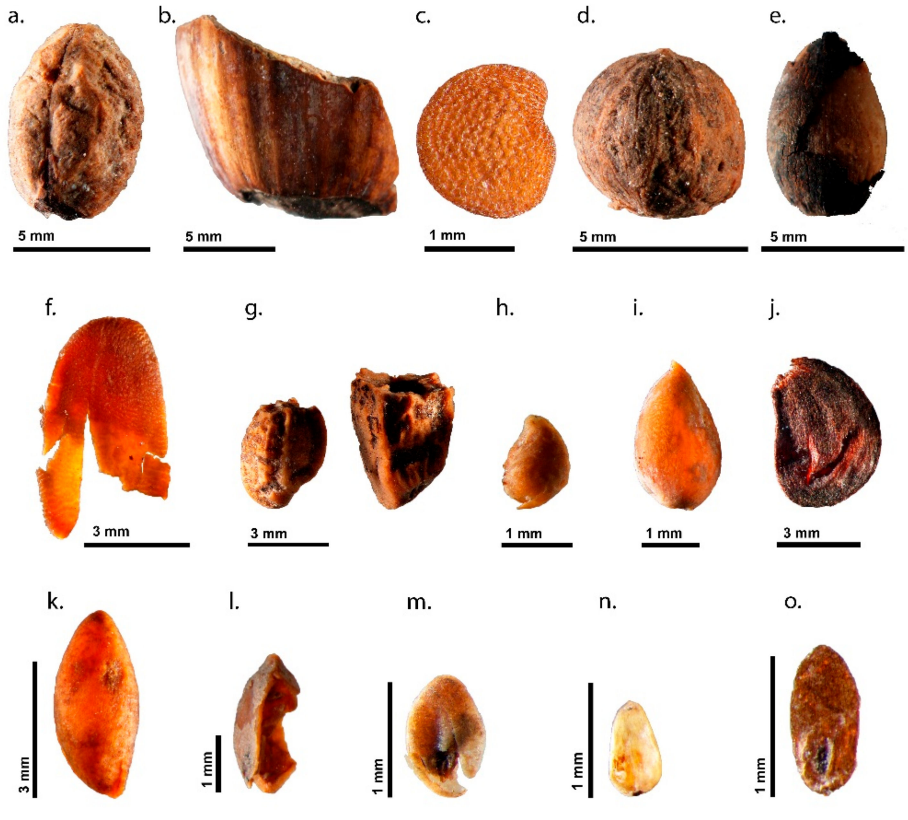

Figure 6. Images of seed and fruit remains of La Draga: (**a**) *Crataegus monogyna*, (**b**) *Corylus avellana*, (**c**) *Physalis alkekengi*, (**d**) *Cornus sanguinea*, (**e**) *Taxus baccata*, (**f**) *Silybum marianum*, (**g**) *Carthamus* cf. *lanatus*, (**h**) *Fragaria vesca*, (**i**) *Viola* cf. *alba*, (**j**) *Pyrus malus* subsp. *sylvestris*, (**k**) *Najas intermedia/marina*, (**l**) *Carex* cf. *hirta*, (**m**) *Linum* cf. *catharticum*, (**n**) *Campanula* cf. *rotunda*, (**o**) *Phragmites* sp. Photographs by F. Antolín.

Pollen analysis (Figure 7) has provided information on the plant landscape and its evolution, as well as on plant availability in the surroundings of the settlement [22,23]. Pollen was sampled at the archaeological site and in the lake sediments. SB2 core was obtained on the western lake shore [23]. Additionally, the stratigraphy of the site was sampled in Sector B [64] and systematic sampling of the surface was performed in Sectors B and A [76].

