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Heathlands, fire and grazing. A paleoenvironmental view of Las Hurdes (Cáceres, Spain) history during the last 1200 years

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Abstract

Aim of study: The diachronic study of vegetation change through palynological analysis of sedimentary deposits is an essential tool both to design sound strategies on landscape management and to understand its anthropogenic dynamics.

Area of study: La Meseguera mire (Ladrillar, Cáceres, Spain) is located in the Hurdes region in the western part of Iberian Central System and started to develop at the beginning of the Islamic period (ca. 770 cal AD), in an area widely dominated by heathland.

Material and methods: Pollen, non-pollen palynomorphs and charcoal accumulation rate (CHAR) combined with historical data are useful indicators to assess the increasing role of human influence on vegetation.

Main results: The use of fire and livestock husbandry represents the main drivers of landscape change in the course of the history. The establishment of forest afforestation plans, from the middle of 20th century, changed substantially the regional features. The sporadic presence of beech pollen is detected until 16th century, which implies the most western location in the Iberian Central Mountain System.

Research highlights: The integration of pollen analysis and historical data is an essential tool when studying the changes in Holocene vegetation. These changes have been mainly driven by anthropogenic disturbances, more specifically by fire and livestock husbandry.

Key words: anthropogenic dynamics; Central Mountain System; microcharcoals; non-pollen palynomorphs.

Introduction

Despite human impact being a major factor on Holocene vegetation dynamics, especially in western Mediterranean areas (Valladares *et al.*, 2004; Riera Mora, 2006), specific studies addressing its influence on iberian montane vegetation are scarce, limited to certain regions like southeastern Iberia (Carrión *et al.*, 2001, 2007) or the Gredos Range (López Sáez *et al.*, 2009; López Merino *et al.*, 2009; Abel-Schaad and López-Saez, 2013; López-Sáez *et al.*, 2013). The use of fire, livestock grazing and cropping during late Holocene have been increasingly recognized as key drivers in the formation of present cultural landscapes (Pausas and Keeley, 2009; Mercuri *et al.*, 2010). Besides the analysis of fossil pollen to establish the patterns of vegetation change, the presence of non-pollen palynomorphs and the concentration of microcharcoal particles have become essential tools to assess the role of anthropogenic dynamics (*e.g*: Carcaillet *et al.*, 2001; Van Geel, 2002; Tinner and Hu, 2003; López Sáez and López Merino, 2007). Non-pollen palynomorphs are reliable indicators of grazing activities (López Sáez *et al.*, 2000; López Sáez and López Merino, 2007) and of variations in the deposit humidity (Mighall *et al.*, 2006; Van Geel, 2006). On the other hand, changes in microcharcoal abundance provide valuable information to compare the fire regime between periods (Whitlock and Larsen, 2001; Gil Romera *et al.*, 2010).

The Hurdes region is located in the western part of the Iberian Central Mountain System, on the southern slope of the Francia Range. It constitutes a natural region inhabited since ancient times, as evidenced by numerous remains of the Chalcolithic and Bronze Age (Fernández Gómez, 1984). Especially remarkable is its cultural landscape, with increasing presence of par-

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cels enclosed in stone wall, which reflects the extension of agricultural practices through history. Moreover, some authors link the name of this region with the abundance of heather (*Erica* sp.), which is spelled "urce" in local dialects (Gordón Peral, 2010). The study of vegetation changes could shed light on the historical dominance of this shrub in the area.

On the other hand, the Central Mountain System is considered a refugium of forest species located at the southern edge of their range (Janssen and Woldringh, 1981; Pulido *et al.*, 2007; Abel Schaad *et al.*, 2009; Sanz *et al.*, 2011), whose populations have declined as a result of climate change and the impact of human activities throughout the Holocene. This makes our analysis especially interesting, particularly in the westernmost area of this mountain chain, where few palynological studies have been carried out (*e.g:* Janssen and Woldringh, 1981; Atienza Ballano, 1993; Van der Knapp and Van Leeuwen, 1995; Abel Schaad *et al.*, 2009; Abel-Schaad and López Sáez, 2013; Morales-Molino *et al.*, 2013; López-Sáez *et al.*, 2013).

This paper describes the main changes in the vegetation of the Hurdes region through the analysis of pollen, non-pollen palynomorphs and microcharcoals obtained in the peat deposit of La Meseguera. The relationship of such changes with the historical processes that have occurred from the onset of the Islamic Period is emphasized. Special attention will be paid to fire impact, crop development and livestock grazing, as major factors shaping the landscape in a changing climate framework.

Study area

La Meseguera mire (Fig. 1) is located on the southern slope of the Francia Range (40° 28' 13" N/6° 13' 15" W), at 900 masl, in the municipality of Ladrillar (Cáceres), in the Hurdes region.

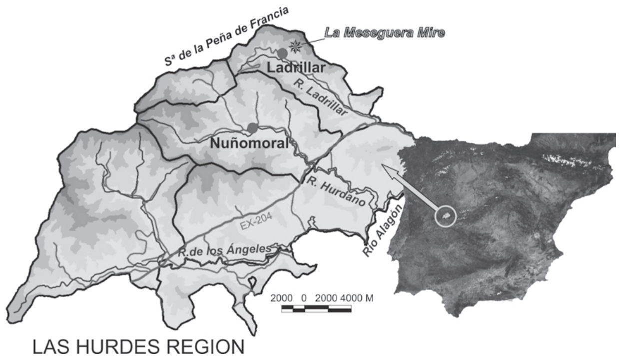

Figure 1. Location of the study site.

