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Forest evolution in the grazed mountains of the Pyrenees

PEDRO MONTSERRAT

Abstract

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The Pyrenees, the Ebro valley and the Montes Ibéricos are mainly Mediterranean and varied. They offered large opportunity for plant and animal evolution for millions of years prior to the advent of shepherding Man. The mountain turf with its dynamics is protected by woods under steppic conditions and climatic stress. *Juniperus*, *Pinus*, *Quercus*, *Buxus* and *Arctostaphylos* are the main woody genera in these open, grazed steppic forests bordering the Mediterranean region. Locally, in mountains the continentality or oceanity of the climate is increased by air circulation. Gregarious animals destroy the forest and may favour desertification, a climatic stress in the top soil that is counteracted by the shade of shrubs, and also by many cultural mechanisms linked to "pastoralism". Plant and animal conservation now mainly depends on the correct use of our ecosystems; especially the preservation of the Mediterranean flora and vegetation will be difficult unless domestic animals managed by educated humans are fully integrated in the ecosystem.

P. Montserrat, Instituto Pirenaico de Ecología (C.S.I.C.), Apartado 64, E-22700 Jaca (Huesca), Spain.

The main climates of the Iberian Peninsula

A simplified map of rainfall seasonality (Fig. 1, after FILLAT 1984) illustrates the main climatic tendencies: rainfall occurs predominantly in winter in the west but in the hotter months in the east (central and eastern Pyrenees). A transect from Serra da Estrella-Pirineos shows the marked continentality of the Meseta and Ebro valley. Autumn and winter rain is stopped by the high mountains (Estrela-Gredos and Pyrenees), whereas it is important in the Balearic Islands, in the Andalucía and in some parts of Valencia and Murcia. Equinoctial rains prevail in submediterranean conditions, and summer rainfall is typical of the more continental mountains (central Pyrenees and Iberian systems). The rain in hot months is not sufficient to protect grassland plants against heavy water stress on warm soil during the night (dark respiration).

Forests on the atlantic side of the Iberian Peninsula, at 1000-1500 m of altitude, mainly consist of *Quercus pyrenaica*, the typical Iberian oak with hairy leaves and deep roots enabling its profiting of water accumulated in the soil. This oak is well adapted to heavy grazing and, as I could see in Avila, Salamanca and León-