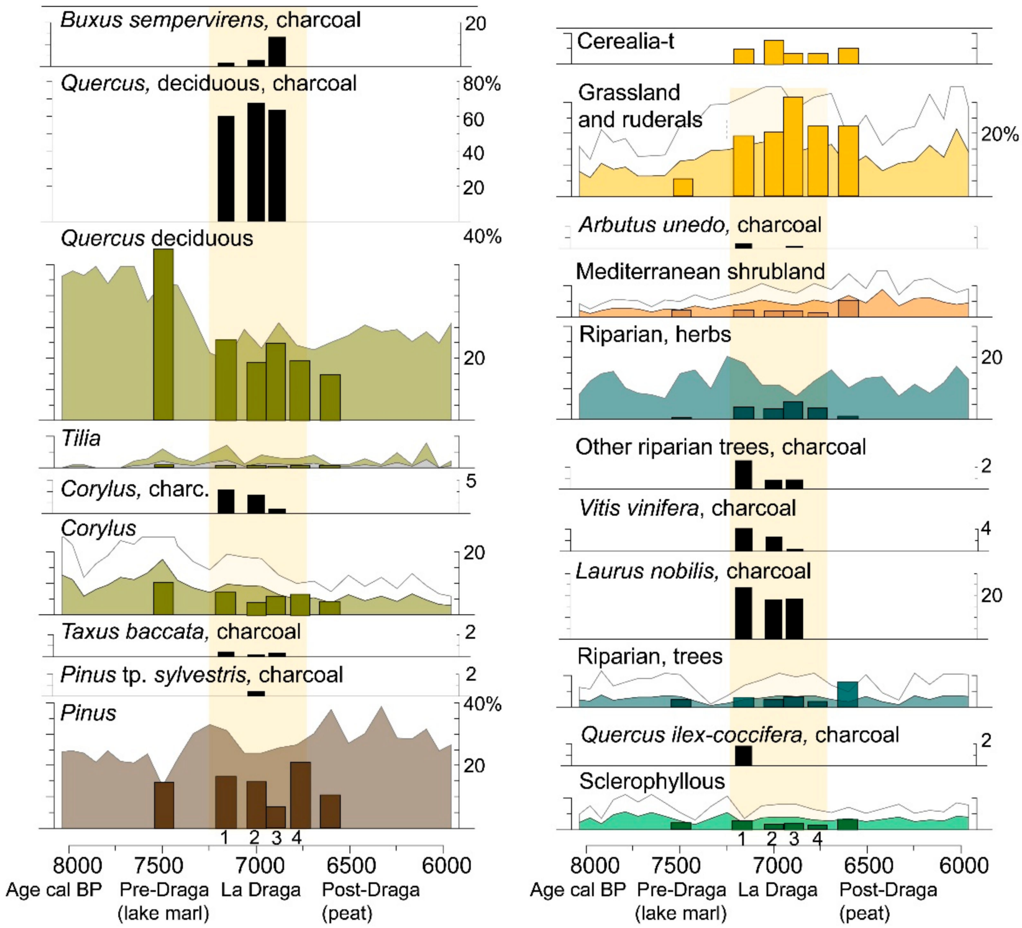

Figure 7. Results of pollen and charcoal analyses of La Draga. Percentage diagram for selected pollen taxa and categories from core SB2 (silhouettes) and pollen (color bars) and charcoal taxa (black bars) from La Draga. Pollen samples from La Draga consist of lake marl previous to Neolithic occupation, sediments from (1) Phase I Sector B, (2) Phase II Sector B, (3) Structures Sector A, (4) Layer 2002 (covering structures Sector A); and finally, samples from post-abandonment peaty layers. Pollen categories: sclerophyllous (*Quercus ilex-coccifera*, *Olea*, *Phillyrea*), Riparian trees (*Alnus*, *Fraxinus*, *Salix*, *Ulmus*), Riparian herbs (Cyperaceae, *Typha*, *Typha-Sparganium*), Mediterranean shrubland, (*Erica*, Cistaceae, *Rhamnus*), grassland and ruderals (Poaceae, *Plantago*, *Plantago major-media*, *Artemisia*, Amaranthaceae-Chenopodioideae, Apiaceae, Lamiaceae, *Galium*-t, *Rumex*, Brassicaceae, *Filipendula*). Anthracological samples consist of (1) Phase I Sector B, (2) Phase II Sector B, (3) Structures Sector A. Charcoal categories: Other riparian trees (*Fraxinus* sp., *Ulmus* sp., Salicaceae).

