State of the Art on Forest Adaptation in the European Atlantic Area

National and Regional Approaches

Background material for REINFFORCE project

Collected on 2009-2010

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1 INTRODUCTION

In the frame of the INTERREG IVB Atlantic Space the REINFFORCE project presents a report on the current climate and forests distribution in the countries and regions involved in the project.

1.a European forest and other wooded lands context

From the State of Europe's Forests country statistics 2011, forests cover more than 1.02 billion ha in Europe, i.e. 45 percent of Europe’s land area. Forest area is unequally distributed over the European territory and the percentage of forest shows significant differences among European countries (Illustration 1).

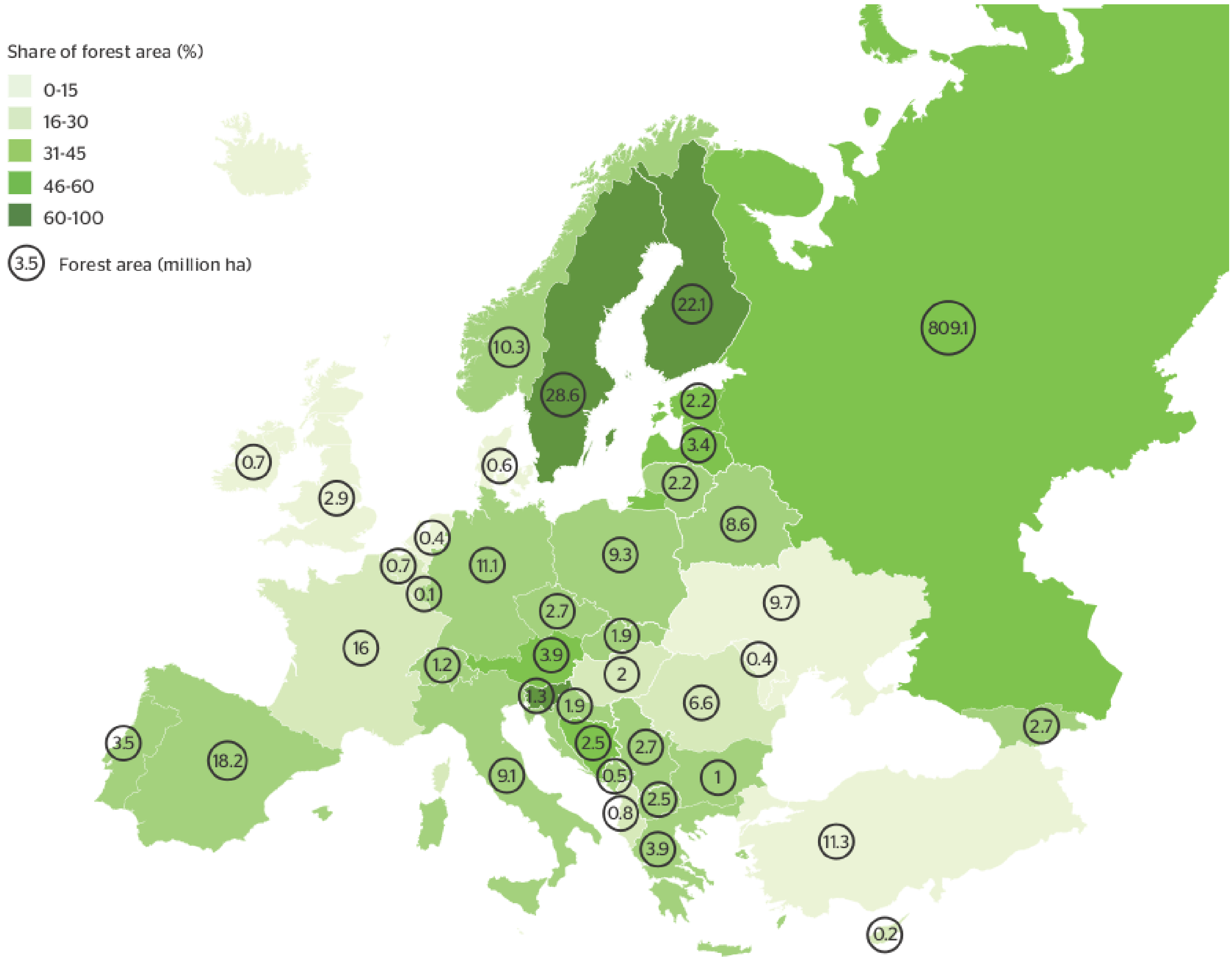


Illustration 1: Forest area (million ha) and share (percent) of land area by country, 2010

Forest area amounts to almost three quarters of the Finnish land area, whereas only 11 percent of the land area of Ireland and the Netherlands is covered by forests. Other Wooded Lands (OWL) represent only a tiny part of the land area, except for South Europe. Indeed, in South Europe the climatic and edaphic conditions favour scattered vegetation. The forests in Europe are mainly made up of predominantly coniferous stands (50 percent) and predominantly broadleaved stands (27 percent). The remaining part is mixed stands, including coniferous and broadleaves (Illustration 2). Due to the climate, conifers are mostly found in North Europe (e.g. Finland and Sweden hold 7.5 percent of Europe's predominantly coniferous forests).

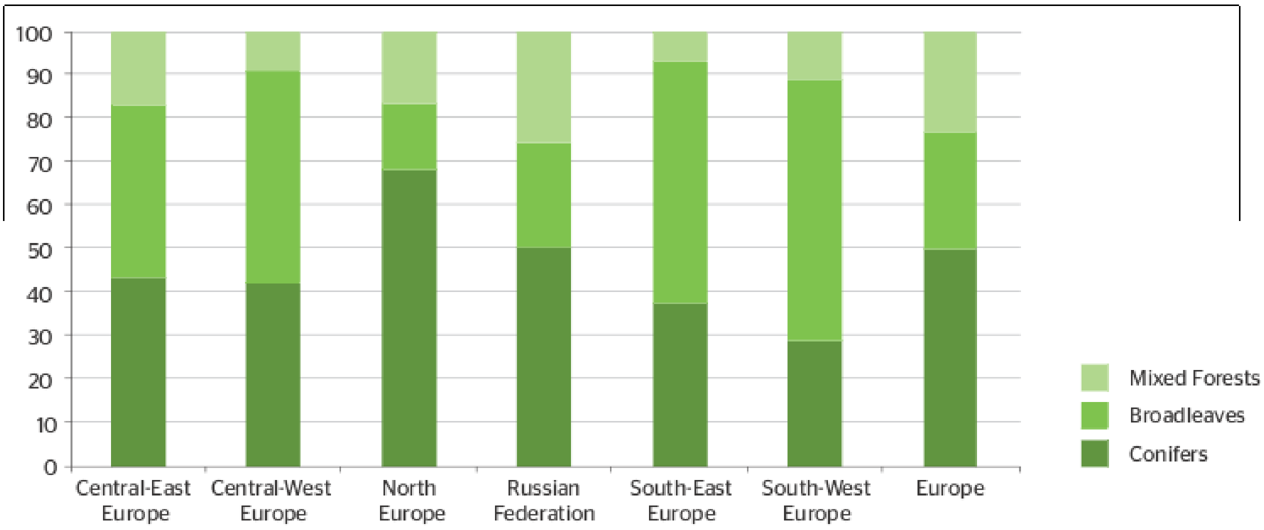


Illustration 2: Proportion of forest area by forest composition, by region, 2010 (percent)

1.b Forest and other wooded lands context of the countries involved in the REINFFORCE project

The area of interest of the REINFFORCE project is represented by the Atlantic rim which covers Portugal, Spain, France and the United Kingdom. This report shows the forest and climatic situations of the regions of the four countries involved in the project.

2 Forest resources statement in the project countries

2.a Portugal

Portuguese forest covers 3,470,000 ha. Forestland ownership is mainly private (84%), local communities hold 12%, State only owns 4 %. In North and Center Portugal forest property is highly divided , the average forestland area for each owner is lower than 5 ha, accounting for more than 400,000 forest owners (DGRF, 2007).

Annual Forest Economic Production is evaluated in 1,2 thousand millions of Euros (stands for 3% of Net Production value). Portugal extracts more income from 1 ha of forest land (344 €/ha/year) than other Mediterranean country (figure 1). In terms of employment, there are about 113,000 direct jobs (2% of active population) created trough the forestry sector.

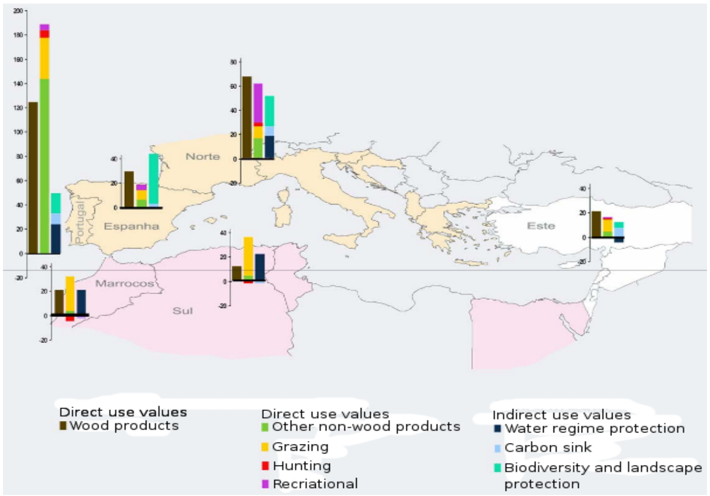


Illustration 3: Forest sector total economical value components in Portugual, Spain and Morrocco, and the averages from north, south and east mediterranean region (in Euro/ha/year) Source: Merlo e Croitoru,

Forest fires are frequent representing a handicap for this sector. Burned forest area represents over 200,000 ha, with *P. pinaster* forest stands more affected than others (116 400 ha) during years 2005 and 2006.

Natural forest is scarce in the Continental territory, however in Madeira Island represents 28% of total forestland. In Portugal, *P. pinaster* and *Q. suber* are the most important autochthonous species in mainland, *Eucalyptus globulus*, an exotic species, plays an important role in pulp and paper industry (Illustration 2).

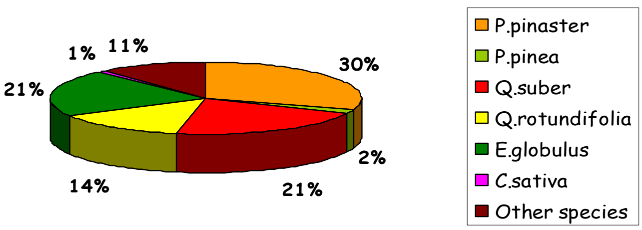


Illustration 4: Portuguese forest species composition. Source DGRF 2007

2.b Galicia (1979)

As in other parts of Europe, forest cover in Galicia has increased. Galicia has a surface area of 2,957,500 ha of which 2,039,575 ha (69%) is forest and other woodlands, with 1,381,722 ha covered by forest (Tables 1 and 2). The rest is mainly covered by scrub, shrub and brushland (Table 3).

Source	**I I.F.N.**	**II I.F.N.**	**III I.F.N.**
Surface (ha)	1,122,348	1,045,357	1,405,451

Table 1: Evolution of forest surface area measured at different National Forest Inventories (I.F.N.)

Type of woodland	**Woodland (%)**	**Surface (ha)**	**Private communities (n°)**
State woodlands	2,2	45,156	
Private community woodlands	29,9	608,729	2,753
Private woodlands	67,9	1,385,690	
TOTAL	100,0	2,039,575	2,753

Table 2: Type of forestland ownership

Nowadays, Galicia is considered to be home of 51 native species, some of which are no more than small trees, but due to temperate climate and high rainfall in the coastal area, a large number of species from other territories grow under 400/500 metres above sea level. Many of these species in natural habitats and other are planted in forest areas for both commercial and ornamental purposes.

Forest type	Surface area (ha)
Forests (FCC < 20)	1,276,651.64
Disperse (10< FCC < 20)	82,140.92
Bare hillsides (5 <FCC < 10)	23,864.42
Temporarily cleared land (cutting, wildfires)	21,075.87
Shrublands and brushlands	596,590.73
Stony and clear lands	13,795.04
Wetlands	25,455.70

Table 3: Different forest cover in Galicia .(FCC = Tree cover fraction)

Indigenous species of commercial interest include:

Pinus pinaster, Pinus sylvestris, Taxus baccata, Quercus robur, Quercus pyrenaica, Quercus suber, Castanea sativa, Betula pubescens ssp. *celtiberica, Fraxinus excelsior, Alnus glutinosa, Prunus avium, Populus nigra.*

The most common non-native species in plantations include:

Pinus radiata, Eucalyptus globulus, E. obliqua, Robinia pseudacacia, Pseudotsuga *menziesii, Juglans regia.*

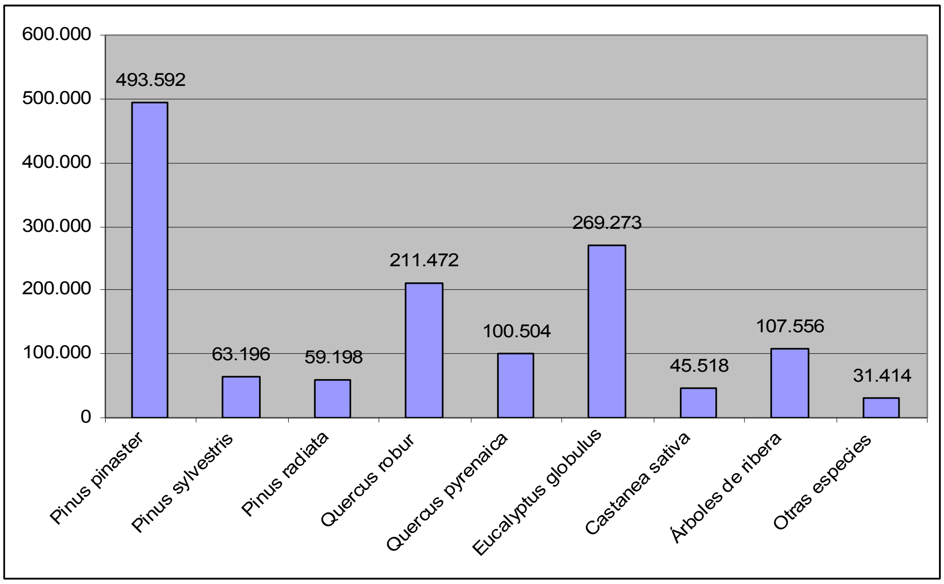


Illustration 5: Surface in ha by main tree species in Galicia forests (Source: Third National Forest

Although some non-native tree species (walnut, fruit trees, willows, etc) and a few plantations of native species were developed earlier, reforestation really started in the early 20th Century, carried out mainly by provincial organisations and the central Spanish government, while private enterprise became more involved as from the 1940s. The most prominent species is maritime pine (*Pinus pinaster*) and then, since the 1930s, eucalyptus (*Eucalyptus globulus*) and Monterrey pine (*Pinus radiata*), as well as increased use of chestnut hybrids (Castanea x couderci) in farming systems, and the introduction of other allochthonous species as Cedrus, Pseudotsuga, Populus, Eucalyptus, etc.

The main tree species in either pure or mixed stands are: maritime pine (*Pinus pinaster*), with 45% forest cover, oaks (*Quercus robur, Q. pyrrenaica, Q. rorundifolia, Q. petraea* and hybrids) (23%), eucalyptus (19%), chestnut (3%), riparian trees (8%) and other tree species (2%) (Figure 3).

The following tables (tables 4 and 5) show the growth characteristics for the most prominent species in forest flora as well as their significance in terms biomass production according to the forest inventory. Galicia produces the 40% of Spanish timber.

Species	Surface (ha)	Stand biomass (m³ wb)	GMY (m³ year⁻¹)	GMY (m³ ha⁻¹ year⁻¹)	Theoretic possible AMG (m³ year⁻¹)
Pinus	493.592	49.151.041	3.219.670	6,5	3.014.151
pinaster	63.196	3.756.840	387.416	6,1	256.322
P. sylvestris	59.198	7.571.425	966.236	16,3	699.444
P. radiate	211.472	16.922.380	655.517	3,1	609.798
Quercur	100.504	6.024.225	211.466	2,1	206.137
robur	269.273	34.800.921	4.919.793	18,3	4.790.958
Q. pyrenaica	45.518	5.639.445	144.962	3,2	166.472
E. globulus	107.556	1.235.221	50.554	0,5	45.864
Castanea sativa	31.414	-	-	-	-
Riparian trees					
Other species					
	1.381.722	**125.101.496**	**10.555.614**		**9.778.146**

Table 4: Surface area, stand biomass, growth and theoretic output of Galicia forests (AMG = Annual Mean Growth) (Source: Third National Forest Inventory)

Species	Harvesting (m^3 w.b.)				Total
Softwoods	3.982.800	2.650.00	1.240.000		**3.890.000**
Eucalyptus	3.678.000	0	930.000	1.336.000	**2.496.000**
Other	409.000	230.000	80.000		**400.000**
hardwoods		320.000			
TOTAL	**7.979.800**	**3.200.00 0**	**2.250.000**	**1.336.000**	**6.786.000**
		195	112	68	**375**

Table 5: (Source: Cluster da Madeira de Galicia)

One of the most severe problems faced by the Galicia forestry sector are forest fires, which are characterised by the high number of outbreaks, mainly during the summer months, although in the province of Ourense, a significant number take place towards the end of the winter (March). The following figures 4 and 5 show the mean monthly figure and burnt surface areas in the four provinces of Galicia, for affected areas of over one hectare.

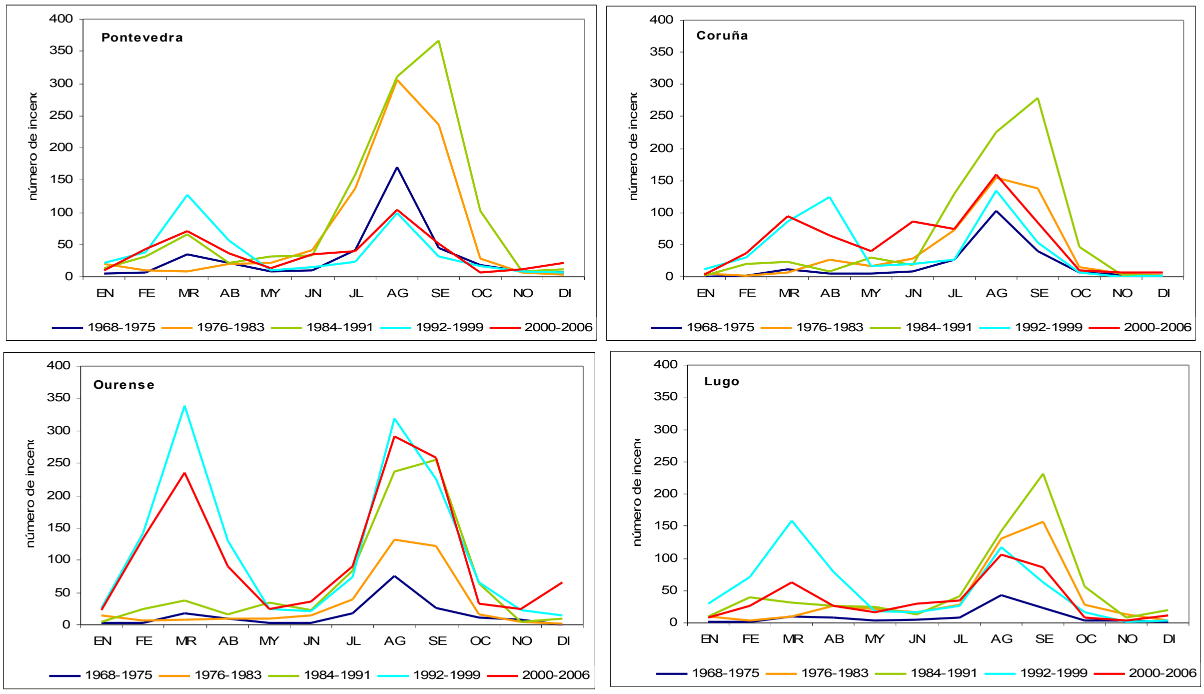


Illustration 6: Monthly evolution of mean number of forest-fires in the four provinces of Galicia, between 1968-2006 (Vega et al., 2009)

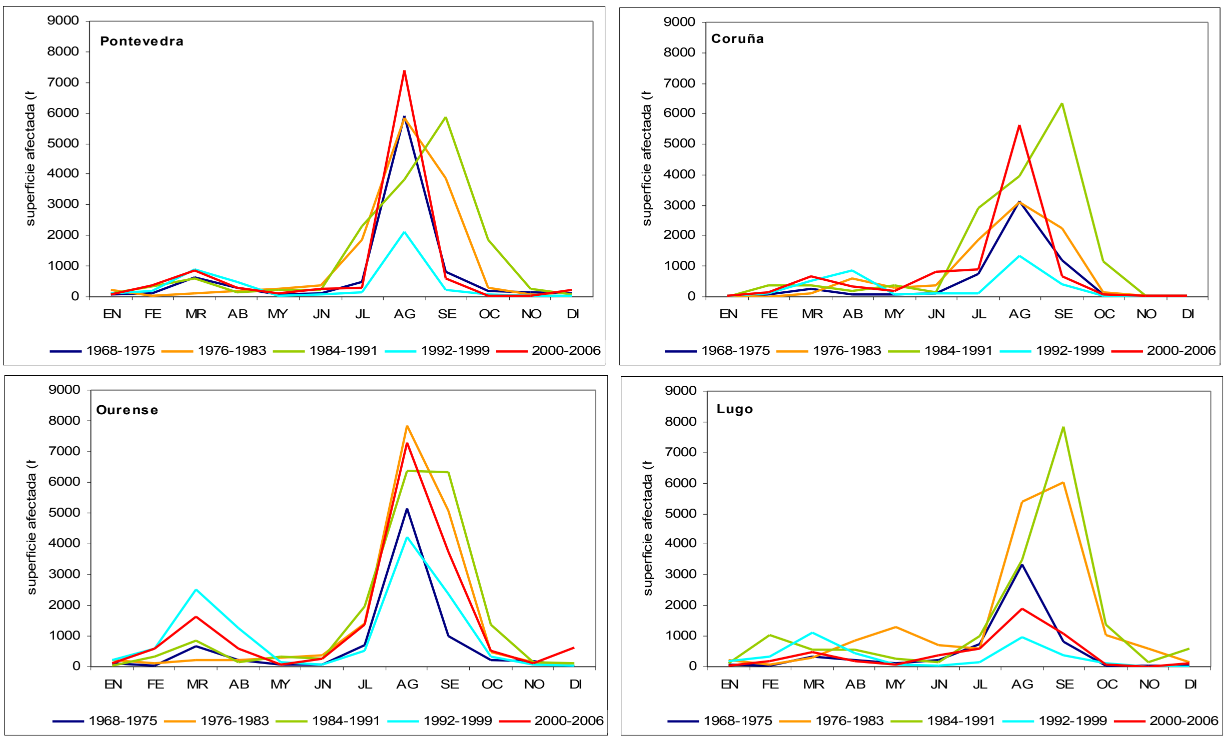


Illustration 7: Monthly evolution of mean number of forest-fires in the four provinces of Galicia, between 1968-2006

Having studied the period 1968-2006, Vega et *al*. (2009) reported a significant negative trend in the conditions in which fires start and propagate in Galicia over the period under study. They noticed that the risk of fires in March and throughout the summer period (June, July, August and September) had worsened during the last decades. This relative worsening is greater in March than in the summer and is also seen to be more significant over periods free of rain than when rainy days are included. At the same time, the enhanced risk of forest fire has been seen to advance in two different directions over time: firstly, from North to South, with a descent in latitude, and secondly towards inland Galicia, as Ourense is estimated to be the province where the future situation could be the most problematical. As an indicator of the fire risk, the amount of moisture in the dead fine fuels in the undergrowth is the clearest evidence of the trends behind climate change (Vega et *al*. 2009b).

