

Forestry in Spain: Sustainable Management and Protection

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Abstract

The paper shows the diversity of roles that forests play in Mediterranean countries besides timber production with specific reference to Spain.

An introductory mention to the Spanish Forest Plan and the “forest country” is followed by brief descriptions of valuable instruments to improve forestry like Forest National Inventory, Forest Map, National Inventory of Soil Erosion, Forest Dictionary and, specially, Forest Research.

The creation of the Red Natura 2000 that cover near half of the territory, the more than one thousand Protected Natural Spaces housing a great number of Centres for Nature Interpretation and the National Parks reveal the importance given to biodiversity conservation.

The three main forest protection axes fires fight, forest health and forest hydrological restoration are dealt with. Specific references concern to preventive silviculture, equipments and personal equipments to fight against fires. Examples of pests, diseases and pollution and possible actions to confront the problem are included. Data on the technical activities through forestation and hydrological restoration in order to torrent correction and reduction of flood avalanches are complemented with engineering activities in riparian corridors and functioning of aquatic habitats.

The main items regarding types of forest management, silvicultural systems, forest certification and forestation are mentioned in the paragraph titled Silviculture and Forest Management. Some data on growing stock and timber logged are complemented with those over non woody products.

An specific section includes information on plantations with fast growing species and some data on forest energetic crops with regard to preliminary work in short rotation forestry for biomass production with eucalypts, poplar and “pawlonia” hybrids. Some observations and research carried out on forestry in the context of climate change mark the end.

Introduction

Forests in the Mediterranean countries play important roles in basin water regulation, erosion avoidance, agricultural crops protection and ecotourism in addition to produce renewable resources (timber, cork, fruits, pastures, wildlife). In Spain, Forestry includes the activities concerning all these subjects.

Woody tree biomass such as source of energy makes the forest industry to take on a new role of becoming a supplier of renewable energy. Also, the carbon sequestration in forest ecosystems and using woody materials as substitute of more contaminant manufacture materials in some industries contributes to mitigate the emission of CO₂ to the atmosphere and is an added beneficial of the forests.

These facts in mind, the Spanish Forest Strategy on Forestry (1999) launched the Spanish Forest Plan (DGCONA, 2004) that puts forward a model based on the functionality and sustainable management of forests and forest industry organized in three axes: Territory, Socio-Economy and Institutions. The first one comprises the following actions: Restoration of Vegetal Cover and Extension of Tree Land, Sustainable Forest Management, Forest Defence and Public Inheritance Protection, Biological Diversity Conservation and Sustainable Use of Forest Resources. The second one deals with Forest Products, Forest Culture, Social Values of Forest, Information and Scientific Research. The Instruments for Coordination and Foreign Forest Politics comprise the third axe. A new Forest Law (LEY DE MONTES, 2003) is the applicable legislative frame concerning forestry.

A general outlook of forests in Spain with regard to conservation, protection and management will be given in the following chapters. Activities on energetic plantations for biomass production are specifically considered.

The Forest Country

The Iberian Peninsula and the Canary and Balearic Isles integrate the Spanish territory (50.90 Mha). The broad field of altitudes (from sea level to 3718 m, Teide volcano), the orographical and topographic peculiarities, the variety of climatic conditions with yearly precipitations from less than 300 mm to

more than 3200 mm, the high range of evapotranspiration (up to 1800 mm in some localities at the southern half of the Peninsula and down to 200 mm at the northern part) and the high seasonal and daily thermic oscillations, all these facts give rise to a rich flora (about 8500 species), with abundant endemismes, mainly under Mediterranean climate (over 600). According to the Anuario de Estadística Agroalimentaria (2007) more than half of the territory is considered as forest (27.64 Mha). Property is distributed as follows (M ha): Private, 11.51; Local Entities, 4.20; State/Autonomic Communities, 1.07; Local Residents 0.31 .