The first farming societies settled in a humid and dense forested area, with the predominance of broadleaf deciduous forests (deciduous *Quercus* and *Corylus*) and conifers (*Pinus* and *Abies*) in the surrounding mountains. The low values of evergreen sclerophyllous taxa (*Quercus ilex-coccifera*, *Olea* and *Phillyrea*) suggest their existence regionally despite being scarce at the local scale. In the settlement surroundings, riparian forests (*Ulmus*, *Fraxinus* and *Salix*) developed along the lakeshore, where hygrophyte (Cyperaceae, *Typha latifolia*, *Typha-Sparganium*, *Juncus articulatus* type, *Juncus effusus* type, *Cladium mariscus* and *Mentha* cf. *aquatica*) and aquatic plants (*Potamogeton coloratus*) were also present [23,64].

Once Neolithic communities had settled at La Draga in ca. 7270 cal. BP, a fall in deciduous *Quercus* pollen values is recorded at the site [64,77,78] and in lakeshore peat deposits [22,23,78]. The space left by oak forests was colonized by herbs (Poaceae, Asteraceae and *Plantago*), shrubs (*Buxus* cf. *sempervirens*, as shown by its expansion in the anthracological record from the second occupation phase at La Draga; [35,79] and secondary trees (*Pinus*, *Tilia* and *Corylus*). Part of the clearances would have been used for cultivation and grazing, but a large part of them remained unused and were colonized by secondary trees, leading to a limited decline in AP. The low values of sedimentary charcoal recorded in the SB2 sequence [23] suggest that burning was not involved in the deforestation process. In that context, the practice of intensive farming practices in small crop fields would have resulted in an almost imperceptible impact of agriculture in pollen records from off-site deposits, and deforestation was linked with the need for firewood and raw material for construction [80].

The forests around the site of La Draga were used persistently for timber, firewood and plant fibers (Figure 8). In the oldest occupation phase, as many as 17 woody species were obtained, mainly in the surrounding broadleaf forest and riparian woodland (Table 1). Hygrophile and aquatic plants were also exploited.

Figure 8. Wooden tools and cordage of La Draga site: (**a**) paddle of *Quercus* sp. deciduous, (**b**) handle axe of *Pinus* sp., (**c**) sickle handle of *Sambucus* sp., (**d**) digging stick of *Buxus sempervirens*, (**e**) ladle of *Quercus* sp. deciduous, (**f**). sickle handle of *Buxus sempervirens*, (**g**) comb of *Buxus sempervirens*, (**h**) small paddle of *Quercus* sp. deciduous, (**i**) bowstring of *Urtica/Linum*, (**j**) wooden sickle of *Quercus* sp. deciduous. Photographs by La Draga team.

Table 1. Non-food plant resources documented at the oldest phase of La Draga, the heading indicates the categories of materials documented.

Taxa	Charcoal	Wooden Tools	Timber	Formless Wood	Fibers	Seeds
Acer sp.	X	X	X	X		
Arbutus unedo	X	X		X		
Buxus sempervirens	X	>50%		X		
Cyperaceae		X			X	X
cf. Leguminoseae				X		X
Clematis vitalba					X	X
Compositeae cf. *Inula*				X		
Cornus sp.		X	X	X		X
Corylus avellana	X	X	X	X		X
Fraxinus sp.	X					
Juniperus sp.	X	X				
Laurus nobilis	X	X	X	X		X
Monocotyledon	X			X	X	X
Pinus sp.		X				
Pinus sylvestris/nigra	X					
Poaceae					X	X
Populus sp.		X	X	X		
Prunus sp.	X					X
Quercus sp. evergreen	X	X	X			X?
Quercus sp. deciduous	>50%	X	>50%	>50%		X?
Rosaceae/Maloideae	X	X	X	X		X
Rosaceae/Rosoideae				X		X
Rubus sp.				X		X
Salix sp.	X	X		X		
Sambucus sp.		X		X		X
Taxus baccata	X	X				X
Tilia sp.					X	X
Typhaceae					X	X
Ulmus sp.	X					
Urtica/Linum						X
Vitis sp.	X			X		X

