**Forest Dynamics in the Spanish Central Mountain Range**

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**Introduction: Objectives and Methods**

The main objective of our research involves characterising the different phases of forestry uses and their impact on forest dynamics on the northern and southern slopes of the Somosierra and Ayllón mountain ranges (Madrid - Segovia, Spain)\(^1\). Thus, we attempt to define long-term models reflecting forest dynamics. To this end, there is a vital need to break down our large study area into smaller zones, known in Spanish as “montes”\(^2\), and to define in each of these the current features of their vegetation and to identify the historical uses and exploitation systems that have shaped them.

Our research project integrates different disciplinary and methodological approaches habitually employed in studies on the history of the environment (Rackham, 1995; Kirby & Watkins, 1998; Agnoletti & Anderson, 2000; Métailié et al., 2003; Rotherham, 2007), and makes use of converging methods:

- Documentary analysis: consultation of different files (local, national, private), and documentary and photographic archives.
- Interviews and consultations with managers: consultation of available technical plans and interviews with forest managers in order to obtain information on current forest management.
- Intensive field work: inventory, geo-referencing of charcoal furnaces and other heritage-related elements (fences, charcoal burners’ trails, canals, etc.), excavation of charcoal furnaces, extraction of palynological cores, etc.
- Biogeographic and forest inventory: characterisation of current forest formations and structures by means of stratified floristic inventories and forest characterisation records (100 m\(^2\) plots) (López Estébanez, 2003).
- Anthracological analysis: we excavated the charcoal furnaces, following standardised methods (Davasse, 1992), in order to identify the forest species that had been charred; we employed an Olympus SZX16 stereoscopic microscope.
- Other analyses: other methodologies (dendrochronology and palynology) are being introduced, as these enable us to increase the time interval analysed and to provide better interpretations.

The study area selected (Somosierra-Ayllón forests) is of particular interest from this multidisciplinary perspective (Figure 1). Indeed, we are dealing with a historically very large area of public land presenting very diverse uses, which can clearly be seen in the present rural landscape. It is a Mediterranean mid-mountain environment (from 1,000 to 2,200 mts. above sea level), lying upon siliceous materials and with a vegetation dominated by formations of Mediterranean oak (*Quercus pyrenaica*, Willd.) and pine (*Pinus sylvestris* L.) which have been conserved mainly in the common forests, as well as of scattered birch (*Betula alba* L. and *Betula pendula* Roth.), beech (*Fagus sylvatica* L.) and holly (*Ilex aquifolium* L.). Lastly, the rapid recent transformations (depopulation, increased forest area, abandonment of agricultural and livestock farming uses…) call for studies on the dynamics of vegetation (Sáez Pombo, 2000; López Estébanez, 2003; Madrazo García de Lomana, 2010; Gómez Mendoza et al., 2010).
Types of forest use over the last eight hundred years.

The ways in which humans have used natural resources in the last millennium have shaped the current appearance of forests. The societies that have participated in this exploitation, managing and using these forests, have constituted the principal driving forces of their transformation. Over centuries, there have been different phases in the use and management of these forests, which have affected the latter’s appearance and dynamics, and which are diverse according to specific European contexts thus giving rise to time periods that do not necessarily coincide (Agnolotti & Anderson, 2002; Clemént, 2002; Metalié et al., 2003; Arnould et al., 2003).

Ultimately, to understand current forest dynamics and to appreciate their cultural values, one needs to go back in time. The temporal perspective of this study involves 1,000 years of forest history, which will oblige us to synthesise the phases of the forests, highlighting the points of interest and the specific forces that have played a role at each moment in time in the management and configuration of these landscapes (Figure 2).

Reoccupation of the territory and administration; forest use and management.

As from the eleventh century, the Christian Kingdoms reoccupied this part of the Iberian Peninsula (González, 1974; Clément, 1993), ending two centuries of scant population and little use of resources. Thus, the foundations were laid for a production-based society, which, with certain nuances, remained stable throughout eight centuries. From the eleventh to the thirteenth centuries, the municipal governments were established, taking over and managing these territories with all their resources, including forests. The administrative boundaries set up at this time were based upon head of communities, (roughly equivalent to county towns), with extensive jurisdiction over all the corresponding villages, lands and forests (Figure 3).