2.c Castilla y León

According to the analyses of the Forest Map of Spain (2005), the total FOWL (Forest and Other Wooded Land) area of Castilla y León is nearly five million hectares (4,896,000 ha). Of this figure, approximately three million are forests (2,980,000 ha), from which 1,782,000 ha are considered as forest with high density and 1,198,000 ha are labelled as low density. These figure of forests represent about 61% of FOWL and almost 32% of the region area.

Thanks to the Regional Program for Afforestation of Agricultural Land a total of 173,000 ha have been added to the land use category of FOWL. This plan also included all the management needed in order this areas could get a proper stocking values. It is expected to get 450,000 ha of FOWL during the period from 2001-2027. With a figure for the category of forest with high density of 2,500,000 at the end of this program.

	Forest with trees	Sparse woodland	Forest with trees + Sparse woodland	Treeless Forest	Forest	Nonforest	Total
CASTILLA Y LEÓN	1.585.408	533.731	2.119.139	2.397.247	4.516.386	4.906.016	9.422.402
SPAIN	10.625.698	3.278.962	13.904.660	12.079.402	25.984.061	24.611.953	50.596.014

Table 6: Values per each category of the FOWL land use type. (Absolute values in hectares)

The table 6 shows the different area per category of the FOWL land use type for the region of Castilla y León in ha, using as source the Second National Forest Inventory (2000).

The table 7, shows the total forest area classified by main specie, for both Castilla y León and Spain, according to data from the Second National Forest Inventory (2000).

Dominant Species	CASTILLA Y LEÓN	SPAIN
Pinus pinaster	312.368	1.008.866
Pinus sylvestris	196.531	678.686
Pinus pinea	42.145	172.859
Pinus nigra	18.206	405.983
Pinus halepensis	14.042	1.046.978
Pinus sp.	198.688	2.048.039
Juniperus thurifera	33.572	75.203
Querqus ilex subsp. rotundifolia	150.120	823.447
Querqus faginea	151.652	263.473
Mediterranean broadleaves	138.796	1.038.430
Fagus sylvatica	22.061	311.115
Castanea sativa	9.292	83.497
Mixture of deciduous	76.475	690.704
Populus sp.	48.054	89.856
Mixed stands of conifers and hardwoods	103.788	1.475.393
Sparse woodland	503.348	3.278.962
Others		413.169
TOTAL	**2.119.139**	**13904660**

Table 7: Forest area values per main species

To implement the regional forest resources, the regional environmental board has launched four plans of county forest resource management (PORF) with extensive participatory processes and addressing environmental questions.

2.d Basque Country

According to the National Forest Inventory (2005) (Eusko Jaurlaritza 2005). the area of forest and other woolands (FOWL) in the Autonomous Community of Basque Country is estimated to be 494,470 hectares. This represents 68.5% of the total land area in this Community. The land use area for the autonomous community by province is shown in table 9.

Area (ha)	ALAVA	BIZKAIA	GIPUZKOA	A.C.B.C.
Woodland	189,018	158,988	146,464	494,470
Agricultural	99,759	42,936	38,035	180,730
Urban	11,581	18,022	12,081	41,684
Water Bodies	3,101	1,286	1.168	5.555
Total	303,459	221,232	197,748	722,439

Table 8: area of different land uses in the different provinces of the Autonomous Community of the Basque Country (A.C.B.C.)

The FOWL reaches to be 55% of the total area of the Autonomous Community: The percentage of the wooded forest cover varies among the different provinces: 47% in Alava, 59% in Bizkaia and 63% in Gipuzkoa. The area occupied by hardwood forests exceeds that of conifers. The extent of forest plantations remains narrowly surpassing the natural forest, mainly because of the area occupied by these natural forests in Alava (Table 10).

Area (ha)	ALAVA	BIZKAIA	GIPUZKOA	A.C.B.C.
Wooded woodland	141,515	130,646	124,540	396,701
Hardwoods	102,030	44,826	54,308	201,164
Conifers	39,485	85,820	70,232	195,537
Plantations	29,830	102,033	77,645	209,508
Public ownership	146,873	44,246	33,815	224,934

Table 9: FOWL in the different provinces of the Autonomous Community of the Basque Country(A.C.B.C) divided by forest type and ownership

Radiata pine (*Pinus radiata*) is the species that covers the greatest area of all the forest species in this community: 137,475 ha, accounting for 35% of the total forest area. It is located in the Atlantic part of the forest area of this Community. It is also the most important forest species in terms of productivity: about the 90% of annual felling. In the Basque Country radiata pine is planted below 600 meters above sea level (masl.) on deep soils. Around 85% of the land in which this species is planted belongs to private owners.

Beech (*Fagus sylvatica*) occupies 54,555 ha and 14% of the total wooded area. It is present mainly in Alava (60%) and Gipuzkoa (32%). Three quarters of the area of this species lies on public forests.

The pedunculate and sessile oaks (*Quercus robur* and *Q. petraea*), occupied large areas in the Basque Country long ago. They are now relegated to small stands scattered due to the past exploitation and to the low value of its timber. The *Quercus robur* is located mainly in valleys with deep and fertile soils that nowadays are dominated by grasslands, crops and urban uses. The sessile oak is more difficult to find in the Community and it is mainly located in mountainous areas, where the beech is more common. The oak woodlands are scarce (15,000 ha), and they present small diameter trees coming from old coppicing.

After the radiata pine, Scots pine (*Pinus sylvestris*) is the second conifer by area in the Basque Country,17,234 ha, about 80% of this area belong to natural forests. Nevertheless, their distribution is radically different from that of radiata pine, as it is a species that it is present in the Mediterranean side and it is mainly located in public owned forests (79% of the area occupied by this species). Because of its resistance to low temperatures and to continental conditions and because of its commercial value, this species has been expanded to the western part of Alava, forming an extension of the Scots pine forests from the Iberian Massif to Bizkaia through the Nervión valley. Its area was expanded in the past through plantations.

Holm oak forests (*Quercus ilex* and *Q. rotundifolia*) are the most representative ones from the Mediterranean woodland covering 27,289 ha. Nowadays these forests grow on shallow soils developed on limestone and associated to a low water retention capacity. These woodlands are mainly located in Alava (74% of its distribution area), but there are some stands in the Atlantic side of the Community.

Portuguese oak (*Quercus faginea*) is mainly located in Alava. Its distribution area has been greatly reduced in size because of the extension of pastures and crops. It is nowadays relegated to scattered stands in the foothills of some mountains, occupying some 27,100 ha in total.

Pyrenean Oak (*Quercus pyrenaica*) is also mainly located in Alava (96% of its distribution area in the autonomous community; around 12,300 ha). This tree species grows on poor sandy, acid and shallow soils in the Mediterranean area.

European Black Pine (*Pinus nigra*) covers an area of 13,560 hectares, mainly in Gipuzkoa (51%) and at altitudes between 600 and 1,200 m a.s.l. Larch (*Larix* spp.) is mainly distributed in the Province of Gipuzkoa (80%) and covers an area of about 8,000 hectares at the same altitudinal ranges as the European Black Pine. Eucalypts (mainly *Eucalyptus globulus*) cover around 13,000 ha at low altitudes, near the coast, in Bizkaia. Anyway, the area planted with *E. nitens* is increasing far from the coast in this Atlantic province. Maritime pine (*Pinus pinaster*) covers 7,275 ha on poor soils that are also located close to the coast. Douglas fir (*Pseudotsuga menziesii*) covers 8,137 ha (70% of this area in Gipuzkoa) planted in the Atlantic part of the Autonomous community at altitudes between 450 and 1,000 m a.s.l.

2.e Navarra

Forest and Other Wooded Land covers 586,513 ha in Navarra. This area represents 56,45% of the total surface of Navarra which is 1,039,69.11 ha (Third NFI) (table 10).

Stand	Hectares	%Navarra surface
Conifers	97,299.55	9.36%
Broadleaves	285,245.42	27.45%
Mixed	80,119.52	7.71%
TOTAL FOREST AREA	462,664.49	44.53%
OTHER WOODED LAND	123,848.82	11.92%
TOTAL	**586,513.31**	**56.45%**

Table 10: Surface of woodland by forest type

In the lasts years due to afforestation in former agricultural lands the total surface of woodlands has grown gradually, as it shows in table 11.

Forest surface 1971 (ha)	Forest surface 1986 (ha)	Forest surface 2000 (ha)
303830	309210	334540

Table 11: Evolution of forest surface in Navarra

In Navarra, the main forest tree species is *Fagus sylvatica* (121,634 ha, third NFI), that mainly covers mountainous areas. Thus more than half of these stands grow between 600-1000 meters of altitude, but it can be found from sea level up to 1,600 m.a.s.l. Beech forests are localized in the northwest of Navarra, Pirineo and pre-Pirineo, where *fagus* forms mixed forests with *Abies alba* and *Pinus sylvestris.*

Mountain pinewoods are the second most important forest type in Navarra. The main tree species is *Pinus sylvestris,* with 67,000 ha, that grows between 800 and 1,200 m.a.s.l. Higher altitudes (1,800-2,200) are covered by *Pinus uncinata* . Even that it has not a large forest area, its phytogeographically role is very important.

There are different types of forest types with *Quercus spp.* as main tree species. In the Atlantic zone of Navarra, the main species are *Quercus robur* and *Q. petraea*, while in submediterranean zone other *Quercus*, like *Q. faginea* and *Q. humilis* are more common. These stands are growing between 500 and 1,000 meters of height at prePirieno areas in Sierra of Leire and Bidasoa river basin. Finally in southern areas with a more typically Mediterranean climate holm oak and oak shrub lands are found. These stands are characterized by *Quecus ilex*, *Quercus coccifera* and *Pinus halepensis* at the range from 400 to 1000 metres

In the shrubs stratus of the *Q. coccifera* and *Q. ilex* a big number of different group of Between stands of *Quercus ilex* and *Quercus coccifera* there is a rich group of different species of bushes like *Rhammnus alaternus*, *Juniperus oxicedrus*, *Junipherus phoenicea*, *Salsola vermiculata* or *Artemisia hera-alba*.

Atlantic riparian forests are mainly made up of Alnus glutinosa, Frangula alnus and Fraxinus excelsior; on the other hand Populus sp, Ulmus and Salix sp. are easily found in the riparian forests of the Ribera navarra (South).

Formación forestal dominate	Cabida (Ha)	%representativo
Fagus sylvatica	121.633,67	26,29
Pinus sylvestris	60.397,61	13,05
Pinus sylvestris con Pinus nigra, Quercus faginea	36.022,19	7,79
Quercus ilex	33.060,69	7,15
Quercus faginea con Q.ilex	26.749,50	5,78
Pinus nigra	22.634,57	4,89
Quercus faginea	17.969,11	3,88
Quercus robur, Q. Petraea con Castanea sativa, Q. Rubra	17.607,19	3,81
Fagus sylvatica con Quercus robur, Q.petraea	16.712,01	3,61
Juniperus spp. Con Fagus sylvatica, Q.ilex, Pinus halepensis	15.337,34	3,32
Pinus halepensis	14.267,27	3,08
Pinus radiata, Larix spp cpn Q. Rubra	13.832,70	2,99
Abies alba, Pinus sylvestris, Fagus sylvatica	11.068,38	2,39
Quercus robur, Q. petraea	9.488,17	2,05
Quercus pubescens (Quercus humilis), Q. pyrenaica	9.239,23	2,00
Populus nigra, Populus x canadensis	7.391,04	1,60
Castanea sativa con fagus sylvatica, Quercus robur	5.392,87	1,17
Mezcla de frondosas	3.008,40	0,65
Matorral con arbolado ralo disperso	16.993,64	3,67
Árboles fuera del monte, ribera arbolada	3.858,91	0,83
Superficie forestal arbolada total	462.664,49	100,00

Table 12: Area of Forest land by main species and share of the stand

2.f France

The French regions involved in the REINFFORCE project are: Aquitaine, Poitou-Charentes, Pays de Loire, Bretagne and Normandie (Haute et Basse).

As to National Forest Inventory, they are part of the following Interregions: North-West Coastal Region, Île-de-France Centre Poitou-Charentes and Aquitaine.

Due to an important change in NFI methods, some data are no more available at a regional level since 2005.

The following text presents information at national, interregional and regional level.

Region	(1000 ha)	
	Total	Dedicated to wood production
Basse Normandie	170	160
Haute Normandie	220	210
Bretagne	350	330
Pays de Loire	350	330
Poitou-Charentes	400	390
Aquitaine	1810	1770
REINFFORCE	3300	3190

Table 13: regional distribution of forest area and growing stock in Atlantic regions of France

(yellow)	North-West Coastal Region
(green)	Île-de-France Centre Poitou-Charentes
(blue)	Aquitaine

With 15.71 million hectares, woodland covers 28,6% of the total area of France (excluding overseas territories).

French forest is mostly broadleaved tree forest types. Broadleaved stands cover 58% of the forested area. Conifers are mainly located in the Landes Forest, in the south-west of France and in mountainous regions.

Three quarters of the French forest (11.69 million hectares) belong to private owners. The public forest, managed by Office National des Forêts (ONF), are divided into state-owned forests (1.53 million hectares) and forest belonging to local authorities (2.49 million hectares).

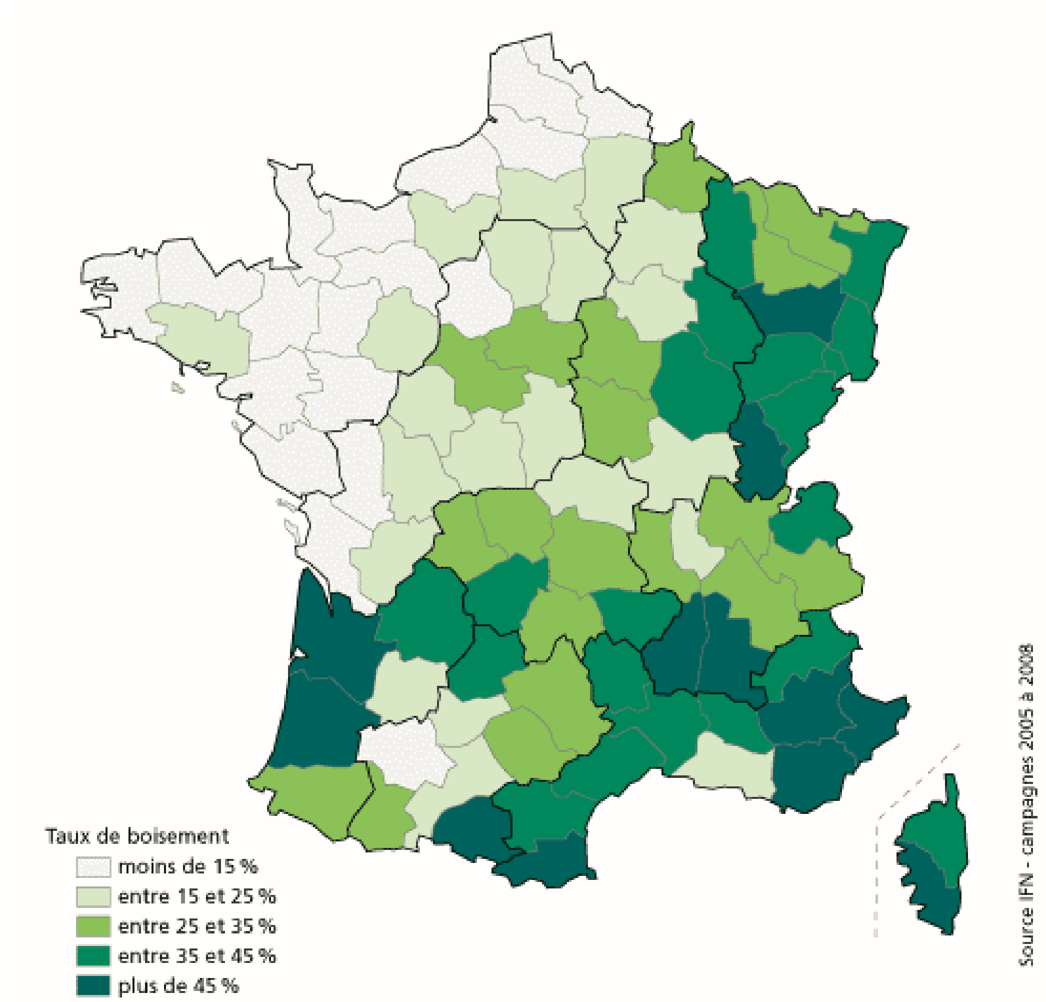


Illustration 9: Share land cover by Forest in France

Interregion	Area (1000 ha)		
	Public forest	Private forest	Total
North-West Coastal Région	270	1250	1520
Île-de-France Centre Poitou-Charentes	230	1400	1630
Aquitaine	150	1660	1810
FRANCE	4020	11680	15700

Table 14: Type of property by region in Atlantic France

Thirteen main tree species make up 80% of the French forest:

Species	(1000 ha)	(million of m³)	(million of m³)
Pedunculate oak	1850	275	8
Sessile oak	1690	289	8
Beech	1390	260	8,4
Pubescent oak	1250	93	2,8
Chestnut	740	118	5,9
Evergreen oak	650	24	0,8
Hornbeam	580	90	4,1
Common ash	540	80	4
Other broadleaves	1690	272	13,9
Total hardwood	10380	1502	55,8
Maritime pine	1100	179	11,1
Scots pine	910	143	4,8
Norway spruce	630	190	9,4
Common silver fir	580	178	7,1
Douglas fir	400	88	6,6
Other conifers	860	127	6,2
All softwoods	4470	905	45,3
Unspecified	120	-	-
Total	14970	2407	101,1

Table 15: Forest areas per tree species in France

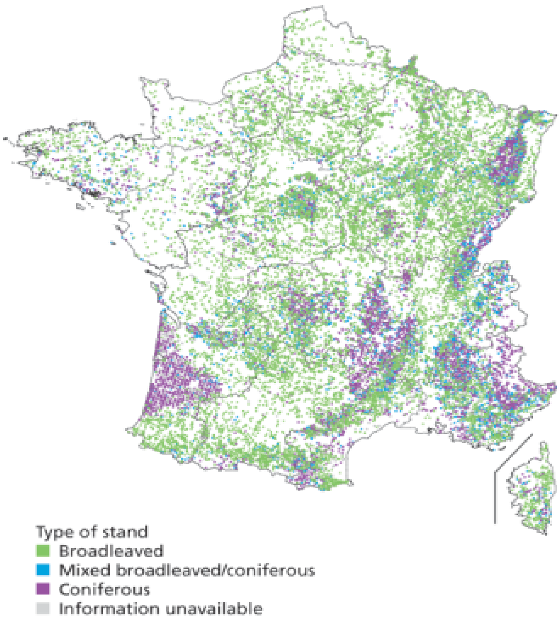


Illustration 10: French forest composition (Source NFI, years 2005, 2006, 2007, 2008)

As for interregions:
The main species are representative of Atlantic climate with mild winters and moderately hot summers.

Species	Area (1000 ha)		
	North-West Coastal Région	Île-de-France Centre Poitou-Charentes	Aquitaine
Pedunculate oak	270	370	320
Sessile oak	210	390	-
Beech	130	-	60
Pubescent oak	-	100	130
Chestnut	100	110	130
Evergreen oak	0	-	-
Hornbeam	50	70	-
Common ash	90	60	-
Maritime pine	100	70	830
Scots pine	50	80	-
Norway spruce	-	-	-
Common silver fir	-	-	-
Douglas fir	-	-	-

Table 16: Trees species areas per region in Atlantic France. Note- indicates an area of less than 50000 ha

2.g United Kingdom

The area of woodland in the United Kingdom is currently estimated to be 2.84 million hectares. This represents 12% of the total land area in the UK, 9% in England, 17% in Scotland, 14% in Wales and 6% in Northern Ireland. Of the total UK woodland area, 0.81 million hectares is owned or managed by the Forestry Commission (in Great Britain) or the Forest Service (in Northern Ireland). The breakdown of woodland area by forest type, ownership and country is shown in table 18.

	England	**Wales**	**Scotland**	**Northern Ireland**	**UK**
FC/FS					
Conifers	146	91	418	56	710
Broadleaves	55	14	29	6	104
Total	201	105	447	61	814
Non-FC/FS					
Conifers	219	65	624	10	918
Broadleaves	709	114	271	16	1110
Total	928	179	894	26	2027
Total Woodland					
Conifers	365	156	1042	66	1628
Broadleaves	764	128	300	22	1213
Total	1128	284	1341	88	2841

Table 17: Area of woodland ('ooo ha) in 2009 by forest type and ownership

Nearly 60% of the total woodland area occurs in the Atlantic region of UK, which corresponds with the main mountain ranges as well as the area with the highest rainfall and exposure. The main climatic axis is roughly north-west to south-east, 'cool and moist' to 'drier and warmer' and the main trends in soils and topography follow the same trend.

After the last ice age, only 37 major tree species recolonised the British Isles, yet the climate and soils are conducive for growing many hundreds of species not only from regions with a similar climate but also from cooler and warmer regions of the world. There are about 500 major tree species that have been introduced from across the temperate forest regions. The relative poverty of native tree species is most pronounced in the conifers, of which there are only three native species: Juniper (*Juniperus communis*), Scots pine (*Pinus sylvestris*) and yew (*Taxus baccata*), of which only the Scots pine is a timber tree. The extensive use of non-native trees in forestry began in the 18th century with species from Europe such as Norway spruce (*Picea abies*), European silver fir (*Abies alba*), and European larch (*Larix decidua*), followed in the 19th century with North American species such as Douglas-fir (*Pseudotsuga menziesii*), Lodgepole pine (*Pinus contorta*) and Sitka spruce (*Picea sitchensis*), and then Japanese larch (*Larix kaempferi*) and Corsican pine (*Pinus nigra* ssp. *laricio*) in the early 20th century. Current proportions of the woodland area occupied by the major conifer and broadleaved species are shown in table 19; conifers are the dominant group, particularly Sitka spruce.

Species	**% category area**	**% total area**
Scots pine	16	10
Corsican pine	3	2
Lodgepole pine	10	6
Sitka spruce	50	30
Norway spruce	6	3
European larch	2	1
Japanese/hybrid larch	8	5
Douglas fir	3	2
Other conifers	2	1
Mixed conifers	1	1
Total conifers	**100**	**61**
Oak	23	9
Beech	9	3
Sycamore	7	3
Ash	14	5
Birch	18	7
Poplar	1	0
Sweet chestnut	1	0
Elm	0	0
Other broadleaves	11	4
Mixed broadleaves	16	6
Total broadleaves	**100**	**39**

Table 18: Percentage area of high forest by principal species (Adapted from Anon.

3 Main impacts of climate change in the European Atlantic Area

3.a Portugal

In Portugal, last century climate variation is similar to the variation occurred in the rest of the world. There were two periods of significant warming, from 1910 to 1945, and from 1975 to 2002, separated by a moderate cooling period (1945 to 1975). In the second warming period, temperature raised of about 0.5ºC per decade, which corresponds to the double of the global rate (*Illustration 8*).