During the first occupation phase, trees were felled in large numbers to build the wooden platforms on which the dwellings were constructed. Indeed, more than a thousand posts were recovered from the excavated area, and 95% consisted of oak. Most of them were felled in the same year and season, although repairs during the 25 years following the first construction have also been documented. Oak wood was also used to make artifacts and implements, as found among the remains from this earliest occupation. It was also the most common firewood during the whole occupation of the site (Table 1). Other characteristic species from the broadleaf forest and its shrub understory were used for particular purposes; for example, *Buxus sempervirens* was utilized to make implements in the first phase and as fuel in the second; *Tilia* sp. was a source of fibers and *Taxus baccata* was employed to make implements and weapons.

The riparian woodland was also widely used in both occupation phases to obtain firewood, particularly *Laurus nobilis*, which was also utilized to make utensils. Other frequently-employed riparian taxa were *Salix* and *Corylus*. Moreover, the remains of basketry and cordage found in the first occupation phase show the wide spectrum of vegetal families used, including both monocotyledon and dicotyledon families. The results of raw material analyses have confirmed the use of Poaceae, Cyperaceae and Typhaceae. The latter two would have been gathered on the lakeshore to obtain plant fibers [81]. Moreover, fibers of nettle/flax (*Urtica* sp. or *Linum* sp.), and the use of linden bark (*Tilia* sp.) and *Clematis* sp. have also been determined in the cordage assemblage [37].

5.3. Coves del Fem

The identification of carpological remains found in the 2013 and 2015 excavations has shown the use of wild resources from the surroundings of the rock shelter during the whole occupation sequence. In the Mesolithic levels, to date only remains of *Pinus* sp. have been recorded, to be exact a cone and several bract scales. In the Neolithic levels, in addition to pine bract scales, acorns (*Quercus* sp.) and wild grapes (*Vitis vinifera* var. *sylvestris*) have been documented [46].

The wood charcoal analysis from the 2015 test pits provided a diachronic picture of forest management in the three chronocultural periods at the site. The 2572 charcoal fragments revealed the existence of a mixed Mediterranean forest where shrub and arboreal species supplied woody raw material used as fuel (Figure 9) [45,82]. While the characteristic broadleaf species were abundant from the start of the Neolithic occupation (7500 cal BP), cryophile pine forests (*Pinus sylvestris* tp.), relics of the Late Glacial period, persisted until the Holocene and dominated the anthracological spectrum until the end of the Epicardial Early Neolithic sequence (6500 cal BP). The dendro-anthracological study of 389 charcoal fragments of the Scots pine type (*Pinus sylvestris* tp.), the dominant taxon in the sequence, determined the minimum calibers of this taxon that were used. The preliminary results suggest a predominance of calibers between 2 and 10 cm, indicating that branches and small trees were exploited [83].