Besides trees, forests include garrigues, shrublands, pastures and wetlands and only 18.09 Mha are tree covered: Broadleaves, 46.80 %; Conifers, 3.50 %; Mixed masses, the rest. Tree formations include as main species: sclerophylls (cork oak, holm oak), sub-sclerophylls (melojo oak, maples), deciduous (beech, oaks), forest similar to taiga (Scots pine, silver fir), hiperxerophylls (Alepo pine, junipers), interzonals (poplars, willows, alder), plantations (Monterrey pine, poplars, eucalypts). In the scale of forest trees, Holm-oak (*Quercus ilex*) surpasses 3.2 Mha in contrast with beech with less than 0.45 Mha. Garrigues and shrublands in general comprise a broad range of species from Fabaceae and Labiatae families (TRAGSA, 2002).

Instruments

The **Forest National Inventory** is a basic element for nature conservation and coordination of territorial forest policies. It gives homogenous statistical information about the state and evolution of the forests in the seventeen autonomic regions. From the first inventory (1973-84), a second one (1986-1995) and a third one (1997-2007) have been also developed. It allows setting up to date information on forests and incorporate new one on ecological, social and economic subjects (DGCONA, 1986-1995; 1997-2007).

As a part of the National Forest Inventory a new **Forest Map** (RUIZ DE LA TORRE, 2005) supplies great information. A more detailed issue (1:200.000 scale) contains 93 volumes with the memories and 92 Map Sheets. A reduced version, on 1: 1.100.000 scale, comprises one volume and one sheet, also in CD. Six structural zonal types of vegetation are described: high mountain (including type taiga woodlands), mesophyll deciduous forests, sub-sclerophylls,

sclerophylls, hiperxeric or hiperxerophylls, interzonal vegetation, plantations and garrigues. The vegetation of the Canary Islands deserves special classification in the Map. The physical ambient and the causes concerning the historical evolution in vegetal cover are exposed together with lists of species classified in relation with size (trees, different kinds of shrubs, herbs and grasses), woody or non woody condition, perennial or annuals, indigenous or exotics and some other specification.

The National Inventory of Soil Erosion (DGONA 2002-2007) is a part of the National Plan for Priority Actions in the field of Forest Hydrological Restoration, Erosion Control and Defence and complement of the Map on Erosive States (1:400.000), useful tool for a global evaluation of erosion at the large hydrographical catchment areas.

The Forest Dictionary, edited by the Spanish Society of Forest Science (SECF, 2005) is a glossary with more than 19000 terms related to 114 thematic sections from seven knowledge areas in Forestry and matters closely connected with it. Terms are translated into English and the inverse translation is also included.

Research in Forestry (in a broad sense) is carried out in different public organizations, particularly INIA (Instituto Nacional de Investigaciones Agrarias y Alimentarias), Centro Forestal de Lourizán, Escuela Técnica Superior de Ingenieros de Montes (UPM) and other academic Centres. It is also worthy to mention the Spanish Society of Forest Science (SECF), a non public organization founded in 1992 to push the research and technical applications in Forestry through presentations and discussions in periodical meetings and national congresses.

Biodiversity Conservation

Red NATURA 2000 is an instrument for conservation of the Biodiversity in the Union European frame. It consists on a network of natural spaces characterized by certain ecological peculiarities (special conservation zones, -ZEC- and special bird zones -ZEPA-) which are defined by the specific legislation. The network takes into account 27 forest types together with pastures shrublands, woodlands, salt-marshes, peat bogs. Forty six percent of the forest

territory with trees forms part of Natura 2000, so forestry management should play an important role in the country.

Relevant figures for Biodiversity Conservation are the **Protected Natural Spaces**, whose number reaches 1147. In the largest ones, **Centres for Nature Interpretation** have been created in order to monitor and control the evolution of flora and fauna and to describe and inform on natural values under a perspective social and educational of cultural diffusion. CENEAM, inside Valsain Scots pine forest, the Doñana Station at the Guadalquivir marshes, the one at the Mediterranean forest at Cabrera Island and that at beech forest Hayedo de Montejo deserve special mention as representations of different types of woodland scenarios.

Thirteen **National Parks** (12 property of the State) and higher number of Regional and Natural Parks, Natural and Integral Reserves, Natural Spots and some other figures with special biological and landscaping interest together with the Protected Natural Spaces sum up 536 Natural Spaces with an extension of more than 3.300.000 ha, that means 4.35 % of the country (TRAGSA, 2002).