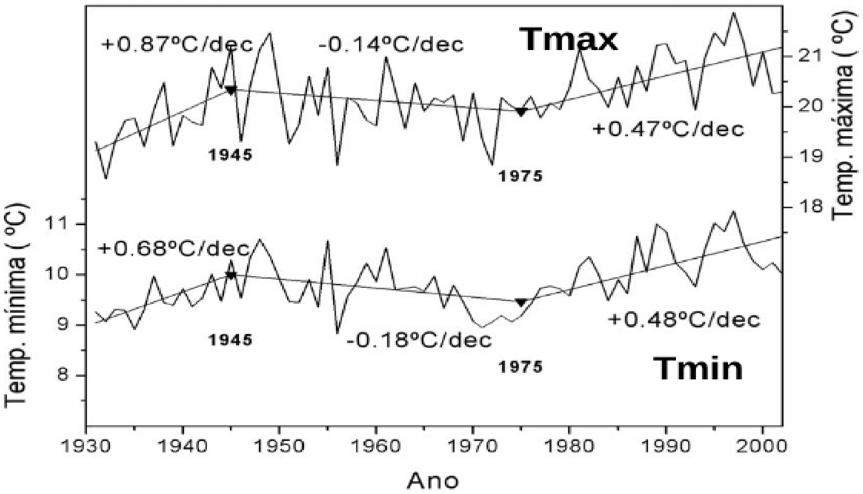


Illustration 11: maximum and minimum average temperature, and variation rates between 1930 and 2001 Source: Santos et al 2002

An increase in cloudiness provides a higher relative humidity, with a reduction in radiations levels and therefore a decrease in daily thermal amplitude. These results are consistent with the same climate variables for Lisbon metropolitan area.

There is no significant trend in rainfall variation for the 1960-2002 period, though a significant reduction in spring time rainfall since 1970 was observed which is associated with North Atlantic Oscillation (NAO) variations (Teixeira et al. 2004) (Figure 12).

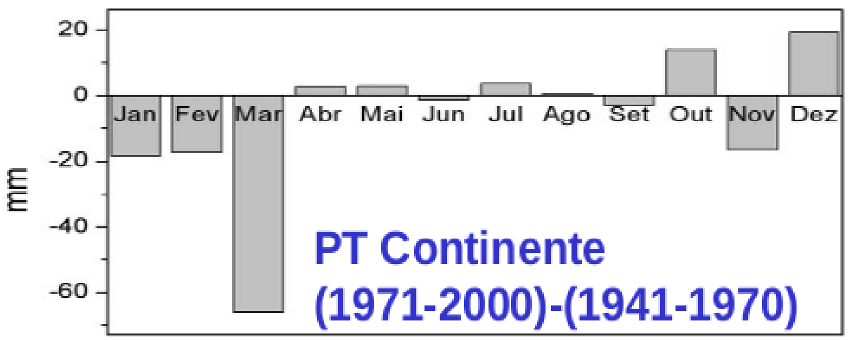


Illustration 12: monthly precipitation comparison between last 30 years and the 1941-1970 period Source: Santos et al 2002

The frequency of extreme event may also increase. The year 2003 was a glimpse of what may be the consequences of water shortage. There was a heat wave in august that lasted 17 days (the longest since 1941), causing personal injuries and an unprecedented extension of burned forest area, almost three times higher than average annual values for the last 25 years period. This drought situation lasted for another two years and, during September 2005, 97% of the country was in severe to extreme drought conditions, were the worst records during the last 60 years. The drought ended in March 2006, but even of that, 2006 was the fifth driest year since 1931.

This climate change affect the survival and propagation of pathogenic agents and their interaction with the hosts, which under more stressful conditions become more susceptible to biotic attacks. The results presented in figure 9 were recording during sampling and monitoring works from the European community Forest Focus Regulation, and show the evident rise, since 1997, of low vitality tree number. Since 1997, these works show a clear increment in the number of trees with low vitality (DGRF 2007).

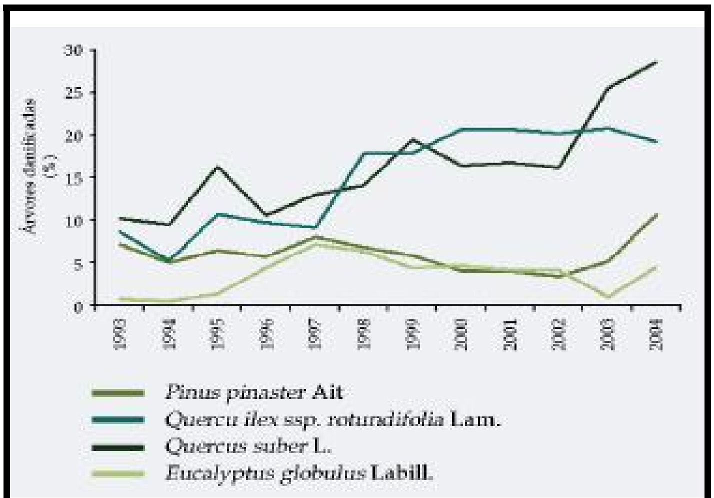


Illustration 13: trees with low vitality between 1998 and 2004, in most representative Portuguese specie. Source: DGRF 2007

The future climatic scenarios for Portugal were developed under SIAM project (Santos *et al* 2002). Projections were based in the IPCC Special Report on Emission Scenarios, coupled with global circulation models. The main results of the scenarios points to a systematic increase in average summer temperatures from 3 to 7ºC, mainly in the North and center East Portugal with more often and intense heat waves.

In the case of precipitation, scenarios are more uncertain, but reductions in annual rainfall of 20 and 40 percent are estimated. This reduction will be higher in the South of the country. Therefore water stress will become the main constraint for primary production (Figure 14).

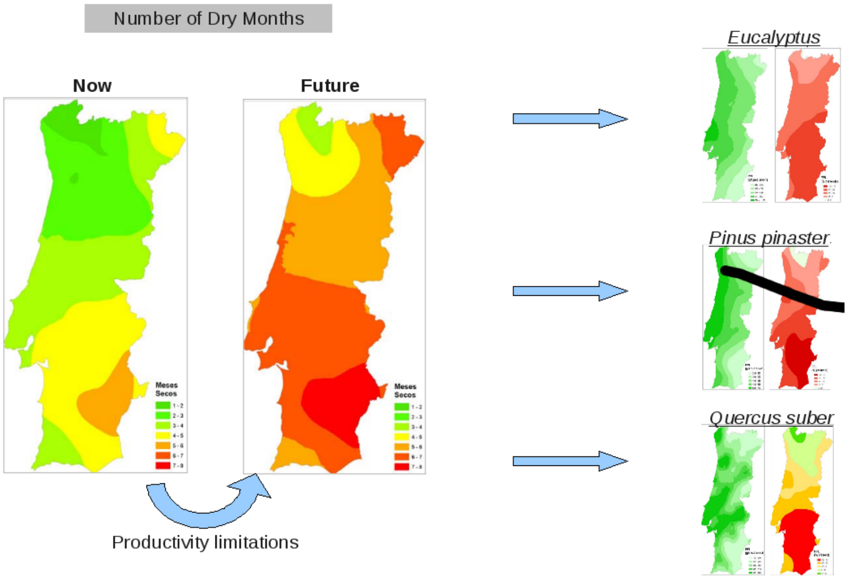


Illustration 14: prediction of future production constrains an consequences in Net primary Production. Source: Santos et al 2002

The combined effects of drought and high temperatures will cause lower carbon sequestration in some areas. Species distribution will be mainly driven by the stress caused by the increment of arid and semi-arid climate along the country (Figure 15).

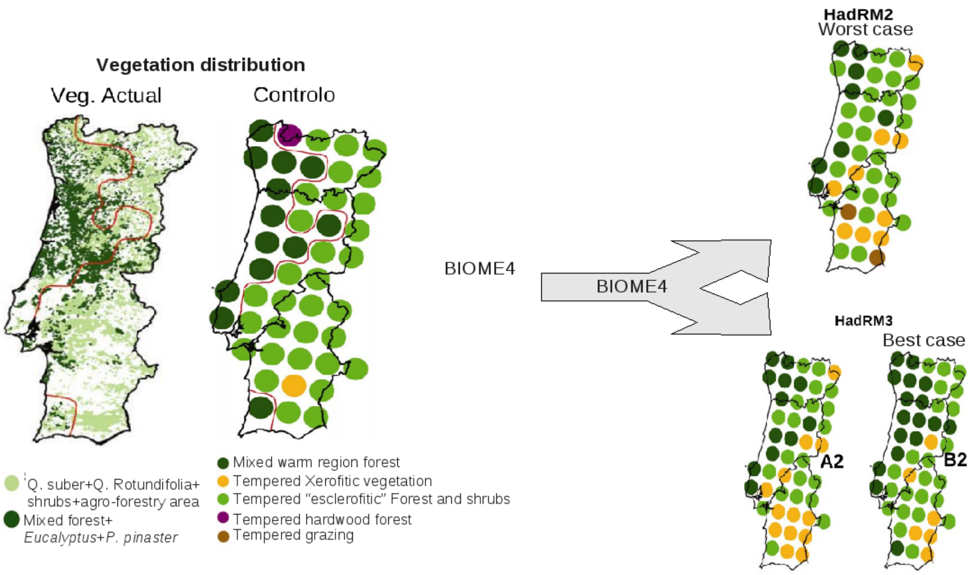


Illustration 15: current and predicted vegetation composition. Source: Santos et al 2002

At some regions winter warming with CO_2 fertilization will be beneficial, mainly in the North.

The South and interior regions may be inhospitable for some of present species like cork oak and *Pinus pinaster*. Another expression of the predicted climate change effect is the rising of forest fire occurrence. In the scenario with double of the actual CO_2 atmospheric concentration (Figure 16), It is expected a higher fire risk and an increased fire season (Santos *et al* 2002).

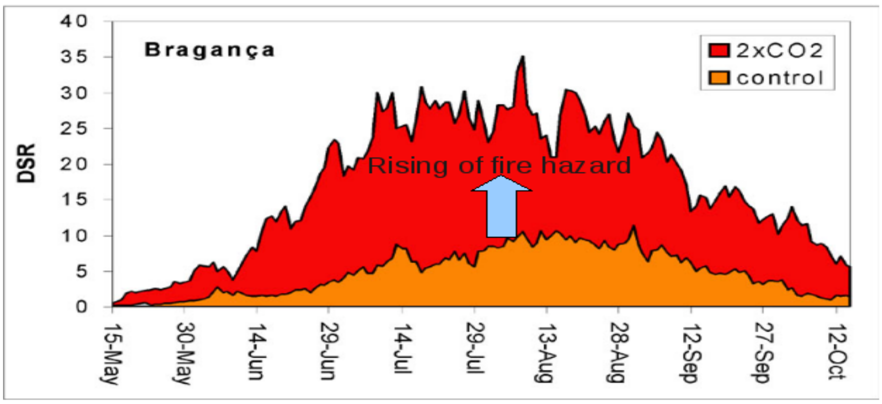


Illustration 16: daily fire risk rise in the predicted scenario (2x actual CO_2 level). Source: Santos et al 2002

3.b Spain

The generally accepted methodology for making estimations of regionalised projections of climate change makes use of the idea of a downscaling from large scales to small scales.

Large scales are estimated using global interconnected ocean-atmospheric models and there is a continual refinement down to smaller scale estimations using different regionalisation techniques.

There are a series of uncertainties in the process of generating regionalised scenarios of climate change: (i) the uncertainties linked to greenhouse gases emissions (GGE); (ii) the uncertainties linked to the different global models; (iii) the uncertainties linked to the internal variability of the model, and, (iv) the uncertainties linked to the regionalisation techniques.

For all that, in the production of this report, use has been made of results from the projects of the 5th Framework Programme of Investigation and Development of the European Union related to climate modelling, dynamic regionalisation (PRUDENCE project – Prediction of Regional Scenarios and Uncertainties for Defining European Climate change risks and Effects), statistics (STARDEX project – Statistical and Regional dynamical Downscaling of Extremes for European regions) and estimation of extremes collected in the follow-up report to the First Working Programme of the National Plan for Adaptation to Climate Change in 2008 (by the Spanish Office for Climate Change.) In presenting the maps of the Iberian Peninsula, the paper produced by Brunet et al (2008) was taken into account. That paper did not take into account a collection of projections such as those being carried out in the ENSEMBLES project of the 6th Framework Programme of the European Union.

The graphics presented are based on the representation of the evolution of mean values and on the spread represented as +/- standard deviation from the mean values of the different global models and different regionalisation techniques. The projections made in the framework of the PRUDENCE project only cover the final thirty years of the XXI century. The main reason for using this type of representation is the empirically demonstrated fact that the systematic errors and uncertainties previously mentioned, as much for the global models as for the regionalisation techniques, tend to cancel out when averaged and to show higher agreement with the observations (OECC, 2006.)

SRES A2 and B2 scenarios are used. These came about from a special report on emissions scenarios of the IPCC (Nakicenovic et al; 2000):

> Scenario A2 describes a very heterogenous world. Its most distinctive characteristics are self-sufficiency and the preservation of local identities. The fertility lines within the regions as a whole converge very slowly, such that a world population in continual growth is obtained. Economic development is basically orientated to the regions, and per capita economic growth, along with technological change are more fragmented and much slower than in other evolutionary pathways. It is characterised by a significant increase in greenhouse gases emissions (GGE) over the next 100 years, with special impact on the CO_2 emissions (Fig 17).

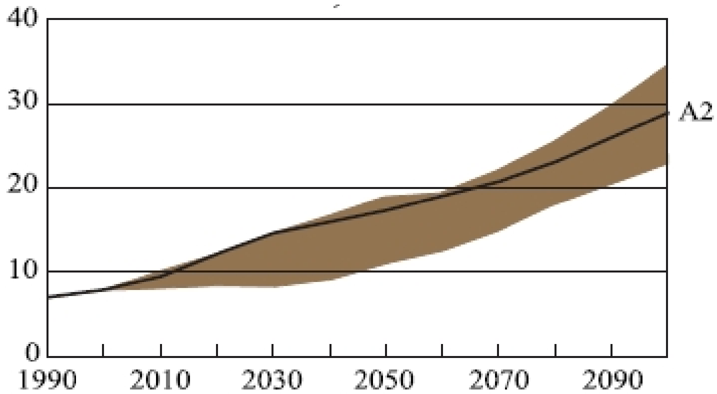


Illustration 17: total annual CO_2 emissions from all sources (energy, industry and land use change) between 1990 and 2100 (in gigatonnes of carbon – GtC year^{-1}) for the SRES A2 scenario

Scenario B2 describes a world in which local solutions to economic, social and environmental sustainability predominate. It is a world whose population increases progressively at a lower rate than that in A2. There are intermediate levels of economic development and less rapid and more diverse technological change than in the B1 and A1 evolutionary pathways. Although this scenario is also orientated towards environmental protection and social equality, it is principally centred in the local and regional levels. This scenario supposes a slight increase in CO_2 emissions over the next 100 years (Fig 18).

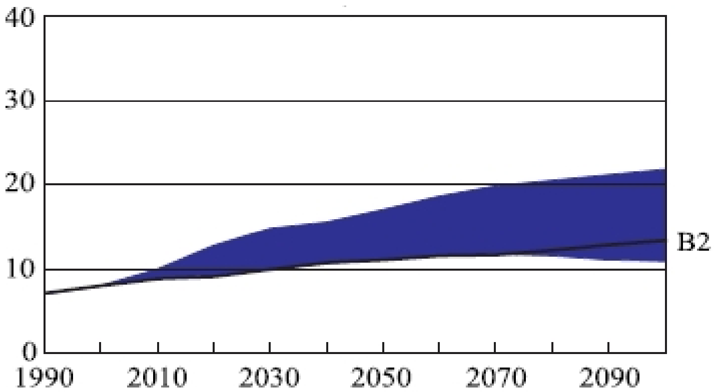


Illustration 18: total annual CO_2 emissions from all sources (energy, industry and land use change) between 1990 and 2100 (in gigatonnes of carbon – GtC year^{-1}) for the SRES B2 scenario

In the light of the results yielded by the different global models and regionalisation techniques, and taking into account the uncertainties associated with the generation of regionalised scenarios as previously mentioned, it is difficult to propose a climate change prediction map of the Iberian Peninsula. Anyway, the change in mean maximum annual temperature for the period 2071-2100 with respect to the control period (1961-1990), provided by the regionalised projections using different global models, is presented as a sample of the uncertainty associated with this process (Fig 19) It remains clear that the selection of the global model, or the collection of global models to regionalise, is key to the final regionalised projections.

Either way, a series of results common to all the models and regionalisation techniques for generating climate change scenarios for the Iberian Peninsula are shown (Brunet *et al.*, 2008):

With respect to change in maximum temperatures

Using emission scenario A2, the maximum temperatures for the period 2071-2100 show an approximate increase between 5ºC and 8ºC in the interior regions of the Iberian Peninsula. Change is more moderate in coastal regions

The yearly spread of change in maximum temperatures is not equal for every month. It shows a greater increase in maximum temperatures in the summer months and a lesser increase in the winter months (Fig 20)

The differences between the various emission scenarios are clearly greater when the prediction timeframe is increased. It can be said that in the first 30 years of scenario generation, great variations with respect to the reference period are not predicted under emission scenario A2.

With respect to change in minimum temperatures

Major diurnal thermic oscillations are predicted due to a greater increase in maximum temperatures and lesser increase in minimum temperatures.

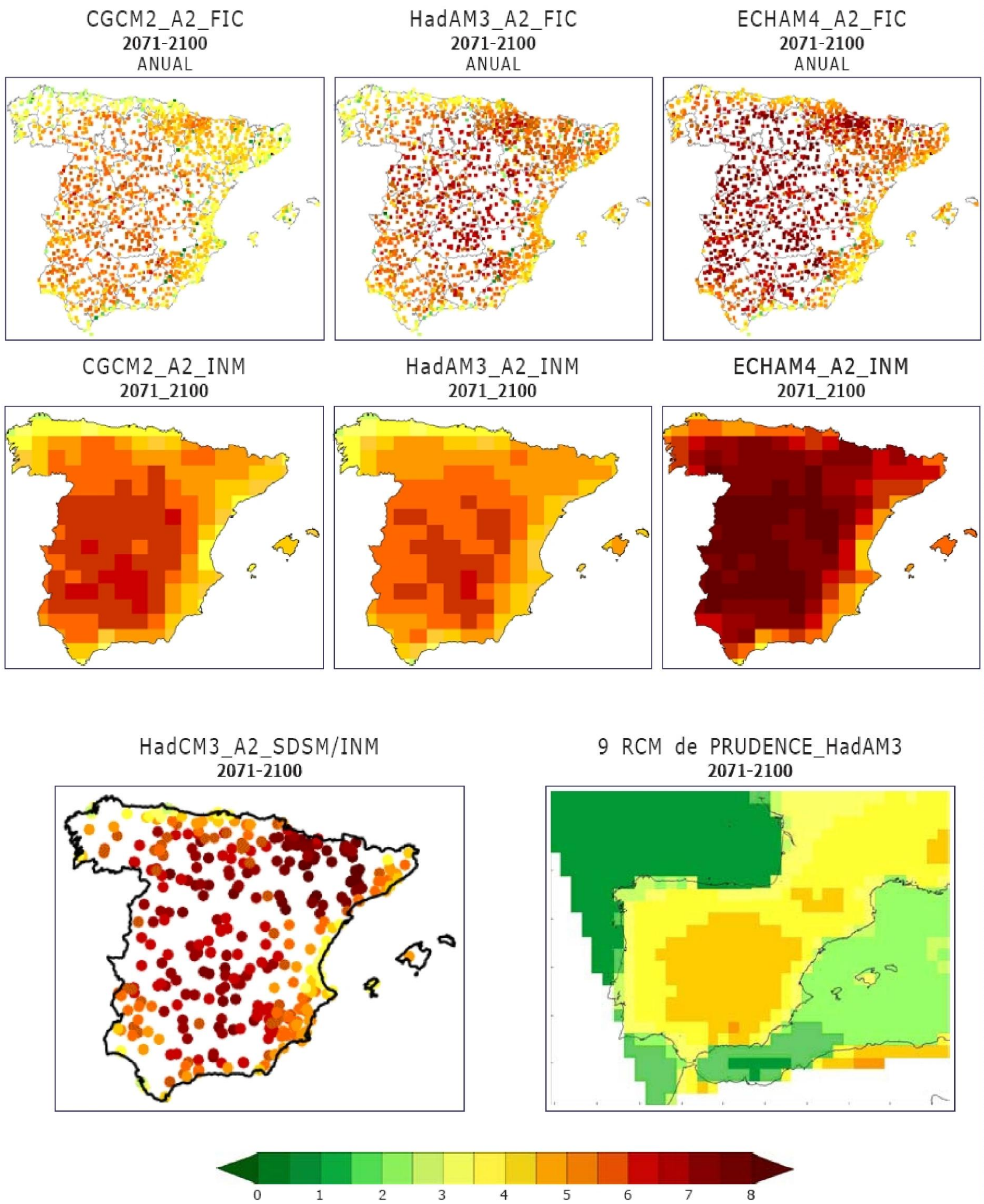


Illustration 19: Comparison of the change in mean maximum annual temperature for the period 2071- 2100 with respect to the control period (1961-90) provided by regionalised projections using different global models (CGCM2 – left, ECHAM4-OPYC – right, HadAM3 - centre, HadCM3 – lower left) and different statistical regionalisation techniques (Anal_FIC – above, Anal_INM – centre, SDSM – lower left) and dynamic regionalisation techniques (average of the 9 PRUDENCE RCM – lower right.) The A2 SRES emission scenario is common to all the models

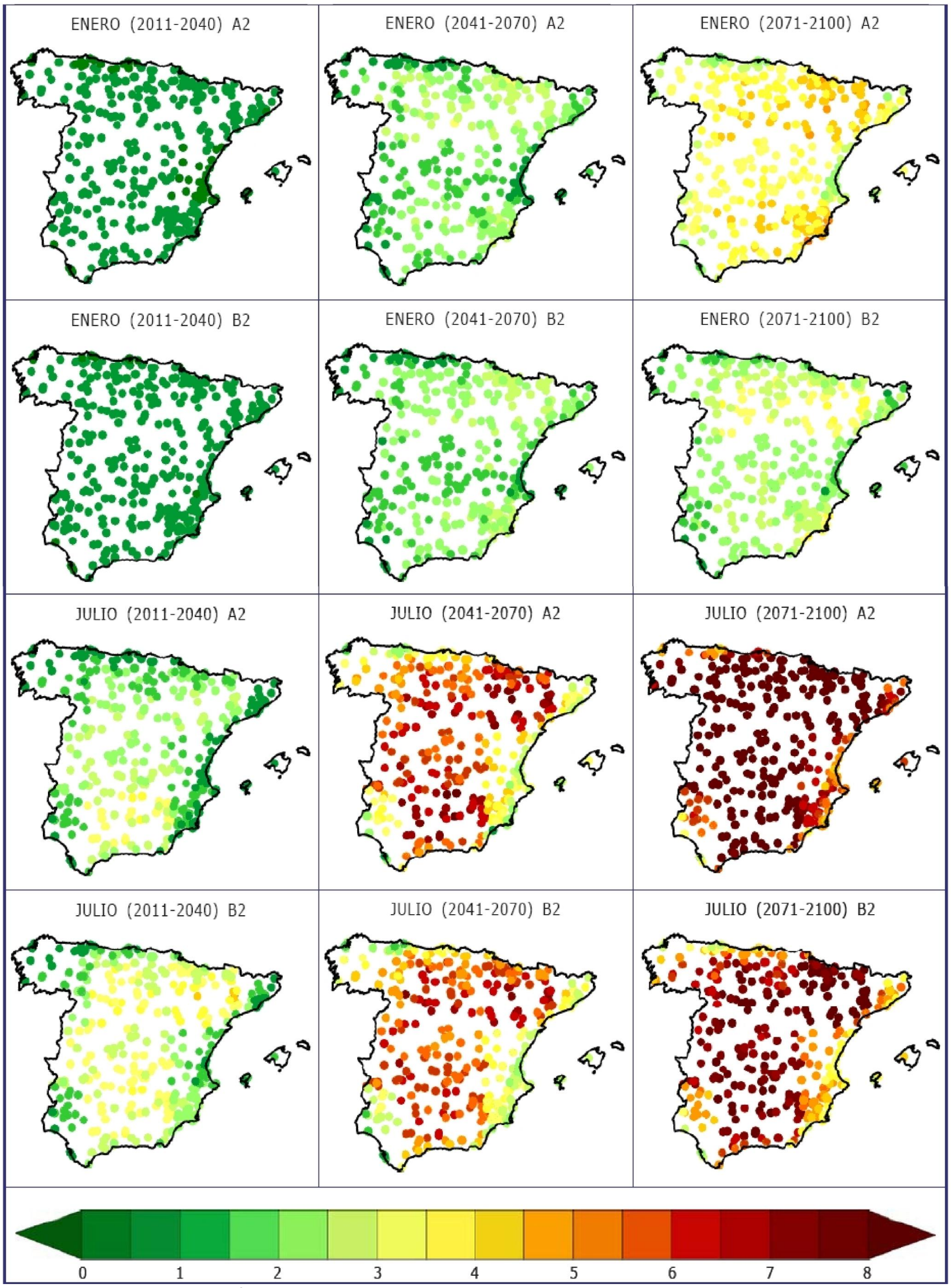


Illustration 20: Mean change for January (2 upper lines) and July (2 lower lines) in maximum temperatures as projected by the HadCM3 global model for the periods 2011-2040 (left), 2041-2070 (centre) and 2071-2100 (right) compared to the current climate (1961-1990) and regionalised using the SDSM regression method for the SRES A2

For the period 2071-2100, the range of values predicted for the peninsula's interior is found between 4ºC and 6ºC higher using the A2 upper-medium emission scenario.

