

Cultural land use and vegetation dynamics in the uplands of northern Portugal from the Middle Ages to the Modern period

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ABSTRACT: In Europe, mountain landscapes have evolved in a long-term relationship with human communities and present-day landscapes reflect that ancient interaction. The present study aims to reconstruct human activity in two mountain areas in northern Portugal using palynological analysis integrated with the available regional historical, archaeological and palaeoenvironmental archives. Pollen records from two sedimentary sequences span the Medieval and Modern periods and show that mixed agriculture and livestock grazing were consistently present in both regions throughout these times. Variations in cultural indicators show that the extent of farming fluctuated throughout time, with a general increase in cultivation during the Medieval period but with contractions likely coinciding with times of social disturbance. Historical sources suggest that sociopolitical factors and population pressure were fundamental in the utilisation of upland spaces. This study did not find any convincing evidence to suggest that fire was a fundamental factor in heathland spread. We conclude that long-term occupation of the uplands was sustained by low-intensity land use throughout the Medieval to post-Medieval periods, and that the present landscape has assumed a very different character following depopulation of the mountain areas and a shift towards commercial forestry.

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KEYWORDS: non-pollen palynomorphs; northern Portugal; pollen; upland landscape evolution; upland land use.

Introduction

Change and disturbance are an integral part of natural ecosystems. To understand how human activities in the past related to these cycles could be fundamental to addressing the challenges faced in the present (Connor *et al.* 2019). In the past, high utilisation of upland resources may have contributed to a reduction of woodland and to the expansion of grassland and scrub in northwest Iberia. Overgrazing of mountain pastures and the use of fire as a land-management tool, particularly from the Medieval period onwards, have been posited as drivers behind the spread of *Erica*-dominated shrubland, which is now the dominant vegetation unit in the mountains of northwest Iberia (Corella *et al.* 2013). Understanding the vegetation history and emergence of anthropogenic habitats in a region has important implications for decisions about conservation strategies (e.g. Ezquerro *et al.* 2019).

This study considers the landscape histories of two upland neighbouring areas in northern Portugal in order to ascertain how two different environments (Atlantic and Mediterranean) have responded to similar human pressure over the last 1000 years. Combining archaeological, historical and palaeoecological data for the two areas, we evaluate the drivers that shaped the local past and present-day landscape, contributing to the wider debate on long-term landscape dynamics and sustainability. Specifically, we assess: 1) the extent to which past social dynamics and economic activities in the uplands influenced woodland and shrubland extension; 2) if the present-day shrubland landscape is the consequence of an intense fire regime and high grazing pressure; and 3) how

palaeoenvironmental data can contribute to informing policies for landscape restoration.

Geographical and archaeological context

Geography

Our two study areas are located in mountain areas: the Cabreira Mountain and the Upper Terva Valley (UTV) in northern Portugal (Fig. 1). Despite their proximity (50 km), both areas are notably different in terms of present climate and vegetation.

The Cabreira Mountain, located in the northwest region of Portugal and with a maximum altitude of 1262 m above sea level (a.s.l.), is part of the Galician–Minho mountain range and integrates the Cantabrian–Atlantic range. The main climatic influence is Atlantic with an average annual rainfall of 2577 mm (Soares *et al.*, 2000). Local geology is dominated by granite and schist. The Cabreira landscape is characterised by shrubland, mainly gorse (*Ulex europaeus* L. and *U. minor* L.) and heather (*Erica cinerea* L. and *E. tetralix* L.). Of the native woodland, including oak (*Quercus* spp.), alder (*Alnus* spp.) and birch (*Betula* spp.), only a few isolated niches remain. The dominant tree cover is mainly composed of continuous areas of commercial plantations of cluster pine (*Pinus pinaster* Aiton) and eucalyptus (*Eucalyptus globulus* Labill.). These have expanded since the mid-20th century and have extended to areas previously occupied by deciduous woodland and shrubland.

The UTV is part of the Barroso plateaux region that rises to 1231 m a.s.l. and the local climate has a strong continental influence (Alberti and Araújo, 1999). Average annual rainfall in

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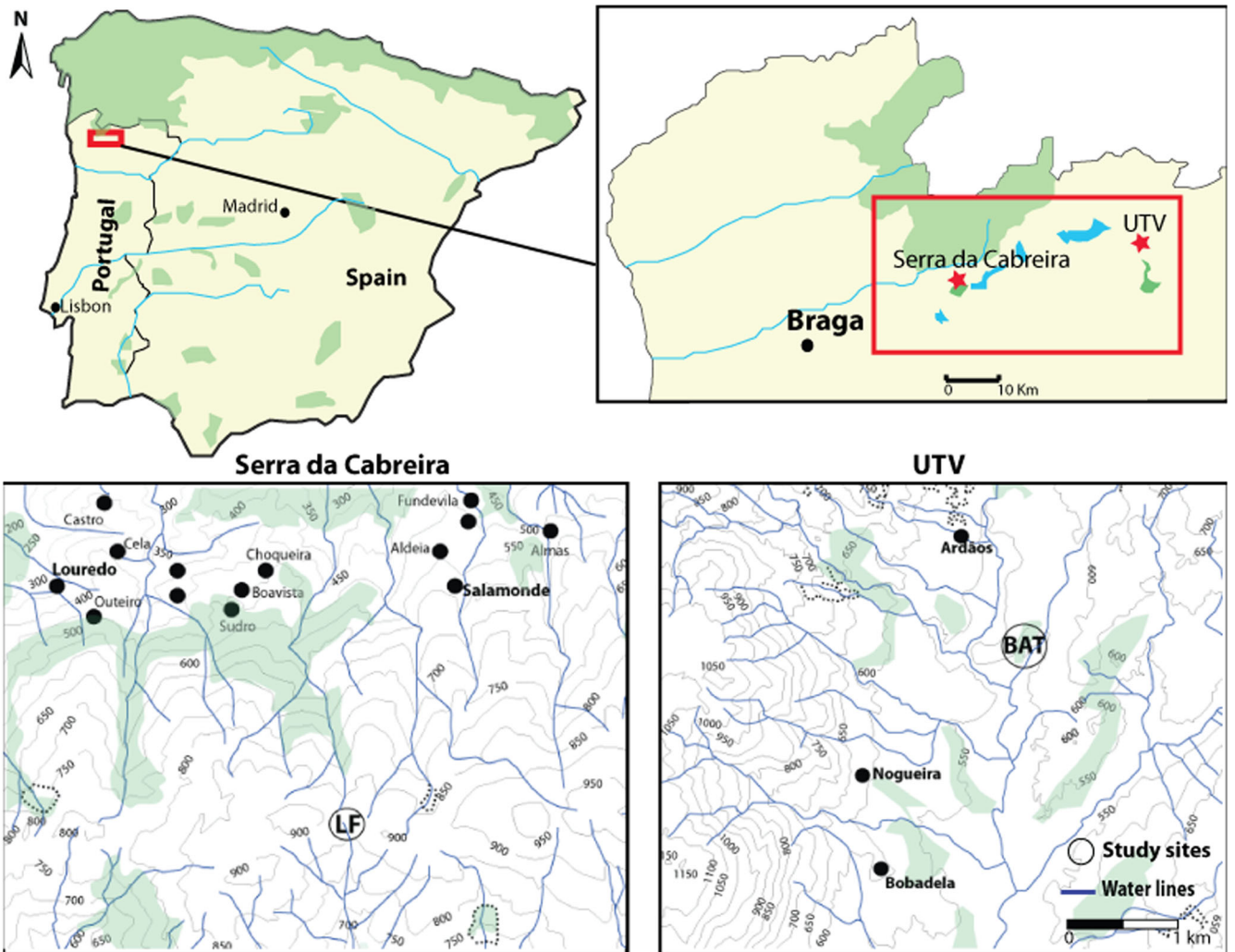