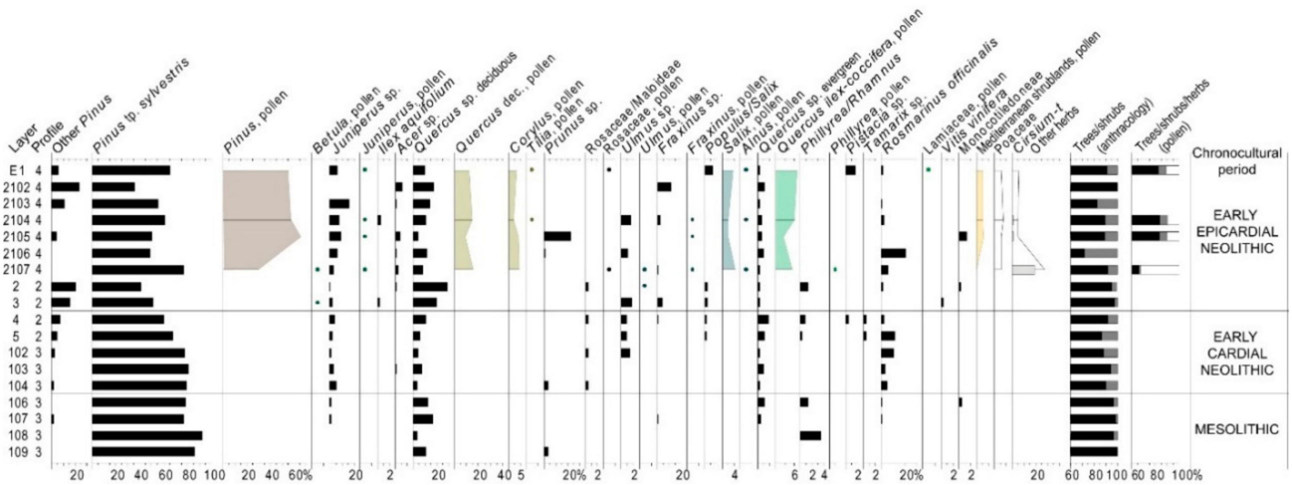

Figure 9. Results of charcoal (black bars) and pollen (color silhouettes) analysis of Coves del Fem. Presence of rare taxa (low values) in pollen analyses is represented by dots. Categories: Mediterranean shrublands (*Erica*, Cistaceae), other herbs (Asteraceae liguliflorae, Asteraceae tubuliflorae, Apiaceae, Amaranthaceae–Chenopodioideae, *Plantago*, *Artemisia*, *Dipsacus*, *Filipendula*).

Wooden remains have also been recovered in small numbers in desiccated conditions. In these cases, the taxon identified is also the main taxon among the charred wood: *Pinus sylvestris* tp. Tool-marks to shape a beveled pointed end have been identified on the surface of one specimen. In this case the diameter is 7.5 cm.

The pollen record is affected by differential preservation in the levels and sectors of the site and so far, it has only been possible to reconstruct the vegetation in the most recent Epicardial Early Neolithic occupation [46]. During this phase, pine forest dominated (*Pinus* sp.) together with important mixed forests of *Quercus* deciduous and *Quercus ilex-coccifera*, indicating more humid conditions than at present in the first half of the Holocene [84]. These results equally indicate very different vegetation from that on the coast, where holm oak dominated from the Middle Holocene, rather than deciduous oak and pine [85,86]. This means that the climate in the area of the Serra del Montsant was more humid than on the coast. Mixed oak woodlands would have been situated in more humid locations with deep soil, and on the higher hillsides, formed by oak, hazel and linden, as well as birch. Holm oak woods would be found on lower and sunnier slopes. In addition, riparian communities on the banks of the Montsant River would have been dominated by *Salix*, together with *Fraxinus*, *Ulmus* and *Alnus*. In general, it was an area of dense woodland with shrubs (*Erica*, Cistaceae) in more degraded areas and grasses (mainly Poaceae and Asteraceae) and ferns in the proximity of the rock shelter. Finally, the high values of *Cirsium*-t (Asteraceae, of short-dispersal pollination and zoophile) in one sample probably indicate the anthropic introduction of this plant to the site.

The use of other plants has been documented at the site. The study of basketry remains at Coves del Fem, parts of the same artefact located in a storage structure, has allowed the identification of Cyperaceae [81].

6. Discussion

6.1. Non-Food Neolithic Plant Exploitation Strategies

The case studies differ in the type of settlement and environmental setting, which involved significant differences in the exploitation of vegetation. Additionally, the unequal preservation of organic matter means that we only possess a partial picture of the exploitation strategies at Cova del Fem and in the PNAESM.

At La Draga, the occupation was of certain importance given the size of the site, the long occupations and different re-uses in a relatively short period of time. In contrast, at the other two sites the occupations were shorter and probably seasonal and connected with animal herding. This would imply much smaller settlements inhabited probably also by smaller human groups.

