Eurasian J. For. Res. 7-2: 109-116 , 2004

Dynamics and Management of Forests with Multiple Constraints in Spain

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Abstract

Forestry practices have been conducted in Spain for centuries and, in some cases, this has led to impoverished ecosystems due to excessive grazing or cuttings. Water stress, fire regime and grazing have created a forest history different to that of other European countries, with new emerging challenges to silviculture. I reviewed the dynamics of Atlantic and Mediterranean woodlands in Spain, with special emphasis on the latter, and described the more characteristic and favorable forestry practices from such environments. The unfavorable climatic conditions for tree growth make forestry a non-attractive activity from an economical point of view. However, Spanish forest species show some characteristics which make them different from typical forest resources: cork production, resin tapping and pine edible seeds production are some examples of these.

Key words: Fire, forest dynamics, forestry practices, Spanish forests

Introduction

One of the most common commentaries I suffer as a Spanish forest ecologist when travelling abroad is "But if there are no forests in Spain!". Most of the times this comes from people living in the temperate deciduous forest region or in Scandinavia and, certainly, when comparing some of the Spanish ecosystems with those from the aforesaid regions, it may give the impression that there are very few forests in Spain. But this is not true, it is just a matter of definition. According to the FAO statistics (where a forest is defined as those areas with more than 20% tree cover), only 17% of the land, that is, 8.4 Mha, is covered by forests. However, according to the definition of forests by the Spanish Forest Law (where a forest is defined as those areas which are neither farmlands, infrastructures nor villages), the percentage of forest increases up to the 51% of the land, that is, 26 Mha. Hereinafter I will refer to the latter definition, since most of the statistics published about Spanish forests also refer to the latter. Nearly the half of Spanish forests (47%) are not covered by trees; around 12% are covered by very sparse trees and 41% are covered by trees (Ministry of Environment, ME, 1998).

Mean annual increments in Spain are around 2 m^3/ha*year, which means that forests grow 30 Mm^3/year. From these, only 15 Mm^3 are logged each year, which means that there is an increasing biomass stock (enhancing fire problems, as we shall see later on). The import rate of woody products is 15 Mm^3/year and the export rate is 5 Mm^3/year. Most of Spanish forests (67%) are private and 33% are public forests. The importance in the Gross Domestic Product ranges between 0.25%, when considering only the value of the work in the forest, and 2.4%, when considering not only the forest work but also all the industry transformations (Rojas 1995).

Spain is placed in between the Mediterranean and the Atlantic Ocean. This has given rise to two very different climatic conditions: the Atlantic climate on the northern part, and the Mediterranean climate on the central and southern part, creating therefore a wide variety of landscapes.

The Atlantic climate is characterized by rainfall higher than 900 mm / year, and more or less evenly distributed throughout the year, where high intensity storms episodes seldom occur (Albertosa-Sánchez 1991). This area belongs to the same climatic area as that of Central Europe.

The Mediterranean climate is characterized by rainfall much lower, ranging from 70 to 900 mm / year. This precipitation is mainly falling during the fall and spring. On summer time, rain falls only occasionally and as high intensity storms (Albertosa-Sánchez 1991) therefore, plants cannot make a good use of it. Moreover, this is enhancing erosion processes, since most of soils in the Mediterranean basin are quite shallow and poor. Winters are mild (mean seasonal temperature is about 8°C), but summers are hot (mean seasonal temperature is about 25°C, in Vilà and Sardans, 1999). These hot summers together with the low precipitation is creating drought conditions determinant for plant development.

Apart from the low percentage of forests covered by trees in the Spanish forests and the dry climate, there are some other constraints to their management, mainly related to the human influence (grazing, fragmentation, destruction of habitats...), to the natural conditions (very high biodiversity, impoverished soils, fire...) and to the combination of both, human influence and

(Received; Feb. 5, 2004: Accepted; Feb. 26, 2004)

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natural conditions.

The objectives of this paper are: to describe the distribution and ecology of Atlantic and Mediterranean forests, and some guidelines about their silviculture and management considering not only current and past constraints, but also climate change. Due to the uniqueness of Mediterranean environments, a bigger emphasis has been put on these ecosystems.