Figure 1. Study areas and location of Lameira de Fiães and Batocas deposits (northern Portugal). [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com/doi/10.1002/jqs.3211)]

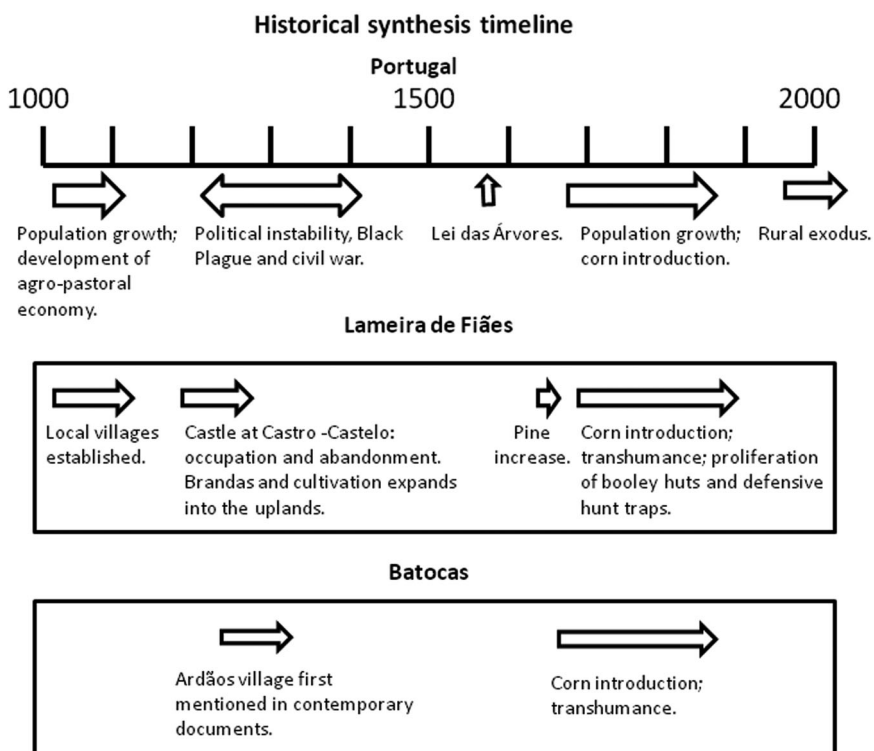


Figure 2 Portugal's historical synthesis timeline from AD 1000 to AD 2000.

this region is 1100 mm (Climate-Data.org). The area's geology comprises mainly granite and schist (Fontes and Andrade, 2010). The landscape is characterised by a vast shrubland of heather (*Erica australis* L., *Calluna vulgaris* (L.) Hull) and gorse (*Ulex europaeus* and *U. parviflorus* Pourr.) with small dispersed areas of woodland: oaks (*Quercus robur* L., *Q. pyrenaica* Willd.) and pine (*Pinus pinaster* and *P. sylvestris* L.) in the uplands, and ash (*Fraxinus excelsior* L.), alder (*Alnus* spp.), willow (*Salix* spp.) and birch (*Betula* spp.) in the sheltered valleys (Borralheiro, 2006).

Archaeological context

Even though the archaeological and historical records are poorly resolved for both regions, work has been undertaken by one of the present authors (LF) and the Unidade de Arqueologia da Universidade do Minho in an effort to map both regions' archaeological sites (see Fontes and Roriz, 2007; Fontes and Andrade, 2010). The archaeological evidence bears testimony to a long-term human presence in the Cabreira and UTV regions (see Fontes and Roriz, 2007; Fontes and Andrade, 2010). Notwithstanding this long history of human occupation, both regions have been neglected in terms of palaeoecological research. As a consequence their vegetation and land-use histories are poorly known. One of the aims of this project is to contextualise the archaeology with respect to its landscape, socio-economic and climate backdrops. A timeline (Fig. 2) was produced to show the main sociopolitical events in Portugal over the last millennium.

Historical sources suggest that after the collapse of Roman power in northwest Iberia there was an increasing ruralisation of society (Keay, 2003). Documentary sources indicate that in the mountains of northern Portugal hillforts began to be reoccupied between the 7th and 10th centuries sheltering a disease-stricken population that was also seeking protection from the advances of Christian and Muslim armies, particularly along areas crossed by the main Roman roads (Fontes, 2011). From the 11th century, historical records document a population growth and the development of an agro-pastoral economy (Fontes, 2011) and the establishment of new settlements at this time (González *et al.*, 2009). Population pressure drove the expansion of cultivation into the uplands and the establishment in these areas of a new type of settlement (Brandas) devoted to seasonal agro-pastoral activities (Fontes, 2011). The 13th and 14th centuries were a time of sociopolitical instability in Portugal with disease, succession crises and civil war (Fontes and Roriz, 2010) which would have upset the existing economic and social structures. In Portugal, in the wake of the bubonic plague (Barroca, 2003), a period of civil war and anarchy followed between 1383 and 1385, known as the *Interregnum* (Mattoso, 1993).

A further rise in population and expansion of agricultural activity were underway during the Modern period. The introduction of corn during the 17th century contributed to the changing structure of upland land use. Lower-yield crops were relegated to upland fields while transhumance and livestock grazing became prevalent over higher ground (Capela and Borralheiro, 2000). During this period, booley huts and defensive hunt traps multiplied throughout the mountains of northwest Portugal.

Study sites

The Lameira de Fiães (LF) deposit (41°39'51.5" N; 008°06'16 8" W; 874 m a.s.l.) corresponds to a small flush or seep area, where the ground is permanently saturated by an upwelling spring formed at the bottom of a gentle northwest-facing slope, on a summit plateau in the Cabreira. The deposit measured approximately 8 m wide and 20 m long (Fig. 3). Local vegetation is composed of bracken (*Pteridium aquilinum* (L.) Kuhn), *Erica* spp. and common gorse (*Ulex europaeus* L.). Pockets of mixed woodland (oak, alder and pine) are located to the north and south of the deposit, circa 350 m and 200 m, respectively. Presently the only human activity in the vicinity of the deposit is livestock grazing.