The change in minimum temperatures shows a marked annual cycle, demonstrating a clear increase in the summer months.

With respect to change in precipitation:

Scenarios produce a predominance of zones with reduced precipitation. The regions of the southern half of the Iberian Peninsula are the most conformed to the different models and regionalisations. The prediction of the 9 PRUDENCE regional models shows a reduction in annual precipitation for all the Iberian Peninsula.

The average of the 9 PRUDENCE regional models shows a tendency to reduced precipitation in the spring and summer months. This tendency may have little significance in the summer months because of the reduced levels of precipitation, in absolute terms, present in those months in general in the Iberian Peninsula.

The projections based on the SRES B2 emission scenario don't show significantly different outcomes in terms of structures to those demonstrated for the A2 scenario, although it shows lesser values of change.

Medium and long term strategies and forecasts are crucial for a better adaptation of natural resources and societies to climate change. Participation of different interested groups are equally needed and expected in designing the whole process of defining strategies.

The Spanish National Plan for Adaptation to Climate Change was adopted in July 2006 after a wide consultation process channelled through the main coordination and participating bodies dealing with Climate Change; the National Climate Council, the Coordination Commission of Climate Change Policies and the Environmental Sector Conference. The process had a wide participation engaging representatives from the public administrations, non-governmental organizations and other stakeholders.

The development of this plan will be implemented through a proposed work program of the Spanish Office for Climate Change. The following table 16 shows a subjective estimation of the adjustment periods across sectors and systems, and we can see the forest sector has a planning horizon for the adaptation of 10 to 100 years.

The sectors and systems are not watertight, but very often interdependent and this must be taken into account in assessment of vulnerability and adaptation options for each, for example, human health, the agriculture or forestry are dependent on the availability of water resources. This will pose a major challenge of integrating and coordinating disciplines and groups of experts working in various spheres.

Sector / Sistema	Horizonte de planificación para la adaptación (años)
Biodiversidad	10-100
Recursos hídricos	10-100
Bosques	10-100
Sector agrícola	1-20
Zonas costeras	10-100
Caza y pesca continental	5-25
Zonas de montaña	10-100
Suelo	5-100
Pesca y ecosistemas marinos	5-20
Transporte	5-50
Salud humana	1-20
Industria y Energía	10-50
Turismo	5-20
Finanzas - Seguros	1-10
Urbanismo	10-100
Construcción	5-50

(Fuente: adaptado de A Preliminary Examination of Adaptation to Climate Change in Finland, 2003 y de Adaptation Policy Frameworks for Climate Change, UNDP 2004)

Table 19: planning intervals for different sectors of societies and natural resources. Bosques (forests)

Next paragraphs show the projected impact of climate change more relevant to the forest sector, as indicated in the publication of the Preliminary General in Spain Impacts of Climate Change Effect (MIMAM 2005)

Climate change along with the regression of the environment can increase the sensitivity of many forest species, since they can not occupy land on which they were previously, due to erosion or other changes. The physiology of forest species can be profoundly affected also. Deciduous species lengthen its growth cycle, the renewal of foliage and fine roots of the evergreens will be accelerated by altering the internal balance of plant reserves. The consumption of carbohydrates in the renovation of structures will increase, thus reducing the reserves of the plant and increasing their vulnerability to adverse events.

The water reserve in the soil will decrease as the temperature and atmospheric evaporative demand will increase. This will be an important factor of stress for the trees. Water deficit can cause changes in the density of trees or species. In extreme cases, shelter areas for forested systems may lose this status, migrating to shrubs and other vegetation types.

With regard to forest fire, rising temperature and lack of water in the soil, will lead to a stronger and longer fuel desiccation. Therefore, the flammability of fuel will be increased. The mean scores of danger will grow over the century and in particular, the frequency of extreme events. The average duration of the hazardous season and the ignitions caused by lightning and negligence will increase too. So, the frequency, intensity and magnitude of forest fires will increase ultimately.

The return of the soil organic matters to leaves and fine roots will be increased while decreasing the production of timber. The amount of carbon returned to the atmosphere, will be increased significantly over time. According to GOTILWA + model to simulate the growth of forests in the Iberian peninsula under different scenarios of the IPCC. Forests can transiently increase the carbon sink effect for several decades, but the second half of this century could reverse the role of sinks to become net emitters of carbon into the atmosphere.

Forest pests and diseases, can play a key role in the fragmentation of forest areas. Some drilling or defoliating species can complete two life cycles within a year or increase its area of settlement as a result of milder winters. Topmost areas of the mountains, xeric environments and riparian forests are some of the areas those may be more vulnerable to climate change.

Therefore, the measures, activities and areas of work for assessments of impacts, vulnerability and adaptation in the forestry sector, to be carried out in developing the National Adaptation Plan, can be noted the following:

- Development of guidelines and evaluation techniques and models to implement an adaptive forest management to climate change: selective thinning techniques, control and adjustment of shifts and intensities of use, selection of seed sources for reforestation, etc..
- Accurate assessment of air-ground biomass and species and Spanish forest systems.
- Development and implementation of forest growth models under climate change scenarios.
- Evaluation of carbon budgets for different types of Spanish forest ecosystems.
- Evaluation of interactions between: drought, fire hazard, occurrence of the same, and the response of vegetation in adverse situations.
- Identification of a system of forest indicators of climate change and development of a surveillance system and early warning.

3.c Galicia

Based on available data, climatic variations have been detected in various places in Galicia, mainly since the beginning of the 20th Century, although such variations have taken different directions (Fernández Cancio & Manrique, 1998; Cancelo & Díaz-Fierros, 2008; Cruz et *al*., 2009). The effect of climate change on Eurosiberian and Northwestern Spain seems to be less acute, at least at present, than in other more seriously affeted areas of the Iberian Peninsula. Such observed variations include (Figures 21-30):

- Annual mean precipitation over Galicia has not changed significantly since records began in 1875. Seasonal rainfall is highly variable, mainly during the last 100 years, but appears to have decreased in Februry and increased in Autumn, although not significantly.
- All areas in Galicia have experienced an increase over the last 45 years in the contribution to autumn rainfall from heavy precipitation events; in Spring, different areas of Galicia show decreases. During the last 55 years, heavy precipitation events most frequently take place on a daily scale.
- A reduction in the North or northwest wind in spring has been observed, together with an increase in southwesterly winds in autumn, which relates to increased rainfall in the Fall. The reason for these changes lies in the position of the low and high pressure troughs in the Atlantic and North Sea.
- Annual mean temperature increased by 0.18ºC per decade over the period 1961-

2006, but this increase was not homogenous, with an abrupt rise since 1972 that doubles the afore-mentioned rate: 0.36ºC per decade. This increase is somewhat more significant and generalized for maximum temperatures.

- In the afore-mentioned period, temperature increase was greater in spring and summer and lower in winter. Maximum winter temperatures increased while the number of cold days diminished. In summer, the number of warm nights also went up while the number of cold nights went down.
- The temperatures of surface air over the sea and of seawater went up at a rate of 0.1ºC per decade, although the increase in seawater temperature was greater and more significant than in air temperatures. The interdecadal variability measured off Galicia has the same pattern as observations made in the North Atlantic (AMO, *Atlantic Multidecadal Oscillation*) and is correlated to the NAO (*North Atlantic Oscillation*).
- As Galicia is situated in an area of cold water outcrops, the season has been observed to start and finish earlier.
- Seawater level has been noted to have gone up by 2–2.5 cms/decade in recent decades.

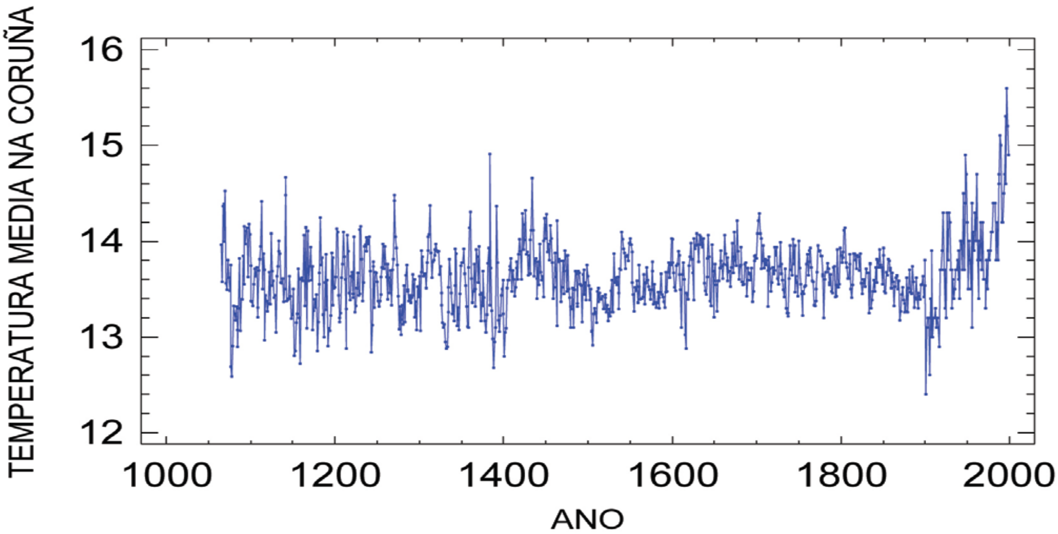


Illustration 21: Evolution of mean temperatures in A Coruña between 1050 and 1999. Between 1050 and 1390, variability is higher due to the small number of dendrochronological series (12) in this period. Between 1450 and 1625, the province was affected by the LIA (Little Ice Age) (Fernández Cancio & Manrique Menéndez, 2009)

In the book *Evidencias e impactos do Cambio Climático en Galicia* (2009), a series of projections for the future climate of Galicia under different emission scenarios were included. It provides probabilistic projections of climate change based on quantification of known sources of uncertainty.

Examples of outputs for different seasons and annual mean temperature and precipitation are shown in Figures 26-30.

Some conclusions can be drawn:

- All areas of Galicia are becoming warmer and such warming is greater in spring and summer than in autumn and winter. The same applies to mean maximum and minimum temperatures.
- The increase will be higher on the coast and in the south of Galicia.
- There is little change in the amount of precipitation (rain, hail, snow, ..) that falls

annually but it is likely that more of it will fall in autumn, winter, and in several areas, in summer, while spring will be drier. In some areas, mainly SW, NE and centre of Galicia, rainfall may increase by up to 20 - 25%.

- Sea level will rise between 0.5-1.4 m, while water temperature will go up by between 1 and 3ºC. The increase will be similar in all parts of the Galician coast.

However, there are significant regional differences in the magnitude of projected changes, which again follows a trend from the W and NE to the S-SE of Galicia. For Central Galicia, the mean temperature will be higher in summer and autumn than in the rest of the region, but on an annual level, temperatures will be higher on the West Coast, North-east Coast and South of Galicia. The number of warm nights will be higher throughout Galicia; during the summer, the number of hotter nights will be higher on the coast than inland Galicia, but in winter, this will be reversed. Annual rainfall will be higher in the SW and NE of Galicia and in the mountains in the centre of Galicia; during summer, rainfall will be decrease throughout the region, but in autumn and winter, it will increase in almost all Galicia, probably by up to 25%. In summer, the increase will mainly take place in NW Galicia, while in several areas it will actually decrease. The rain season will be reduced by an increase in climate mediterranity, with drier and hotter springs and summer than at present. The effect of such predicted changes on tree survival and growth therefore needs to be studied.

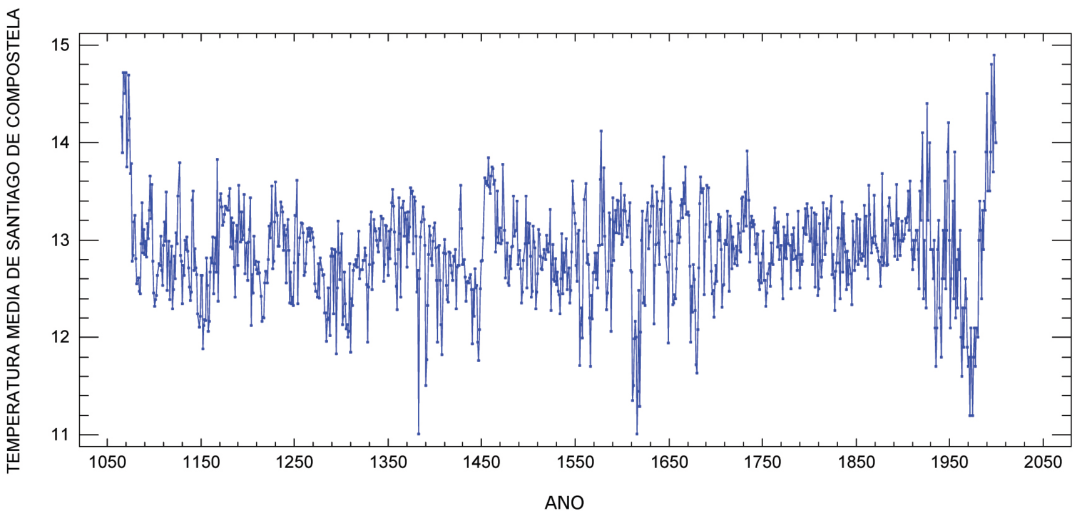


Illustration 22: Evolution of mean temperatures in Santiago de Compostela between 1065 and 1999. Between 1450 and 1625, the area was affected by the LIA (Little Ice Age) (Fernández Cancio & Manrique Menéndez, 2009)

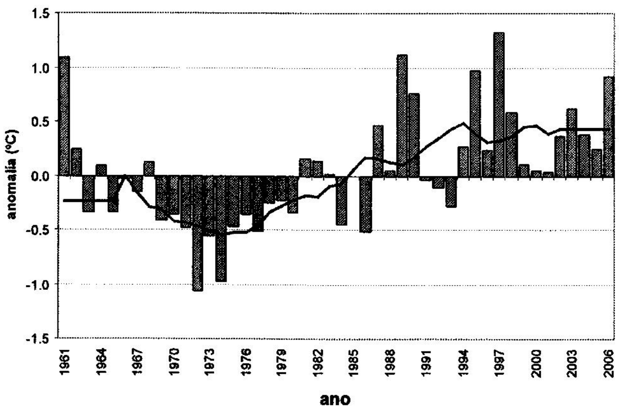


Illustration 23: Mean daily temperature in Galicia, shown as an anomaly in reference to the period 1971-2000. The right line is a mobile mean for periods of 10 years (Cruz et al., 2009)

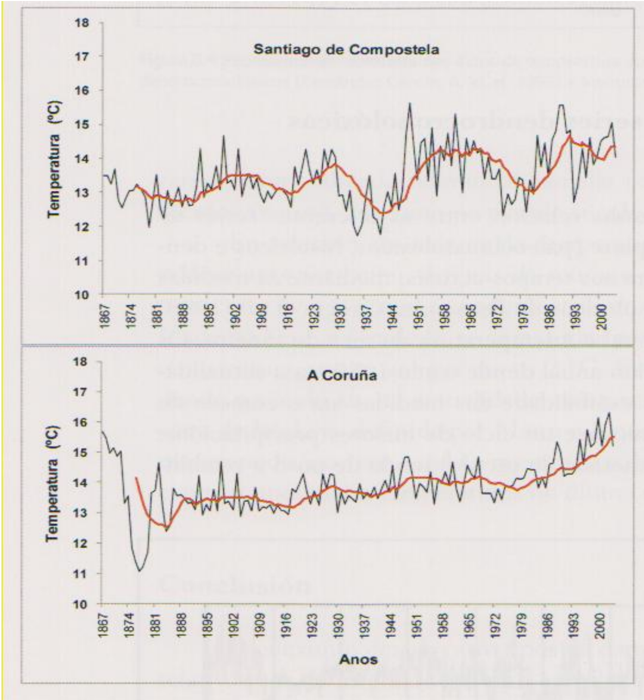


Illustration 24: Evolution of mean annual temperatures in Santiago de Compostela and A Coruña between 1875-2004. The red line is a mobile mean for periods of 10 years

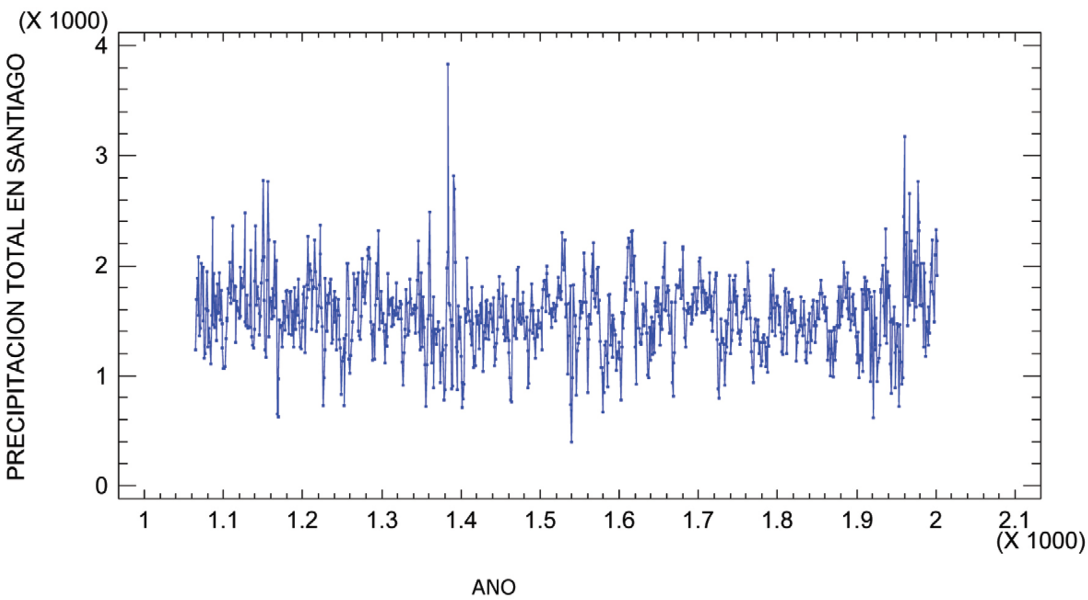


Illustration 25: Evolution of rainfall in Santiago de Compostela between 1065 and 2002. In 1380, there were 17 chronologies and variability decreased. The highest value in 1384 was 3,830 mm and has not been excluded because the next highest value took place in 1960 with 3,169 mm, which was true data. The dry seasons at the end of the 14th Century are well-documented and appear as extraordinary events. (Source: Fernández Cancio & Manrique Menéndez, 2009).