Tree-covered forest types

Hardwood forests occupy nearly the same surface as coniferous forests, 44% and 45% respectively, whereas mixed forests only account for the 11% of the surface (ME, 1998)

Figure 1 shows the percentage in volume of the most abundant tree species in Spain. *Pinus pinaster* is the most abundant one. This is a very plastic species which may be found on a wide variety of substrates. *Pinus sylvestris* is a mountain species that can be found up to 1600 m. *Fagus sylvatica* is the most common of the hardwood species. It is mainly growing in Northern Spain, on moist and acidic substrates. *Pinus nigra* is mainly growing on calcareous lands, that is, on western Spain. *Pinus halepensis* is the most litoral species and is able to grow from next to the Sea up to 900 m. *Quercus ilex* is the most representative from all the Mediterranean species because of its sclerophyllous leaves, its adaptation to drought conditions and because it is also one of the most litoral species. *Pinus radiata* is the most abundant from all the introduced species and it can be found in Northern Spain, in places with high rainfall and with mild temperatures. The decicuous oaks, *Q. robur* and *Q. petraea*, are the oaks which are better adapted to high mountain conditions. *Eucaliptus* spp, has been introduced in two very different locations: in N and NW Spain as well as in SW Spain. *Quercus pyrenaica* is the most common from the marcescent oaks and *Castanea sativa* is a species requiring moist, acidic grounds (Pemán García & Navarro Cerrillo 1998).

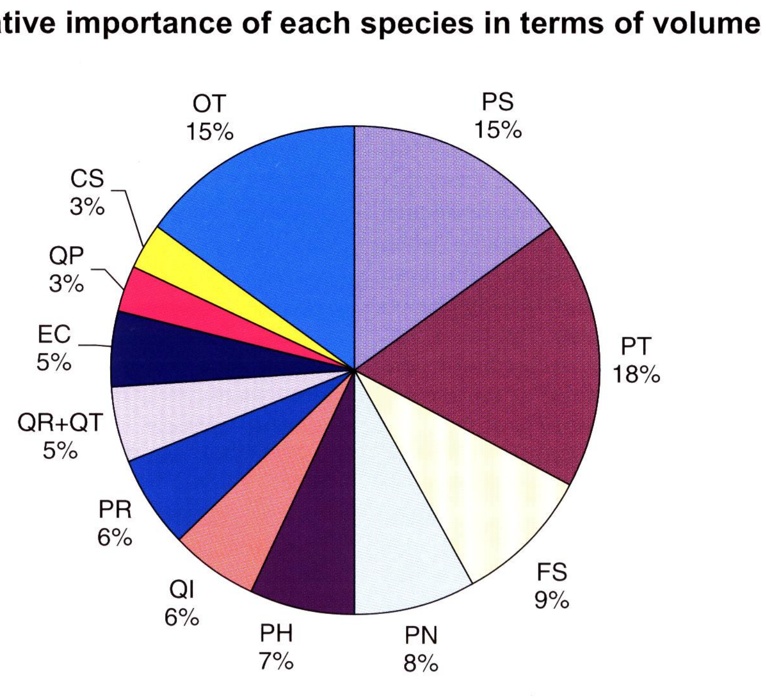

Fig. 1. Percentage in volume of the most abundant tree species in Spain: PS: *Pinus sylvestris*; PT: *Pinus pinaster*; FS: *Fagus sylvatica*; PN: *Pinus nigra*; PH: *Pinus halepensis*; QI: *Quercus ilex*; PR: *Pinus radiata*; QR+QT: *Quercus robur* and *Q. petraea*; EC: *Eucaliptus* sp; QP: *Quercus pyrenaica*; CS: *Castanea sativa*; OT: Others. Data from ME, 1998.