Thus, the jurisdiction of the territory had a notable effect on forestry uses (Sáez Pombo, 2000; Madrazo García de Lomana, 2010). Basically it would govern ownership and management of the montes, so that management of some forests was transferred to the village, in the form of common lands.
Common lands (Concejiles): With some exception, all villages – regardless of their size – owned an area of forest, ceded by the communities. As owners of this forestland, these villages managed it as they considered fit and defended it from any intrusion of livestock belonging to outsiders and from forbidden uses. This defensive attitude in relation to their forestland heritage reveals two fundamental aspects with regard to characterising the history of these forests.

On one hand, semantic confusion exists, as much of this forestland consists of dehesas. This denomination has nothing to do with the kind of forest vegetation, but is rather a simple evolution of the term défesa (“defense” in Latin), referring to the fact that the area is physically demarcated by boundaries. Thus, these dehesas are not always dehesas from the point of view of vegetation (open forests), as one is often dealing with shrubland or mixed vegetation (trees and shrubs).

On the other hand, these forests are of great value to local people, due to the fact that they constitute authentic forest reserves, which indicate the importance of protecting and managing them. To this end, some basic rules were established to regulate forestry uses (charters), which from the fourteenth to the sixteenth centuries, were extended in Ordinances (ordenanzas concejiles), and became more specific and generally stricter (Gómez et al., 2009). These common-land
forests generally constitute a good example of adaptation of specific techniques for management of unique ecosystems (Berkes & Folke, 1998).

Community lands: The heads of communities continued to own many of the forestland estates in the mountain ranges until well into the nineteenth century, when they were legally revoked. Among the forest lands they owned, we can differentiate two types: pastures, heaths and fields of Spanish broom (Cytisus), which were rapidly deforested, but still called montes, and some big forests exploited for timber. The interest of the former lay in the management of these pastures, vital to the livestock farming economy in these mountains (García Sanz, 1977), whereas the large pine forests (P. sylvestris, L.) in Valsaín, Cabeza de Hierro or Navafría, became strategic reserves of forest products at regional scale. Ancient historic references to these masses of conifers (Manuel Valdés & Rojo Alboreca, 1994; Rojo Alboreca & Montero González, 1996; Martínez García, 1999), along with pollen records (Franco Múgica et al., 1998) identify these masses as historical pine forests, differentiating them from other pine forests resulting from reforestation in the twentieth century.

The two models of ownership and administration of forests during the old regime (villages and communities) came to determine the appearance of forest masses. Therefore, considering the forested areas as a whole, one can appreciate a repetition of the distribution patterns (López Estébanez & Sáez Pombo, 2001). Thus, the dehesas concejiles were usually situated in the vicinity of the villages that owned them, on the lower slopes of the mountains, forming green patches among pastures and croplands. The upper slopes and summits of these mountains belonged to the communities and were mostly deforested, at least from the fifteenth and sixteenth centuries (Madrazo García de Lomana, 2010). Falling outside this system were the historical dispersed pine forests, totalling approximately 26,000 ha throughout the Mountain Range (Rojo Alboreca & Montero González, 1996).
To synthesise, forest landscapes in the Guadarrama Mountains at the end of the Old Regime reflected a livestock farming economy with some agriculture and forest reserves. On one hand, these mountains had long supported a heavy livestock load, although the need for new croplands, arising from population increases, was addressed by occupying common lands. On the other hand, two forces, aimed at protecting forests, attempted to prevent depredation of resources. Firstly, the communities and villages themselves, which, by means of bylaws, promoted rational use of forest resources. Secondly, the Crown, after moving to Madrid (1562), developed an increasingly interventionist and punitive forest policy (Hernando Ortego, 2003, Madrazo García de Lomana, 2010). The Crown considered it crucial to respect forest boundaries in the surroundings of the Capital, as it relied on forestland for energy and other resources.