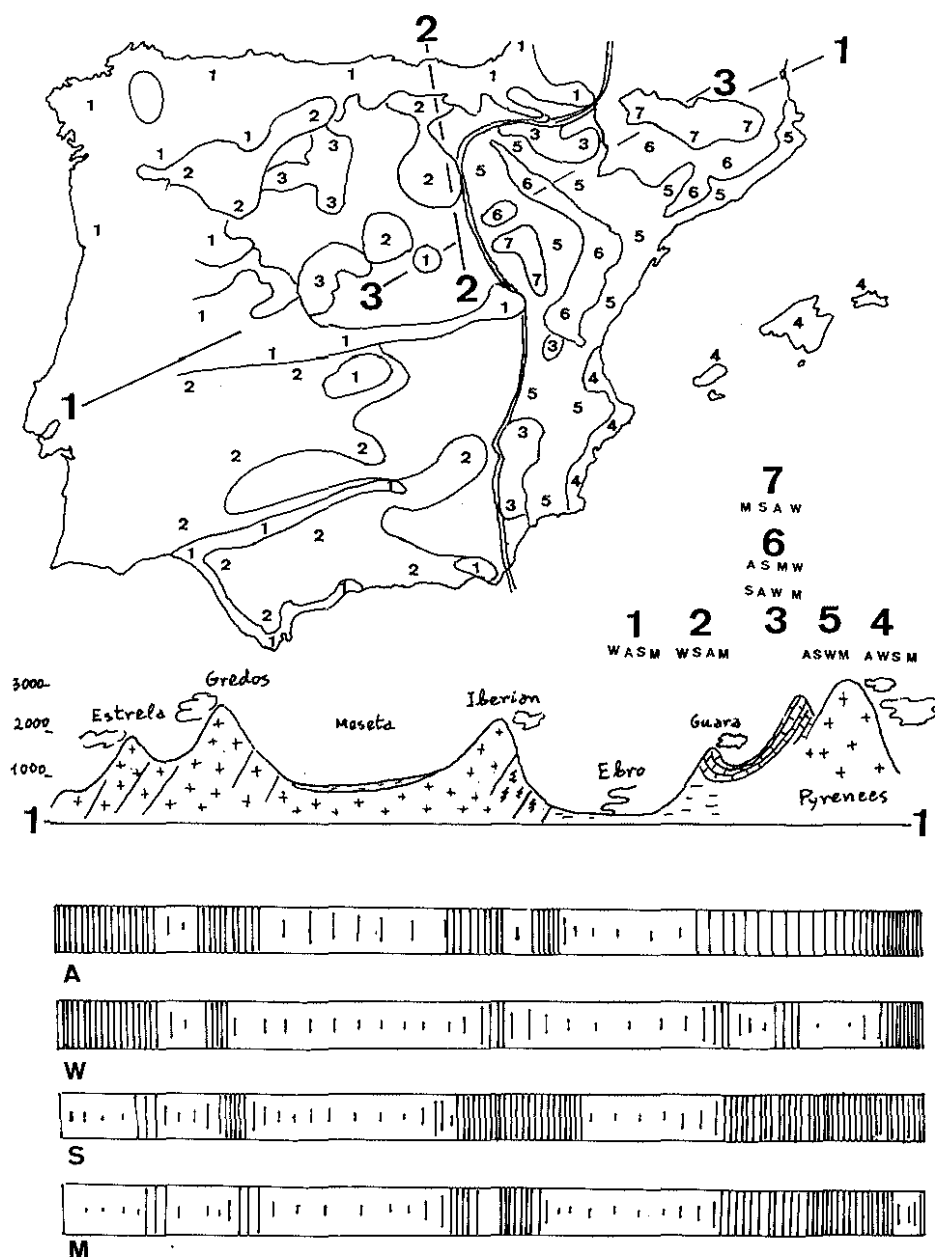


Fig. 1. Rainfall seasonality in Spain. Two regimes prevail: higher levels of rain in cold months (west) or in warm ones (east), with seven types: 1-3, mainly winter rain; 4 and 5, autumn rain; 6 and 7, mostly summer rain. The first transect, geophysical, with mountains stopping winter raining. Scheme showing seasonal distribution of the rainfall: A autumn, W winter, S spring and M summer. 2 and 3 are the vegetation transects of Fig. 2.1 and 3a, respectively.

Palencia, can form grazed forests with many stunted "trees" just 20-40 cm tall, and only a few normal ones. Grazing by domestic animals (oxen, cows, mules, horses, donkeys) was sufficient till 1950 to stabilize this type of grazed forest, but has now been abandoned. In the Iberian mountains the grazed forest ("bardal"), was important, it now subsists as relicts on deep, colluvial soil named "raña".

Transect 1 (Fig. 1) explains the main landscapes with their marked climatic dynamism and their many different niches for plants. Behind the Gredos mountains, on the Meseta (800-1000 m), yearly rainfall reaches only 300-600 mm with some salinity coming from endorheism and saline depth water. Close to the Cantabrian mountains and on the Iberian ones, at 1000-2000 m, the increasing continentality and animal farming maintain many open grazed forests, the "páramos", always in contact with "*Erinacetalia*" and "*Ononidetalia*" vegetation, a diversified oromediterranean type of grassland. In the lowest parts of deep valleys, a thermic inversion of temperature favours steppic grasslands and *Juniperus thurifera* forest, a relict from the boreal climate in the Holocene.

The Iberian mountains border the Ebro Valley with its many types of grasslands, forests and local climates. Some types of climates, of forest-grasslands and of human cultures linked to this mosaic of landscapes will now be presented.