Just 3 km southwest of LF lies the Castro-Castelo hillfort occupied from the Roman period through to the Medieval period (Fontes and Roriz, 2010). The northern slopes of the Cabreira Mountain are crossed by the Roman road Via XVII running less than 2 km down-slope from LF. All the parish churches at the centre of the present-day villages in the Cabreira were mentioned in documents of the 11th century (Fontes and Roriz, 2007), suggesting that the villages were in existence at that time. The closest villages to LF are Salamondre (1.7 km NE) and Cantelães (2.2 km S). A castle was established around the 11–12th centuries at the Castro-Castelo, the centre of the Cabreira territory. The dates of its construction and abandonment are not known, but it is not mentioned in 13th century documents (Fontes and Roriz, 2010). Archaeological evidence suggests, however, an abandonment of the castle during the late 12th to early 13th century, possibly following an attack that is suggested by a burnt level and by arrowheads around the perimeter wall (Fontes and Roriz, 2010). Also dating from the middle centuries of the Medieval period, Gorgolo is a Branda located 1 km to the east of LF. Several defensive hunt traps and booley huts with a Modern (circa 18th century) chronology lay in close proximity to LF (Fontes and Roriz, 2007).

The Batocas deposit (41°45'18.58" N; 7°35'58.10" W; 550 m a.s.l.) in the UTV corresponds to an area where material accumulated within a pond deposit, the site of an opencast

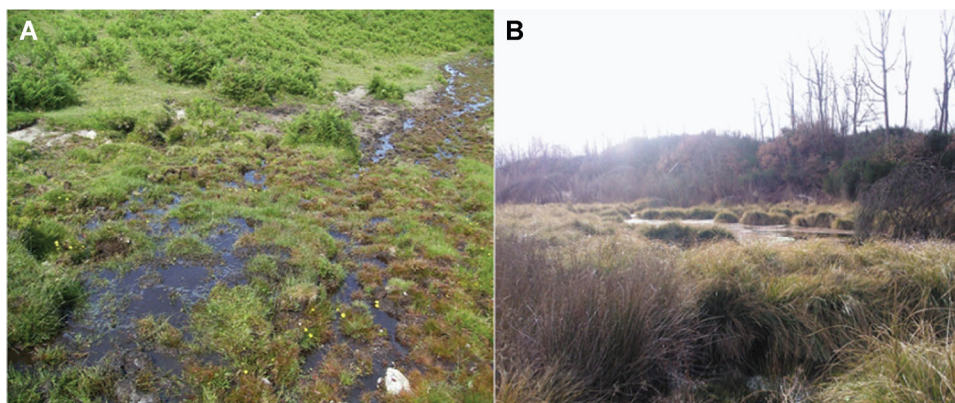


Figure 3. A- Lameira de Fiães viewed from the west; B- View of Batocas deposit, from the southwest. [Color figure can be viewed at wileyonlinelibrary.com]

Roman gold mine (Fig. 3; Fontes and Andrade, 2010) and is located at the bottom of an artificial crater at the edge of a small hill. The site measures approximately 120 m in length by 20 m wide. The immediate vegetation is composed mainly of sedges (*Carex* spp.), mosses (*Sphagnum* spp.) and cross-leaved heather (*Erica tetralix* L.). Oak (*Quercus* spp.), birch (*Betula* spp.) and cluster pine (*Pinus pinaster*) make up the local woodland. The adjacent area is grazed by a small herd of goats and agricultural fields are located in the immediate vicinity of the deposit.

The suggested chronology for the Batocas mining complex ranges between the 1st and 4th centuries AD and although at the centre of an important gold mining region during Roman occupation, archaeological data show no evidence of continued mining activity after the Roman period at Batocas (Fontes and Andrade, 2010). Equally absent from the archaeological record is evidence of human occupation during the early centuries of the Medieval period although, considering the scarceness of archaeological and historical data for this period, a continuation of settlement cannot be excluded. The present-day Ardãos village lies only 1.5 km northwest of Batocas and is first mentioned in 13th century documents although its establishment could have been earlier than this date as suggested by the existence of anthropomorphic graves in the vicinity, dating from the 10th–12th centuries (Fontes and Andrade, 2010). Even though there is no evidence of transhumance support structures in the vicinity of Batocas, livestock had a vital role in the upland economy during the Modern period (Capela *et al.*, 2006).

Methods

Pollen, non-pollen palynomorphs (NPP) and microcharcoal

Cores from both sites were collected using a Russian peat corer with a 50 cm long and 5 cm wide chamber (Jowsey 1966). The LF deposit was sampled to a depth of 160 cm and Batocas to 225 cm. Cores were transported to the Palaeoecology Centre, Queen's University Belfast (QUB). Lithology was recorded following Troels-Smith (1955).

Palynological samples were taken at 2 cm resolution for LF and 4 cm for Batocas. Pollen processing followed standard laboratory techniques, as per Faegri and Iversen (1989) and Moore *et al.* (1991). Counting was conducted at a $\times 500$ magnification and, where pollen concentrations and preservation permitted, a minimum of 500 terrestrial pollen grains was counted for each level. Pollen identification was aided by the identification keys from Faegri and Iversen (1989), Moore *et al.* (1991) and Reille (1992), and the pollen reference collection at the Palaeoecology Centre, QUB. Pollen preservation was generally poor in both sequences which hindered taxonomic resolution beyond genus. Fungal ascospores were counted simultaneously and identification followed van Geel and Aptroot (2006) and van Geel *et al.* (2011).

To determine the pollen source area at each sampling site, samples of fresh plant material were collected from surface deposits at each location, processed as above, and the pollen content counted to a sum of 200 pollen grains. Percentage pollen assemblages were calculated for each site and subsequently compared with the local and regional vegetation (Vieira do Minho Municipal Vegetation charts; Google Earth) to determine the likely source area of the pollen reaching the sites.

Pollen taxa were divided into groups, following Behre (1981), to facilitate the identification of changes in land use and to establish the nature of human activities (Gaillard, 2013;

Kozáková *et al.*, 2015). Recent palynological and genetic studies have demonstrated that both *Olea* and *Castanea* survived the Last Glacial Maximum in Iberia (Carrión *et al.*, 2013; López-Sáez *et al.*, 2016) and can be considered native to the Peninsula. However, pollen records demonstrate that both taxa became widespread cultivars in Iberia and the Mediterranean during Roman times (Mercuri *et al.*, 2013; López-Sáez *et al.*, 2016). In this study, both taxa are regarded as cultivars.

Pollen percentages are based on total pollen sum (excluding aquatic pollen and spores) while NPP are presented as a percentage of total pollen plus NPP (Riera *et al.*, 2006). Data were plotted using Tilia 1.7.16 (Grimm, 1992, 2011). Pollen zones were determined using CONISS (Grimm, 1987) on the basis of taxa whose values reached a minimum of 5%.

Microcharcoal

Microcharcoal recorded during routine palynological analysis mainly derives from regional sources and it is a useful, if sometimes crude, proxy for past fire regimes and fire intensity (Finsinger and Tinner, 2005). Considering that pollen processing methods can affect the original size distribution of charcoal due to breakage of larger particles, the number of particles present on a pollen slide is sufficient to reconstruct past fire events (Conedera *et al.*, 2004; Mooney and Tinner, 2010/11). Microcharcoal particles with a minimum length of 10 μm were counted at the same time as pollen, spores and NPP (Tinner and Hu, 2003; Tinner *et al.*, 2005). Charcoal particle counts were converted to concentrations (Olsson *et al.*, 2010) and accumulation rates were calculated following Whitlock and Larsen (2001).

Loss on ignition

As neither of the sites studied is ombrotrophic, the mineral content in each sequence may reflect shifts in hydrology and/or soil erosion. Contiguous 1 cm^3 samples were taken from each sequence and their organic to inorganic ratios were determined using loss on ignition (LOI) following Dean (1974).