Biological monitoring programs (BMP) help to give a deep knowledge of these ecosystems, that leads to continuous analysis of ecological indicators leading to biodiversity preservation, prior objective of the Sector Forest Planes.

Forest Protection

Forest Fires, damages due to soil erosion phenomenones in bare mountain heads and those derived of tree parasitism in woodlands are potential enemies of foresters. The fight against them marks traditionally the technical works of the forest engineering.

Forest fires

Fires have an adverse influence on the stability of forest ecosystems and contribute to accentuate the erosion. Large summer dryness and high temperatures and strong winds, together with socio-economic causes (land abandonment, farming residues and pastures burning, improper use of recreational forest areas, speculation) favour the profusion and intensity of

forest fires. Historical series (1995-2006) show a decrease tendency for the number of forest fires ranging between 25.827 in 1995 to 16.334 in 2006. Nevertheless these figures do not match with burned areas whose values are more erratic, being the non tree-forests the most affected. In the worst year (2006), 71.083 ha and 84.280 has for woodland and non tree-forests respectively were burned (MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO, 2007).

The preventive silviculture (breakfires, tree cover reduction, cleaning), the administrative measures regarding prohibitions and penalties and, in any case, the early detection and extinction are being put forward using modern deployments. The celebration in Spain of international meetings on forest fires with the sponsorship of UNISDR (United Nations International Strategy for Disaster Reduction) has helped to improve the fight against fires taking in mind scientific, technical and socioeconomic recommendations put on the table (VÉLEZ,2000).

Forest Fires occupy the first place in the range of forest prior money inversions in the Mediterranean countries as Spain. Different improvements have been incorporated in the means to fight against forest fires in the country: A national telematic network provided with a high number of vigilance towers are connected to fight centres in the province capitals for fire detection; LANDSAT images together with geographic information system (GIS) and screen photographic system equipments (SPS) connected to operative centre do permit the siting and rapid access of workers team to the sinister place taking information on the topography of the ground and meteorological data in real time; the incorporation of modern and abundant aerial (aeroplanes for water throwing and helicopters for people) and also terrestrial, pumping water systems and individual tools and fireproof clothes for workers are complementary available means of fight. These infrastructures permit to say that Spain is in the van of progress in fighting forest fires (PARDOS, 2009).

Forest health

Sustainable forest management compeles to keep healthy and vital woodlands. Pests, diseases, pollution of water and atmosphere, climatic stresses

(for instance, large dryness) are main causes of forest decline in Mediterranean forests. Preventive sanitary measures and their incorporation in the silvicultural practices, as well as the integrated fight, have been a crucial progress in the phytosanitary control of insect pests. As an example may be mentioned the efficacy in the control of *Thaumathopea pityocampa* populations by biological fight using *Bacillus thuringiensis*, application of pheromones, some growth inhibitors (obstruction to quitine biosynthesis) and piretroids (TRAGSA, 2002).

Genetics may be another approach to control some diseases as the Dutch Elm disease. Some progress has been made through the selection of 280 natural genotypes of *Ulmus minor* and the obtaining of some hybrids that show some tolerance to the fungus *Ceratocystis novo ulmi* (Gil et al, 2004).

The pandemic occurrence of the fungus *Sirococus strobilinus*, that causes dead of buds and twigs in *Pinus halepensis* forests at central areas of the Iberian Peninsula alerts on presumable effect of climatic change and should be in mind (MUÑOZ, 1995).

An increase in phloem damage caused by the borer *Phoracantha semipunctata* in *Eucalyptus globulus* at plantations in south-west related under summer dryness conditions has been also detected, that fact may be related to climatic change.

Singular case regards to the holm-oak forests (dehesas), historical system of agroforestry in Mediterranean countries whose mortality has been related with parasites (fungi, bacteria) and physiological disturbances (water stress) in connection with lack of silvicultural practices (pruning, ploughing). Some work has been also carried out on forest decay at pine, fir and juniper woodlands caused by pollution (SO₂, O₃) (PEÑA, 2001). The incorporation of Spain to the European Network regarding the program "Monitoring of damage in European Forests (ICP- Forests) has lead to obtain a broad and detailed knowledge on the evolution of pollution effects in the spanish forest systems (MONTROYA & LÓPEZ ARIAS, 1998).