Main differences with the temperate deciduous broad-leaf forests

Grazing

Whereas strong winds or storms are the most important disturbances in the temperate deciduous forests, grazing and fire are the ones with the bigger effect on Spanish forest ecosystems. Grazing by domestic animals (photo 1) is a common feature all around Europe. However, in Spain it has been done with a much higher intensity compared with that of the rest of the continent (photos 2 and 3). It has greatly affected the Spanish landscape in both, "negative" and "positive" ways. In the middle ages, the *Mesta*, the shepherds association, could take their livestock anywhere in order to feed them, independently from the stage of the forest. They could, therefore, enter a forest which was being regenerated at the moment. Some authors think that this factor, together with other unsustainable agricultural practices has enhanced some regeneration and erosion problems we are currently facing, especially, on the Mediterranean part of Spain (Blondel & Aronson 1999; Mesón & Montoya 1993). However, some other authors have suggested that these degraded ecosystems are not because of human influence, but because of the geological, soil, climatic conditions and other physical factors that are given (Grove & Rackham 2000).

The Mesta shepherds have been doing some migration on summer time, and they are taking their livestock to new places to graze through some special paths named as *cañadas*. These cañadas are currently considered to be of great importance in the conservation of biodiversity since they are ecological corridors, and the administration is doing great efforts in order to preserve them. In fact, some authors state that the heavily grazed woodlands and shrublands are of the plant communities with the highest alpha-diversity in the temperate region. This is due to differences in the intensity of grazing and to the ability of annuals to survive with multiple stresses created by fire, grazing, drought and cutting (Davis *et al.* 1996).

Fire

The number of fires differs yearly, from 9595 up to 25287. They are mainly caused by farm fires, negligences from tourists (that is, by barbecues, lighted cigarettes,...) and only 10% is caused by lightnings. The percentage of land which is burnt each year depends upon the scale: whereas in the whole Spain the 1% of the area is burnt, in some regions, like Galicia (NW Spain), the 11% of the land is burnt. Most of these fires (62%) are smaller than 1ha, and only 0.1% are large fires, that is, bigger than 500ha (Ministry of Environment, 2002). However, despite their low percentage, large fires are the ones which are affecting more the structure of the forests, since their regeneration may be difficult due to the lack of mother trees.

One of the most important factors to understand the effect of fire is the fire regime which, for the purpose of this paper, is going to be defined as intensity (a function of the flame length), severity (the degree of affection of the fire on vegetation) and frequency (how often fires occur). On these large fires, the differences on intensity and severity are going to be very important since they are going to create some relatively unburnt areas, from where mother trees will be able to regenerate the stand.

Each of the different species we can find in Spain have been more or less adapted to a different fire regime. These adaptations may be mainly classified as persistence, where the population survives the fire, or as resilience, where the population is killed, but it can grow again after the fire (Moreno & Cruz 2000).

We can find the persistent strategy in some species such as *Quercus suber* (the cork tree) which has developed a thick and inflammable bark made of cork, able to resist fire (Moreno & Cruz 2000). Another example of this strategy is the one adopted by most of the hardwood species like *Quercus* and *Betula* which are able to resprout after the fire.

Some typical examples of the resilient strategy are the serotinous cones of *Pinus halepensis* and *Pinus pinaster*. These cones are closed by a resin which acts like a glue preventing the seeds to be released, and only after thermal scarification this resin loses its effect and the seeds can go out and germinate (Tapias & Gil 2000). Moreover, these seeds also find some optimum ground conditions to germinate, since after the fire, available nitrogen concentration increase (Ruiz del Castillo 2000). Serotinity is often accompanied by high viability of old seeds (more than 60% of the cones were viable in 20-30 years old cones) and early flowering (the first flowers have been observed when the trees are 4 years old for serotinous pine species and when they are 10 years old for non-serotinous species) to provide enough regeneration in case the recurrence of fire is very high (Tapias & Gil 2000).

Since the early 1960's, there has been a fire suppression policy consisting on extinguishing all the fires as soon as possible. This policy has not taken into consideration the essential ecological requirements from most of the forest species and therefore many ecosystems have lost its structure and become very dense stands with a vertical and horizontal fuel continuity. This fact, together with the increasing biomass stock I mentioned earlier is enhancing the appearance of new large fires, that is, of huge areas with regeneration problems, therefore enhancing erosion problems (Molina 2002).