The geological substrate consists mainly of slates and graywackes (IGME, 1990). Above them mostly Leptosols are deposited (García Navarro, 1995). The climate is of a Mediterranean subhumid type, with monthly average temperature of 14.4°C and annual rainfall of 1,137 mm.

The current vegetation is profoundly altered due to human-induced disturbances over time. Furthermore, pine plantations were installed in 1940-1950 in 80% of the land. Recurrent fires of these afforestations have resulted in a landscape dominated by regeneration pine stands, grasslands, heathlands and broom communities, where only small patches of holm oak (*Quercus ilex*) and cork oak (*Q. suber*) woods survive at mid elevations. At higher altitude oak forests of *Q. pyrenaica* have virtually disappeared, whereas broom communities with *Echinospartum ibericum* characterize the uppermost belt.

Material and methods

To sample the mire a core of 120 cm was obtained with a Russian core sampler. Samples were studied at intervals of 4 cm, resulting in 30 samples in this record. A sediment characterization of the mire (Aaby and Berglund, 1986) was made in order to clarify certain important events in its formation and evolution (Table 1).

Four samples of bulk organic sediment have been dated in the National Accelerator Centre (CNA, CSIC, Sevilla, Spain) (Table 2). Calibrated dates were calculated using CALIB v.5.0.2. program (Stuiver *et al.*, 1998). An age depth-model has been built (Fig. 2) with the average dates by means of linear interpolation, taking into account the maximum probability interval at 2 sigma ranges. This allows the calculation of the approximate sedimentation rate of the mire.

Palynological analysis of the samples followed the classic chemical procedure (Faegry and Iversen, 1989; Moore *et al.*, 1991), using Thoulet heavy liquid for densimetric separation of pollen and non pollen palynomorphs (Goeury and Beaulieu, 1979). Palynological concentration was estimated by adding a *Lycopodium* tablet to each sample (Stockmarr, 1971). Data processing and graphic representation was performed with TILIA and TGView softwares (Grimm, 1992; 2004). Local pollen assemblage zones were determined with a cluster analysis made by CONISS (Grimm, 1987).

Table 1. Sediment characteristics at La Meseguera mire (Cáceres, Spain)

Depth (cm)	Characteristics
0-56	Light brown, slightly humified peat with many herbaceous detritus: $Tb^2$2, Dh2
56-96	Darker brown, moderately humified peat with moderately humified silt, some herbaceous detritus and low presence of sands: $Tb^2$2, $Ld^2$2, Dh+, Gmin+
96-100	Lighter brown, moderately humified peat with moderately humified silt: $Tb^2$2, $Ld^2$2
100-110	Darker brown, moderately humified silt with presence of some sands, clays and few gravels: $Ld^2$2, Ag1, Gmin1, Gmaj+
110-120	Lighter brown, moderately humified silt with presence of some sands, clays and gravels: $Ld^2$2, Ag1, Gmin1, Gmaj1

Table 2. Chronology of the pollen sequence of La Meseguera. Calibrated dates were calculated using CALIB v.5.0.2. program (Stuiver *et al.,* 1998)

Laboratory code	Depth (cm)	^{14}C Age	2σ Calibration (95% probability)	Mean age cal AD
CNA 753	30	Modern	1954-1956 cal AD (95%)	1955
CNA 754	60	38 ± 30 BP	1444-1524 cal AD (66%) 1558-1631 cal AD (33%)	1520
CNA 755	80	640 ± 30 BP	1283-1329 cal AD (43%) 1340-1396 cal AD (57%)	1340
CNA 295	120	1270 ± 60 BP	654-888 cal AD (95%)	771

Ferns, hydro-hygrophilous taxa and non pollen palynomorphs have been excluded from the total pollen sum (> 500 pollen grains) in the pollen diagrams (Figs. 3-6) (Wright and Patten, 1963). Pollen sum have also been increased to reach 200 pollen grains excluding *Erica arborea* type ones, due to the high percentages of this type, in order to make the rest of taxa more visible. Besides, a chart showing the total pollen concentration has been added (Figs. 5-6).

Microcharcoals in the same slides used for pollen (Tinner and Hu, 2003; Finsinger and Tinner, 2005) were counted and sorted into different size classes (Morrison, 1994; Vannière *et al*., 2008), in order to reconstruct the historical dynamics of fires in the area (Whitlock and Larsen, 2001). *Lycopodium* spores were also considered to estimate their concentration. The charcoal accumulation rate (CHAR) (Figs. 5-6) was calculated by dividing the concentration of microcharcoals by the sedimentation rate of each sample obtained from the age-depth model (Long and Whitlock, 2002).

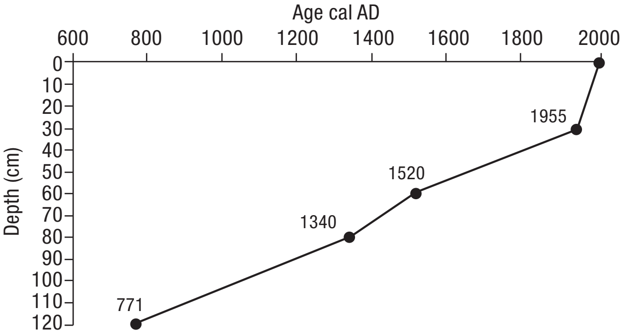

Figure 2. Age-depth model for La Meseguera mire.