Forest Hydrological Restoration, Ecohydrology and Ecohydraulics

Forests play an important role in the basin stabilization and forestation protects against torrential events (MINTEGUI, 2007). The National Plan of Prior

Actions on Forest Hydrological Restoration, Erosion Control and Fight against Desertification” aims to the reduction and regulation of rapid run off erosion in the mountains, soil conservation and agricultural crops protection avoiding desertification under Mediterranean climate and fixation of continental and coastal dunes (DEL PALACIO , 1999).

The construction of 2171 dikes along 73 streams complemented with the forestation of slopes with pines on the basin of Jiloca river (Aragón) and the correction of Aras torrent at the Pyrenees to reduce rush floods avalanches are examples of the works in this subject (PARDOS, 2009).

The engineering on woodlands and riparian corridors takes in account the knowledge given by disciplines like Ecohydrology and Ecohydraulics. River restoration and the structure and functioning of aquatic habitats, that match hydraulic conditions to aquatic fauna living and impact evaluation are matters object of forest technical actions (GONZÁLEZ DEL TÁNAGO & GARCÍA DE JALÓN, 2007).

Forest Genetics and Tree Improvement

In 2003 took effect the Spanish Royal Order for adaptation to European Directive concerning commercialization of reproductive material in forestry (ALÍA ET AL, 2005). Previously (CATALÁN et al 1991, among others), actions were undertaken to delimitate provenance regions (bioclimatic characterization) and selected populations and stands of the main tree species (*Pinus* sp., *Quercus* sp.) and establishment of provenance assays, clonal seed orchards and banks and progeny tests (*Pinus* sp) not only for commercial purposes but for germ plasm conservation (MARTIN et al, 1997).

Some progress has been made on: the characterization of genetic structure of some populations (*Pinus canariensis*, *Quercus* sp) by means of chloroplast microsatellites (GÓMEZ et al, 2005); the role of introgression for forest tree genetic resources conservation (*P. sylvestris* at Sierra Nevada) and the construction of genetic map of *P. pinaster* (GONZÁLEZ MARTINEZ et al, 2005).

The integration of Spain in EUROFORGEN and the constitution of a Spanish Forest Genetic Network are important steps forward in the subject.

Silviculture and Management

Stands corresponding to about half of the tree forest area (51.90 %) are managed as high forests, just a little less (45.90 %) are named as coppice with standard forests and the rest as coppice forest (ANUARIO DE ESTADÍSTICA AGROALIMENTARIA, 2007).

Standard silvicultural actions (thinning, felling, logging, regeneration) are followed and commonly put in practice in woodlands devoted to timber production. In this case, public forests are normally managed to maximize sustainable, economic and ecological yield. Additionally, some forests are subjected to specific regulation management regarding logging units, thinning, rotation and regeneration; they reach up 13.78 % of tree forest area. Certificated tree forests (Forest Stewardship Council and Paneuropean Forest Certification) sum near 500.000 ha (ANUARIO DE ESTADÍSTICA AGROALIMENTARIA, 2007).

Modelling is becoming of interest at research level to be applied in the use of forest resources (not only timber) taking into account the three yield requirements above mentioned (SECF, 2004).

Forestation plays an important part of forestry activities in the country: Near 700.000 has have been planted along 1994-2006. The forest nurseries sum a number of 174. (ANUARIO DE ESTADÍSTICA AGROALIMENTARIA, 2007).

The use of machinery in the forest operations has contributed to cost reduction in logging and timber extraction operations. The development in Spain of machinery for soil preparation before planting to be specifically used on high slopes (like-spider tracktor) means a significant progress for forestation in a hilly countryside (TRAGSA, 2002).

Growing Stock and Cutting

According to the 3rd National Inventory the total timber stock in the forest (data were taken along 10 years, then values given for different stands do not correspond to the same year, so the sum is not real) reaches 787.46 M m³ (bark included).