The only resource documented at all three sites is firewood. The comparison of the procurement strategies for fuel reveals differences as regards its availability in the environment. Whereas, at La Draga, *Quercus* sp. deciduous and *Laurus nobilis* were the most commonly used species, at the other two sites it was conifers, particularly the *Pinus sylvestris/nigra* type. Therefore, the natural differences in the vegetation in each geographic area determined the availability and consequently the choice of wood resources.

In each case study, the same pattern of fuel acquisition, as regards the main species that were targeted, was maintained throughout the sequence. However, quantitative variations are seen in the percentages in which they appear in the course of the different sequences. The changes in the fuel acquisition strategies may reflect alterations in the availability of resources owing to either environmental or anthropic causes during the Neolithic. At both La Draga and Cova del Sardo, the use of shrub species increased after the first occupation: at La Draga *Buxus* was added as a fuel in Phase II, while in Cova del Sardo, *Juniperus* was introduced in Phases 7 and 5. In both cases, the use of these shrub taxa has been interpreted as a consequence of the opening up of the vegetation by human activity. Felling and clearing woodland favored the expansion of box, which colonized degraded areas in the oak forests [87–89]. Similarly, *Juniperus* scrubland frequently expands in place of pine forests [90].

The inclusion of these colonizing shrubs in the firewood should be interpreted as their addition to the range of available plants and not as the result of the absence or reduction of the arboreal species that were used at first, as these continued to be present in the surroundings of the site. The use of colonizing shrubs may have been a strategy to maintain the clearings opened previously free of woody vegetation. The spread of colonizing species around Cova del Sardo would have taken place in spaces that were opened up by burning to obtain pastures. In contrast, at La Draga it would have been the result of the massive deforestation to obtain timber for building materials and firewood.

The use of building timber on a large scale has only been documented at La Draga. It is the only settlement with a continual occupation during at least a generation, or probably longer based on the radiocarbon dates, in addition to relatively important re-occupations very close in time [43]. At this site, the permanent occupation of the same place meant that the proximate forests were utilized during many years to obtain wood for building and also to make tools and produce energy. The study of the remains of *Quercus* sp. wood at the site has not revealed evidence of the management of this species; the community used individuals for which no type of management prior to their acquisition has been identified. The wooden elements at La Draga have been studied with a methodology that considers that diameter of the trunks and branches and their growth rings. It has determined a clear trend towards the use of non-managed woodland [91].

In contrast, a very different trend has been observed at Coves del Fem. Although changes are seen in the use of fuel between the older Mesolithic and Neolithic phases, in this case no evidence associates them with alterations to the forest cover caused by human activity in the area, and they would be due to climate change. While post-holes and remains of wood have been found at the site, it does not seem that any large building would have existed nearby. Therefore, the decrease in the proportion of oak in the Early Neolithic compared with the Mesolithic can be linked to the 7.4 kyr event and the later recovery of this taxon at the end of the Early Neolithic would be a consequence of climate amelioration. The location of Coves del Fem in a narrow ravine above the river, surrounded by steep hillsides, would not have been favorable for agriculture or pastureland, although the presence of domestic cereals has been identified in the Neolithic levels, indicating their cultivation in proximate areas.

The identification of sedges and cattails in fiber-based craft production in La Draga and Coves del Fem indicates the exploitation of riparian and wet environments where these taxa were available. In La Draga, they were also identified by palynology [22,23,64] and carpology [21,47], as well as probably by a tuber belonging to a species of this family. Their identification demonstrates the use of local aquatic plants from Lake Banyoles and the Montsant river range. These families are commonly present in waterlogged niches and have colonized many sites after natural or anthropic disturbances [92,93].