Dating

As sufficient identifiable plant remains could not be extracted from either sequence, bulk sediment samples were submitted for accelerator mass spectrometry (AMS) ^{14}C dating to the ^{14}C Chrono centre, QUB. Radiocarbon dates were calibrated with CALIB 7.0 (Stuiver and Reimer, 1993) using the IntCal13 data set (Reimer *et al.*, 2013). Age–depth models for the analysed sequences were constructed using Bacon (Blaauw and Christen, 2011). Due to a dramatic change in pollen taxa around 98 cm at LF, two closely spaced dating samples were taken to determine if there were a sedimentary hiatus. *A priori* accumulation rates were used to construct the age–depth models, with a mean of 20 cm^{-1} . The age models were evaluated with the aid of LOI values, stratigraphical records and pollen concentration in order to obtain a better understanding of changes in accumulation rates throughout time.

Results and discussion

Radiocarbon dating and age–depth models

Results from the AMS ^{14}C dating are presented in Table 1. The age–depth models (Fig. 4) show that both sequences span the period from the late 10th century to the present. Despite a substantial change in the nature of the sediment at LF between 100 cm and 94 cm, also reflected by an abrupt drop in LOI

Table 1. Radiocarbon dates from Lameira de Fiães and Batocas (n.d. indicates no data). All samples consisted of bulk sediment.

| Depth (cm) | Lab ID | ¹⁴ C Date BP | δ ¹³ C | Cal date AD 68.3% | Cal date AD 95.4% |
|-------------------------|-----------|-------------------------|-------------------|-------------------|-------------------|
| Lameira de Fiães | | | | | |
| 26–27 | UBA-28222 | 396 ± 28 | n.d. | 1446–1612 | 1439–1624 |
| 94–95 | UBA-28223 | 762 ± 23 | n.d. | 1252–1277 | 1224–1280 |
| 99–100 | UBA-22685 | 845 ± 35 | –25.7 | 1161–1251 | 1051–1265 |
| 132–133 | UBA-22686 | 1005 ± 32 | –22.4 | 989–1115 | 975–1152 |
| 159–160 | UBA-16552 | 1060 ± 26 | –31.7 | 973–1017 | 898–1022 |
| Batocas | | | | | |
| 111–112 | UBA-28225 | 628 ± 28 | n.d. | 1297–1390 | 1289–1398 |
| 165–166 | UBA-22368 | 1027 ± 29 | –28.7 | 922–1022 | 900–1117 |
| 170–171 | UBA-21337 | 1118 ± 26 | –24.1 | 894–969 | 880–990 |

percentages, the ¹⁴C results indicate that there was no noticeable hiatus. The age model suggests a rapid accumulation rate of, on average, 4.76 a cm⁻¹ for much of the sequence, falling to an average 15.12 a cm⁻¹ above 26 cm. Uncertainty ranges between ±49 years at 2 cm and ±248 years at 13 cm. The Batocas age–depth model indicates an average age uncertainty of ±170 years, increasing to ±200 years between 100 cm and 29 cm. The model suggests a steady accumulation rate of 6.2 a cm⁻¹ from 170 cm until the top of the sequence.

Palynological results

Pollen source areas

Relatively high arboreal (especially *Pinus*) pollen in the surface sample from the LF suggests that the pollen catchment extends

at least 1.5 km, predominantly to the northwest, encompassing the area that is presently occupied by settlements (Fig. 5). Taking into consideration the topography surrounding the Batocas deposit, surface pollen data indicate a likely pollen catchment area extending to an area within 1 km to the northwest and/or south. At both sites, cultivar representation in the surface samples is limited to *Olea*, highlighting the limited dispersal capacity of pollen from the arable and horticultural crops presently grown in neighbouring settlements.

Palynological results

The main changes in the pollen records for the two study sites are summarised in Table 2.

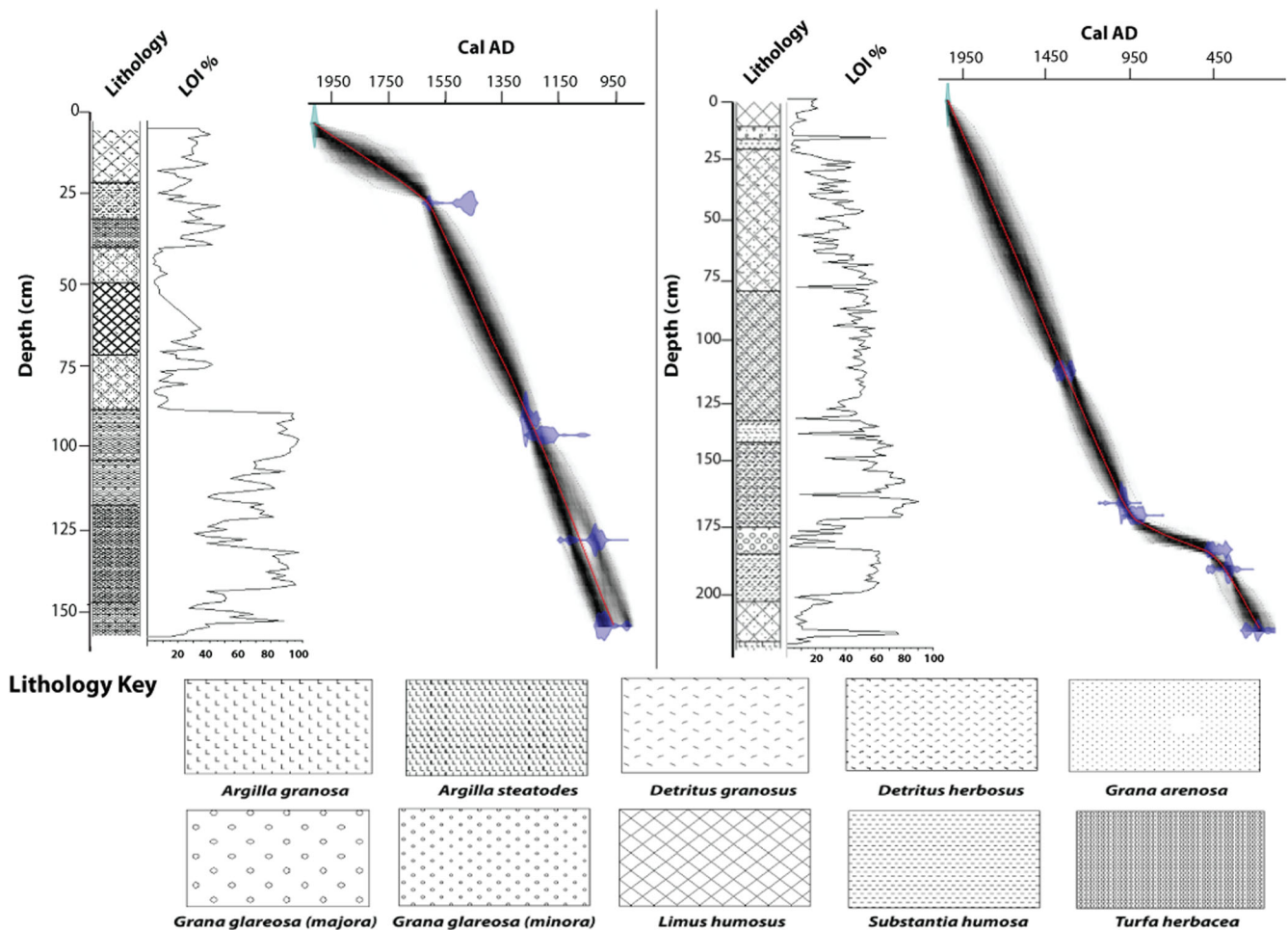


Figure 4. Lameira de Fiães (left) and Batocas (right) age–depth models, loss on ignition (LOI) and lithology. The age models show 95% confidence intervals plotted against the sediment depth. [Color figure can be viewed at wileyonlinelibrary.com]