Alterations of ownership and management of forests. Persistence of use models.
Halfway through the nineteenth century, the idea began to spread of the need to regenerate forests in Spain, and in the Guadarrama Mountains, this scientific current could be seen in a call for reforestation, founded upon a “forestry vocation” (Gómez Mendoza, 1992). These ideas relating to forest management, however, promoted by forestry engineers, would require over one hundred years to take root, with the initiation of an intensive reforestation programme in 1940 (Gómez Mendoza & Mata Olmo, 1992).

In the years after 1855, the forests in the Iberian Peninsular suffered a terrible blow with regard to ownership and administration. From 1855 to 1870 most of the land that had belonged to the communities were privatised in a process (desamortización) not exempt from opposition by the forestry engineers, who believed that these lands should be public and reforested, and by the communities, who lost ownership of their lands. According to the 1862 Forestry Law, public land covered by pines, oak or beech were not privatised and came to be managed by the public administration through the recently created Forestry Engineering Corps, which meant that the villages ceased to manage them.

But these substantial changes in forest ownership and administration did not immediately affect the physiognomy of forest landscapes. Forests continued to be exploited for one hundred years, and the forest area hardly varied, with an unchanging vegetation. This lack of change was related to backward agriculture on the Iberian Peninsula: only after 1950 did an exponential increase in inputs (energy, fertilisers, machinery, etc.) do away with ancient conditioning factors for agricultural production, thus accelerating the exodus from the country to the city and causing forests to lose their old functionality and intensive use (Naredo, 2001).

In short, one can see that ideas advanced more rapidly than did practice in each territory. This is reflected in the one hundred years that transpired between the spread of the reforestation discourse and the definitive transformations in forest cover halfway through the twentieth century.

Current management models
A reforestation plan was started in the 1940s involving the planting of over 3.3 million hectares from 1940 to 1986 (Gómez Mendoza & Mata Olmo, 1992). Prior to the start of this “Forestry crusade”, reforestation had already been initiated in high-risk territories (dunes, high-mountain ravines, etc.). Examples exist of this early reforestation in our study area (Lozoya, Canencia perimeter, Alpedrete de la Sierra, etc.), as it contains the headwaters of the rivers that provide Madrid with its water (Sáez Pombo, 2000).

But it was between 1940 and 1986 when many of the slopes and summits of the Somosierra and Ayllón ranges were repopulated, after remaining deforested for several centuries. For these reforestations, Pinus sylvestris was chosen due to its similarity to the patches of “historical pine forest”, although there was occasional testing with other conifers (Pinus nigra Arnold, Pinus Uncinata Mill., Pinus Pinaster Aiton), and
some of these exotic (Pinus ponderosa, Dougls., Chamaecyparis lawsoniana Par, Cedrus atlántica Endl.).

Forest planning has changed in the last few decades, due both to the new administrative organisation of the Spanish State and to the acceptance of certain criticism of the reforestation processes under Franco. But in practical terms, discourse and rhetoric apart, one can see that there has hardly been any change in technical interventions in forests (Madrazo García de Lomana, 2010). However, present-day silviculture does not fully adjust to the post-industrial discourse (Milbourne et al., 2008) that has emerged, more sensitive to the environmental and cultural values of forests. As we previously stated in relation to the nineteenth century, it seems that discourse precedes reality.

Characterisation of forest vegetation based upon their exploitation: charcoal, livestock farming and timber.

The different models of forest exploitation in this territory have shaped them in a way that, in many cases, can be seen to the present day. In some of the forests studied, we only found vestiges of the most recent uses, associated with the agro-silvo-pastoral uses from the start of the twentieth century. In others, however, the structure and floristic composition of the canopy enables us to reconstruct the different phases of exploitation.

In order to characterise the different facies that have lasted to the present in these forests, we typified these areas by means of the regeneration method (main use) they have, in many cases, presented over centuries.

**Exploitation of Quercus pyrenaica coppices for charcoal**

The most widespread type of forest in this sector of the Central System comprises coppices of Quercus pyrenaica, characterised by woodlands with clear signs of degradation caused by long periods of clear cutting in short turns (ten to twenty years). The physiognomy of these coppices and stumps results from intensive exploitation for charcoal (López Estébanez & Sáez Pombo, 2002; López Estébanez, 2003). This exploitation dates back, in some cases, to 1300 (Fuero de Sepúlveda) (Sáez, 1953), when the activity was regulated. After the sixteenth century, the area of these formations...
is very much associated with demand to supply Madrid, and its royal factories and palaces (Gómez Mendoza et al., 2010).