Due to the importance of fires in modeling the forest structure and to the low investment that is done on forests, some authors say that fire is nowadays the main forester in such ecosystems (Castellnou, M pers comm.).

Some new generations of foresters, following the American example, are beginning to carry out prescribed fires in order to obtain certain benefits. Although the specific purpose for each prescribed fire is different, the main aims from such operations are to diminish fire hazard (through eliminating the vertical or horizontal biomass continuity), to accelerate succession or to maintain those structures which are adapted to a certain fire regime (Molina 2002).

Competition or water limitation?

Many authors have shown that competition is expected to play a small role, especially on the Mediterranean part of Spain, since water limitation is a factor much more important (but see review by Vilà & Sardans 1999) in structuring the ecosystems. This factor is being enhanced by the shallow and impoverished soils we can find.

Silviculture and forest managemant

Atlantic Area

Intensive silviculture is mainly applied on plantations with foreign species such as *Eucaliptus* spp and *Pinus radiata*.

Eucaliptus globulus stands are managed as coppice forests: at the end of the rotation period (which normally lasts 10-13 years) all the stems are clear-cut and one year and a half later, one ramet per stump is left. Average annual increments are around 10 m^3/ha*year and densities of 1,100-1,600 stems/ha (González-Río *et al.* 1997).

P. radiata has similar annual increments and rotation time, but after the final harvest (generally through clear-cutting) has to be planted again, since it is not a resprouter, and its natural regeneration is quite poor (Alemany 1994).

The shelterwood system is mainly applied on those species we can also find in Central Europe such as *P. sylvestris*, *P. nigra* and *F. sylvatica*, among others. There are some differences in the management for each species and for different locations. Some common characteristics are the rotation time, normally between 80-120 years, that thinnings are made once or twice during the growing season and, normally, there are two final loggings.

Selective logging is only applied on shade-tolerant species, such as *Abies alba* (photo 4). This species can tolerate selection system and group selection system, provided that the openings are big enough for the saplings in the saplings bank to grow, and small enough so as to prevent photoinhibition.

Selective logging is also applied in some mixed forests found in the Pyrenees composed by *Abies alba* and *Fagus sylvatica*. This is the perfect example on how human influence may affect the structure of the forest, since forestry normally logged more on the conifer, creating bigger gaps, and making it easier to regenerate to the beech, since this is a less shade-tolerant species than silver fir (Blanco *et al.* 2001).

Mediterranean Area

The Mediterranean area (photo 5) has some constraints that make it impossible to apply the same silvicultural systems as those used by classical Central European silviculture. These constraints can be divided as follow (Madrigal 1993):

- Heterogeneity: These ecosystems have a very high biodiversity, not only of plant species, but also from animal species and those from the other kingdoms. In fact, in South-Eastern Spain there is a hot spot for biodiversity.
- Unstability: The intense storms we face on summer time, when there are drought conditions, together with the shallow soils, unsustainable grazing and forest fires, create some unstable conditions for forest dynamics. Some authors also argue that the high biodiversity may enhance unstability, however, further research is needed on this point.
- Low rentability: The low annual increments, and the twisted way of growing of the stems make it difficult to obtain an economical benefit from the wood in the absence of strong subsidies.
- Externalities: From an economical point of view, these forests mainly produce externalities, such as C sequestration, erosion prevention, and others which unfortunately, are not remunerated yet.

Therefore, some adaptations have been made to these conditions in order to take profit from the forests.

Clear-cutting and intensive silviculture is applied on *Populus* spp. It is necessary to water the plantations (unless a very intense site preparation is conducted) and make some tall prunings to increase the wood's economic value. The rotation time is around 15-17 years, and the annual increments are around 24 m^3/ha*year. No thinnings are conducted before the final harvest. The site preparation is intense since the cut stumps must be removed before planting new propagules. These planted individuals normally are 1 or 2 years old (maybe the age of the stem and that of the root is not the same) and they have been genetically improved (Aunós, 2002a).