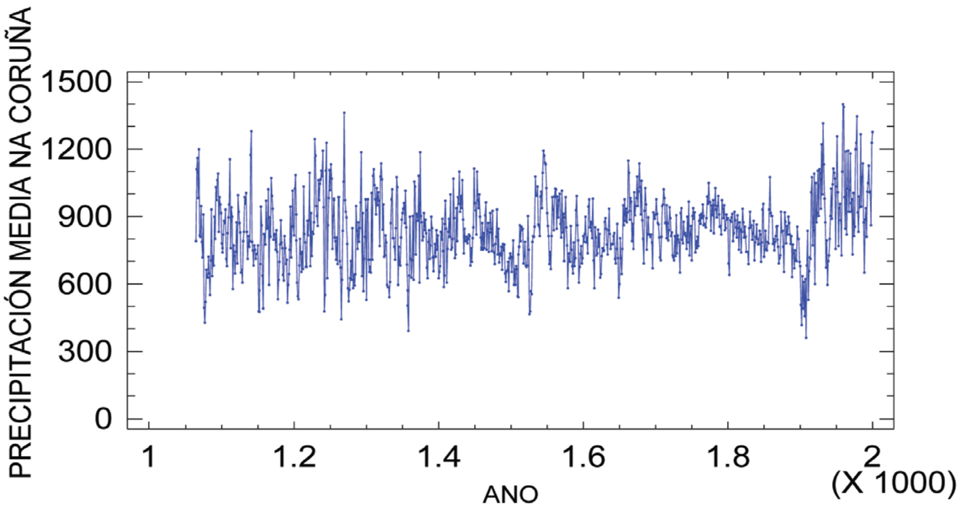


Illustration 26: Evolution of rainfall in A Coruña between 1050 and 2002. Between 1050 and 1360, variability increased as a result of the small number of dendrochronological data dates (12) in this station. In any case, these trends are valid (Fernández Cancio & Manrique Menéndez, 2009)

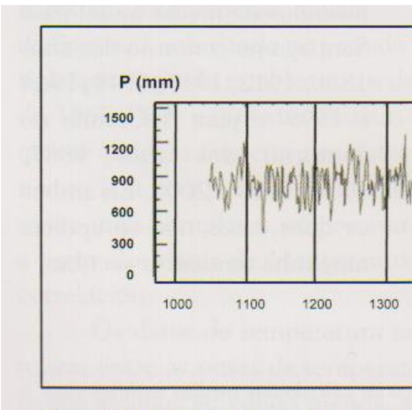
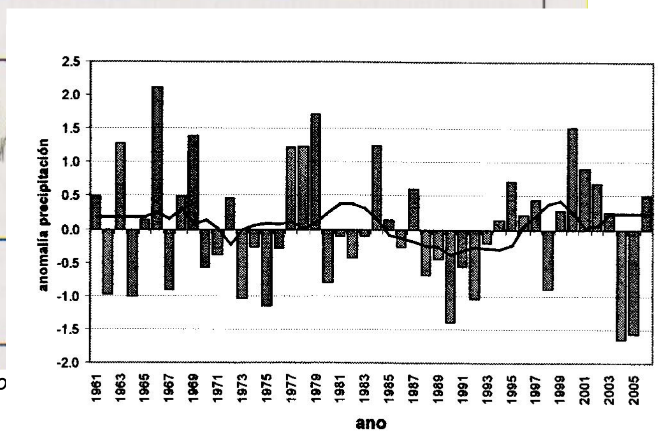
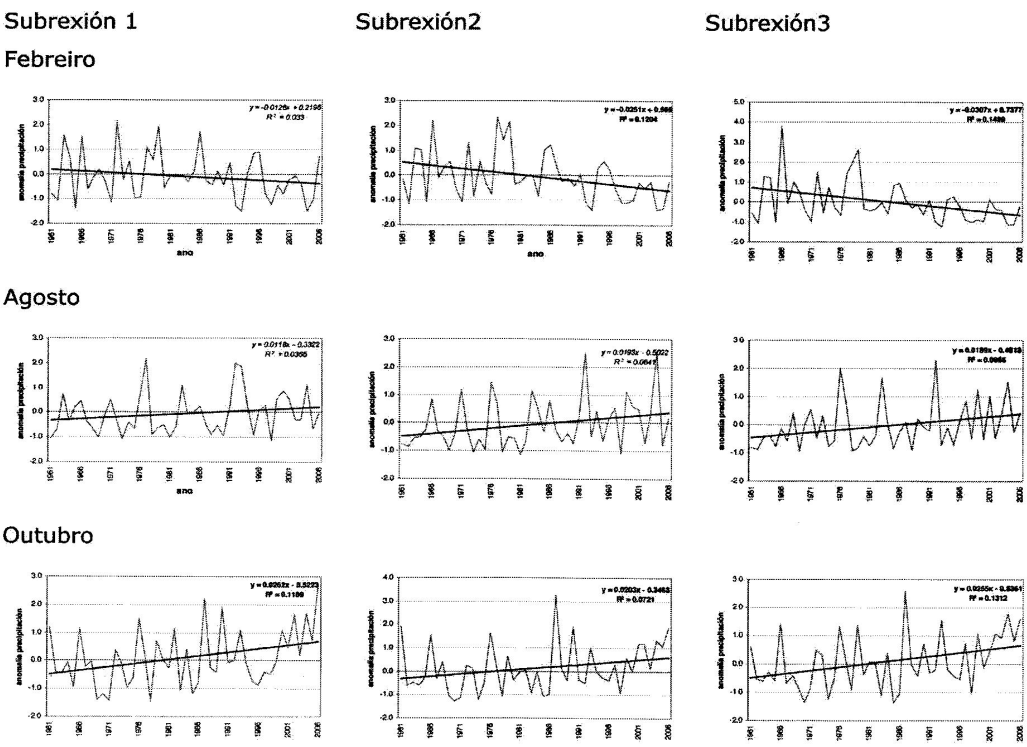


Illustration 27: Dendrochronological evolutio
& Manrique Menéndez, 1998)



llustration 29: Evolution of mean annual rainfall in Santiago de Compostela and A Coruña between 1875-2004. The red line is a mobile mean for periods of 10 years (Source: Cruz et al., 2009)



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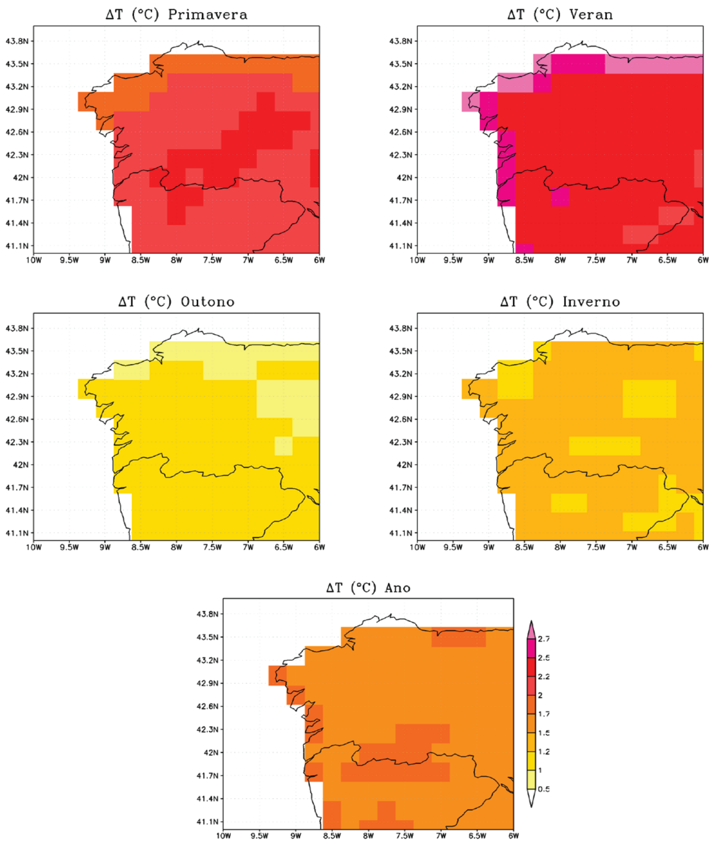


Illustration 31: Changes in mean temperatures (ºC) in different seasons primavera (spring), veran (summer), outono (autumn), inverno (winter) and ano (mean annual temperature) for Galicia between the mid-21st Century (2034-2051) and recent times (1984-1995), based on the Regional Climate Model RAMS using conditions taken from the global climate change model HadCM3 for emission scenario A1B.

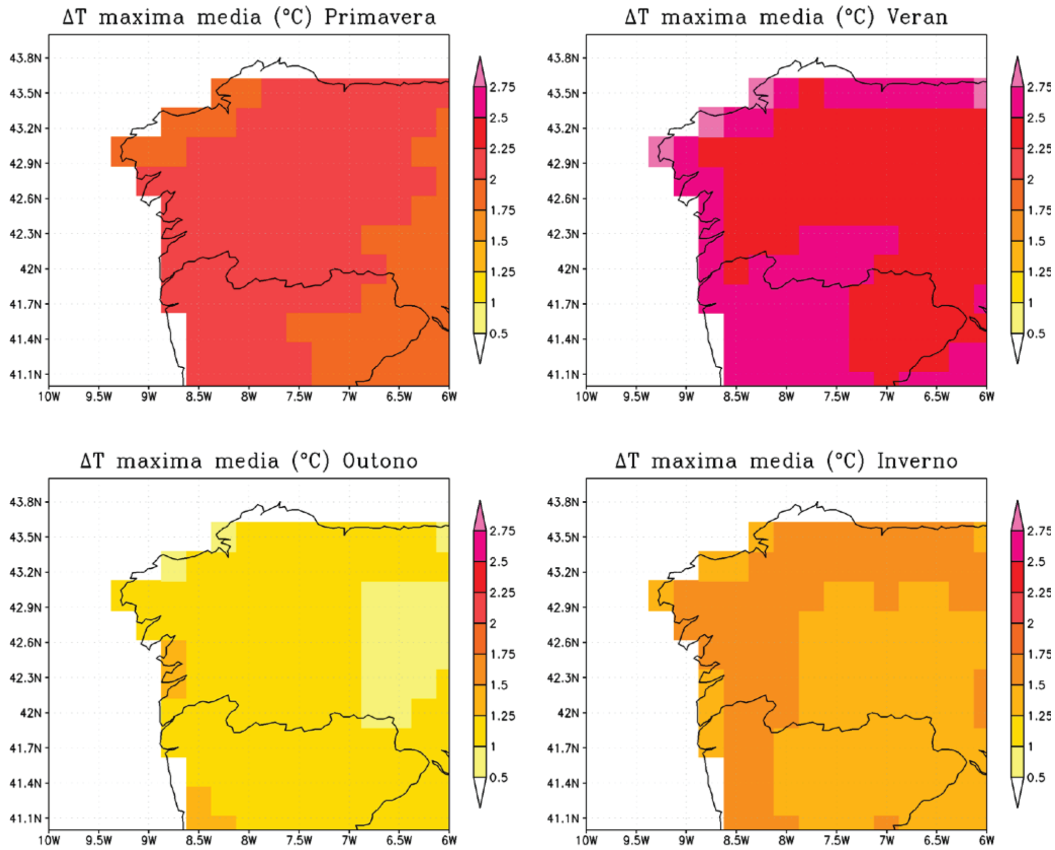


Illustration 32: Same key as in figure 23 but for mean maximum temperatures

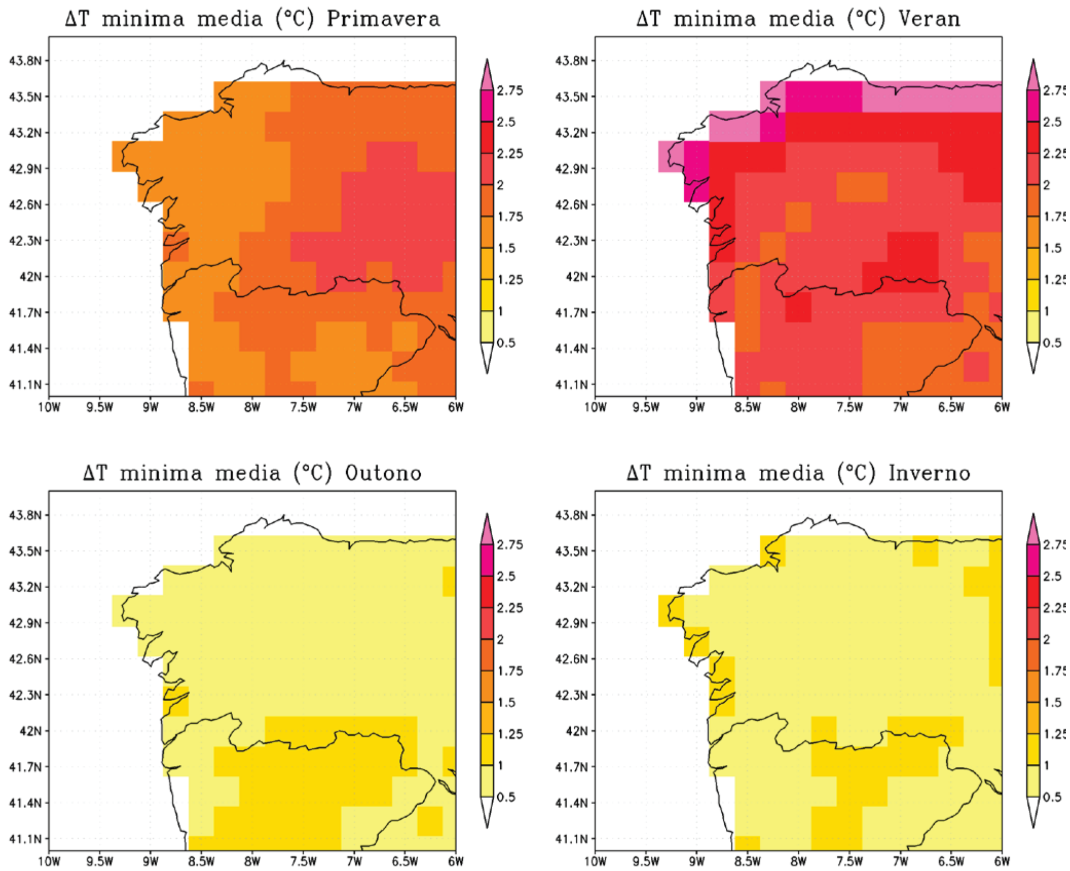


Illustration 33: Same key as in figure 23 but for mean minimum temperatures

By extrapolating the trends in the various indicators of the risk of forest fires calculated using climate simulations for the period 2000-2060, a significantly worse likelihood of forest fires is forecast for the summer months, with increases in the number of risk days and the number and surface areas of affected timberlands, whereas no significant trends are detected in March (Vega et *al*., 2009b). This trend is partly due to a reduction in moisture levels in the fine wood fuels in forest undergrowth. Likewise, the ecological impact of forest fires and increased difficulty to extinguish them can also be forecast. Although this paper does not take topographical variables into account, the risk of forest fires is seen to be greater to some extent in inland Galicia (SE) than on the coast as a result of current differentiating conditions between both areas.

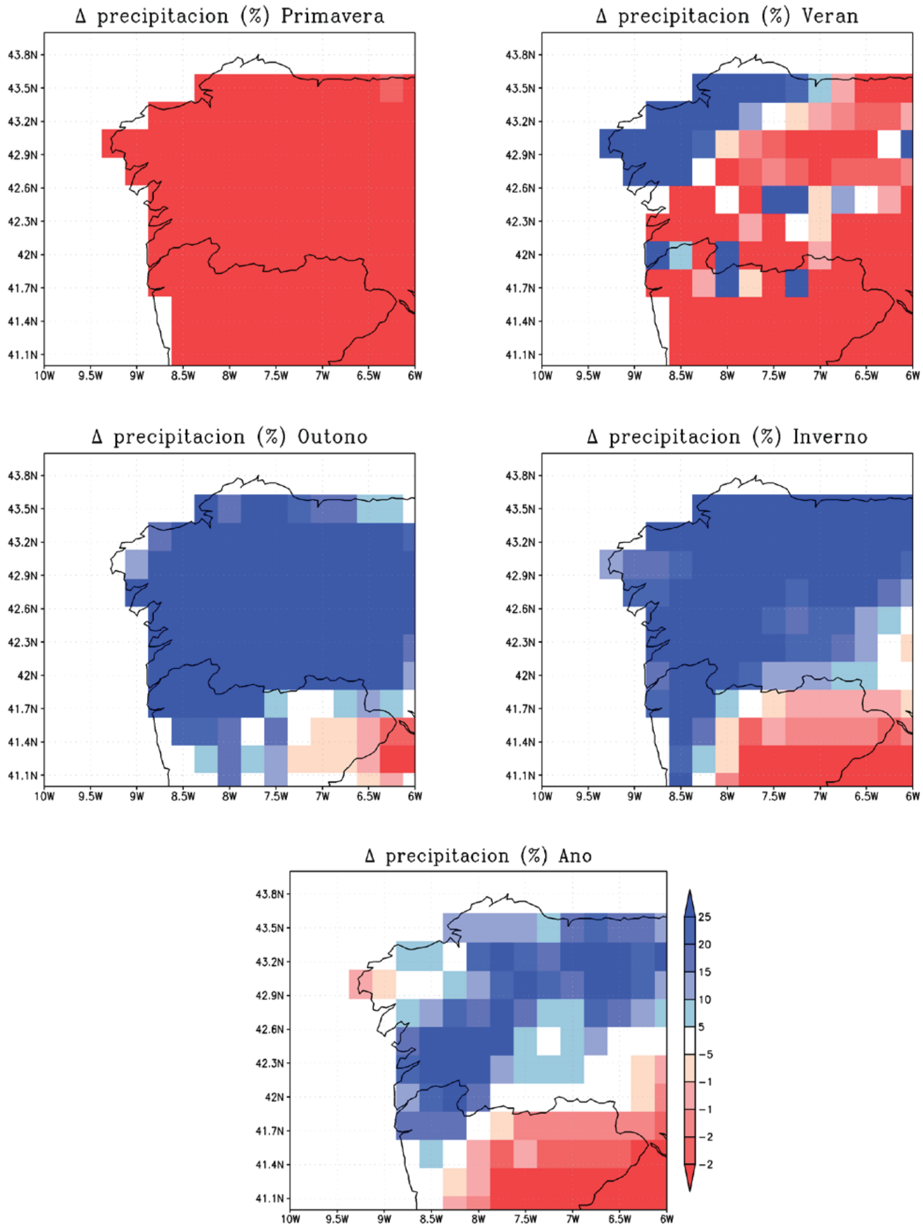


Illustration 34: Changes in mean rainfall (%) in different seasons primavera (spring), veran (summer), outono (autumn), inverno (winter) and ano (mean annual) rainfall between mid-21st Century (2034-2051) and recent times (1984-1995), based on the Regional Climate Model RAMS using conditions from the global climate change model HadCM3 for emission scenario A1B

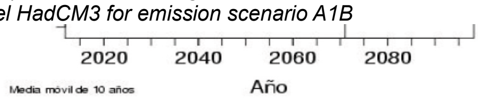


Illustration 35: Evolution of mean annual max temperature (upper left) and mean annual minimum Temp (centre left) based on different global models, regionalization techniques, and emission scenarios in relation to mean reference value in the period 1961-1990. Evolution of the mean value (continuous line), and mean value + standard deviation (shadowed) to T_{max} (upper right), T_{min} (centre right), and rainfall (lower) [The rainfall curve is the mean mobile value for a period of 10 years]. Source: Primer informe de seguimiento sobre el desarrollo del Plan Nacional de Adaptación al Cambio climático 2008, Dirección General de la Oficina Española de Cambio Climático of Ministerio de Medio Ambiente y Medio Rural y Marino

Illustration 36: Distribution of frost-free areas (Zona libre de xeadas) in Galicia in the period 2075-2099 (From Pérez Muñuzurri et al., 2009)

A study of pathological processes over the period 1977-2008 confirms that changes in environmental conditions, mainly of a climatic nature, affect the health of forest species, with significant variations in length of life and intensity (Fernández de Ana-Magán, 2009). When such changes last for a relatively short period of time – between 3 and 5 years – their effects are generally shortlived and cover very homogenous geographical areas, which enables a cause-and-effect relationship to be clearly established. On the other hand, when such changes last longer, the affected areas, even though they do maintain certain common characteristics, reveal greater heterogeneity in their environmental protraits, so that the presence and dynamics of the pathogenic agent are more difficult to justify in regard to climate change. Examples of short-lived changes are attacks by *Altica quercetorum, Phoracantha semipuntacta, Xyleborus dispar* or the dry withering of E*ucalyptus* and maritime pine. The latter case includes attacks by the *Phytoptora spp*. pest affecting various species of forest and fruit trees.

3.d Castilla y León

To predict and monitor the evolution of climate change which was done by previously developed techniques and databases of existing regionalized projections. It has made use of results from projects under the 5th Framework Program for Research and Development of the European Union related to climate modelling, dynamic regionalization (PRUDENCE project) and statistics (based teams), and estimation of extremes.

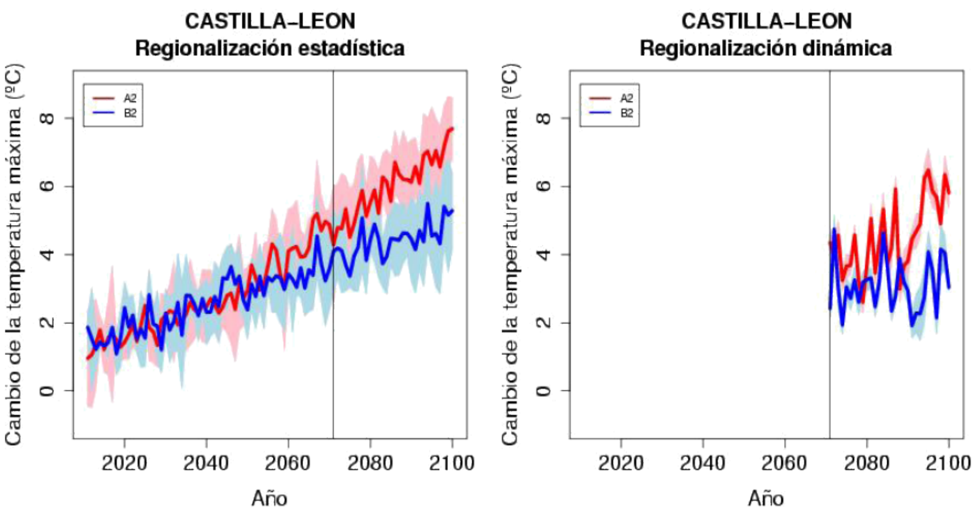


Illustration 37: Aggregation of all regional statistical projections (left) and dynamic (right) available for Castilla y León of the change of average annual high temperature

To facilitate this, we have generated an aggregate of information available from precipitation and temperature extremes in Castilla y León, using all projections from regionalization based on statistical and dynamical methods. And again, studies are comparing different methods of regionalization. Figure 36, shows the different range of uncertainties in projections that are obtained when added separately regionalized projections based on statistical methods and methods based on dynamic (PRUDENCE project).

Then there are two types of graphs for each variable (maximum temperature, minimum temperature and precipitation) in Castilla y León. In one (left of each panel) shows directly to the intermediate projections for each model annual global emission scenario and method of regionalization. The other type of graphic (right of each panel) is based on the representation of evolution of the average values and dispersion (spread) represented in the form of + / - standard deviation around the mean value.

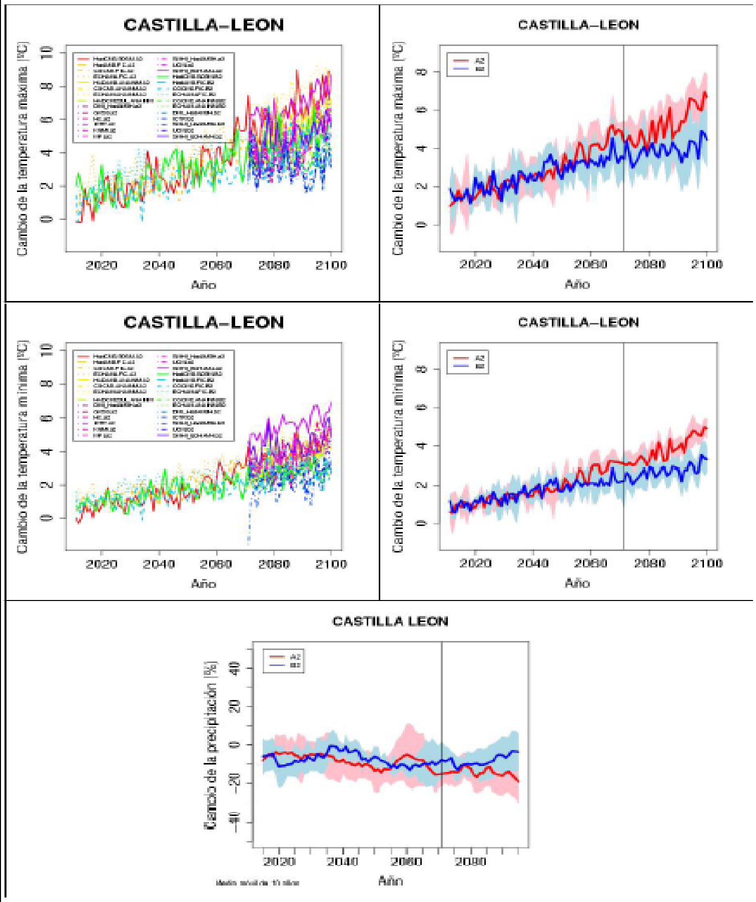


Illustration 38: evolution of the change in T max (above left) and T min (centre left) average annual Castilla y León global models obtained with different techniques, regional and emission scenarios of the average reference period (1961-1990). Evolution of the average value (solid curve) and mean + / - standard deviation (shaded) to T max (up right) T min (centre right) and precipitation (bottom). [The curve for the average rainfall is centred moving average for a period of 10 years]

3.e Basque Country

The Autonomous Community of the Basque Country does not form a homogeneous climatic region. There are three different climatic areas: (i) the north characterised by the Atlantic climate, (ii) the transitional area in the centre and (iii) the Mediterranean side in the south entering the Ebro depression (figure 6).