The Ebro geosystem, a Mediterranean world

When climbing the Cantabrian mountains and Pyrenees from the "páramos" of Burgos-Palencia to the green meadows of the Pasiego country (Transect 2, Fig. 2) or from the dry orophytic steppes of the Sierras de la Demanda, de Urbion and Cebollera-Moncayo, to the pine (*Pinus sylvestris*, *P. pinaster*) and oak forests, "sardas" and saline steppes of Aragon (Transect 3, Fig. 3), one crosses the main landscapes that enable to understand the basic concepts linked to the ecological management of that area.

Transect 2 illustrates the end of the Iberian Meseta (Hesperic Massif) with its many falls and very dry grasslands bordering the Ebro valley. Many endemic species and some steppic ones (*Pulsatilla rubra*, *Scabiosa graminifolia*, *Genista teretifolia*, *Festuca hystrix*, *Poa ligulata*, *Plantago atrata*, *Arenaria erinacea*, *A. vitoriana*, etc.) have survived here from past geological times. The "páramo" is an open forest, heavily grazed and adapted to dry and cold climates; wind and grazing animals are important to maintain this system, now and also in the past.

Colluvial soil was covered with *Arbutus unedo*, *Pinus pinaster* and *Erica scoparia* forest, but near the rivers the local climate and human action created a nice mosaic of environmental conditions. *Berberis garciae*, *Spiraea hispanica*, *Juniperus phoenicea*, *Artemisia alba* and *Adonis vernalis* are typical of more steppic conditions, but nearby it is possible to find humid forests in a puzzling combination, bearing great promise for landscape ecology.