The use of other taxa for technological purposes has also been identified in La Draga. This is the case of bast fibers obtained from the phloem of the stem of fibrous plants like nettle or flax. La Draga has provided seeds of nettle [21,47] implying its availability in the site surroundings. The use of linden tree bark as raw material in craft production has also been recorded in La Draga. The selection of linden bark is a kind of forest management also described for other sites in Europe during the Neolithic [94]. Palynology indicates the availability of linden at local level, but the absence of charcoal remains of this taxon suggest the inhabitants of La Draga transported only the strips to the site. In addition, fruits of *Tilia platyphyllos* agg. were also identified and related to economic purposes or even as a medicine or remedy [47]. In fact, at La Draga, several species with medicinal properties have been documented, such as: strawberry tree (*Arbutus unedo*) with antiseptic, astringent and diuretic properties; common box (*Buxus sempervirens*), with numerous applications as an alternative, antirheumatic, cathartic, cholagogue, diaphoretic, febrifuge, oxytocic and vermifuge among others; bay leaf (*Laurus nobilis*) with several applications as an antiseptic, aromatic, astringent, carminative, diaphoretic, digestive, diuretic, emetic in large doses, emmenagogue, narcotic, parasiticide, stimulant and stomachic; and blackberry/raspberry (*Rubus* sp.) with some species being anti-inflammatory, astringent, decongestant, ophthalmic, oxytocic and stimulant, or the abovementioned *Tilia* sp., still being used as an antispasmodic, diaphoretic, expectorant, hypotensive, laxative and sedative [95].

Cultivated plants also yielded non-edible by-products that were either used to feed domestic animals, as at La Draga [96], or for other purposes such as roofing, basketry or temper material. So far, the multidisciplinary analyses performed have detected the use of grasses for basketry, but it is currently not possible to ascertain if cereal straw was used for this purpose.

To sum up, during the early Neolithic, settlement surroundings were intensively exploited for firewood, wood raw material, timber and plant fibers. The resources were obtained mainly from deciduous and pine forests, depending on the site localization, but also from riparian zones. The diversity of plants exploited was high, not only trees but shrubs and herbs. The combination of this exploitation with other agropastoral activities favored the expansion of colonizing species and enhanced biodiversity at local scale.

6.2. Landscape and Human Impact

6.2.1. The Case of PNAESM: Contribution of Phytoliths to Landscape Reconstruction, Contrasting with Other Proxies

The comparative study of phytoliths and other vegetal remains from the Neolithic occupation at Cova del Sardo between 7300 and 6300 cal BP has proved to be an extremely useful tool for the reconstruction of the social practices of the first Neolithic communities who occupied the high mountain valleys in the central axial Pyrenees. The study of the test pit at Forcall de Sant Esperit (AS2), 530 m from Cova del Sardo and at a similar altitude (1771 m asl) has revealed two phenomena. First, that the human occupation of the valley took place two or three centuries before the use of the rock shelter, as the first anthropized palaeosoil documented in the valley bottom has been dated between 7243 and 6882 cal BP, whereas the first reiterated use of the rock shelter is dated between 6776 and 4319 cal BP. However, the site had been occupied briefly at an earlier time, between 7513 and 7326 cal BP [28].

Second, the comparative study of phytoliths, macro-and micro-charcoal, pollen, organic and chemical matter in the area outside the site indicates an early intense modification of the forest in the valley bottom, formed by mountain pine (*Pinus mugo uncinata*) and birch (*Betula pendula*), through the iterated use of burning in the Early Neolithic, between 7300 and 6300 cal BP. The archaeobotanical and palaeoenvironmental results are compatible with the maintenance of woodland with clearings, suitable for forestry and livestock use, while maintaining the vegetation cover. This type of non-arable anthropic Neolithic landscape has been determined with a similar methodological approach in the middle Rhone valley, in the montane altitude zone [97].

The scarcity of domestic cereals or other cultivated species in the carpological and palynological record [31] does not completely rule out the creation of cropland in the area of the Sant Nicolau valley. However, the analyses of phytoliths from the interior of Cova del Sardo and its outer terrace, and from Forcall de Sant Esperit, have not revealed significant evidence of crops in the area of study.