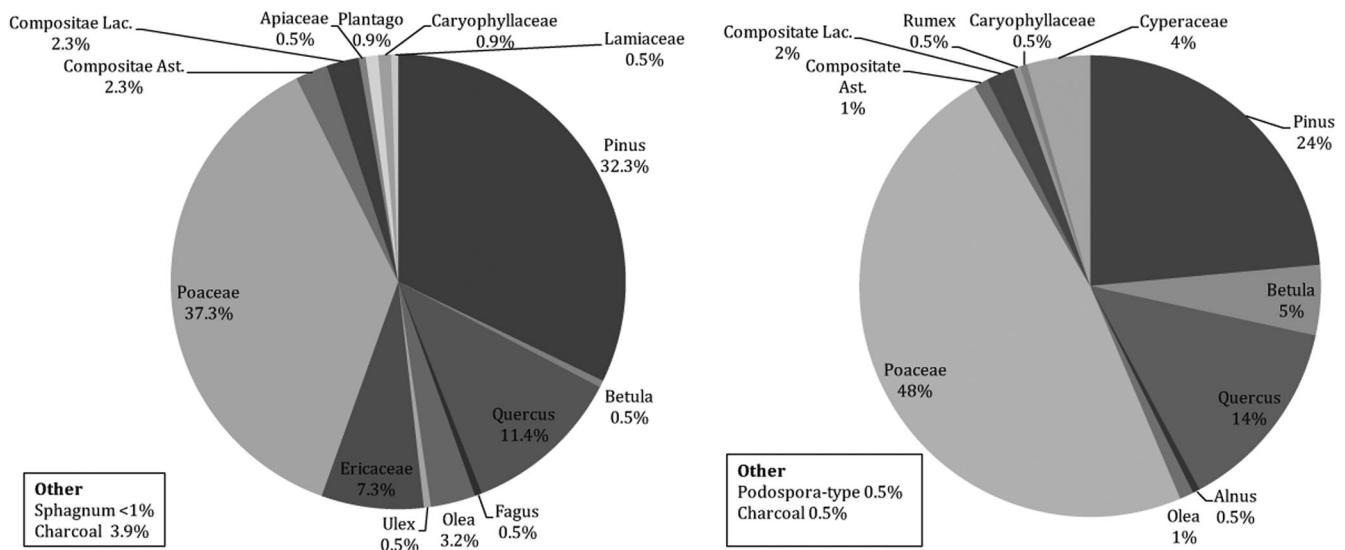


Figure 5. Proportions of pollen taxa recorded in the Lameira de Fiães (left) and Batocas (right) surface pollen samples (total pollen count Lameira de Fiães 220; Batocas: 195 grains).

The start of the LF sequence (Fig. 6) *circa* AD 970 is characterised by well-established mixed woodland. By *circa* AD 1120 (122 cm), there is a period of brief woodland contraction, recovering by *circa* AD 1150 (116 cm); during this interval, grassland communities expand. *Circa* AD 1235 (98 cm), the sediment shows an increase in mineral content and the landscape surrounding the deposit changed dramatically with a substantial and sudden decline in tree cover. Open conditions are dominated by grassland, but Cerealia-type increases, indicating an expansion of agriculture towards the study site. From *circa* AD 1525 (42 cm), tree crops increase while Cerealia-type retract. Sporadic peaks of charcoal are recorded thereafter and appear to coincide with short-lived peaks in Cyperaceae and Ericaceae percentages and simultaneous dips in *Quercus* values.

The Batocas diagram opens in the 10th century. By this time the landscape is dominated by shrubs and grassland (Fig. 7).

Coprophilous ascospores are abundant up until *~*AD 1200. *Betula* and *Pinus* are the main components of the local woodland until AD 1200 when both taxa contract and *Quercus* becomes the dominant tree, albeit with a modest presence. An Ericaceae-dominated shrubland persists until the 14th century, when Poaceae percentages begin to rise in tandem with a sustained decline in Ericaceae. Cerealia-type pollen is recorded for the first time during the second half of the 15th century (92 cm) and cultivars are regularly present from this period onwards. *Olea* and *Castanea* values peak *circa* AD 1800 (36 cm) when *Vitis* first appears on the record. Cultivars, along with coprophilous ascospores, continue to be present until the close of the sequence.

Despite spanning a similar time interval, the vegetation histories of the two sites are very different. Woodland evidently persisted in the Cabreira until the 13th century, after which an expansion of mixed farming appears to have led to almost complete woodland clearance. The open

Table 2. Summary of main changes observed in the Lameira de Fiães and Batocas pollen records.

| Site | Depth (cm) | Modelled age [median] (cal AD) | Main landscape changes |
|------------------|------------|--------------------------------|---|
| Lameira de Fiães | 14 | 1680–1915 [1800] | First appearance of <i>Eucalyptus</i> |
| | 26 | 1580–1635 [1610] | <i>Pinus</i> begins a sustained rise; increase in mineral input into deposit |
| | 42 | 1455–1575 [1525] | Decline in Cerealia-type; increase in <i>Olea</i> and <i>Castanea</i> ; expansion of Ericaceae shrubland |
| | 98 | 1195–1255 [1235] | Woodland replaced by grassland – abrupt fall in arboreal pollen percentages; higher mineral sedimentation into deposit; cereal cultivation and agriculture intensifies, particularly between 98 and 88 cm (until 1195–1335 [1300] cal AD) |
| | 118 | 1060–1195 [1150] | Woodland recovery; grassland declines |
| | 135 | 980–1125 [1070] | Woodland contraction; grassland and tree crop expansion; mixed agriculture |
| Batocas | 160 | 890–1015 [970] | Open, mixed woodland with areas of grassland and some mixed cultivation— <i>Olea</i> and <i>Castanea</i> most abundant cultivars |
| | 8 | 1905–2010 [1975] | <i>Pinus</i> begins to re-establish and mixed woodland expands |
| | 36 | 1680–1900 [1800] | Increase in cultivation |
| | 80 | 1415–1670 [1530] | Grassland becomes dominant vegetation type; shrubland declines further; woodland expands slightly; cultivars increase; from this time burning is not major feature |
| | 112 | 1275–1395 [1335] | Grassland begins to expand; ericaceous shrubland begins to decline |
| | 140 | 1025–1250 [1150] | Shrubland dominates, peaking simultaneously with an increase in charcoal; woodland declines further; grassland indicators expand but evidence for local grazing decreases |
| | 170 | 790–1000 [945] | Landscape dominated by shrubs and grassland; low woodland representation; cultivation and grazing in the vicinity |