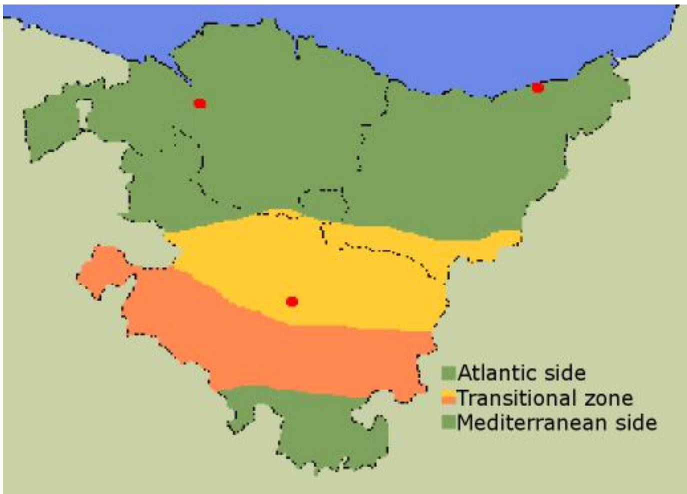


Illustration 39: Climatic areas in the Autonomous Community of the Basque Country

The Atlantic side is characterized by moderate temperatures and it is very rainy (1200-2000 mm year^{-1}), without summer drought. The transitional zone is characterised by a (i) sub Atlantic climate (in yellow) with and Atlantic climate with smaller precipitations and by a (ii) sub Mediterranean climate (in orange) in which the summers present higher temperatures and dryer months. The Mediterranean side is characterised by a dry < 30mm and hot summer >22ºC. Precipitations present a monthly mean <50mm.(Euskalmet) [1]

The topography of this community has as a consequence significant differences in the climatic parameters of its various areas. The orography of the Iberian Peninsula itself influences the general climatic characteristics of the Community as well. The main effect is that oceanic air masses that cross the peninsula in SW-NE direction are dried and when they descend to the Cantabrian Sea and the plains of South-western France, the get warm. When the air flows from the NW, the Basque mountains determine that the Atlantic air masses pass preferably over the Community towards the Mediterranean Sea. The

1

Source http://www.euskalmet.euskadi.net/s07-5921/es/contenidos/informacion/cla_clasificacion/es_7264/es_clasificacion.html strong winds blow these air masses over the Basque massif and they get cold, they condensate and precipitation occurs. That's why the Basque coast is the wettest across the Bay of Bizkaia. And that is the reason why the areas downwind of the mountains and, especially the lands of the Rioja Alavesa, and around the southern half of Navarra, receive so little precipitation.

An increase of between 1.5ºC and 4.5ºC for average annual minimum temperatures in the Basque Country is predicted over the next 100 years according to different global models and regionalisation techniques under the SRES A2 and B2 scenarios. This is with respect to the reference period (1961-1990) (Fig 38) For annual maximum temperatures, the prediction is between 2.0ºC and 6.0ºC (Fig. 39).

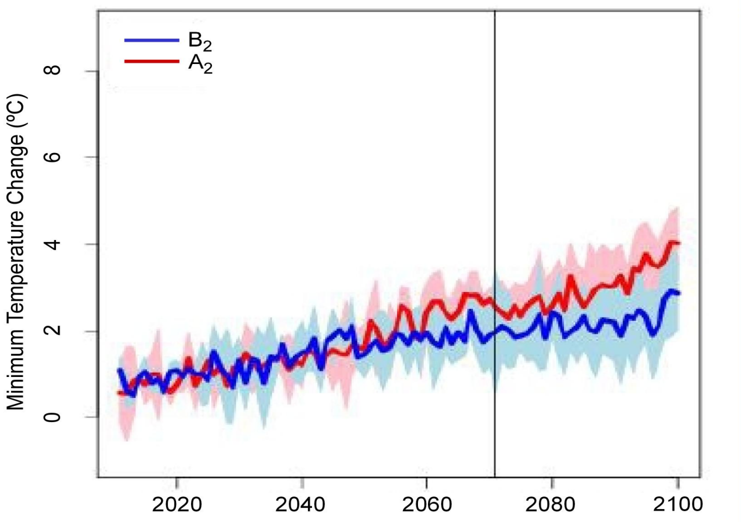


Illustration 40: evolution of change in the mean value (continuous curve) and the mean value +/- standard deviation (shaded) of the annual mean Tmin in the Basque Country, averaged out for different global models and regionalisation techniques according to emission scenarios, with respect to the average reference value in the period (1961-1990)

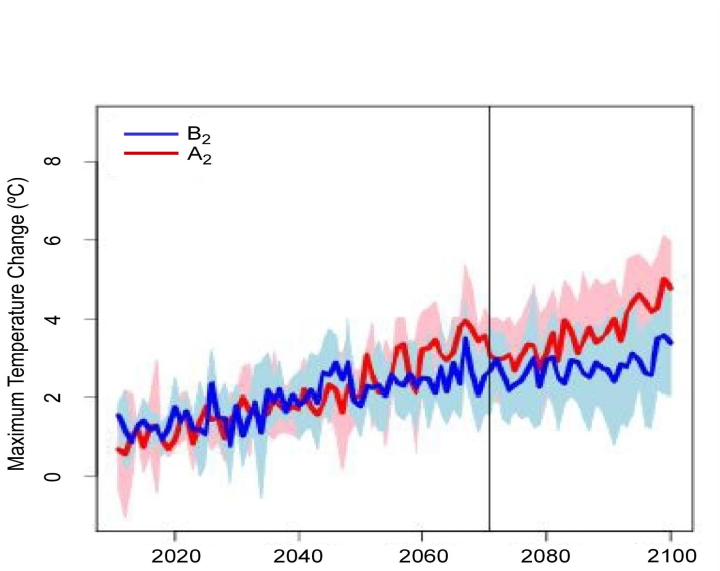


Illustration 41: evolution of change in the mean value (continuous curve) and the mean value +/- standard deviation (shaded) of the annual mean Tmax (ºC) in the Basque Country, averaged out for different global models and regionalisation techniques according to emission scenarios, with respect to the average reference value in the period (1961-1990)

In the same way and under the same suppositions, it is predicted that the impact of the increase in greenhouse gases GG could bring about a reduction of some 20% in precipitation with respect to the reference period (Fig 40).

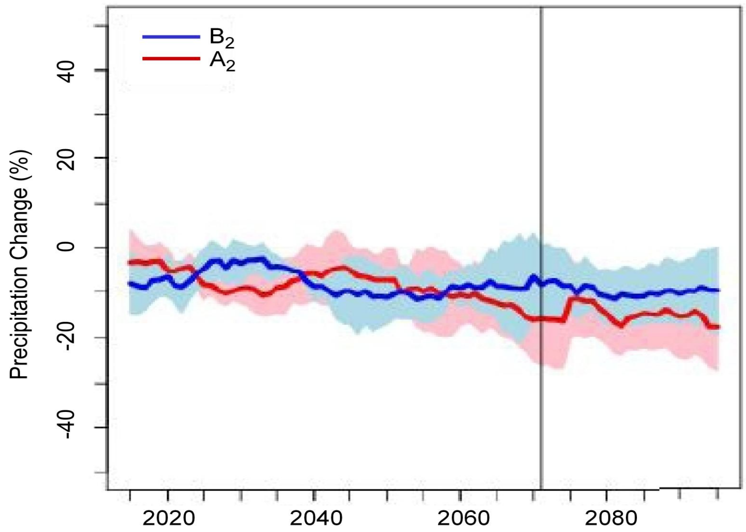


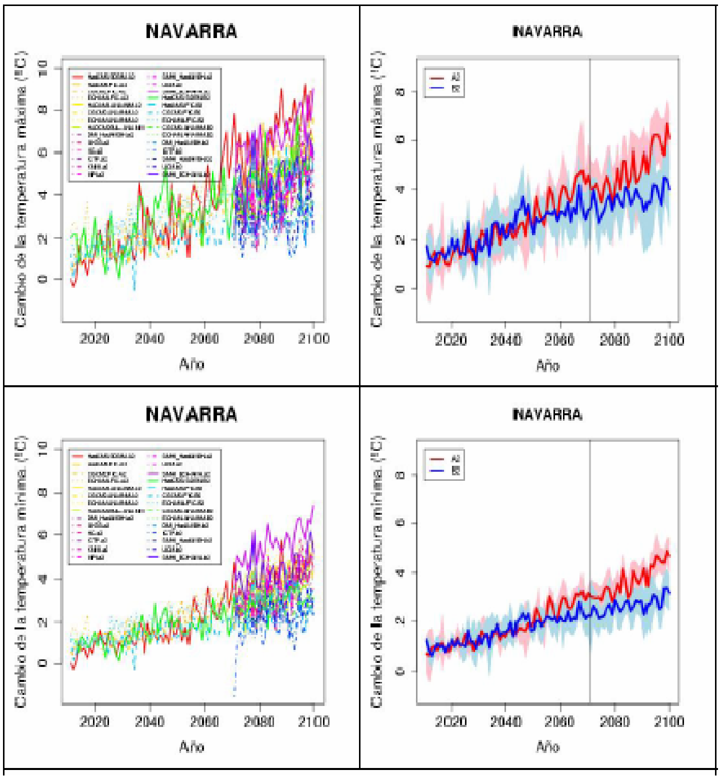
Illustration 42: evolution of the percentage of the mean value (continuous curve) and the mean value +/- standard deviation (shaded) of the annual mean precipitation in the Basque Country, averaged out for different global models and regionalisation techniques according to emission scenarios, with respect to the average reference value in the period (1961-1990)

3.f Navarra

Climate projections, by using global climatic models, show us an important and uniform rise in temperature in Península Ibérica throughout 21st century. About 0'4 ºC/ decade during winter and 0'7 ºC/ decade during summer (A2 scenario); 0,4 ºC and 0,6 ºC respectively according to B2 scenario. (Figure 41). Taking into account these data, at the end of 21^{st} century, temperature can became 4ºC and 7ªC higher during winter and summer respectively.

Intensity and frequency of extreme climatic events are expected to increase, specially heat waves in the summer.

At the same time reductions in rainfall annual values are expected in Iberian Peninsula, during the second half of the present century. This decrease will be more important in the northern half of the peninsula. In the case of Navarra, climatic sceneries indicate that annual average rainfall values will reduce circa 5% during the first half of the century. These reductions will achieve values between 15% and 25%, at the end of the century. These reductions would be maximum during spring and summer. Extreme events are not expected, although frequency of rainfall and seasonal distribution will change.



I

llustration 43: temperature evolution in Navarra 2000-2100. (source: Plan de Acción por el Clima en Navarra)

For the two climatic regions in Navarra (temperate and moist in the north, drier and more continental in the centre, south and Ribera), the main climate change impacts affecting the forest resources of Navarra are described below:

- Hydric shortage is not important in Navarra currently, but, throughout this century water availability will be lower.
- Edafic resources will be affected seriously by rising in temperature. In this way, organic carbon stock will drop around 6-7% per every increased grade.
- According to several studies there will be changes in some factors likel flowering, foliation and fructification, that could affect the distribution of forest tree species. These phases will be earlier; latitudinal, longitudinal and altitude movements. In this aspect, deciduous and high mountain species are the most vulnerable. Riparian forests, in the south of Navarra, will be damaged seriously, due to the rise in temperature and a drier environment, water table will drop.

- Higher risk of forest fires, new pests and diseases. It could be a bigger number and more severe damage caused by both biotic and non biotic agents.

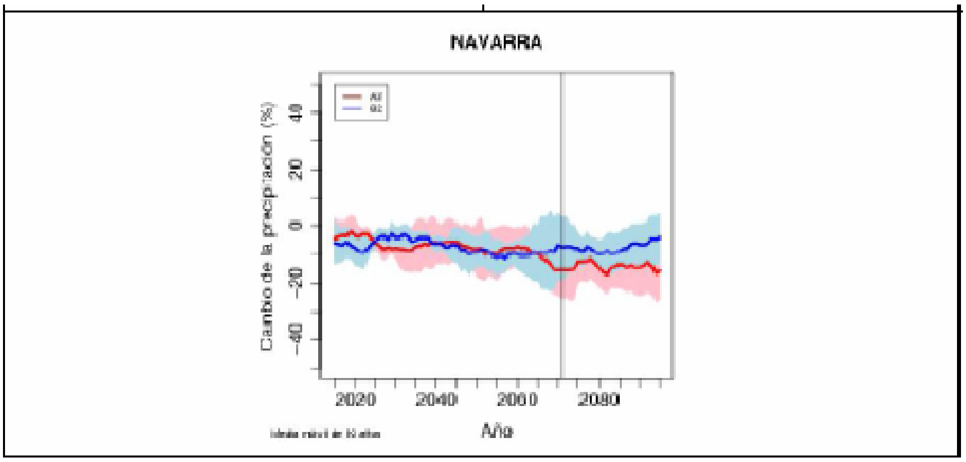


Illustration 44: Rainfall evolution in Navarra 2000-2100. (source: Plan de Acción por el Clima en Navarra)

3.g France

There are considerable variations of climate within France, therefore it is most convenient to describe briefly what can be found in the climatic regions involved in the REINFFORCE project:

Northwestern France:

This area comprises the coasts and adjacent inland from Upper Normandie to the River Loire. It has the most atlantic climate in all France. Winters are generally mild and frost and snow are not too frequent. Rainfall is equally distributed throughout the year.

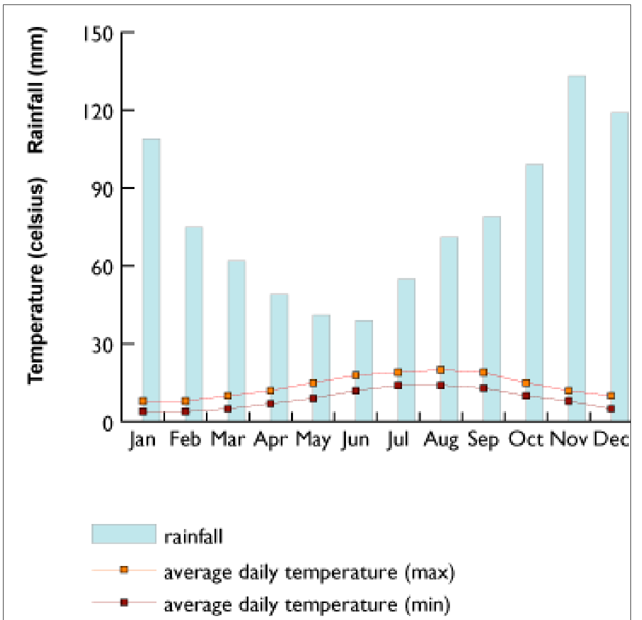


Illustration 45: Temperature and rainfall in Cherbourg (source: MeteoFrance – traitement Helicon publishing)

Southwestern France:

This area is mainly a lowland region. Winters are generally mild and cold spells do not last for long.

The summers ares significantly warmer and sunnier than in northwestern France. They can be rather wet, particularly towards the Pyrenees and the spanish border, though there is a marked rainfall gradient from south to north and from west to east.

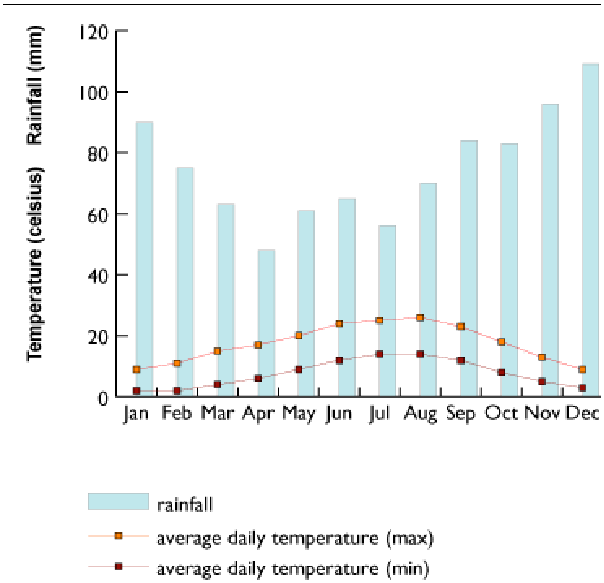


Illustration 46: Temperature and rainfall in Bordeaux, source meteoFrance – traitement Helicon publishing

France has two climate models, one developed by Meteo-France and CNRM (National Center for Meteorological Research), and the other by IPSL (Institut Polytechnique Simon Laplace), which mainly differ in ther atmospheric components.

The simulations made for the 4th IPCC report cover climate from 1860 to the present as well as projections for the 21st century. As for 20th century, the trends simulated with the two french models are consistent with temperature observations, both at global scale and for France.

Several national and European projects allows to use those models for regional projections, at national scale:

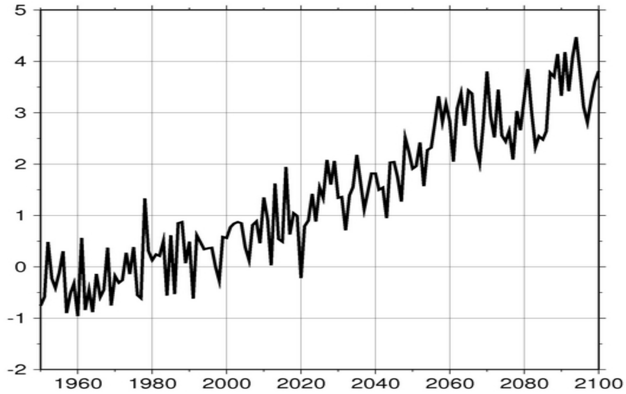


Illustration 47: Renationalisation of simulation ESCRIME-CNRM (scenario SRES-A1B) with ARPEGE with solved variable: average year in south France

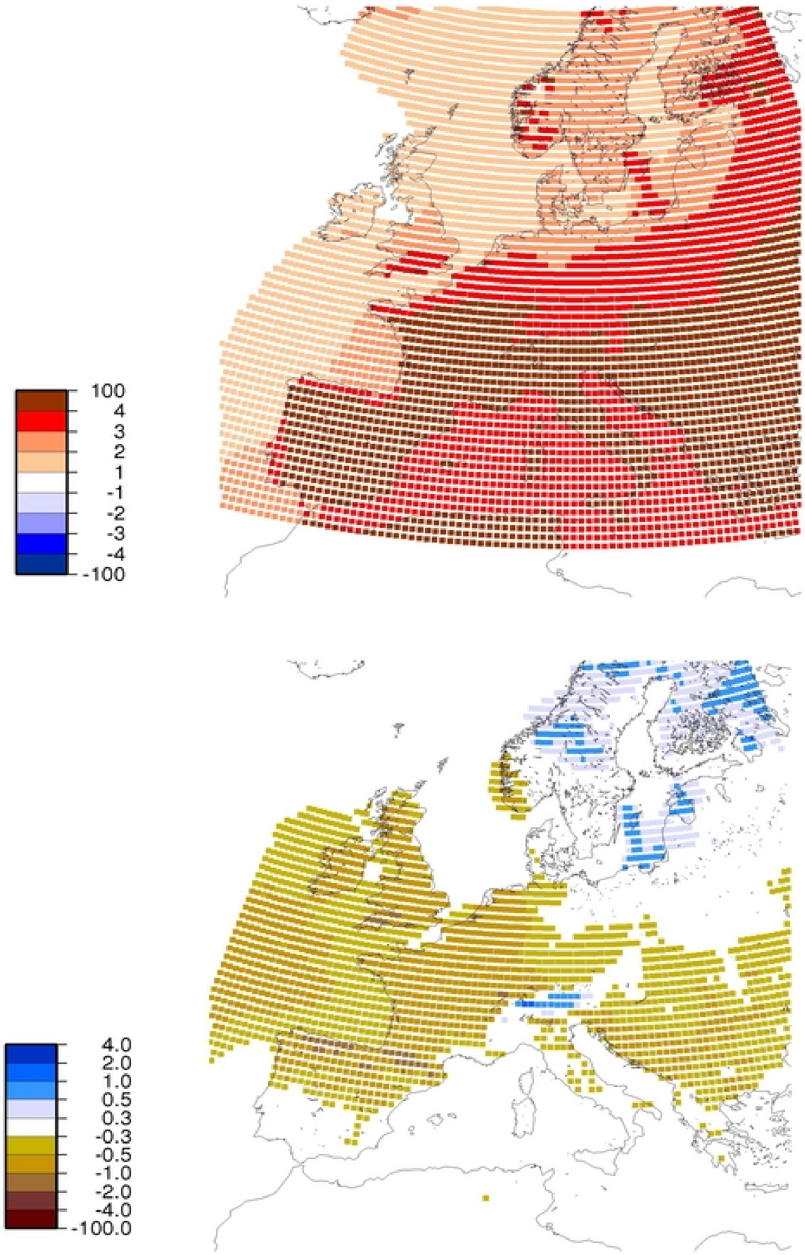


Illustration 48: Regionalisation of simulation ESCRIME_CNMR (scenario SRES-A 1 B) for Europe: a) temperature effect (K) and b) rainfall (mm/day) in summer for period 2071-2100. Source: white book Escrime

In France, the climate projections show an increase of temperature in all seasons, more important in summer. Rainfall should decrease in winter in the South and increase in the north of the country.

As for extreme weather events, high resolution simulations were produced with the IPSL and CNRM models for the A2 scenario. The results show a substantial increase in heatwaves, moderately increasing risks of heavy winter rain.

There is no clear trend about high winds but the models show a negligible impact.