The traditional management for most of *Quercus* populations has been as coppice forest. The rural abandonment and the low price of the products is turning this silvicultural system less and less common every year. The rotation time is between 15-30 years depending on the species and location. There are two ways of management. On the first one, all the sprouts in an area are at the same age, therefore they are clear-cut at the end of the rotation period: the forest is divided into different stands and only one is cut at a time. The second one is applied when stems at different ages are mixed. Then, all the forest is logged at a time, but only those stems from the diameter wanted are cut, and the others are kept, so they can grow more (Serrada *et al*, unpublished).

Most of these forests have been abandoned and have become some very dense stands which are very inflammable, therefore, the conversion of such forests into high forest is a current issue in Spanish forestry. The most common method of conversion consists of tall thinnings, which are conducted once the stand is old enough so as not to have many resprouts. Once the selected individuals are big enough, seed regeneration can begin (Serrada *et al*, unpublished).

Pinus pinea can be found between 0-100 m a.s.l. with rainfall higher than 250mm (the optimum is between 400-800mm) on acidic grounds. This is one of the few pines whose seeds are edible. The silvicultural system (photo 6) applied to obtain seeds follows the following pattern: initial densities between 1100-2500 stems/ha. Three or four low thinnings of less than 1/3 of the basal area are required so as not to develop some individuals very tall and slim. At the age of 50-70 years, final densities of 80-120 stems/ha are required. The rotation period is around 120 years. Prunings are conducted to improve the quality of the log and facilitate the cones harvesting as well as to increase cones production (Montoya-Oliver 1990). Artificial regeneration is preferred in these stands so as to plant improved trees and not to lose the seeds harvest during some years. The main competitor for these plantations are the *Pinus koraiensis* plantations from China, since it takes one year less for the cone to be ripened compared to that of Pinus pinea (Aunós, 2002b).

Quercus suber is a species growing on acidic grounds, where the rainfall is higher than 400 mm (the optimum is between 700-1000mm) and up to 1300 m above sea level (the optimum is between 500-600 m). Its bark is very appreciated for wine taps, since it is composed of cork. The first time that the cork may be removed is when the ritidome is around 3 cm thick, that is, at the age of 25-35 years old. Prunings are required in order to obtain a long stem with no branches and no knots. A few years after the cork has been removed, the bark must be split in order to facilitate cork removal and obtain straight cork sheets. The management of these stands is very different on distinct regions.

In Catalonia (NE Spain), after the first bark removal, the following ones are conducted every 14-15 years up to 1.7m. Final densities are around 350 stems/ha, with basal area of $25m^2$/ha and only cork production is obtained (Aunós 2002 c).

In Extremadura and Andalusia (SE Spain), after the first bark removal, the following ones are conducted every 9-10 years up to 3m (photo 7). Final densities are about 60-120 stems/ha, with basal area around 6-$10m^2$/ha and some savanna-like forests called "Dehesas" (photo 8) are formed, where not only cork but also livestock production (mainly cattle and pig) is obtained. These stands face several problems such as lack of regeneration and soil impoverishment due to the high grazing and to the low basal area respectively (Aunós 2002c).

Resin tapping is practiced in *Pinus pinaster*. Early thinnings are conducted in order to obtain around 277 stems/ha with dbh bigger than 32 cm (the minimum legal diameter for resin tapping is 30 cm) at 35-50 years. There are different ways of performing resin tapping:

- *A muerte*: It opens at once cuts of 50-500 cm long and 11-12 cm wide, on 6 sides of the trunk.
- *Hughes*: It makes 40 tappings / year of 12-15 mm long or 30 tappings / year 16-18 mm long.

Rotation time is between 80-95 years, and log quality is severely diminished because of this practices (Mesón & Montoya 1993). Unfortunately, the low economical value from this operation is the cause for its current abandonment.

It is an accepted technique to plant trees in order to prevent from erosion. However, in some degraded forests, the soil is too shallow and trees could not grow, but still they need some vegetation cover. On these arid lands bush or grass restoration, by means of plantation or sowing is the only possibility to keep the soil.