On the other side of the river, close to the Cantabrian mountains, the pasiego

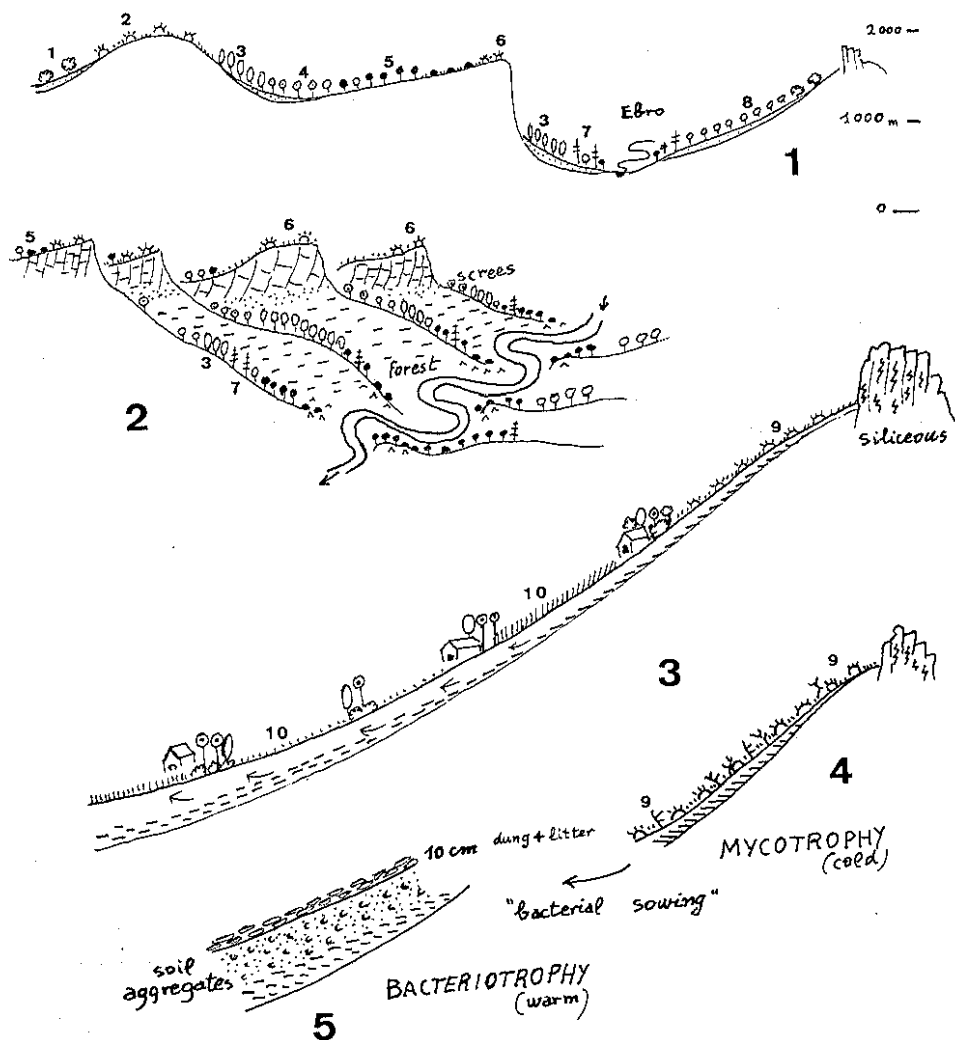


Fig. 2. 1. Transect from the "páramos" of the Iberian Mountains to the river Ebro and the pasiegos country. (1) *Quercus pyrenaica*; (2) dry oromediterranean grasslands; (3) beech forest; (4) mixed forest; (5) "páramo"; (6) oromediterranean plants; (7) *Arbutus unedo* and *Pinus pinaster*; and (8) oak forest. 2. Perspective of the Bureba region with its many different microhabitats. 3. Meadows in the Pasiegos Country with scattered houses and trees. 4 and 5. Heathland in the highest parts (mycotrophic), with *Agrostis curtisii*, explaining the pasiegos method to convert poor soils to good meadow soils.

man makes "milk from grass" in a very good grassland built on forest soils (mainly beech forests), heavily manured to prevent and counteract the washing-off of the soil by heavy rains. Continentality expresses itself mainly by cold nights, favourable to grass digestibility: cooler nights make "sweet grass", full of soluble sugars. Dark