Results

The main features of pollen diagrams are shown in Table 3.

Discussion

The onset of mire formation. Islamic Period (ca. 770-940 calAD). LPAZ MES1A1

La Meseguera mire was formed at the end of 8th century, as a likely consequence of intense forest clearance activities developed in earlier times, in an uns-

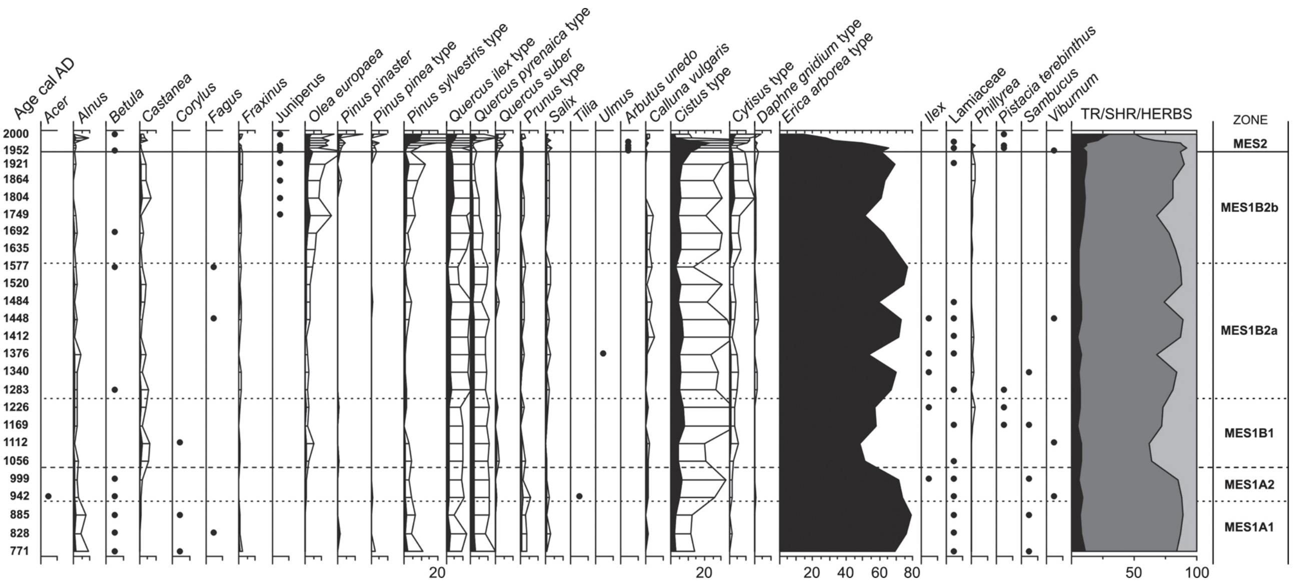

Figure 3. Pollen diagram of La Meseguera. Trees and shrubs.

table climatic scenario, which characterizes the Early Medieval Cold Period (Desprat *et al*., 2003).

Tree crops would be represented by chestnut, with the onset of its continuous curve, and olive, whose early traces are located at the beginning of 10th century.

By this time, pastures occupy a limited area, with grasslands as their major element. Nitrophilous taxa scarcely appear, pointing to the lack of intense livestock husbandry, as also indicated by the low levels of coprophilous fungi spores (López Sáez and López Merino, 2007). Both the presence of fire indicators and the high values of CHAR, with a maximum in the transition to 10th century, show the great incidence of fires in this period.

A seminomadic livestock grazing model could be hypothesized for this period, based on uncontrolled shrub burning, with a low stocking density in relation to the large amount of pastures which could be potentially available. Historical data about the early Islamic Period describe an economic model based on livestock