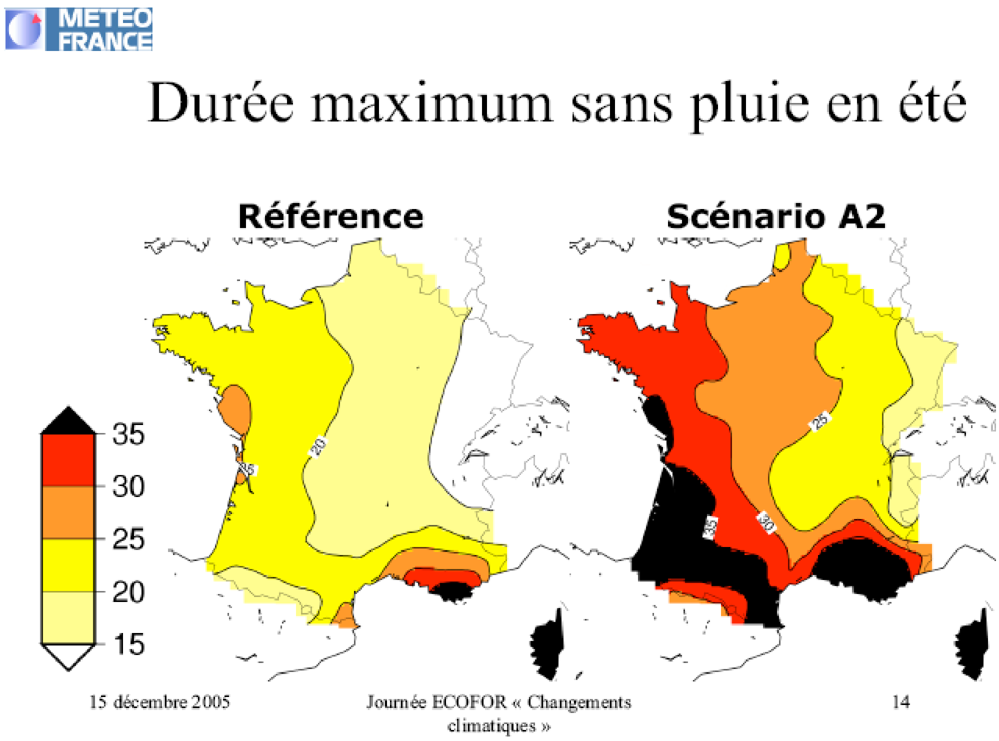


Illustration 49: Maximum period without rain in summer: situation in 2000 and prediction en 2100 with GIEC scenario “A2” (+4°C). (Source Déqué 2005)

S. Jousseaume, D. Armand, P. Delecluse, B. Seguin, V. Journé, R. Delmas et M. Gillet, 2007. Climate Change Research in France. Institut National des Sciences de l'Univers. 19 p.

The Carbofor project (2002-2005), coordinated by INRA – UMR EPHYSE, made an estimation of the consequences of climate change on forest ecosystems in France. The research work was based on the GIEC's scenario called « B2 ». It supposes an increase of average temperature about 2,5°C from now to 2100 (between 1,8 to 4°C – GIEC 2007)

The increase in the concentration of atmospheric CO_2 have an influence on photosynthesis. The doubling of this parameter leads to an increase of 20 to 30% in the photosynthetic production of forests.

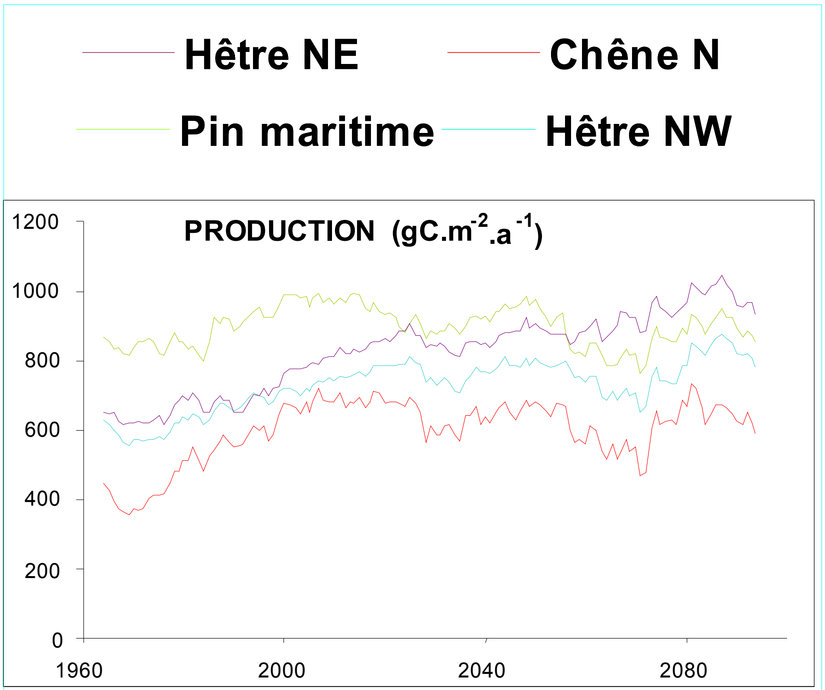


Illustration 50: Evolution of production in four forest types in France from 1960 to 2100 (source: CARBOFOR)

Physical impact of climate change on forests can be characterized by an increasing of forest production from 2030 to 2050, then a stable period or decline from 2070 to 2100.

The growth can be superior in northern part on France. In southern regions, gross productivity is supposed to be more affected by water stress (soil and/or atmosphere), due to the more marked evolution of the difference of precipitations between summer and winter.

The evolution speed is a worrying question as for the adaptation capacity of tree species. Research team from INRA have estimated the future repartition of several group of tree species in 2100.

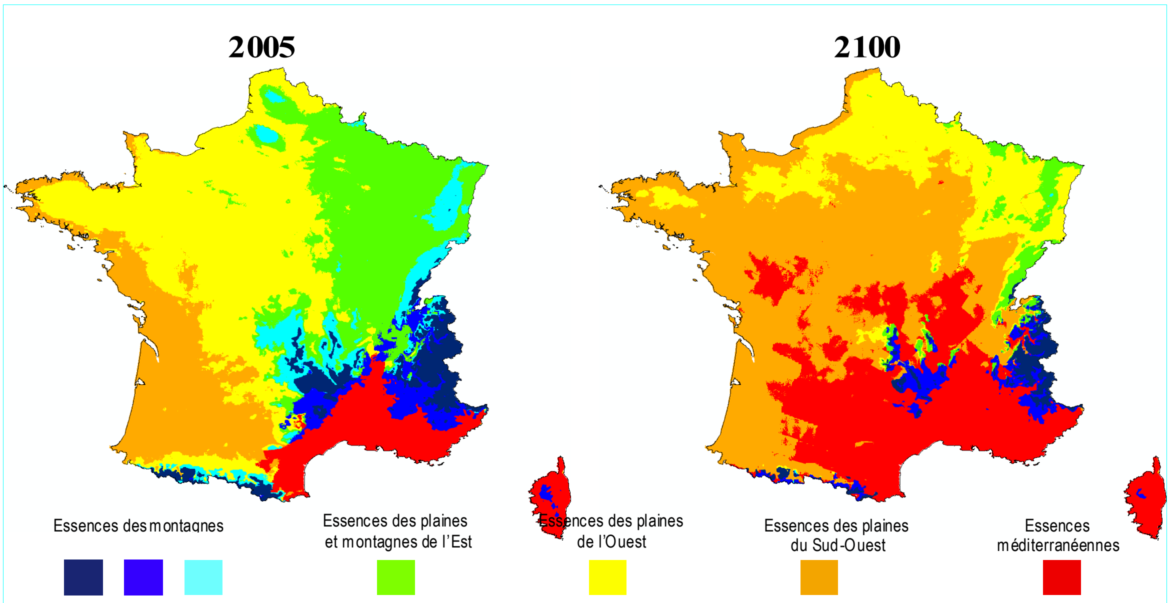


Illustration 51: Evolution of the potential range of distribution of biogeographical groups of species from 2005 to 2100 (source: CARBOFOR, Badeau et al. 2005)

In terms of risk evolution, global warming may induce more frequent extreme climatic events such as droughts, barrages and floods or even storms. Therefore the trees ans stands may become less resistant to pests and diseases.

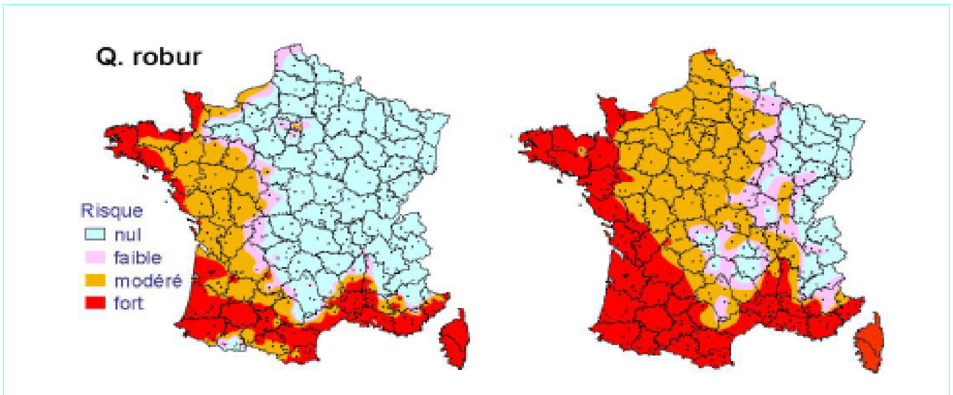


Illustration 52: Model evolution of Oak canker potential distribution from present situation (1968-1998) on the left to future (2068- 2098). (Source: CARBOFOR – Marcais and Desprez-Lousteau

Climate change can have consequences on tree pathogens biology or spatial distribution (*Illustration 49*).

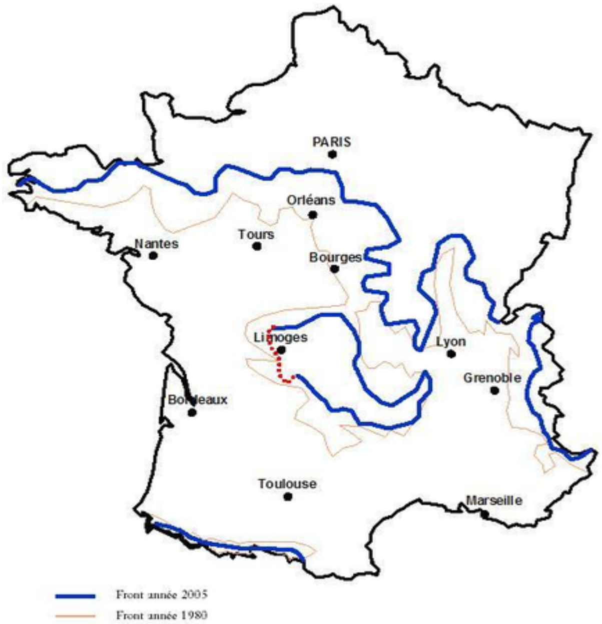


Illustration 53: Expansion of processionary caterpillar in France from 1980 to 2005

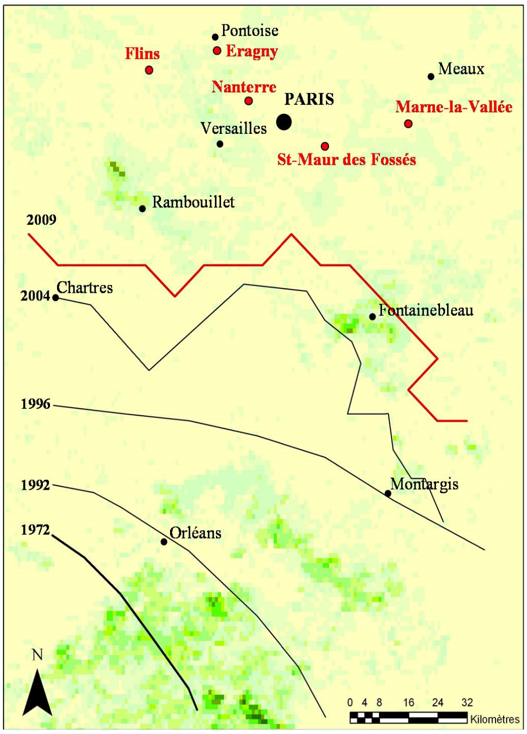


Illustration 54: Expansion of processionary caterpillar in Paris area from 1972 to winter 2008-2009

3.h United Kingdom

There is clear evidence that the climate of the UK has changed over recent decades (Jenkins, Perry and Prior, 2009):

- Annual mean precipitation over England and Wales has not changed significantly since records began in 1766. Seasonal rainfall is highly variable, but appears to have decreased in summer and increased in winter, although with little change in the latter over the last 50 years.
- All regions of the UK have experienced an increase over the past 45 years in the contribution to winter rainfall from heavy precipitation events; in summer all regions except NE England and N Scotland show decreases.
- There has been considerable variability in the North Atlantic Oscillation, but with no significant trend over the past few decades.
- Severe windstorms around the UK have become more frequent in the past few decades, though not above that seen in the 1920s.
- Sea-surface temperatures around the UK coast have risen over the past three decades by about 0.7 ºC.
- Sea level around the UK rose by about 1mm/yr in the 20th century, corrected for land movement. The rate for the 1990s and 2000s has been higher than this.

Over the past 30 years, phenology (the study of the times of recurring natural events especially in relation to climate) records have provided clear evidence that spring is arriving earlier. Many species of tree, for example, that are sensitive to spring temperature are producing leaves earlier (Sparks and Gill, 2002).

In the UK, the United Kingdom Climate Impacts Programme has produced a series of projections for the future climate of the UK under different emissions scenarios. The most recent (UKCP09[1]) is the fifth generation and is the most comprehensive produced to date. It provides probabilistic projections of climate change based on quantification of known sources of uncertainty.

Examples of outputs for summer and winter mean temperature and precipitation are shown in Figures 50-53.

Key findings for the UK are:

- All areas of the UK get warmer, and the warming is greater in summer than in winter.
- There is little change in the amount of precipitation (rain, hail, snow etc) that falls annually, but it is likely that more of it will fall in the winter, with drier

1http://ukclimateprojections.defra.gov.uk/content/view/868/531/

summers, for much of the UK.

- Sea levels rise, and are greater in the south of the UK than the north.

However, there are significant regional differences in the magnitude of projected changes, which again follows a trend from the north-west to the south-east of Britain. Projections for northern Scotland, show moderate increases in winter and summer temperatures, a moderate increase in winter rainfall, and a small decrease in summer rainfall. Whereas projections for Southern England show an increase in the seasonal temperature ranges with milder winters and much warmer summers, combined with wetter winters with much drier summers. The trend towards warmer temperatures and milder winters is likely to have positive benefits for tree growth; however, an increase in the frequency and severity of drought, particularly in southern Britain will have adverse consequences for growth and survival. Increased frequency of storms and heavy rain days will also have negative

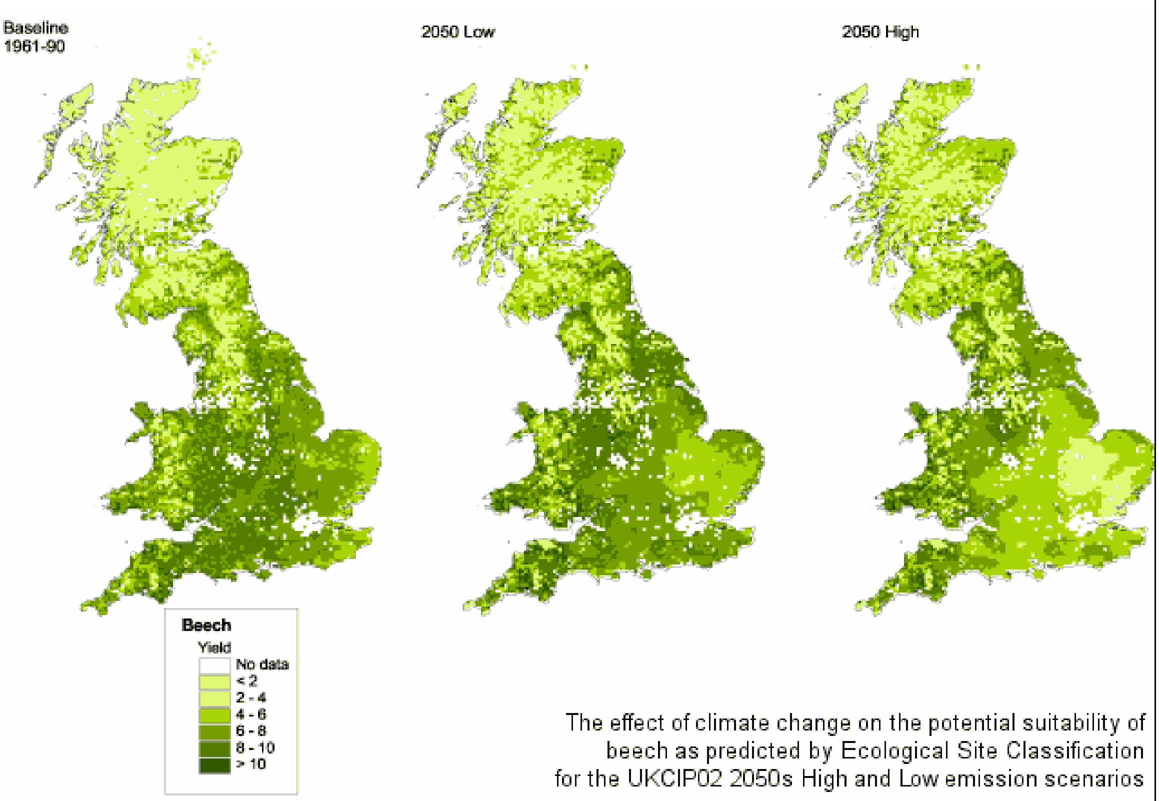


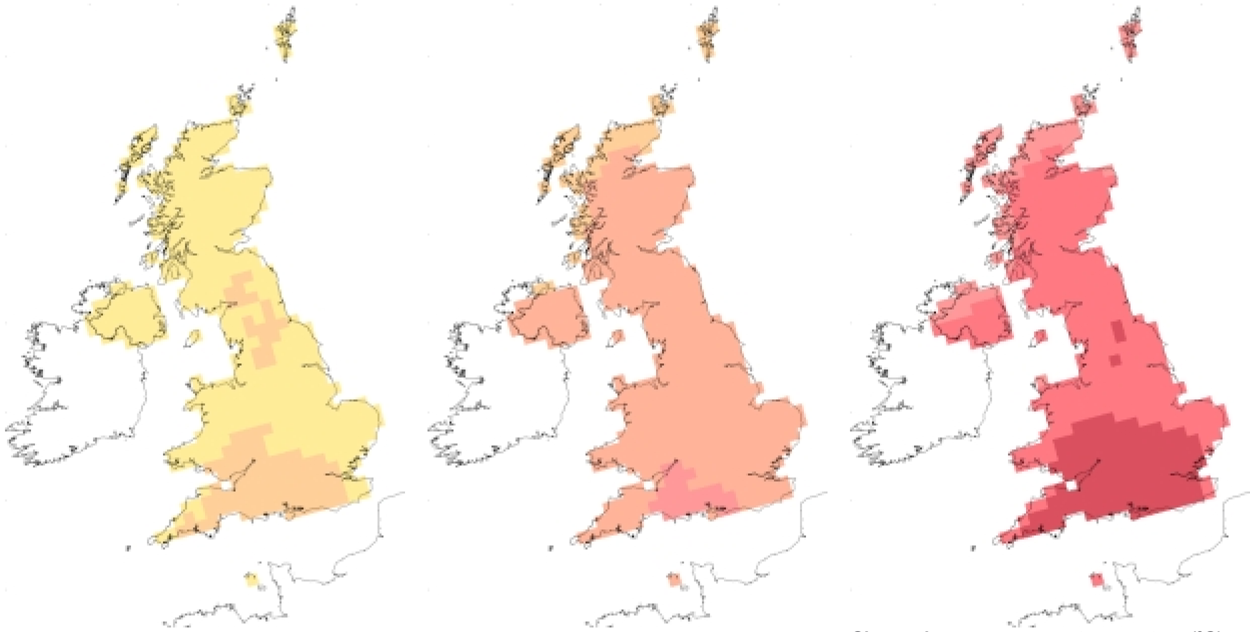
Illustration 55: Effect of climate change in potential station of beech in Great Britain

impacts on forestry.

10% probability level:
very unlikely to be less than

50% probability level:
central estimate

90% probability level:
very unlikely to be greater than

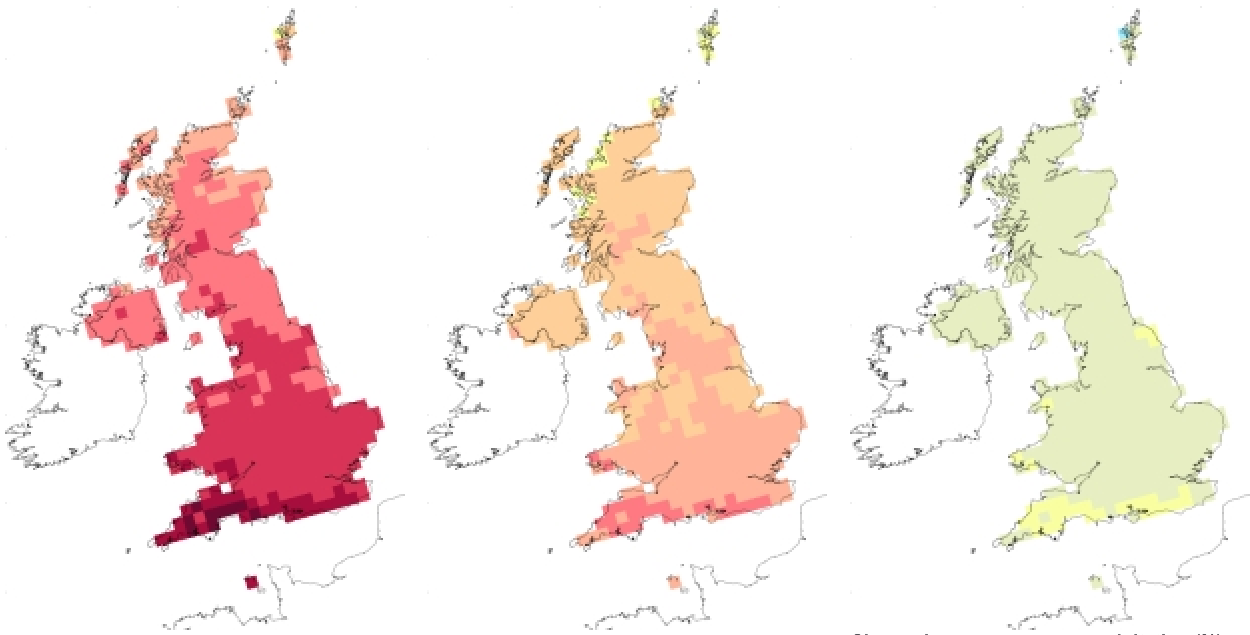


Change in summer mean temperature (ºC)
Medium emissions

10% probability level:
very unlikely to be less than

50% probability level:
central estimate

90% probability level:
very unlikely to be greater than



Change in summer mean precipitation (%)
Medium emissions

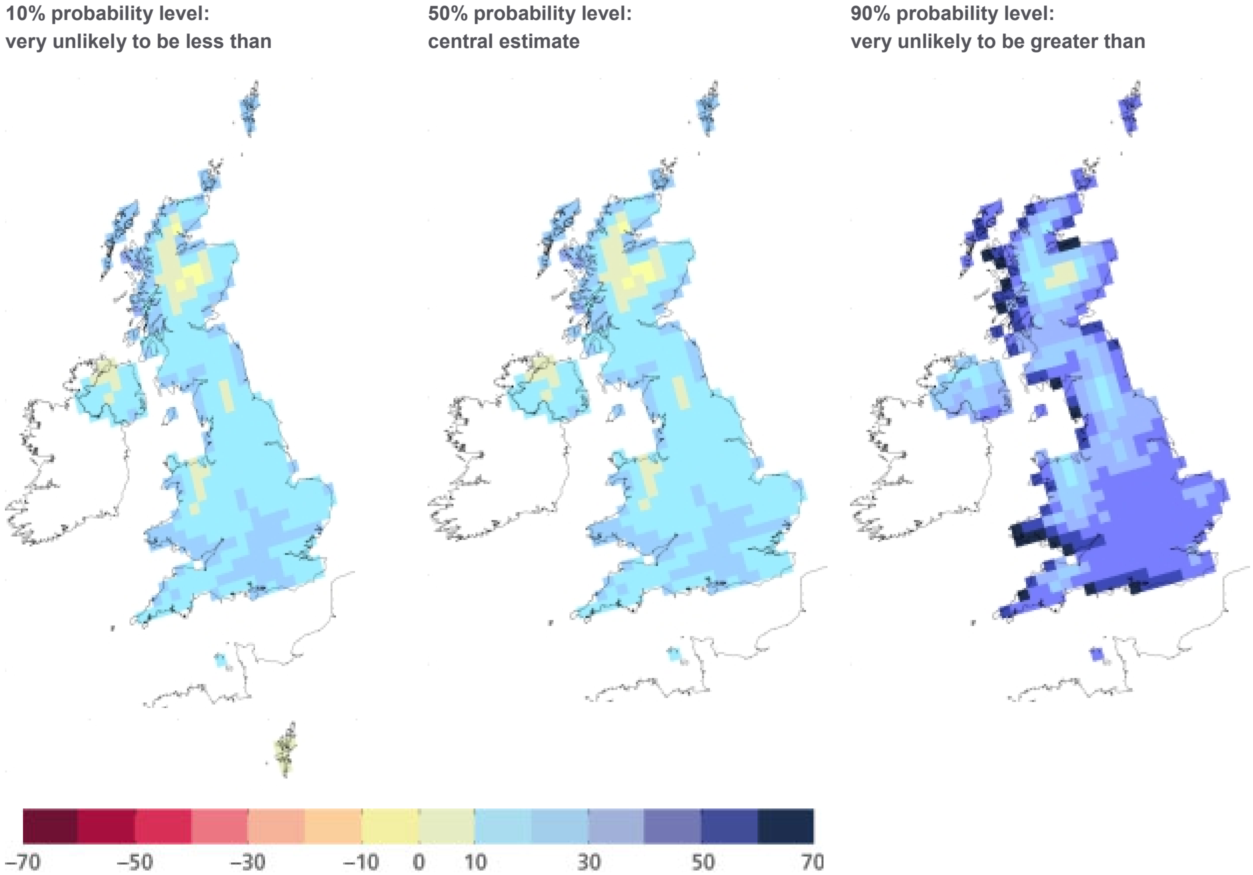


Illustration 56: Change in winter mean precipitation for the 2080s under a medium emissions scenario

4 Forest adaptation to climate change in the Atlantic European Area Potential Options for Management.

During the last years several scientific publications have been addressing the impact of climate change on forest resources. Mainly focusing on a long term impact on the forest species under a future climatic scenario presenting, of course, a certain grade of uncertainties. In this context the REINFFORCE project set up two methods:

- a network of arboreta with weather stations to know the exact climatic characteristics for productive species
- a network of demonstration sites to demonstrate the benefit of adaptive management compared with business, as usual.