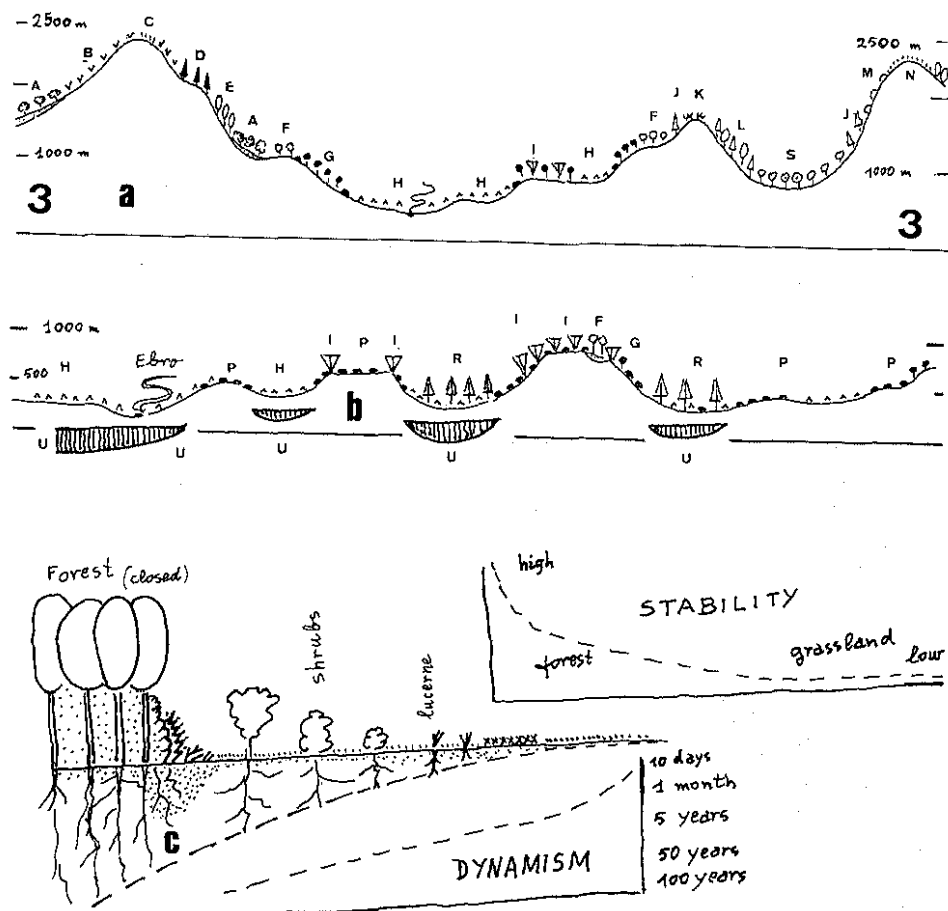


Fig. 3. a, Transect from Moncayo to the Pyrenees. b, the Monegros transect with areas of thermic inversion in winter (U), covered by *Juniperus thurifera* (R). (A) *Quercus pyrenaica*, (B) dry grassland complex, (D) *Pinus uncinata* (planted), (E) *Fagus sylvatica*, (F) *Quercus* forest, (G) *Quercus ilex* plus *Q. coccifera*, (H) steppic complexes with *Lygeum*, *Salsola*, *Artemisia*, etc, (I) *Pinus halepensis* (no thermic inversion), (J) *Pinus sylvestris* and box, (K) spiny scrub, mainly *Echinopartum*, (L) *Pinus sylvestris* and beech, (M) *Juniperus sabina*, (N) dry grasslands, (P) "*Rhamnococciferetum*", (S) mixed forest on wet soils. c, Ecotonic dynamism at the forest border (scrub, spiny scrub and herbs), showing depth of biological soil activity. Root penetration is connected with stability, being shallow in the more dynamic grasslands.

respiration, in contrast, makes "fibrous grass". Human culture, as the pasiego one, evolves together with ecological conditions; the former forest has been wiped out or reduced to a few scattered trees.

The pasiego method of manuring soils is very appropriate for transforming the heather soils with their "mycotrophy" into typical soils with "bacteriotrophy"; dung

and litter provide a bacterial sowing, surely the quickest technique to pass from a poor to a rich soil. There are many studies on the pasiego country (MONTERRAT & FILLAT 1978, ORTEGA VALCARCEL 1975 and TERAN 1947).

In Transect 3, the "páramo" in Soria shows a mosaic, on deep soils, of relictic dry pasture and open forest dominated by *Juniperus thurifera* or *Quercus rotundifolia* and heavily grazed. Carpets of *Arctostaphylos uva-ursi* often form a "mini-forest", influencing the microclimate just above the top soil.

The summit of Moncayo is steppic, with hard grasses (*Festuca indigesta*, *F. gr. ovina*, *Deschampsia flexuosa*) and dwarf shrubs. Beech once formed the upper forest limit at 1000-1700 m, but *Pinus uncinata* has now been planted there, at 1700-2200 m. On deep soils *Quercus pyrenaica*, *Q. petraea* and *Q. faginea* constitute grazed forests, together with *Q. rotundifolia* on poor soils.

The sedimentary terraces near the Ebro river are mostly cultivated, but in some parts they are brackish and steppic, mainly where the valley narrows and strong winds blow (Venturi effect). Hot summers favour the C₄ plants like *Atriplex* and *Salsola* ("Salsolo-Peganion" BRAUN-BLANQUET & BOLÒS 1957). This steppe of *Chenopodiaceae* used to be grazed in winter time, but now irrigation has changed the whole landscape.

The Bardena is a typical landscape where salt has accumulated in the top soil. Two types can be distinguished: one in Navarra and another in Aragon. Scrub of *Tamarix gallica*, *T. canariensis* and *T. africana*, and grasslands with *Cynodon dactylon*, *Trifolium fragiferum* and other grasses adapted to heavy grazing, form rangelands formerly used mainly by transhumant Pyrenean shepherds wintering with their herds in the lowlands.

The Monegros country also is very dry, and is full of small, saline temporary lakes (endorheic depressions). Till 1950, it was grazed during winter by transhumant shepherds from the Pyrenees. In some parts there is a very poor cereal production; now that irrigation will mobilise the subsurface salt deposits everything will change.

Climbing to the Somontanos and Sierras Exteriores (Prepirineos) the scrub or "sarda" mainly consists of *Quercus coccifera*, *Rhamnus lycioides* and many grasses (*Brachypodium retusum*, *Koeleria vallesiana*, *Avenochloa bromoides*, etc.). This type of scrub burnt every 20-30 years was grazed mainly by sheep or goats; now this is changing quickly, and fire is more dangerous than in the past.