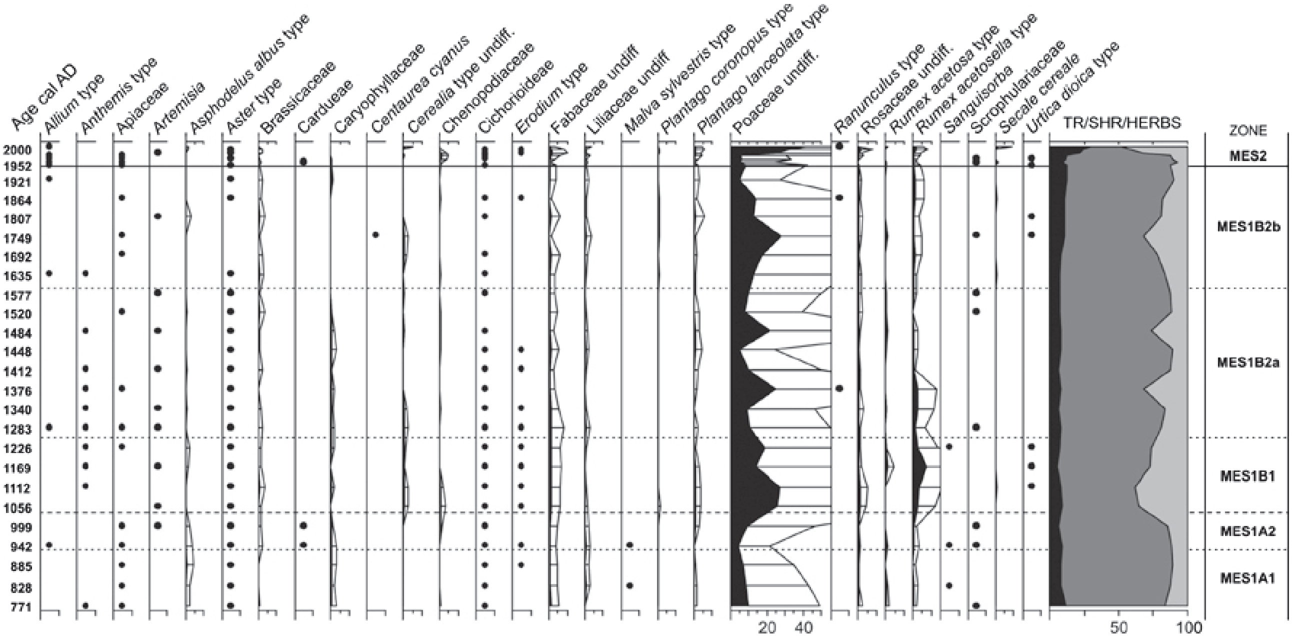

Figure 4. Pollen diagram of La Meseguera. Herbs.

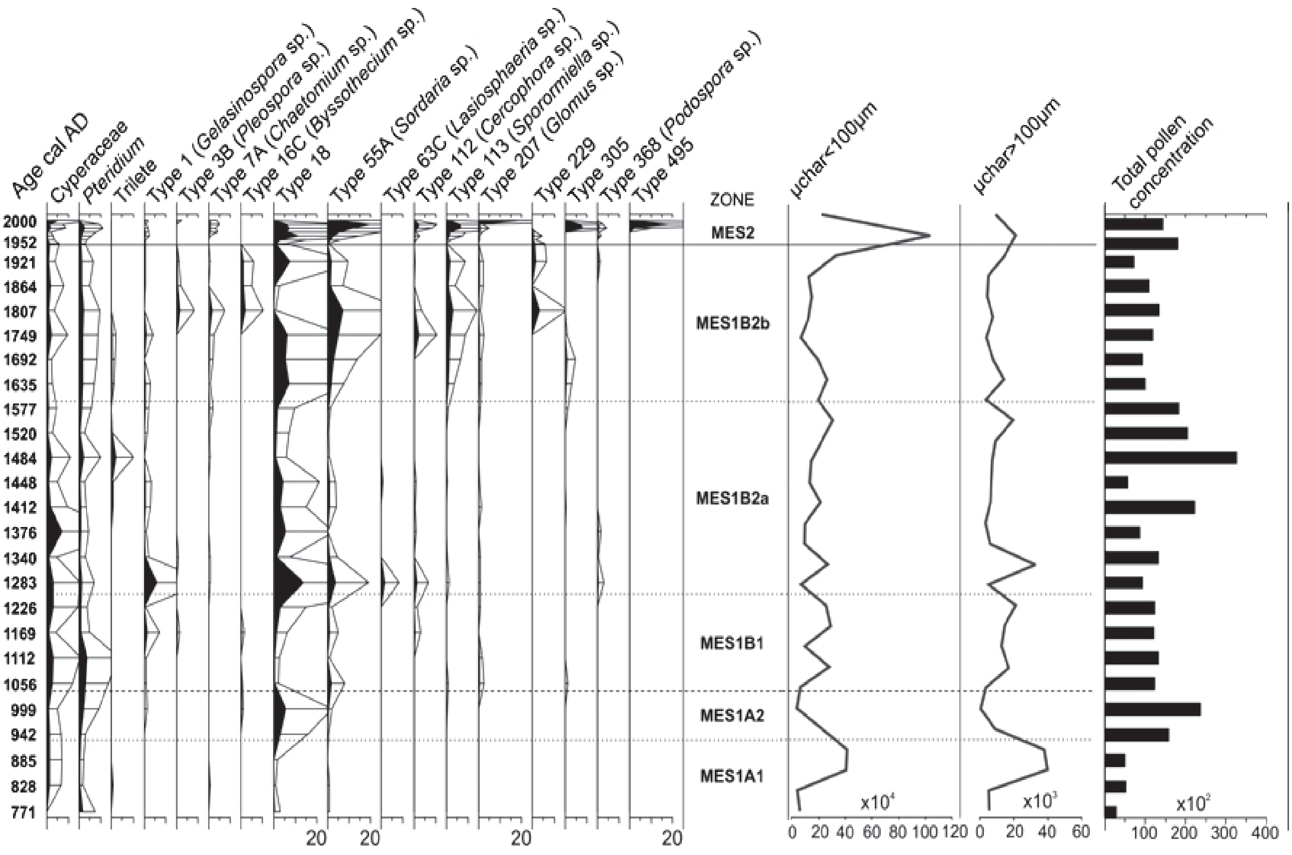

Figure 5. Pollen diagram of La Meseguera. Hydro-hygrophilous taxa, non-pollen palynomorphs, charcoal accumulation rate (CHAR) and total pollen concentration.