In the period 1990- 2006 conifer timber cutting summed 123100 m³ with a yearly range of 5525 m³ to 8527 m³ and 8270 m³ (bark included) for the last year. Yearly average value for broadleaves timber reached 5144 m³ (bark included). Adding to these figures the one for timber without classification (48692 m³), the total timber cutting for the 17 year period summed up 256788 m³. The highest timber cutting for 2006 were *Pinus pinaster* (4685840 m³) for conifers and *Eucalyptus* (mainly *E. globulus*), (4150819 m³) for broadleaves (ANUARIO DE ESTADÍSTICA AGROALIMENTARIA, 2007).

Complementary data from the same source give the following figures (m³ with bark) for the different kind of products:

Species	Saw timber	ply	panels	pulp	Poles & logs	biomass	Pelets chips, bricks	others
Conifers	378095	65124	1882773	343379	101918	1176	9469	---
Broad-leaves	465302	241738	1089968	1933467	92149	85032	---	385000
Total	4443397	306862	2972741	2276846	194067	86208	9469	385000

Non woody products

A combined exploitation of cork-oak tree stands and pasture for livestock, also holm-oak stands to feed pigs with the acorns are traditional silvopastoral uses at the Iberian Peninsula (Spain and Portugal) named as “dehesas”, from defessa that means defended (SERRADA & SAN MIGUEL, 2008).

Grazing at the colder northern mountains during summer and going back to the more temper pastures in the Autumn allow the existence of a transhumance livestock whose displacement gave place in the Middle Age to a network of cattle tracks.

The oleoresin obtained by tapping some pines (*P. pinaster* and *P.halepensis*) has given some important benefits in rural areas. Some work dealing with selection and propagation of high resin yield trees has been done to improve this exploitation. The harvesting of cones to get the edible seeds from *Pinus pinea* has also economic projection in large rural areas of central Iberian Peninsula.

Other noteworthy tangible benefits from forests in Spain are those concerning edible mushroom species (it may be speak a mycological silviculture, ORIA et al, 2008), the commercial harvesting of medicinal plants (mainly for infusions) and, mainly, honey from the near to 2.4 M of beehives established at Mediterranean forests in 2006 with a honey production of near 32 tons. A recent research has lead to overcome the pandemic disease caused by the arthropod mite “varroa” that had caused a very high number of dead bees. Finally is right to mention the extensive livestock living in the forest ,as a part of the total livestock (57,73 M animals) in the country. The rich fauna also deserves attention. Hunting and fishing are extensively practiced. In 2006, big game reached more than 260000 captures (soar and deer the highest), small game near half million and volatile hunting surpassed 10000000 captures (rabbit, 80%). Similar figure regards fishing captures, trout with the highest number (ANUARIO DE ESTADÍSTICA AGROALIMENTARIA, 2007

Fast growing species plantations

Timber, mainly logged in mountains and under Atlantic climate, is used for building structures, poles, furniture and pulp. Some tree selection research has lead to obtain “plus trees” and establish clonal seed orchards and clonal banks for forestation purposes.

Poplars, eucalypts and pines (*P. radiata*) are the three main species for extensive plantations. Their traditional uses for timber and pulp are nowadays complemented for those regarding biomass production and CO₂ sequestration. The hybrid *Platanus hispanica* (*P.orientalis* x *P. occidentalis*) has also planted as a forest tree at the northeast of the country.

The “insignis pine” (*P. radiata*) occupies near to 300.000 ha. It is mainly planted at the north of the Iberian Peninsula under Atlantic climate. Growth can vary among 15 and 25 m³ ha⁻¹ year⁻¹ according to site quality (SANCHEZ & RODRIGUEZ, 2008.)