Based upon the fieldwork conducted in the coppices studied, we drew up detailed maps of the charcoal furnaces that were still recognisable (Figures 4 a and b), subsequently analysing some of these. The results obtained from this analysis show that the specific composition of the coppices has varied, and some species found at the base of the furnace layers (Braojos 2, Riaza 2) disappeared towards the top (Taxus baccata L. or Quercus petraea subsp. petraea) at the same time as the proportional relationship between the dominant species varied (Figures 5 a and b). The forests contemporary with the lower level of each charcoal furnace appear to present a multistratum canopy, albeit dominated by Ilex aquifolium in the case of Braojos 2 and with a noteworthy presence of Quercus pyrenaica at Riaza 2. Towards the top of these two furnace layers, we observed a big change in composition, due to the fact that the possible holly wood in Braojos gave way to masses of Quercus pyrenaica with other oak species (Quercus ilex Samp. and Q. petraea subsp. petraea); and the mixed forest of Quercus pyrenaica, Quercus petraea subsp. petraea and Ilex aquifolium at Riaza 2, tends to become an oak forest of Quercus pyrenaica, accompanied by the remaining species. At present, the biogeographic inventories conducted at the two stations sampled (Braojos 2 and Riaza 2) reveal formations of Quercus pyrenaica, which is dominant throughout the woody strata.

From the forestry point of view, those coppices are characterised by a dominant tree canopy that, in unfavourable edaphic and topographic conditions, becomes arborescent (1-5 m) (Figure 6). Furthermore, they are monospecific formations, dense and contemporary, except for specimens from ancient coppicings with standards, which remain as unique forest elements within these woods.

The lower woody strata of the coppices present a certain degree of diversification, fundamentally of bushes, although species such as Ilex aquifolium appear to re-colonise these old woods.

Figures 5 a and b. Analysis of the percentage of forest species found in the charcoal furnaces at Braojos 2 and Riaza 2

A) BRAJOJS 2
L.1 (0-5 cm)  
L.2 (5-10 cm)  
L.3 (10-15 cm)  
L.4 (15-20 cm)  
L.5 (20-25 cm)  

B) RIAZA 2
L.1 (0-5 cm)  
L.2 (5-10 cm)  
L.3 (10-15 cm)  
L.4 (15-20 cm)
These forests are now quite aged, exhibiting little vertical growth, high density, many dead trees and bushes, a high risk of fire, poor fructification, etc. (Serrada Hierro, 2008). But although these formations are very degraded, some authors highlight their high ecological value (protection against erosion, carbon sinks, landscape value) (Rotherham, 2007).

More recent interventions in these forests attempt to transform the coppices of *Quercus pyrenaica* into seedling forest, thinning out the coppices in order for the forest to become more vigorous, and even to enable silvo-pastoral use. This is the case in several management areas of the forests studied (Horcajo, Braojos, Dehesa Bonita, Dehesa del Alcalde) where a new forest *facies* of semi-open forest is being developed, which initially would take the form of old growth on stumps but which, after a few years, would become seedling forest for possible livestock farming.

Livestock farming in the Guadarrama Mountains: *Quercus pyrenaica* dehesas and holly wood with oak (*Quercus pyrenaica*, *Quercus petraea* subsp. *petraea*)

The *Quercus pyrenaica*: From forest to dehesa

Before exploitation for fuel transformed much of the *Quercus pyrenaica* forest in these mountains, livestock fanning was the principal use (eleventh to thirteenth centuries) (Sáez Pombo, 2000; López Estébanez, 2003).

Livestock herding gave rise to the configuration of a dehesa-type structure maintaining the canopy, comprising oak (*Q. pyrenaica* and *Q. petraea* subsp. *petraea*), mountain ash (*Sorbus aucuparia* L., *Sorbus aria* L.) and holly. From this canopy, wood was extracted, branches for livestock and sticks for firewood, under strict bylaws which, among other matters, established how to prune. These livestock farming and pruning systems are still in practice and are an essential part of forest physiognomy, involving the conservation of old specimens (Figure 7). The reduced livestock load has favoured colonisation in the lower woody strata, where one can observe a tendency towards increased specific richness, with the appearance of new species (*Juniperus thurifera* L., *Juniperus communis* L., *I. aquifolium*).