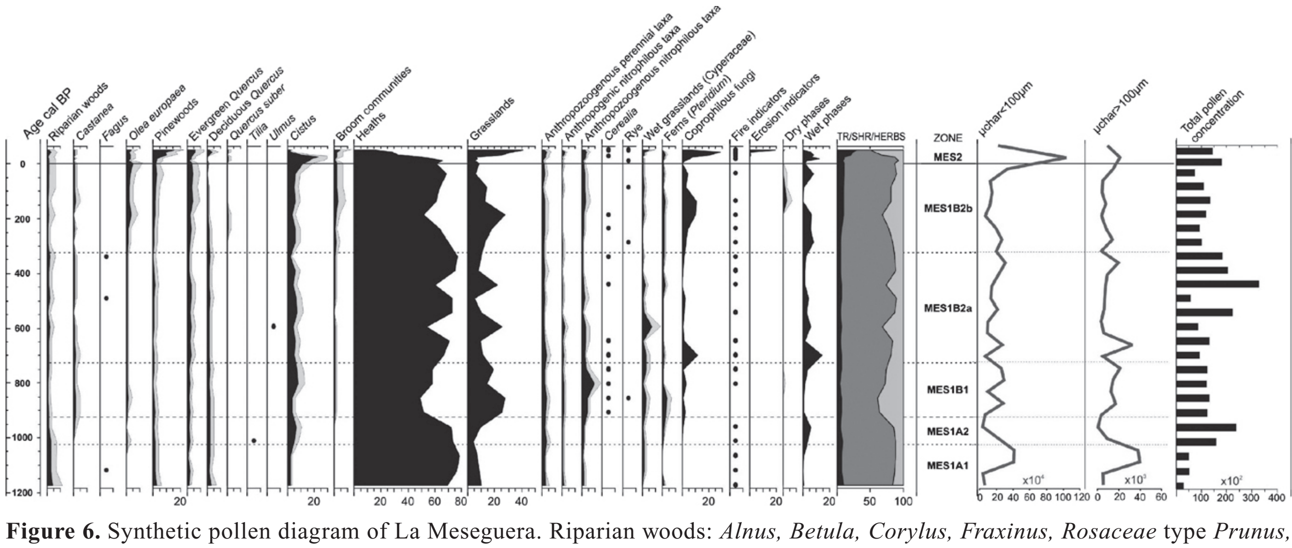

Figure 6. Synthetic pollen diagram of La Meseguera. Riparian woods: *Alnus, Betula, Corylus, Fraxinus, Rosaceae* type *Prunus, Salix, Ulmus, Ilex* and *Sambucus;* Anthropozoogenous perennial taxa: Apiaceae, Brassicaceae, Campanula, Caryophyllaceae, Fabaceae, Liliaceae, Rosaceae and Scrophulariaceae; Anthropogenic nitrophilous taxa: Aster type, Cichorioideae, *Erodium, Malva;* Anthropozooenous nitrophilous taxa: Chenopodiaceae, *Plantago* sp., *Rumex* sp. and Urtica dioica type; Coprophilous fungi: *Gelasinospora* sp. (Type 1), *Sordaria* (Type 55A), *Cercophora* (Type 112), *Sporormiella* (Type 113) and *Podospora* (Type 368); Fire indicators: *Chaetomium* (Type 7A); Erosion indicators: *Glomus* (Type 207); Dry phases: *Pleospora* (Type 3B), *Byssothecium circinans* (Type 16C) and *Lasiosphaeria* sp. (Type 63C); Wet phases: Type 18.

Table 3. Description of pollen zones

Zone	Trees/Shrubs	Herbs	Non-pollen	Char
MES2 (30-0 cm)	— Trees maximum (>30%) — *P. sylvestris* (>10%), *Olea* (5%), *P. pinaster* (3%) and *P. pinea* (2%) — *Q. ilex* (6%) and *Q. suber* (>1%) — *Erica minimum* (14%). *Cistus* (2%) and *Cytisus* (4%) — *Castanea* (<1%) and *Fagus*	— Poaceae maximum (>40%) — Slight increase of nitrophilous taxa — Cerealia (>1%) and Secale cereale (2%) maxima	— Coprophilous fungi maxima — Type 7A final rise — High levels of Type 18	Final sharp maximum
MES1B2b (54-30 cm)	— Retreat of *Erica* (51%) and final recovery (69%) — *Cistus* (6%) and *Cytisus* (3%) — *Q. ilex* (5%), *P. sylvestris* (2%) — *Castanea* (>1%) and *Olea* (3%) — *Juniperus, Q. suber* and *P. pinaster*	— Poaceae initial maximum (28%) and final minimum (5%) — Low presence of nitrophilous taxa — Sporadic presence of Cerealia and Secale cereale	— Coprophilous fungi increase — Type 7A rise — Alternating levels of Type 18 and Type 3B	Rise with peaks in the middle of this zone
MES1B2a (82-54 cm)	— *Erica* maximum (>70%) — *Cistus* (7%) and *Cytisus* (1%) — *Q. pyrenaica* (2%) and *Q. ilex* (2%) — *Castanea* and *Olea* <1% — *Fagus, Ulmus* and *Q. suber*	— Poaceae oscillations (5-25%) — Fabaceae and Rosaceae >1% — Nitrophilous taxa drop — Sporadic presence of Cerealia	— Initial Coprophilous fungi increase and final disappearance — Low levels of Type 207 — Sporadic Type 7A — Type 18 initial maximum	Oscillations and final stabilization
MES1B1 (102-82 cm)	— *Erica* minimum (48%) and *Cistus* maximum (8%) — *Q. pyrenaica* (2%) and *Q. ilex* (2%) — *Castanea* and *Olea* >1% — *P. sylvestris* and *Q. suber*	— Poaceae (27%) — Fabaceae and Rosaceae >1% — Rise of nitrophilous taxa, specially *Rumex* spp. (>8%) — First appearances of Cerealia and Secale cereale	— Coprophilous fungi increase — Type 207 appears — Type 18 minima — Sporadic presence of Type 3B and 16C	Initial minimum and final increase
MES1A2 (110-102 cm)	— *Erica* (72%) and *Cistus* (5-6%) — *P. sylvestris* (<1%), *Q. pyrenaica* (2%) and *Q. ilex* (2%) — *Castanea* and *Olea* continuous curve — *Tilia*	— Poaceae <10% — Fabaceae and Rosaceae >1% — Nitrophilous taxa <1% — *Asphodelus albus*	— Coprophilous fungi increase — Type 18 rise	Sharp reduction
MES1A1 (120-110 cm)	— *Erica* (78%) and *Cistus* (2%) — Riparian species maxima (5%) — *P. sylvestris* (2%), *Q. pyrenaica* (3%) and *Q. ilex* (2%) — *Castanea, Fagus, P. pinea* and *P. pinaster*	— Poaceae <10% — Fabaceae >1% — Nitrophilous taxa <1% — *Asphodelus albus* maximum	— Coprophilous fungi minima — Low levels of Type 7A	Final maximum