Quercus rotundifolia and *Q. faginea* s.l., with *Aphyllanthes monspeliensis* and *Bupleurum rigidum*, are the major constituents of the transitional pastures ("transitos", "aborrales") between the winter quarters in Monegros and the alpine grasslands of the central and western Pyrenees. *Pinus sylvestris*, *Pinus nigra* subsp. *salzmannii* and *Buxus sempervirens* are also typical.

The "Depression Media", cut by many transversal Pyrenean valleys, introduces a big topographical diversification, with many local climates and grazed forests or grasslands. Its driest part, that has been burnt or cultivated by shifting agriculture since Middle Ages, at 1000-2000 m, houses many oro-mediterranean plants, such as *Genista cinerea*, *G. teretifolia*, *G. scorpius* and *Echinopartum horridum*; *Pinus sylvestris* is dominant, together with box and many shrubs like *Rosa* spp., *Crataegus*

monogyna, *Prunus spinosa*, *Berberis garciae* etc. Now cereal culture is declining, and good opportunities for profitable shepherding and diversification arise.

Ecotones in a landscape organization

The forest border is full of ecotonic dynamism, favouring soil activity and regeneration of forest; it can be compared to the cambium layer in plant anatomy. Forests will invade grasslands when pastoralism decays; animals, mainly grazing cattle, ruminants or equides, stop before entering the forest and favour the shrubby border with its hedges of *Rosa*, *Crataegus*, *Buxus*, *Eleagnus*, *Rubus*, etc.

Tall herbs and meadow plants make up an active herbaceous forest border (*Geranietae*, *Origanetalia*, etc) linked to the presence of animals, mainly ruminants, resting in the cooler shade. Bacterial activity and *Lumbricidae* improve this ecotonic structure, connecting forest stability with grassland dynamism; accumulation of chemical and biological fertility is also typical of this essential structure.

Heterogeneous contacts (trees-shrubs/herbs-grasses) between stable and dynamic systems are found at each level of the ecological organization; climate and soil, plant physiology and ecology, animal behaviour and human culture, exemplify such contacts.

This principle is also evident in many other contacts: of stomata and green palissade cells in leaves; also in the digestive tract, especially in earth-worms (*Lumbricidae*) in which bacteria are making soil aggregates; and, again at the forest border, in artificial edges created by avalanches, by animals, by selective felling, or by planting hedges in the modern agricultural landscape.

At the landscape level, we found that in the Ebro valley, too, heterogeneous elements and a very old cultural evolution benefited from the mountain-valley diversity. It will now be possible to improve the intermediate region ("aborrales", "tránsitos") by diversifying its submediterranean conditions, at 500-1500 m alt., so as to improve the possibility of shepherding in winter in the lowland and climbing to the high mountains in summer. Animals will always profit from and contribute to diversity. They all are essential elements in landscape dynamism.

Combination of the nomadic-tribal with a more sedentary agriculture is evident in the pasiego country; in this part of the Ebro valley, the past cultural evolution is full of admonishments for the future. This living model of man, animal and plant adaptation, being the result of evolution from the precultural roaming of gregarious animals to the modern condition on its way to a promising future, can but benefit from ecological knowledge.

Plant conservation

Plants and animals are one system; diversified ecosystems, with many ecotonic

contacts, are natural and combine forest stability with grassland dynamism. Grasslands in dry summer conditions become fibrous and lignified in the open, but remain green under a diversified shade.

Prickly forest borders stop grazing animals, so that valuable forest stands are spared from trampling and browsing. On the other hand, without trees the climatic contrast increases; topographic and continental climatic conditions, caused by grazing, may preserve some steppic plants, thereby contributing to controlled grazing that integrates animals and Man into the system.

In the future, ecological training of young people will mainly be based on shepherding for improving the diversity of the plant cover. Grazed open forests, and planted trees on abandoned fields (olive and almond trees, etc.) will also be essential elements of a new conservation policy.

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