Other uses of the oak forests: wooden beams and pastures

In some sectors of the oak forests we identified scattered stands of *Quercus pyrenaica* which, at certain time in history, were used for the production of wooden beams for house building while their seedling forest structure also facilitated livestock farming under the canopies (Figure 8). The forest inventories present intense progressive dynamics in the lower wood strata, with specimens of *Taxus baccata* and *Ilex aquifolium* in the arborescent stratum (1 to 5m), whereas in the bush and under-shrub strata, we can highlight *Quercus pyrenaica*, with up to 60% dominance and *Crataegus monogyna* Jacq. Along with *Quercus*
pyrenaica, other unique forest species used for this activity were beech (Fagus sylvatica) or Spanish juniper (Juniperus thurifera). Of interest are these two records from the eighteenth century, "A. Sánchez requests 50 feet of beech for a house, to be cut down in the beech forest of the Sierra", or "in 1816 the residents of Arcones request the cutting of 800 trees, Spanish juniper and oak, from their forests, to rebuild their houses."

The holly woods: recent expansion of anthropic forests

Both on the northern slopes of the Mountains (Prádena de la Sierra) and on the southern ones (Robregordo), estates have been conserved whose dominant formation is the holly woods (I. aquifolium). These forests, whose ecological scope reaches the centre of the Iberian Peninsula (Oria de Rueda, 2003), appear to have been more abundant in these mountains in past times (López Estébanez, 2003; 2006). The uses that shaped these formations are fundamentally browsing for winter feeding for livestock and coppicing, which has generated a structure of very dense stands with covers reaching 100%. Within these woods, there are old specimens of Quercus pyrenaica, Quercus petraea subsp. petraea, Sorbus aria and Sorbus aucuparia, remnants of what were likely the original forests. These old deciduous forests gave way to Ilex aquifolium, partly due to anthropic action, intended to favour this species which covered the needs of winter livestock feeding (browsing), pastures and refuge within these curious coppices (Figure 9).

The extremely high density of this holly forest, which resprouted from cut stumps has generated a very simple structure: a tree or arborescent stratum dominated by Ilex aquifolium, with some of the above mentioned deciduous species and some holly seedlings in the under-shrub woody stratum, all of which demonstrates the extreme floristic poverty of such a dense facies².

Guadarrama’s historical pine forests for forestry use

As has previously been mentioned, historical formations of Pinus sylvestris have been conserved, although their use for timber production since the end of the nineteenth century accounts for their current physiognomy to a great extent. This is the case of the pine forest in Navafria (northern slope) or of Cabeza de Hierro (southern slope). The former has belonged to the community of Pedraza since the Middle Ages, and since 1895, a forest management project

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Figure 7. Pollard of Quercus pyrenaica in the Dehesa de Horcajo de la Sierra (Madrid)

Figure 8. Old specimens of Quercus pyrenaica used for wooden beams at the Dehesa Boyal in Horcajo de la Sierra (Madrid)
has regulated the arrangement and structure of tree ages (García López, 1994). The latter, which belonged to the community of Segovia, and since the seventeenth century, to the El Paular Monastery, was acquired in 1840, during the ecclesiastic desamortización, by the Compañía Belga de Pinares (Belgian Pine Forest Company). Its exploitation has undergone several stages since then, selective cutting currently being imposed, as a result of its lesser environmental impact, as this pine forest is located within an area of outstanding natural value (Rojo et al., 2001).

The present physiognomy of the forests results from their management system, based upon natural regeneration and extraction of the oldest individuals, individually selected, all of which favours a multistratum structure in which Pinus sylvestris is the dominant species, although in other sectors, Quercus pyrenaica and Ilex aquifolium become established, favoured by the shade of the pine forest (Figure 10).