grazing, by Berber people, in a sparsely populated land (Franco Moreno, 2005).

Pollen concentration is very low in this zone (Fig. 6), pointing to adverse conditions for the development of vegetation, in spite of the gradual amelioration of weather (López Sáez *et al.*, 2009). This could again reflect the high intensity and frequency of fires.

The relative consolidation of the islamic settlement (ca. 940-1050 calAD). LPAZ MES1A2

Tree crops start to develop, in agreement with increasing requirements of an expanding population. Cork oak also seems to advance, pointing to a greater importance in relation to tanning and apiculture (Ezquerra Boticario and Gil Sánchez, 2008). Riparian woods are affected by this higher human impact, due to the likely use of river and stream banks for the setting-up of irrigated orchards, with the new techniques introduced by Berber people (Franco Moreno, 2005).

Maxima of CHAR initially continue, indicating fires on shrublands, which allow grasslands and also *Cistus* communities to expand. Besides, a slight increase in the percentages of pollen of taxa linked to livestock grazing and spores of coprophilous fungi suggests the establishment of more sedentary livestock settlements.

Historical data tell about some autonomy of this region with regard to Córdoba Caliphate during 10th century (García Oliva, 2007), reinforced by population isolation within Hurdes intrincate mountain ranges. The border with Christian Kingdoms would be located north of the Central Mountain System (Barrios García, 1985).

The onset of the Medieval Warm Episode (Desprat *et al*., 2003) is associated to milder climatic conditions, with increasing temperatures and rainfall, as indicated by the significant rise of Type 18 levels (Mighall *et al*., 2006). The lower presence of gravels in this sedimentation level (Table 1) would show less torrential episodes in rainy periods.

Space occupation in the border (ca. 1050-1280 calAD). LPAZ MES1B1

Human pressure becomes more pronounced in 12th century. Tree crops, chestnut and olive trees, reach new maxima and so does cork oak. On the other hand, pinewoods disappear, probably related to the needs for timber. Low pollen rates of *Cerealia* and *Secale cereale* are insufficient to indicate their local cultivation (López Sáez and López Merino, 2005) but they are probably grown not far from the mire. Agriculture is favoured by irrigation systems and the use of manure as fertilizer (Franco Moreno, 2005).

However the most outstanding event in vegetation is the retreat of heathlands at the expense of grasslands. This change would be related to livestock expansion, as shown by the high pollen percentages of nitrophilous taxa and the increasing levels of coprophilous fungi. The lack of fire indicators in initial samples is also significant, pointing to shrub control by livestock, most likely driven by goats.

At the end of 12th century (ca. 1190 cal AD) a sharp drop of crops and a clear decrease of grasslands extension are observed, coinciding with growing values of CHAR and the first appearance of dry phases indicators. A severe regional drought can explain these facts. Meanwhile, in the surroundings of the mire, livestock grazing could remain thanks to the water provided by nearby springs.

This broad intensification of human action during the onset of the Christian Kingdoms domination is also verified by historical data. Two castles are built at the end of 12th in this region (Martín Martín, 1985; Montaña Conchiña and Clemente Ramos, 1994)

Population settlement and the beginning of Early Modern Period (ca. 1280-1580 calAD). LPAZ MES1B2a

At the end of 13th century the interests of transhumant livestock breeders reached their highest protection thanks to the creation of La Mesta (Ezquerra Boticario and Gil Sánchez, 2008). Its impact on the study region was very low due to the absence of significant livestock tracks and the location of large summer grasslands areas in adjacent regions (Terés Landeta *et al*., 1995). Intense livestock use was also precluded by the donation of *"Dehesa de Jurde"* from Granadilla to La Alberca in 1289 (Fernández Gómez, 1984), accompanied by several ordinances preventing its use by outsiders.

The need of more pastures triggered shrub fires (Fig. 7), until a sharp reduction of livestock activity is detected by the mid 14th century. It coincides with a dry phase, indicated by *Pleospora*, and with the onset of Little Ice Age (Manrique and Fernández-Cancio, 2000; Desprat *et al*., 2003). This crisis would be also related with a pollen concentration minimum (Fig. 6).

A wide extent of grasslands is detected during the 15th century without a parallel increase of livestock indicators. This could be linked to a phase of transhumant livestock predominance related to a change of property in favor of Duke of Alba in 1,444 (Pino García, 1985). New ordinances at the beginning of 16th century (Llorente Pinto, 1992) triggered the drop of livestock indicators and a slight increase of forest taxa.