Poplar plantations fill about 132. 000 ha with a year production of 700.000 m³ . Different clones, most of them belonging to *P.x euroamericana* (*P. deltoides* x *P. nigra* hybrids) have been planted during many decades mainly for timber to be used in mill work, chips for plays and peeling (high quality). Rotation varies

between 10 and 20 years as a function of timber destination. I-214, Campeador, Avanzo, Flevo, Canadá Blanco, are among the clones mostly planted, preferably at small densities (5 m x 5 m up to 7 m x 7 m), irrigated (either on sites with high water table), sometimes fertilized, felled at 18-20 years old for peeling (SIXTO et al, 20008) .

Some Eucalypt species, mainly *E. globulus*, *E. maidenii*, *E. viminalis*, *E. camaldulensis* among others, have been planted since the end of the nineteenth century for pulp, covering bare land and as ornamental. Productivity may reach exceptionally 60 m³ ha⁻¹ year⁻¹ in the best soils at the Atlantic zones of the country and it goes down to 3 -7 m³ ha⁻¹ year⁻¹ at the Mediterranean south and increases to 12-13 m³ ha⁻¹ year⁻¹ in some places with fertilization. It is not recommended to surpass 1100 trees ha⁻¹ for the northern plantations and among 700 to 1000 trees ha⁻¹ at the southern plantations depending of site quality. Normally the plantation is carried out with seedlings (either with stecklings from plus trees in clonal plantations) and after the first rotation (9-11 years) two coppice rotations are harvested (RUIZ et al, 2008).

Short Rotation Forestry

Some species belonging to genus *Eucalyptus*, *Populus* and *Pawlonia* are mainly used in short rotation for biomass production.

Eucalypts

Seedlings of *E. maidenii*, *E. camaldulensis* and *E. gunii* are planted by ENCE (Empresa Nacional de Celulosas) at Huelva (Southwestern peninsular Spain) with densities from 2500 to 3500 trees. ha⁻¹ and 2-3 years rotation. After the first rotation and harvest, at least the two following generations of coppices are cultivated and harvested. As an average, the production is estimated on 15 t ha⁻¹ year⁻¹ (dry mater), but great differences exist among sites (genotypes x site interaction) and silvicultural treatments such as soil preparation, watering and , fertilization (RUIZ, personal information).

Poplar hybrids

In the last decades there has been risen new interest for biomass production with short rotations, from 1 to 5 years. A high range of plantation density has been applied: from 5000 trees ha⁻¹ (2m x 1 m) to 300000 trees ha⁻¹ -1 m x 0.33 m- (SIXTO et al, 2007). On figure A are shown some data on biomass production for different clones and growing conditions in Spain. Additional data (personal communication by Sixto (on clone I-214), and GARCIA FERRIZ (on clone Viriato) are shown in table B. Preliminary results evidence that site conditions and silviculture (soil, watering, fertilization) are very determinant in the amount of biomass obtained (and survival) with a high clone x site interaction.

P. deltoides x P. nigra Trees ha ⁻¹	Rotation	Harvest	Mg ⁻¹ ha ⁻¹ year (dry mass)
Clone I-214			
5000	2	1	10.90
5000	3	1	10.10
5000	4	1	12.40
5000	5	1	17.30
10000	4	1	16.90
33333	2	1	15.10
Clone Campeador 10000	5	1	12.10
P.trichocarpa x P.deltoides			
Clone Boelare 10000	5	1	16.60
Clone Raspalije 10000	5	1	19.80

Figure A: Taken from Sixto et al (2007)

Mixture of clones Trees ha ⁻¹ 30000	3	1	6.00-30.00 (1)
Clone I-214 30000	3	1	7.00-18.00 (1)
P. deltoides x P.deltoides Clone Viriato			High perspectives from preliminary field trial (2)

Figure B: Information given by Sixto (1) and García Ferriz (2)

Pawlonia hybrids

Some clones of the hybrid *P. elongata x fortunei* have been imported from USA in the last years and large plantations under different site conditions (non irrigated and irrigated land during different periods) are in the way (COTEVISA, 2006). Expectation among cultivators is high, with presumable greater growth potential than another tree specie cultivated in the country with some irrigation.

Plantation density of 1600 trees per hectare, at 3 m x 2 m, that permits mechanical ploughing, harvesting and other silviculture practices, irrigated the two first years, predict 35- 45 t ha⁻¹, 30 % water content, at 2-3 years rotation; as well as in the other mentioned fast growing trees for biomass production the yield of *pawlonia* is highly dependent of site conditions and silviculture practices (García Ferriz, personal information).