Riparian forests

This is the ecosystem with the highest biodiversity in Spain because of its high productivity, among other reasons. This ecosystem is currently at a crossroads since this high productivity makes it a very appreciated land for farming. The surface occupied by these forests is much lower to what it used to be, and the ones that still exist have been severely impoverished, for instance, the dams construction has severely altered the water regime.

These forests are adapted to periodical floodings and to changes in the water level. We can find a species gradient, which is controlled by several factors such as the macroclimatic conditions (due to differences in altitude or others), a horizontal axis of differences in moisture, some river parameters, such as the velocity, the amount of oxygen or the nutrients concentrations, etc. This is resulting in some aquatic plants in the river, with all their parts below the water (examples are *Ranunculaceae* and *Ninfeaceae*); then come the helophitic vegetation, with the lower part of their culms and their roots below the water, but the upper part above water (such as *Scirpus* spp or *Phragmites australis*); then come some trees and shrubs able to resist floodings for a long time (mainly *Salix* shrubby species); then come forest vegetation which suffers flooding only occasionally (generally some short-lived and fast-growing species, such as those from the genus *Salix* and *Populus*); then come forest vegetation still affected by high ground moisture (here we can find some long-lived and slow-growing species such as *Ulmus* spp); finally come the vegetation which is not affected by the river (Blanco *et al.* 2001) (Photo 9).

Ulmus populations have been severely diminished because of the existence of the Dutch-elm disease caused by the fungus *Ceratocystis* (*Ophiostoma*) *ulmi*, and transported by beetles from the genus *Scolytus*. The last epidemic was 15 years ago and only some isolated inviduals or elm forests have survived so far (Gil 2001).

Nature conservation

According to the Spanish legislation, there are different degrees of protection, where National Park is the highest one and it implies that there must be no human influence, and it is designated according to its uniqueness of ecological, and socio-cultural values.

Spain is inside the "the coherent European ecological network of special zones for conservation called Natura 2000", which was established in order to preserve representations from all the natural habitats and flora and fauna taxons declared of interest for the European Community (EC). All the countries must nominate which places from their own territory will be inside the network, and the EC should finally decide which ones will be incorporated. Spain is expected to finish the nomination by the year 2003 (although the deadline was originally for 1998) and six years later the network should be finally established. So far, the 6 % of the land is protected (0.4% as a National Park, photo 10), and in the last suggestion for candidate areas, this percentage increased until 22%. 85% of these areas belong to the Mediterranean region (Mulero Mendigorri 2003).

Apart from the State and European conservation areas, there are also some lists of species to be protected and the measures to carry it out.

Global warming

Global change is a new challenge to an already complicated forest management. Climate change is expected to increase the surface covered by bushes and diminish tree-covered areas in Spain. This could be encouraged by the irruptions from plagues, pests, fires and other disturbances; moreover, landscape fragmentation will difficult species migration. Annual increments are expected to decrease and so the income from the forests. Reafforestations are necessary in order to ensure that the best adapted species and varieties will grow in a site, even though they may be different from the ones currently occupying the area and these reafforestations should be planned in order to maintain ecosystem functioning (Resco de Dios, Colinas and Fischer *in prep*).

Acknowledgements

I am grateful to Prof Dr Takayoshi Koike, for his encouragement to write this paper and to Francesco de Bello, Jordi Romà i Vega, Míriam Piqué Nicolau, Mercè Colomina and Iñigo Rebollo, for kindly allowing me to use some of their pictures for this paper. I thank the economical support received by Asia and Europe Foundation, Hokkaido University and University of Lleida, and the logistical support from Ms Liisa Tahvanainen, Prof Dr Rosairo Fanlo and everyone else at the Silva Network.