Higher human pressure and spread of scrubland (ca. 1580-1950 cal AD). LPAZ MES 1B2b

Shrub taxa suffer a strong retreat in a first phase, leading to minimum values around mid 18th century, while grasslands spread. In addition, the rise of spore values of coprophilous fungi shows a higher impact of livestock grazing while the average incidence of fires increases.

A widespread agricultural development occurs at a regional scale throughout the 17th and 18th centuries (Ezquerra Boticario and Gil Sánchez, 2008), with the expansion of cereal and olive tree crops. However, livestock husbandry would keep on being the economic base of the Hurdes region, although a clear advance of olive tree cultivation, an upturn of cereal during the 18th century and occasional rye crops are observed on the pollen diagram.

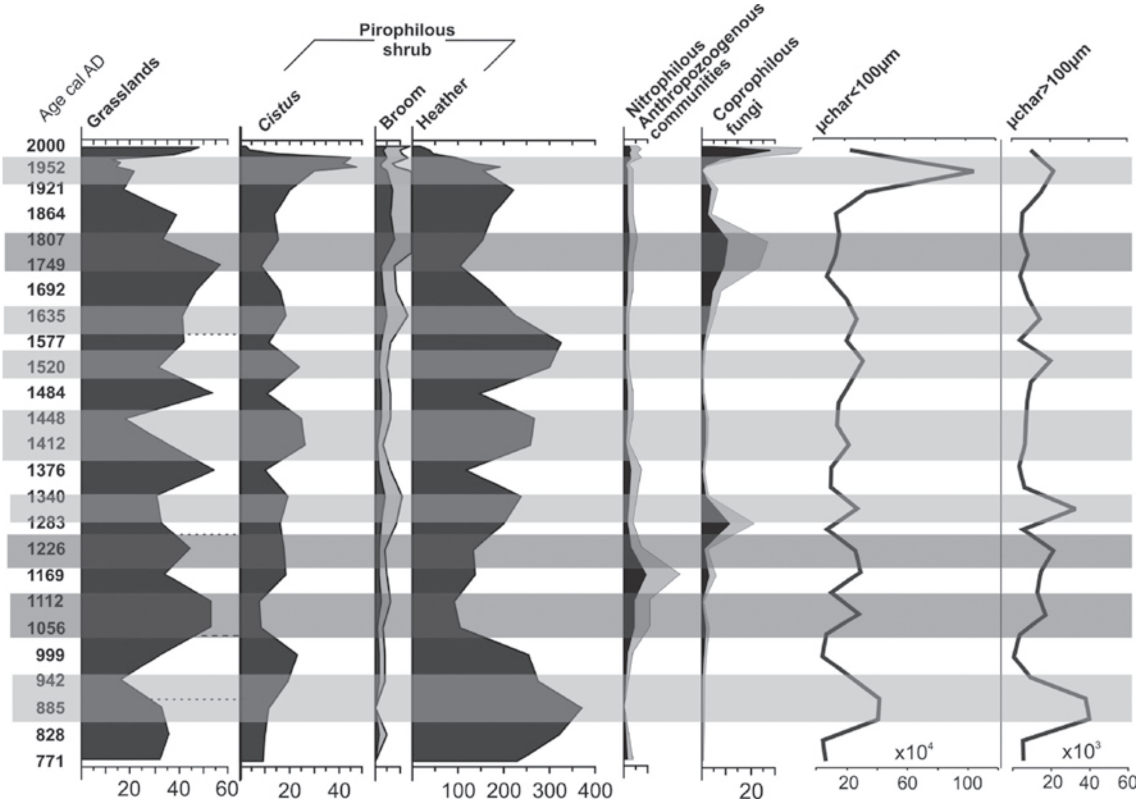

Figure 7. Response to fire and influence of livestock intensity on grasslands and pirophilous shrub. Fires enable the extension of grasslands (light grey). If livestock intensity is high, grasslands run out as shrublands spread (dark grey). New fires begin this process again.

Climatic conditions are relatively wet until the end of the Early Modern Period, as corresponds to the second phase of the Little Ice Age (Bradley and Jones, 1993) and the high levels of Type 18 indicate.

From the beginning of the Late Modern Period livestock husbandry steadily increases, with maxima at the beginning of 19th century, after the clearance of oak forests to open new pasturelands. This maximum livestock pressure coincides with a new change of property in the area (Llorente Pinto, 1992; Granjel, 2001). Subsequent Confiscation Laws would have led to felling of already limited oak forests, in order to defray the costs of farms (Cruz Reyes, 1983). This fact, along with a livestock activity decrease, would have favoured the maximum extent of scrubland at the end of this period. The progression of shrub legumes parallel to the decline of oak forests should also be stressed.

Afforestation Plans, fire and current landscape (ca. 1950 cal AD-present). LPAZ MES2

Forest taxa reach their maximum values in the uppermost samples, due both to pine afforestations, especially with *Pinus sylvestris*, and to final livestock abandonment. Meanwhile, scrubland reaches its minimum extent, as a consequence of the spread of pinewoods, forestry and, above all, fire, with levels reaching maxima during this period. *Cistus* and broom communities are initially favoured against heathlands.

Grasslands extend sharply to the maxima of the profile thanks to fire influence. Spores of coprophilous fungi disappear in the uppermost sample, after their maxima of the profile, coinciding with a *Glomus* maximum, pointing to an erosion event likely related with the incidence of fire. The broad spread of pinewoods would have triggered the reduction of pasturelands. Then, stock density would increase in the more propitious areas left, like the mire, so that the signal produced by coprophilous fungi would also improve. Subsequent fire proliferation would have helped grasslands extend therefore reducing this stock density signal.