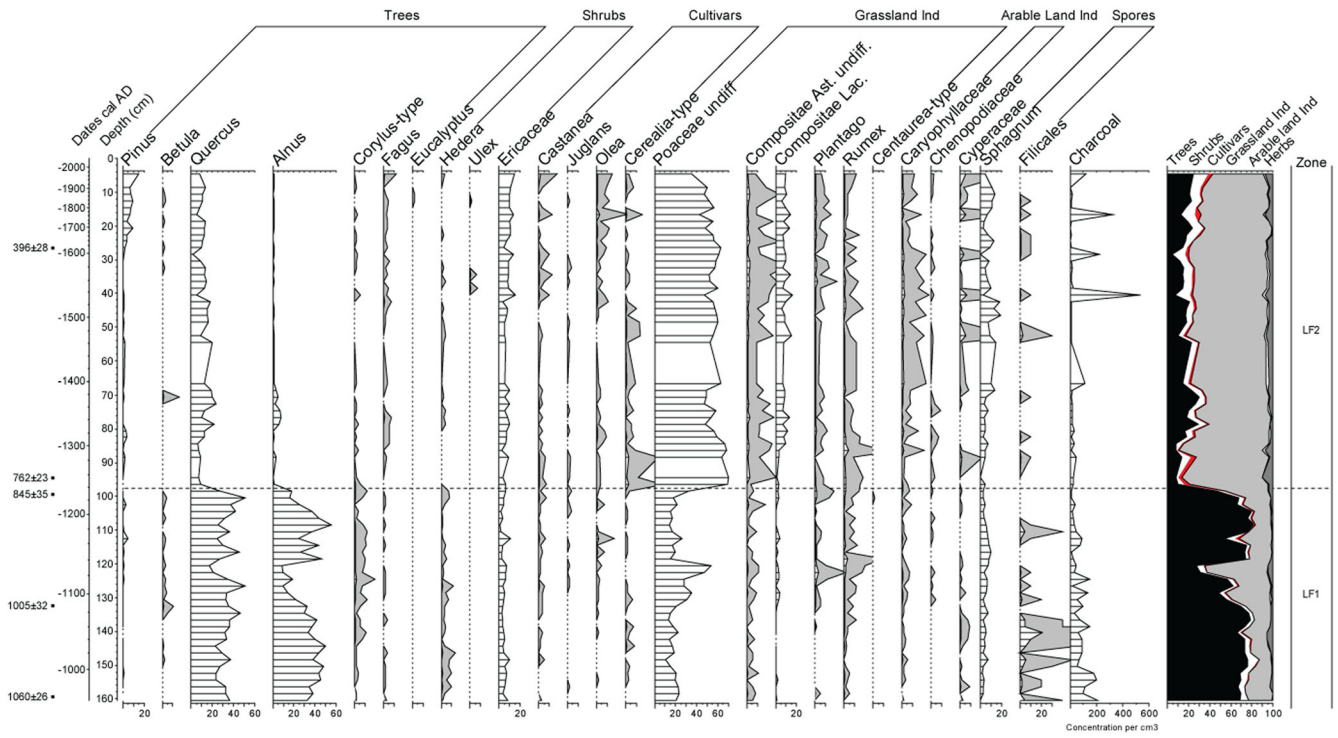


Figure 6. Lameira de Fiães pollen percentages and microcharcoal concentration diagram. ¹⁴C dates in years BP and one standard deviation shown to the left of the diagram. Curves of taxa with low representation were exaggerated ×10. [Color figure can be viewed at wileyonlinelibrary.com]

character of the site today can therefore be traced back to the Middle Ages. At Batocas, in contrast, a scrub-dominated landscape was prominent until the 15th century, and woodland is poorly represented. Subsequently, an expansion of farming again coincides with a change in the nature of the vegetation, as grasslands came to dominate the area around Batocas.

Olea, the only cultivar represented within the pollen surface samples, was recorded at higher values in the Cabreira Mountain. The northern slope of the Cabreira Mountain has a much higher settlement density than the UTV. Since the Cabreira sites' main catchment areas appear to lie to the north and with fields extending up the slopes, a stronger cultivation signal is not surprising in these sequences.

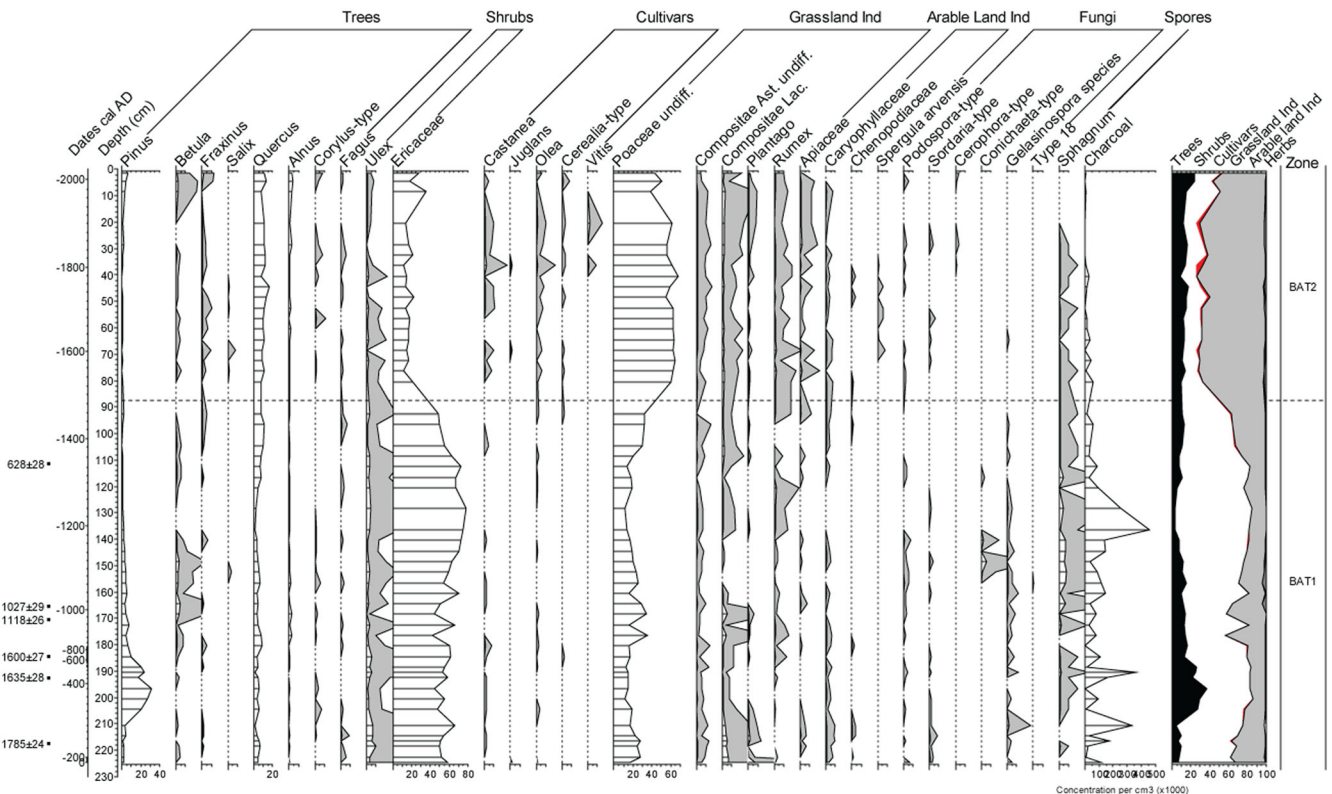


Figure 7. Batocas pollen percentages and microcharcoal concentration diagram. ¹⁴C dates in years BP and one standard deviation shown to the left of the diagram. Curves of taxa with low representation were exaggerated ×10. [Color figure can be viewed at wileyonlinelibrary.com]