It therefore seems likely that the model of forest management applied by the first agropastoral communities in the Sant Nicolau valley in the Early Neolithic (7300–6300 cal BC) involved the deliberate transformation of the vegetation around the inhabited areas, through the iterated use of fire and the introduction of small flocks of domestic animals in the surroundings of the rock shelters. The local cultivation of crops has not been demonstrated, only their sporadic consumption in Cova del Sardo. The environmental conditions in the valley, at least in the shady humid areas, would not have been optimal for cereals, although the occasional consumption of barley (*Hordeum vulgare* L. var. *nudum*) has been documented [21]. These were probably grown in another part of the valley or nearby area, because the tools discarded by the occupants of Cova del Sardo had also been used for harvesting [98]. This dynamic of the management of medium and high mountain territories would not correspond to any kind of specialization in animal husbandry by the Pyrenean Neolithic communities [99]. Instead, a dynamic of seasonal altitudinal mobility might have been established, with the occupation of the higher areas in summer and autumn. The smaller shelters and sites in high mountain areas, like Cova del Sardo, would not have been occupied all year, unlike other larger sites at medium altitudes [99,100].

6.2.2. La Draga: Archaeopalynology High Resolution Pollen Record

Comparing intra-site and off-site pollen records has addressed the intensity and scale of the impact of human activities in the landscape. Coeval pollen records from Lake Banyoles and La Draga confirmed the reliability of archaeological deposits in the determination of vegetal landscape evolution during several occupation phases [64], while the archaeopalynological study at La Draga provided relevant data to assess site formation processes and social use of space within the settlement [76] and plant and fungi uses at the site [101].

The integration of palaeoenvironmental data from natural and archaeological deposits assessed the intensity of human activities on the landscape at local and extra-local levels. Thus, the settlement of the first farming societies in the Lake Banyoles area was the cause of major land-cover changes, leading to deciduous oak woodland deforestation. Regarding agriculture, a high concentration of Cerealia-type pollen is documented in both occupation phases at La Draga. Crop fields could not be in the immediate surroundings of the settlement, because it was established in a swampy area unsuitable for cultivation, and high concentrations of Cerealia-t pollen within the settlement have to be understood in terms of anthropic input of spikelets, either for storage of crops or by-products. The impact of husbandry practices on the landscape shows similar trends. At the extra-local level, grazing pressure is imperceptible in off-site deposits (absence of spores of coprophilous fungi, [23]. Nevertheless, high concentrations of these spores are recorded at La Draga [64], pointing to the keeping of flocks within the settlement and to a limited impact of grazing on the landscape at a regional scale. Finally, local-scale deforestation in oak and riparian woodlands induced soil erosion episodes in the lakeshore margins, a process attested both within the site (2nd phase, ca. 7160–6750 cal BP) and in natural deposits, progressively increasing from 7250 cal BP onwards [23].

7. Conclusions

In this paper, we show the relevance of interdisciplinary archaeobotanical research to study human-environment interactions during the Neolithization, integrating data of vegetal macro and microremains from archaeological sites.

This work has revealed different landscape composition in the studied regions of NE Iberia during the Mid-Holocene, with the predominance of deciduous broadleaf forests in the inland lowlands around Lake Banyoles and La Draga, and of pine forests in high-mountain areas (Pyrenees) and in the Ebro valley.

The macrobotanical data of the three sites indicate that during the early Neolithic wild plants were intensively exploited for obtaining a variety of resources. In addition to food, they obtained firewood, wood raw material, timber, and plant fibers. The diversity of plants exploited was high, which implied a good botanical knowledge and a diversity of strategies of plant acquisition. The combination of these plant exploitation strategies with other agropastoral activities favored the expansion of colonizing species and changes in biodiversity at local level.

The micro remains (pollen and phytoliths) have allowed identifying the human impact in the settlement surroundings of Cova del Sardo and La Draga. In the case of Cova del Sardo not significant evidence of crops have been identified in the area of study. However, an early intense modification of the forest in the valley bottom through the iterated use of burning in the Early Neolithic has been documented between 7300 and 6300 cal BP. In the case of La Draga the settlement of the first farming societies in the Lake Banyoles area was the cause of major land-cover changes, leading to deciduous oak woodland deforestation. In contrast, the case of Coves del Fem shows a very different trend, no evidence of alterations to the forest cover caused by human activity have been identified, in relation to short-term occupations by small groups.

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