Pine afforestations and fire mark the current landscape evolution of the Hurdes region. The most recent years are characterized by large fires, which lead the arboreal pollen percentage to the minimum of the profile.

On the presence of beech (*Fagus sylvatica*) in the western Central Mountain System

The pollen diagram of La Meseguera mire shows the sporadic presence of *Fagus* pollen in three samples, dated approximately in the 9th, 15th and 16th centuries (Fig. 3). These constitute the most western location in the Central Mountain System found to date.

There are a large number of current *Fagus sylvatica* references in the eastern part of the Central Mountain System, especially in Ayllón and Somosierra ranges (*e.g.:* Rivas Martínez, 1962, 1963; Mayor, 1965). They decrease to the west, with scattered citations in the Gredos Range (Amor *et al*.,1993), the Francia Range (Casaseca, 1975; Fernández Díez, 1976) and the Gata Range (Pulido, pers. com.).

As for the pollen record, the oldest dated citations are located in the Bejar Range, with sporadic appearances from 5850 calBP (Ruiz Zapata *et al*., 2011), and in the Ayllon Range, around 4100 calBP (Franco Múgica *et al*., 2001). Its presence is dated in the Gredos Range from 3000 calBP (Ruiz Zapata and Acaso Deltell, 1981; Franco Múgica, 1995), and more recently in Guadarrama (Vázquez, 1992) and Rascafría (Franco Múgica, 1995). It has been not detected westwards, neither in the Gata nor in the Estrela Range (Abel Schaad *et al*., 2009).

The scarcity of sequences covering longer chronological periods prevents the detection of older appearances, which could shed light on the possible establishment of glacial refugia in the area. This hypothesis would be supported by the presence of pollen from other current species, like hornbeam (*Carpinus betulus*) in the Estrela (Van der Brink and Janssen, 1985) and the Bejar (Atienza Ballano, 1993) ranges in Mid Holocene; lime tree (*Tilia* sp.), which appears more recently in both ranges and around 1000 calBP in La Meseguera mire; or chestnut (*Castanea sativa*), located before its expansion during Roman Period throughout western Central Mountain System (Abel Schaad *et al*., 2009; Abel-Schaad and López-Sáez, 2013).

The ability of beech to respond to disturbances (Leuschner *et al*., 2006) would help its survival, despite the high intensity of human impact, against other species, like *Tilia* or *Carpinus*, which would go extinct by this action (Turner, 1962; Gardner and Willis, 1999).

However, its low pollen productivity (Andersen, 1970) and small range of dispersion (Moore *et al*., 1991) hinder this species' appearance in pollen records (Jacobson and Bradshaw, 1981; Conedera *et al*., 2006). Moreover, beech seeds are mainly dispersed by birds (Valsecchi *et al*., 2008), allowing its expansion in a pattern of isolated stands, whose signal shows a sporadic and intermittent character (López Merino *et al*., 2008). This constitutes a problem when detecting possible expansion routes of beech from East to West (Martínez Atienza and Morla Juaristi, 1992; Costa Tenorio *et al*., 1997), since there is no gradation in the presence of pollen. Neither dates seem to agree. First appearances in Navamuño, in the Bejar Range (Ruiz Zapata *et al*., 2011), or in Pelagallinas, in the Ayllon Range (Franco Múgica *et al*., 2001), are older than recent expansion of beech in the Iberian Mountain System (López-Merino *et al*., 2008), so they may be proposed as refugium areas. This agrees with models presenting potential distribution areas of *Fagus sylvatica* during Late Glacial Maximum along the western sector of the Central Mountain System (Benito Garzón *et al*., 2007). These areas move northwards in the Mid Holocene, with very scarce presence in western Iberia, likely due to the isolation of its populations.

Hence, possible refugia of beech could have existed in the western Central Mountain System, in absence of older deposits. Intense human activity would have prevented its expansion in the Mid Holocene, causing the extinction of many stands. More recently, the steady climate continentalization would have produced a general decline (Magri, 2008).

Concluding remarks

La Meseguera mire was formed around the middle of Early Medieval Cold Period, in a landscape dominated by heathlands, as a result of an intense deforestation on soils with limited ability for regeneration.

First phases of territorial occupation by Berber people are based on a semi-nomadic livestock husbandry related to shrub fires, and emerging tree crops such as chestnut and olive trees. In the transition to the new millennium human pressure increases, specially by livestock grazing and, to a lesser extent, with the introduction of new agricultural techniques, favored by climate amelioration.

Christian Kingdoms do not alter substantially land use patterns, beyond an intensification of livestock husbandry and tree crops. Changes of ownership and distance from major transhumant routes prevent this region joining the widespread development until the beginning of Early Modern Period. The use of fire causes a cyclic alternation between grasslands and heathlands.

From Early Modern Period anthropogenic action steadily intensifies. Livestock grazing, olive tree crops and a great incidence of fire characterizes the region's landscape until the mid 20th century, when the maximum extent of heathland is detected. More recently, pine afforestations and large fires constitute the main features, as well as the decline of livestock activity.

The most western pollen record of *Fagus sylvatica* in the Central Mountain System is dated in this mire. This and other nearby ones suggest the presence of beech before its expansion in Mid Holocene.

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