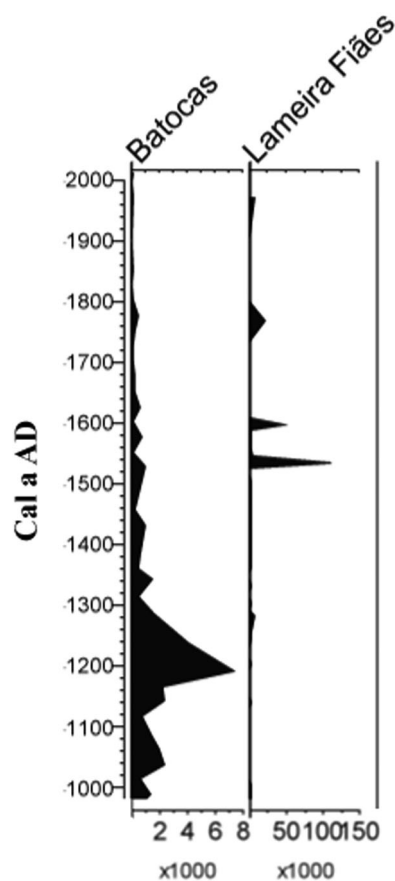


Figure 8. Charcoal influx ($\times 1000$ particles per cm^2 per year) present in study sites.

Microcharcoal accumulation rate

Microcharcoal accumulation rates have been calculated and plotted against a common timescale, based on each site's age model (Fig. 8). Taking into consideration the age uncertainties at each site, the age ranges of each episode of burning were plotted to examine their synchronicity between the study sites.

The high influx rates cannot be associated with a period of maximum scrub representation in either pollen diagrams. These results suggest that fire was not a constant feature of either region, nor was fire frequency specific to any time period. Peaks recorded in the 13th century in both regions possibly indicate a common driver.

Discussion

Vegetation, social and economic dynamics

Possibly due to low interest in the late Holocene palaeoenvironmental dynamics, palaeoenvironmental studies covering the Medieval period onwards in northwest Iberia are not abundant and many lack temporal resolution. Nevertheless, authors agree that from the 10th century a sustained process of deforestation took place in the uplands of northwestern and northern Iberia, and it was attributed to population growth and a rise in human pressure (Martínez-Cortizas *et al.*, 2005; Rubiales *et al.*, 2012). Pollen records from the western Cantabrian range suggest that, at this time, cultivation expanded onto higher ground (Rubiales *et al.*, 2012) while, from AD 950 pollen sequences from Sierra de Guadarrama (Mugica *et al.*, 1998) recorded a rapid woodland contraction. Mugica *et al.* (1998) propose that this woodland retraction was associated with a rise in cultural indicators, such as Cerealia-type, *Olea* and *Castanea*. Not all regions in northwestern and

northern Iberia experienced such a marked deforestation during this period, as shown by the pollen sequences from the Teleno Mountains and Bocelo Range (Morales-Molino *et al.*, 2011; Silva-Sánchez *et al.*, 2014). For the most part, indicators of farming intensification accompanied deforestation where it occurred – Serra da Estrela (van der Knaap and van Leeuwen, 1995), the Algarve (Schneider *et al.*, 2016) and Sierra de Guadarrama (Mugica *et al.*, 1998).

Neither the LF or Batocas sequences indicate a woodland contraction at this time, but the Batocas catchment is already mainly shrub-dominated by the opening of the record in the 10th century. Here, a stable *Betula* presence could indicate a colonisation of open areas by this pioneer taxon, as recorded in a pollen profile from the Sil valley (Jalut *et al.*, 2010). At neither site are intense agricultural or pastoral activities evident in the early centuries of the second millennium. *Olea* and *Castanea* were recorded at both locations although Cerealia-type was only present at LF. Conversely coprophilous ascospores were only present in the Batocas vicinity, suggesting that the deposit's catchment was used mainly for livestock grazing rather than for cultivation. It could also signify the absence of a main settlement in the immediate area and, if the Ardãos village was already settled, arable cultivation did not extend beyond its immediate limits. In contrast, the vegetation around LF was dominated by deciduous woodland. The evidently limited presence of cultivation may explain the permanence of woodland at LF.

Towards the end of the 11th century, however, woodland contracted in tandem with an expansion of grassland and cultivars, particularly tree crops, which may reflect the establishment of the neighbouring villages. The impact was short-lived, and by the 12th century woodland had recovered. The reason behind this limited period of agricultural expansion is difficult to comprehend. Civil war in the first quarter of the 13th century caused widespread social unrest throughout the Portuguese territory (Fontes and Roriz, 2010) which, considering the uncertainty in the age model and LF proximity to Castro-Castelo, could be the cause of the agricultural decline at LF. In Batocas by the early 13th century grazing contracted and only *Olea* was present, implying that the national conflict could have constricted economic activity here too.

Driven by a population increase in the 13th century, agricultural fields in northwest Iberia began to extend into mountain areas (González *et al.*, 2009; Fontes, 2011). The drastic clearance of woodland at LF in the mid-13th century could have been associated with a greater demand for grassland or timber, perhaps in tandem with the establishment of the Gorgolo Branda, contributing to heightened soil erosion in the catchment. Increased soil erosion was also recorded in upland sequences from Lake Sanabria (Luque and Juliá, 2002), Cruz do Bocelo mire (Silva-Sánchez *et al.*, 2014) and Lake Arreo (Corella *et al.*, 2013), where it was associated with an increase in population pressure. Although less visible than at LF, an expansion of human occupation was similarly underway at Batocas from the mid-13th century, when Ardãos village was first mentioned in contemporary sources. Although only *Olea* continued to be recorded, land clearance is suggested by the demise of pine and loss of birch woodland. The warm and humid conditions associated with the Medieval Warm Period in northwestern Iberia (Mighall *et al.*, 2006; Moreno *et al.*, 2012) may have facilitated an upland expansion of cultivation.

During the 14th century, a woodland recovery and general reduction in land use was observed at both locations. This has a parallel in the upland area of Madriu Valley in the eastern Pyrenees, where a mid-14th century forest expansion and cultivation retraction was associated with an economic and

demographic crisis (Ejarque *et al.*, 2009). On the other hand, Martínez-Cortizas *et al.* (2005) refer to historical evidence for soil exhaustion and poor harvests in northwest Iberia during this period. The persistence of crops at both LF and Batocas does not readily support this argument, however. The plague and the *Interregnum* would have caused widespread economic and social disruption, driving the cultivation contraction.