Conclusions

In Somosierra and Ayllón, as in the rest of Spain, traditional uses remained in force until halfway through the twentieth century. In spite of the fact that changes occurred in the ownership and management of these forests, the type of use remained stable up to 1940. This simple fact leads us to two conclusions: firstly, the succession of types of uses of forests has been very slow in comparison with other European territories (Kirby & Watkins, 1998; Tsouvalis, 2000; Agnoletti & Anderson, 2002; Métailié et al., 2003; Arnould et al., 2003); secondly, all this, together with the slow growth rate of Mediterranean forests, led to the permanence of inherited forest physiognomies and structures which had disappeared from other parts of Europe (Rotherham, 2007). We believe that the natural and, above all, cultural values of these forests have not been fully appreciated. Indeed, the technical prescriptions of current managers consider these formations to be dysfunctional and are therefore promoting the transformation of these structures (coppices to...
seedling forests) to accommodate new uses (livestock farming, reforestation, recreation etc.).

As a result of our intense efforts with files, fieldwork and laboratory work, we have been able to confirm that, throughout the long period of traditional exploitation of these forests, their composition has varied, with impoverishment of the tree canopy and modification of the dominant tree formations. The relevance of uses in the different types of forest has given rise to our exhaustive study aimed at characterising these forgotten forestry uses. As we have already stated, charcoal production has constituted an important element shaping the forest landscapes of these mountains, and as proof of the significance of these uses, we have developed an accurate cartography of the charcoal furnaces distributed throughout this area (Figure 3); these present a higher density than in other European mountain territories (Gómez Mendoza et al., 2010).

Will these forest landscapes disappear? Will the absence of uses bring about their extinction? Should managers and technical experts create instruments for the conservation of these cultural forests? Indeed, these types of forest have been disappearing over the last forty years and along with it any traces of their traditional exploitation. In view of what is occurring in other parts of Europe where, due to their scarcity, these formations are being increasingly valued, perhaps we should start to pay greater attention to the value and uniqueness of these forests on the Iberian Peninsula.

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Notes
1. Research carried out with the support of Proyecto I+D+I “Transformaciones históricas de los paisajes forestales de montaña: Somosierra-Ayllón (Madrid –Segovia, España)” (2010-2012).

2. *Monte* is the most common Spanish term used to define forest areas. There are two problems: one is that it has multiple meanings, as it can also be used to refer to a mountain; the other is its lack of accuracy, as it can be used to refer to woodlands and shrublands, and even to pastures, barren lands and dunes. On the other hand, its major advantage is that its flexibility allows it to include all form of forests and woods in the widest sense.

3. In the historical literature, this area was known as **Castile’s Extremadura**, which constituted a no-man’s-land from the ninth to the eleventh centuries, with little population and which served as a border between the Christian Kingdoms to the north of the peninsula and the Muslim ones to the south. But this time lapse with scant occupation does not mean that for several millennia there had been a stable human population in the area. The pollen data indicate that the initial human impacts on the vegetation date back to 3,750 BP (Franco Múgica et.al., 1998).

4. An example is that halfway through the nineteenth century, the villages of Sepúlveda’s community grew crops on 430 ha occupied on common lands, on the barren mountain slopes (Madrazo García de Lomana, 2010).

5. The non-existence of mineral coal mines in the vicinity of Madrid meant that charcoal became fundamental for energy until the start of the twentieth century, much later than in other European cities. *Vid.* Malanima (2001).

6. This expression, habitually used during Franco’s regime along with others such as “Golden Age of Spanish Forestry”, reflect the enthusiasm of the Forestry Engineering Corps.

7. In recent years, work is being done in the dehesa of Robregordo (Madrid) intended to transform this forest from coppices to seedling forest through selective cutting, as is done with the coppices of oak.
8. Cabeza de Hierro pine forest has been governed by a management plan since 1957. In 1977 a new report was drawn, revised in 1987 and finally in 1999, the current project was designed, establishing six management areas, five of these of a productive nature and one for protection.

9. The denominations given to the transitions between forest models have varied throughout history, depending upon countries. Although in almost all cases we are dealing with a change from forests of pre-industrial societies to other industrial and even post-industrial ones (Milbourne et al., 2008).

Bibliography