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Photo. 1. Grazing by domestic sheeps in Mediterranean Spain.
Courtesy by Francesco de Bello

Photo. 2. Northern aspect of an overgrazed hill.
Courtesy by Francesco de Bello

Photo. 3. Southern aspect of the same mountain as in photo 2. Drought and overgrazing effects are much higher on this aspect.
Courtesy by Francesco de Bello

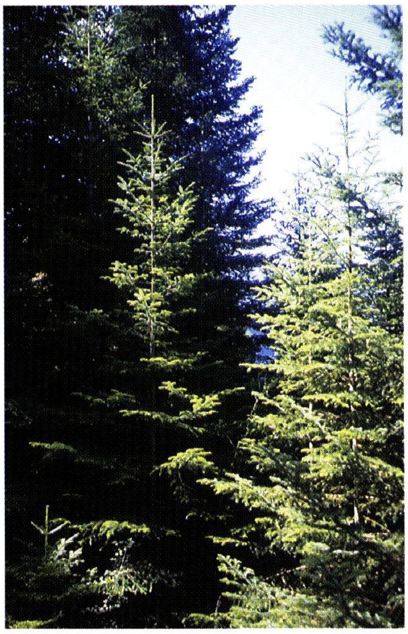

Photo. 4. Selective logging is performed on *Abies alba* stands.
Courtesy by Míriam Piqué i Nicolau

Photo. 5. Example of Mediterranean coastal forest.
Courtesy by Míriam Piqué i Nicolau

Photo. 6. *Pinus pinea* stands. Group selection logging is conducted and open stands are formed. Courtesy by Míriam Piqué i Nicolau

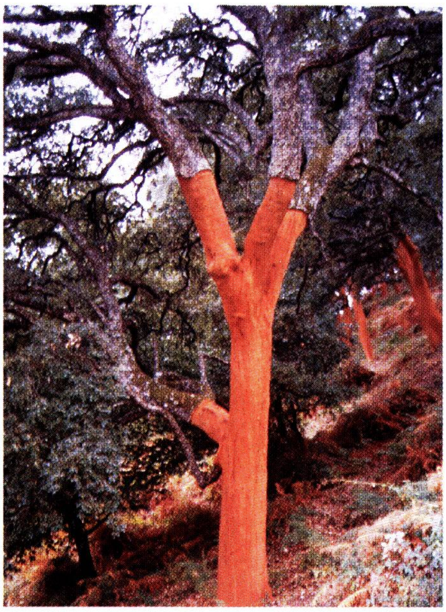

Photo. 7. *Quercus suber* after bark removal. Courtesy by Míriam Piqué i Nicolau

Photo. 8. Savanna-like forests in SE Spain. Courtesy by Mercè Colomina

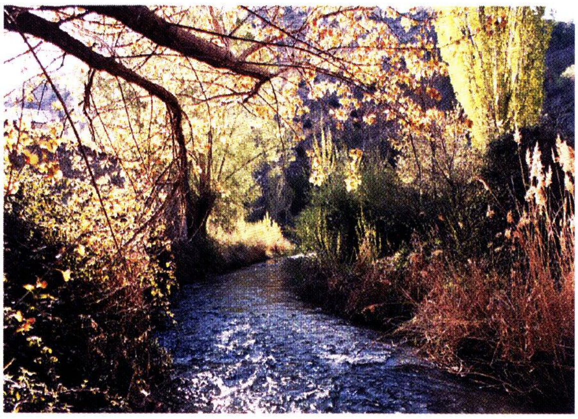

Photo. 9. Riparian forest where the species gradient may be observed. Courtesy by Iñigo Rebollo

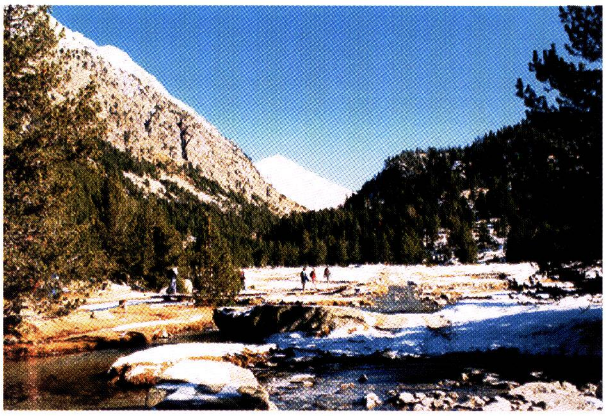

Photo. 10. National Park in Pyrenees. Courtesy by Iñigo Rebollo