In the early 16th century, grassland replaced shrubland as the main vegetation unit in Batocas as cultivation increased and livestock grazing expanded. A shrubland expansion was recorded at LF at this time, where cultivation also expanded. By the close of the century, both regional economies appear to have been based on a non-intensive agro-pastoral system. By the mid-17th century, a pine expansion was seen at LF. This rise followed the AD 1565 *Lei das Árvores* promoting the forestation of uncultivated and common land with pine, to supply wood to the shipyard industry and fuel for the population (Devy-Vareta, 1986). A contemporaneous pine increase was recorded in a pollen profile from Serra d'Arga and considered to be related to the implementation of the *Lei das Árvores* (Ramil-Rego *et al.*, 2015). No increase in pine was recorded at Batocas at this time. It may be that the area surrounding the site was not suitable for afforestation as it was being exploited for cultivation, and that the pine expansion was not linear in northern Portugal.

The introduction and fast adoption of corn (*Zea mays* subsp. *mays*), a crop with higher yields than traditional cereal crops, could have been a factor in fuelling a notable population growth, particularly from the 18th century. Census data from 1810 show a strong population increase and a doubling of the agricultural area in the upland valleys of the Portuguese northwest (Fontes, 2011). During the 18th century, corn, mainly cultivated in the valleys, became the dominant crop in the Cabreira and UTV (Fontes and Roriz, 2007). *Zea mays* pollen was not recorded at LF or Batocas, perhaps because it was only cultivated at lower altitudes, and *Secale* was also absent from the records. *Panicum millaceum* is not distinguishable from wild grasses (Behre, 1981) and its cultivation could not therefore be assessed. The demise of arable cultivation appears to have begun in the 17th century, even though it never had much expression at Batocas. This decline cannot clearly be associated with the introduction of corn although, considering the chronological uncertainties of the pollen sequences, this could have been a factor. A change in climate could have been significant as the period associated with the Maunder Minimum (AD 1645–1715) is thought to have been one of the coldest phases of the Little Ice Age (Desprat *et al.*, 2003; Moreno *et al.*, 2012). Adverse climate conditions at both Cabreira and UTV are mentioned in documents from AD 1758 (Capela and Borralheiro, 2000; Capela *et al.*, 2006). These documents equally refer to the importance of *Castanea*, which is well-represented at both sequences, because its fruit was a staple of the human diet (Capela *et al.*, 2006). Acorns are also mentioned as a valuable crop (Capela and Borralheiro, 2000), and their importance could be the reason why *Quercus* woodland was maintained at both sites even during periods of intense deforestation.

Cultivation rose at Batocas during the 19th century, while it contracted overall at LF. Here *Eucalyptus* was recorded for the first time but, due to the lack of further records and its absence from the surface pollen samples, plantations seem to be located outside the deposit's catchment area. The LF landscape has not changed considerably since the 19th century. By the turn of the 20th century the landscape around Batocas was dominated by grassland, mixed cultivation was

taking place and not dissimilar to the present-day landscape. The 20th century is poorly resolved at both sequences but an absence of cultural indicators is evident in both records.

Charcoal as a proxy for landscape degradation

Although the origin of the microcharcoal in the LF and Batocas sequences cannot be determined with confidence, its abundance and association with other taxa can be evaluated to determine whether fire was associated with a specific vegetation unit or landscape pattern. Due to the proximity of settlements, microcharcoal levels at LF and Batocas during the 13th century could reflect domestic fires.

The expansion of shrubland and increased burning in the uplands of northwest Spain from the 16th century are generally attributed to intense pastoral activity and pasture management (Morales-Molino *et al.*, 2011). Neither the LF or Batocas records reflect the high microcharcoal values or the shrub expansion identified elsewhere in northwest Iberia. On the contrary, during the 16th century grassland was expanding at Batocas, while shrubland retracted. Livestock was present in the deposit's catchment, as indicated by the presence of coprophilous ascospores, but a link between fire and pastoral activities was not observed. A slight expansion in shrubland at this time was recorded at LF but here too the rise in shrubland or microcharcoal peaks cannot with certainty be attributed to overgrazing or pastoral fires. Hence, a link between fire and shrubland expansion was not evident at either sequences, contrary to what has been suggested to have been a widespread dynamic in northwest Iberia (cf. Carrión *et al.*, 2010). In both study sequences fire activity is not associated with the Medieval Warm Period, Little Ice Age or Modern Period, and both records appear to indicate local rather than climate drivers. It appears that the present-day shrub-dominated landscapes are mainly the product of the transformation and disaggregation of the traditional agro-silvo-pastoral economies as both sequences suggest that shrubland spread was mainly driven by local dynamics rather than fire, overgrazing or climatic pressure.

Natural environment and ecosystem restoration

The landscapes of both the Cabreira Mountain and UTV are presently degraded, with forest areas often dominated by commercial plantations of pine and exotic species (mainly eucalyptus), whose introduction has negatively impacted soils, local fauna and vegetal communities causing disruption to the ecological equilibrium (Soares *et al.*, 2000). In recent years, landscape degradation has intensified, even though this process had its genesis in the past. Moreira *et al.* (2011) highlight the necessity of reversing the present landscape deterioration and decline in mountain populations underway since the 1960s by supporting traditional agricultural and pastoral practices and to cease the afforestation of the landscape with monoculture areas of pine and eucalyptus, prioritising deciduous and mixed woodland. The long-term perspective offered by this study supports the argument that such an approach to occupation and land use in the uplands of northern Portugal is viable, and that the 'natural' landscape cannot sustain an intense, large-scale economy such as the vast monocultures of the present day. The promotion and permanence of traditional landscape management and low impact practices could prove fundamental to promoting habitat and landscape regeneration.

Conclusions

This paper presents insights into the evolution of two mountain landscapes in northern Portugal over the last millennium. Dominant narratives in the consideration of the role of humans in shaping the present-day environments in such areas have tended to view overgrazing and the use of fire as the main drivers of shrubland expansion. At the two sites examined in this study there is no evidence of fire or overgrazing ultimately leading to a shrubland-dominated landscape. They present land-use stories that diverge from the dominant narrative in northwest Iberia. This study highlights that the present-day landscape degradation in both regions is not a product of fire, overgrazing or any specific climate regime as it is generally accepted in the wider northwest Iberia region. Rather, it has its genesis in the past as the product of shifting local economic structures, changing land uses and utilisation of upland resources. Small-scale agriculture and extensive upland grazing appear to have been the prevalent economic system in both regions during most of the last millennium. Social dynamics and population growth were likely significant factors driving human activity in the uplands, and the vegetation communities in both regions responded in a similar manner to different levels of human pressure.

Our findings illustrate how palaeoecology can contribute to the restoration and preservation of landscapes by exploring their long-term dynamics and the effects of both human and climate forcing. In the particular context of the two analysed uplands, our study highlights the importance of traditional management systems in maintaining health ecosystems and landscapes. The demise of traditional land-management practices and traditional economic activities in the uplands contributed to the present-day landscape degradation, be it in the form of the vast commercial monocultures or shrubland-dominated vegetation that characterise most of the mountain landscapes in northern Portugal.

Data Availability Statement

Data available on request from the authors.

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