Some data given by COTEVISA for energetic crops are the following:

- Implantation cost 3.200 € ha⁻¹
- Cost ha year⁻¹ 378 €
- Income ha year⁻¹ 1781€
- Average profit 1404 €

Forestry in the context of climate change

The increase of summer temperatures and changes in rainfall regimes are perceived to come in Mediterranean countries consequence of climatic change related to the increment of atmospheric CO₂ (GRACIA et al, 2006)

Phytoclimatic approaches, perturbation responses in flora and fauna, carbon sequestration against its future emission in forest ecosystems and forestry management are open questions to deal with and some research is being carried out to improve knowledge and take possible steps.

The reconstruction of regional phytoclimates in the last centuries using growth rings from old trees and polynomial of 15 years frequency of cold and rainy years (MANRIQUE & FERNÁNDEZ CANCIO, 1995), the correlation between radial growth and temperature and rainfall in the last fifty years (Bogino & Bravo, 2008), different works on diagnoses phytoclimatic and digital phytoclimatic maps, establishment of phytoclimatic boundaries of some tree species and foreseeable consequences of climate changes, all these works based on the initial work on phytoclimate by ALLUÉ (1990), are some of the topics dealt with in the field of phytoclimatology and climatic change.

The carbon content in the biomass of the main forest tree species and its capacity of carbon sequestration has been estimated using data from the National Inventory (MONTERO et al, 2005). Some altitudinal and latitudinal changes have been detected in populations of forest parasite insect like the caterpillar *Thaumathopea* and some borer insects like *Ips acuminatus*; pandemic effects in some diseases (*Sirococus strobilinus*) and the dangerous entrance in the country of the pine nematode *Bursaphelenchus xylophilus* through the vector insect *Monochamus*. Some observations indicate also changes in the behaviour of migratory birds (MONTROYA, 1998). Some others effects have been detected on sclerophyll vegetation such as shortening of leaves life, reduction (transparency) of stand canopy and reduction of the amount in fine roots (LÓPEZ et al, 2001).

The attention given to forests for CO₂ mitigation has lead to works concerning estimation of carbon content in some woodlands (Macías & Rodriguez Lado, 2003)(figure 1) and the simulation of carbon sequestration in eucalypt plantations (Cátedra ENCE, 2003),(figure 2).

Specie	Area (ha)	t C year ⁻¹	Efficiency t C ha ⁻¹ year ⁻¹	Productivity m ³ ha ⁻¹
<i>Eucalyptus globulus</i>	229.970	1.181.421	5,14	12,80
<i>Pinus pinaster</i>	284.332	450.041	1,58	
<i>Pinus radiata</i>	77.412	86.066	1,11	
<i>Castanea sativa</i>	94.384	94.384	0,52	

Figure 6.1: Capacity of carbon sequestration in the forest biomass of tree species for timber with reference to year 2000 (Macías and Rodríguez Lado, 2003).

Area (ha)	Rotation	Coppice generation	Biomass (t C ha ⁻¹)	Efficiency (t C ha ⁻¹ year ⁻¹)	l Efficiency (t C ha ⁻¹ año ⁻¹)
12	12	3	215,74	5,99	6,30
12	12	4	255,46	5,32	
18	18	3	279,10	5,16	5,20

Figure 6.2.: Simulation of carbon sequestration in *Eucalyptus globulus* plantations under different rotation and coppice generation following CO2FIX model to field data (Adapted of Cátedra ENCE, 2003)

Ecological models (Zavala, 2004) and process based models (Gracia et al, 1999.) have been developed to get more information on the predictable changes in the forests in Spain and try to put forward silvicultural measures to mitigate their effects. The perspective of carbon sinks changing to carbon sources in next decades at the Mediterranean forests due to decrease of rainfall and increase of temperatures has been suggested using the GOTILWA+ model (Gracia et al,1999). Much research is necessary to cope with the uncertainties implied in models.

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