4.a

Most of the information of these paragraphs come from ECHOES-COST[1] action country reports (United Kingdom, France and Spain), the European Commission DG Agriculture[2] report "Impacts of Climate Change on European Forests and Options for Adaptation",[3] and more traditional references of forest management and Silviculture[4]. This review is focused on how to address the European Atlantic Forests adaptation to climate change through forest management.

Climatic changes will bring many and complex effects for forests over different EU bio-climatic regions. Rising atmospheric CO2 concentration, higher temperatures, changes in precipitation, flooding, drought duration and frequency will have significant effects on trees growth. These climatic changes will also have associated consequences for biotic (frequency and consequences of pests and diseases outbreaks) and abiotic disturbances (changes in fire occurrence, changes in wind storm frequency and intensity) with strong implications for forests ecosystems[2].

From the previous chapters is possible to gather that the most common events or perturbations that the European Atlantic Forest will face are more frequent and intense extreme episodes of wind, floods, snow, drought and fires as well as a continuous change

1 http://www.gip-ecofor.org/publi/page.php?id=107&rang=0&domain=37&lang=en_GB

2 http://ec.europa.eu/agriculture/analysis/external/euro_forests/index_en.htm

3 ttp://www.fwpa.com.au/Resources/RD/Reports/PNC068-0708_Research_Report_Climate_Change.pdf?pn=PNC068-0708

4 Chapters 5, 6, 7, 8, 10, 11,12 and 13 from Savil, P. et al, 1997. Plantation Silviculure in Europe. Oxford University Press.
Chapters 2,3 and 4 from Matthews, J.D. Silviculture Systems.1991.Oxford University Press.
Chapter 19 from Smith, D.M. The Practice of Silviculture. 1997 John Wiley and Sons.

2 http://ec.europa.eu/agriculture/analysis/external/euro_forests/index_en.htm

towards increasing temperatures and reducing air humidity.

Partly following the suggestions of the European Commission DG Agriculture[2] "Impacts of Climate Change on European Forests and Options for Adaptation" the measures are grouped in the following categories: forest regeneration, intermediate treatments, forest operations, forest management, forest protection, plant production and tree breeding.

Forest regeneration

Forest regeneration offers a direct and immediate opportunity to adapt tree species or provenances to the changing climatic conditions. Regeneration is the stage at which the species and genetic composition of the stand get established, where diversity builds up and can be manipulated. The choice between natural and artificial regeneration is crucial in the measure that it will influence all the growth process. The artificial seedling allows to accelerate the process of adaptation, planting species or provenances that already show a positive reaction to the impacts of climate changes on a specific site but limiting the expression of local diversity. But limiting the expression of local variety.

- *Selection of well adapted or adaptable provenances and species.* The regeneration phase is sensible to changes in climate (Spittlehouse and Stewert, 2003) as young seedlings and plants are particularly sensitive to drought (Oliet et al., 2002) or other extreme climatic conditions. It is during the regeneration phase that a first "selection" of species and provenances can be done on the base of their reactions. But this process does not have to abstract from the fact that a well adapted seedling can grow up fast and consequently increase the resources demand.

- *Promotion of mixture and diversification of species, provenances and genetic units.* A selection of a wider range of species and genetic diversity may improve the resilience of forests to climate change autonomously. This diversity can be supported by use of natural regeneration techniques (Spiecker, 2003; Badeck et al., 2005; Broadmeadow et al., 2005; Resco De Dios et al., 2007). The use of the natural regeneration and natural regeneration techniques can be promoted in low or constant changing rate of the climate. But if sudden changes happen the artificial regeneration can allow to use the better adapted species or provenances to the new climatic conditions. In this extreme situation it is not possible to use artificial regeneration techniques using local or mixed genetic resources to increase the genetic pool.

- Reduction of drought stress of stands by:

- Decreasing density in plantation forestry and/or adaptation plantation seedling schedules

- Switching of the main species of stands. In the case of a mixed forest it can be possible that one species shows a better adaptation than others in the new climatic conditions. In this case a good practice could encourage the better adapted species even if it will

2 http://ec.europa.eu/agriculture/analysis/external/euro_forests/index_en.htm

replace the main species of the stands.

- Increasing the soil-root potential interface throughout soil cultivation
- Weed control to limit competition for water
- Using mulching materials or biochar to improve water capacity of soil
- Micro-catchments reducing run-off and increasing infiltration to the plant roots

Intermediate treatments

The intermediate treatments like thinning and tending and complementary operations are classic silvicultural practices applied to enhance growth, quality, vigor and composition of the stands. In the frame of the adaptation of the stands to climate changing, modification of frequency and intensity of tending and thinning are mostly aiming at improving stand structure's stability particularly for temperate and mountainous regions. That should aim at reduce the stands' susceptibility to biotic and abiotic disturbances.

- *Changing the thinning regimes making the stand more stable at their maturity to extreme events*. Generally, the thinning practices have to be more intensively applied to increase the proportion of valuable large-dimensioned timber on the total harvest volume. Additionally, intensified harvesting may have some effect on site productivity by altering the nutrient cycle and reducing competition for light, nutrients and water (Kellomäki et al., 2000; Spiecker, 2003). At drought prone sites more intensive thinnings are reducing stand evapo-transpiration and thus counteracting increasing drought stress (Kellomäki et al., 2000; Spiecker, 2003), especially if understorey is weak.
- *Lower stocking values at the early stages in the development of the stand for increasing the resources availability per individual tree.* Particularly, in poor site soil this practice can be important to avoid species competition for the available resources.

REDUCTION OF FIRE RISK	- Maintenance of forest edges
REDUCTION OF FIRE AND DROUGHT RISK	- Management of ground vegetation for minimising evapo-transpiration and increasing the nitrogen fixation - Weed control - Management of the residuals of operations chopping or mulching slash or debris - Continuous cover techniques
REDUCTION OF WIND DAMAGES	- Promotion of self-thinning mixture of species or provenances
OTHER	- Using short term weather for tactical application of fertiliser and regeneration cuts

Table 20: some maintenance operations to enhance the intermediate treatments objective

Forest Management

Forest management and planning is becoming more challenging in the perspective of climate change. New planning and decision support tools are needed to deal with uncertainty and risk in long-term forest planning. Flexible adaptive planning, which takes into account all conceivable scenarios and allows to consider multiple options for future development, may be the best suited alternative.

- *Development of flexible management plans.* In this scenario, a flexible plan is the base that can ensure not only a long term adaptation, but it has to be conceived as something that can face sudden changes.
- *Use of expected climate within the specie-site selection criteria.* It is advisable to choose the climatic species distribution on the base of the available studies of the future climate scenarios.
- *Early identification of seed trees for a good crown and taper stem development.* Both this and the next practice can accelerate the adaptation process and thus reduce the considerable lead times of silvicultural measures.
- *Reducing of rotation periods to accelerate the growing rate of the stands.* To reduce the exposure to risk and benefit of increased growing rates. From the other hand it is important to consider that this practice can result in an over production of the site.
- Using of new maturity definition for stands implementing other aspects than economic ones.
- *Sequences of cutting in successive strips advancing to windward.* Especially in the wind affected areas this practice can help to reduce the wind damages.
- *Improving the forest stand edges management according to forecast climate.*

Forest protection

Forests will need to be protected against increasing fire risks, wind and snow damages but also against biotic attacks. Damage risk can be decreased by appropriate species selection, stand treatments and harvest planning.

FIRE MANAGEMENT	• Promotion of species with fire tolerance mechanisms • Fuel reduction • Improvement accessibility for control of outbreaks and fire suppression activities • Prescribed burning
PEST DESEASES MANAGEMENT	• Early intervention for pest and diseases outbreaks • Changes of time for prunning according to potential pests and diseases risks

Table 21: some maintenance operations to ensure the protection against fire and pest diseases

Plant production and tree breeding

The European regulations about trade and use of forest reproductive material (either OECD guide lines or the European directive 105/99/E) permits to to mix seedlings at the nursery stage coming from different seed stands of the same provenance regions. This practice can increase diversity of reproductive material used in artificial stand regeneration. The only way that breeding activities may take into account climate change requirements is to maintain diversity within the varieties produced by seed orchards at latitudes that would be higher than for standard utilizations.

4.b REINFFORCE (REsource INFrastructures for monitoring, adapting and protecting european atlantic FORests under Changing climatE) TRIALS

The main aim of the REINFFORCE project is to set up a trials' network to monitor disturbance in trees life cycle, introduction of new pathogens, misadaptation of trees to local conditions, caused by climate changes and test adaptive measures efficiency. This network will mainly cover the European Atlantic area (*Fig?*) as it is founded by INTERREG.

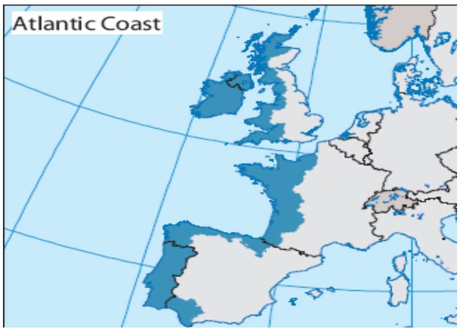


Illustration 57:

The Report "Impacts of Climate Change on European Forests and Options for Adaptation" will be used as guideline for the adaptation strategies to be applied to the project's trial network.

The first phase of the trials constitution was to select the species and provenances to plant. The selection was done emphasizing the promotion of mixture and diversification of species, provenances and genetic units (*Species and genetic units selection process for REINFFORCE Arboreta* [?]).

32 trial sites will be set-up and a series of management practice "climatic risk addressed" will be applied:

MANAGEMENT	Wind	Growth	Regeneration	Drought	Frost	Biotic

?

(http://www.siam-cma.org/cligal/page.do;jsessionid=4B7C2DDA7262D2AEEA7A5DC738679EF9?paxina=evidencias_libro

Site preparation	X					
Density management	X			X		
Species composition			X			X
Edge management	X					X
Species switch/ comparison/mixture / provenance					X	
Stand structure		X	X			X
Soil organic matter enrichment				X		
Understorey management				X		

Table 22: management alternative practices aimed at mitigating the related risks

5 National and regional actions related to climate change and forest resources

5.a Portugal

The Portuguese Climate Change Commission was created in 1998 under to the law *Resolução do Conselho de Ministros n.º 72/98, de 29 de Junho.* This was done for fulfilment the demands from EU and International Greenhouse gas reduction commitments. The commission formed, designated the National Authority for the flexibility mechanisms of the Kyoto Protocol, that the following objectives and missions:

- Development of state actions state, as part of Kyoto Protocol, for creating an international emission license systems for carbon trading.
- Implementation of clean and sustainable development systems at national, local and international levels.
- Contribution to fulfil the commitments made in the Kyoto Protocol.

The Climate Change Commission proposed a National Strategy for Climate Change Adaptation that was under public discussion during the summer of 2,009. For the forest sector, the main proposed measures are:

- Changes in the plantation schedules

- A spacial changes of forest species composition for a better adaptation to the predicted impacts of climate change under different scenarios
- Selecting the reproductive forest material from provenances/varieties better adapted to drought including the replacement of some species by others less water demanding.
- Improvement of forest operations and silviculture for addressing the new climate conditions predicted.
- Assuring the forest contribution to the global carbon cycle.

One action presently undertaken within the context of climate change adaptation, and implementation of the National Forest Defense Plan against Fire – *(Resolução do Concelho de Ministros 65/2006,)* was the extension of forest fires prevention period, due to the observed increasing length of the dry period beyond the summer months.

Other sector that is increasing its importance under the climate change mitigation is the energy production. The Programs that support and incentive the use alternative energy sources (such as solar and wind) intend to reduce about 1,2 M tons of CO_2 emissions in Portugal in the commitment period.

The National Energy Strategy also emphasis the use of forest biomass, mainly coming from forest residues, with the purpose of producing energy and reducing structural fire hazard (circa one milion tons of highly combustible biomass extracted from forest). For the reduction of the level of forest fuels in the forest resources a new network of biomass powerplants is planned. A total of 7 for 10-11 MVA maximum output power and 8 for 2-5 MVA maximum output power, with a total of 100 MW of power production capability. The distribution is showed in figure 43. This distribution will not overlap other large biomass consumer centers like pulp or paper mills.

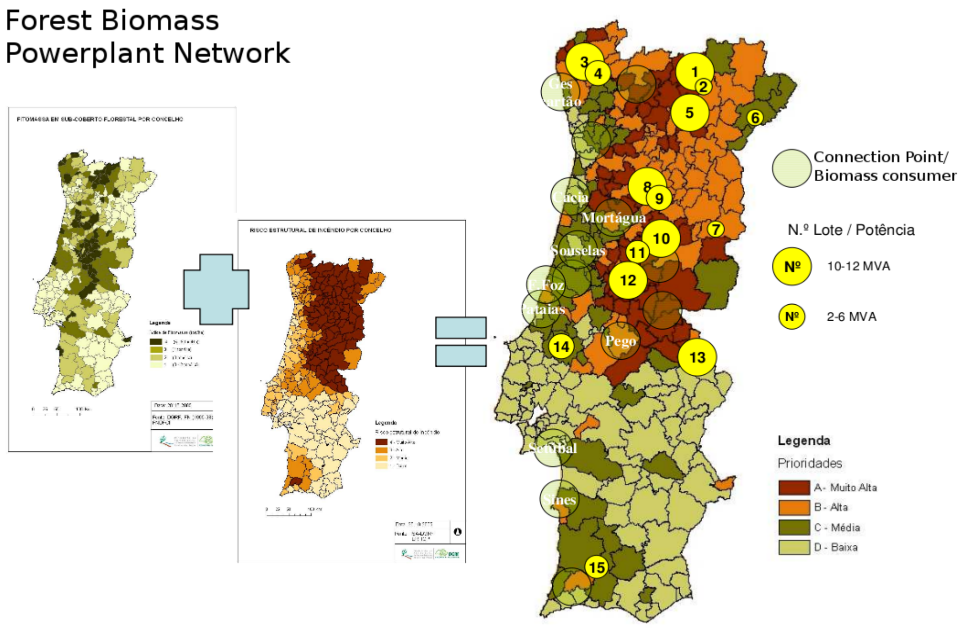


Illustration 58: Biomass powerplant network to be implemented.Source: National Energy Plan, 2008

Old vehicles replacement programs (by *Decreto-Lei n.º 72/2009, de 6 de Agosto de 2009*), personal financial incentives for solar and wind power production programs and the implementation of a Voluntary Carbon Market (for example the *CarbonoZero* label, maintained by E.Value), are also intend to meet the CO2 emission reduction objectives.

Some local Autorities had already implemented plans to cope with climate change (see for example the PECSAC - *Plano Estratégico do Concelho de Sintra face às Alterações Climáticas*), monitoring local changes in order to predict and prevent local hazard situations, support adaptations strategies for urban, coastal, agricultural and forest areas and also identifying potencial CO2 sinks.

5.b Galicia

There currently exist several different programs that study the effect of climate change on forestry. Information on climate change and natural and anthropogenic ecosystems (terrestrial, cultivated and marine) can be found in Pérez Muñuzurri et *al*. (2009) *Evidencias e impactos do Cambio Climático en Galicia* [1]).

Research on forests and climate change is carried out by CIF-Lourizán, the University of

1(http://www.siam-cma.org/cligal/page.do;jsessionid=4B7C2DDA7262D2AEEA7A5DC738679EF9?paxina=evidencias_libro

Santiago de Compostela, the University of Vigo and INIA-Madrid, with the aid of the Xunta de Galicia regional governemnt and the Spanish Ministry of the Environment, Rural and Marine Media. These centres are carrying out wide-ranging climate change-related research programs that include impact assessment and monitoring, adaptation and mitigation.

Within Galicia, the General Directorate for Sustainable Development is responsible for all matters related to climate change and as such has participated in several measures involving the climate and, more concretely, climate change, such as the publication of books like the *Atlas Climático de Galicia*, *el Inventario de Emisiones de Gases de Efecto Invernadero en Galicia* y *Evidencia e Impactos do Cambio Climático en Galicia,* or setting up regional regulations to govern the control and trading of Greenhouse Gas emissions. Part of these measures includes the design of the Galician Strategy against Climate Change (*Estrategia Gallega frente al Cambio Climático*[2]), adopted in 2005, which aims at energising and co-ordinating all public policies in Galicia to reduce greenhouse gas emissions (GGE) and to comply with the objectives established in the Kyoto Protocol. The final Objectives of this regional plan match those of the Spanish Strategy against Climate Change.

The Galician Strategy includes the following measures:

- Improving knowledge about the climate and climate change in Galicia, as well as at collecting data, building knowledge and climate surveillance schemes,
- Modelling and projecting future climate scenarios and forecasts and obtaining data about Galician contribution to climate change mitigation, emission reduction policies in energy processing, transport, industry, agriculture and cattle farming, fossil fuel and SF_6 consumption, waste treatment and management
- Other cross-sector initiatives and measures designed to minimize the effects of climate change, together with other policies aimed at promoting the forests' role as carbon sinks.

The measures to be taken within the forestry sector itself include:

- Assistance in farmland reforestation.
- Creation of infrastructures for forest fire-fighting.
- Co-operation agreements with other forestry associations.
- Assistance in land management and technical schemes.
- Timberland improvement plan.
- Implementation of Sustainable Forest Management certification.

All these measures fall under the responsibility of the General Forestry Directorate of the Regional Government of Galicia.

Also, exit several research projects, carried out by research institutes (e.g. CIF-Lourizán)

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2 http://www.siam-cma.org/cambioclimaticogalicia/Descargas/EGCC.pdf

and Galician universities that deal with various forestry issues and the effects of climate change.

5.c Castilla y León

Multifunctionally of forests is increasingly contributing to the reduction of greenhouse gases levels in the atmosphere. Forests absorb CO_2 mainly in two forms, by one side thanks to the increment in timber volume (accumulation in the biomass). But this absorption also occurs thanks to the increment of forest area values (accumulation in soil). Therefore, if forests are intended to contribute to reducing greenhouse gases in the atmosphere, it seems clear that we must act on both fronts.

The legislation has been enacted in various thematic areas, since the mid-nineties has tried to enhance the multifunctional aspects of forests by promoting reforestation, sustainable management practices, transformation of forest products and fighting against forest fires. All this, with the main aims of biodiversity conservation, rural development and help to alleviate the causes of climate change. In this regard, there are various strategies like European Forest Strategy adopted in 1997, Spanish Forest Strategy in 1999, and the Spanish Forestry Plan in 2002.

At the same time, after the adoption of the Spanish Strategy and Plan, other legal documents were approved for Castilla y León. These documents are the Decree 115/1999 of 3 June sets the Forestry Strategy Castilla y León, as a basis for preparing the Regional Forest Plan. And the Decree 55/2002 of 11 April that approves the Forest Plan of Castilla y León, which will manage the natural resources of Castilla y León for a period of 27 years.

The main objective of these documents are to redefine the role of forest resources at the regional level. They are divided in nineteen thematic programs, eleven are vertical and focus on one aspect or problem of natural resources like vegetation cover recovery, preservation and improvement of forests or hunting management. The rest are cutting, impacting simultaneously on different facet or forest management activities.

This arrangement, together with others related to the prevention and suppression of wildfires and subsides forest plantations, have achieved the goal of more and better trees, as it has been proof by the third National Forest Inventory results. This fact is contributing to the reduction of the current levels greenhouse gases in the atmosphere.

Below are some measures that we consider as priorities for enhancing the sink capacity of the Castilla y León forest resources.

- Increment in forest area. Reforestation and afforestation measures contributes to the production of biomass, conservation and soil improvement. For these reasons all the measure related with the increment of forest area cover should be considered as high priority. Afforestation can be done in abandoned agriculture lands and may stop carving due to the high degree of aging of the rural population. Furthermore, the use of those forests in aside land can be perfectly compatible with the requirement of compliance required for the perception of the Common Agriculture Policy subsidies. In other degraded environments such as from open pit mining, tailings or the riverbanks, these measure should be reinforced.

- Fire fighting. As forest fires can change the value of forest from sinks to emitters of CO_2, measures for reducing the occurrence of forest fires should be implemented. This is not meaning just suppression works, but all preventive measure as well. In this sense, education activities are essential since the vast majority of fires have anthropogenic origin (accidents, negligence or intentional).In addition, prevention work must be done in order to reduce the magnitude of the fires. In this sense, all investment like wedding, pre commercial thinnings, grazing, or sanitary cuts, should be favoured since they are reducing the spread rate of forest fires and, consequently the suppression cost and efforts.
- State of forest health. It is necessary to improve information on health status, prevent and control diseases before they become mainstreams where drastic actions are necessary (scale felling). It is also important to analyse and control the various agents that may adversely affect the development of forests, including climate change itself.

- Forestry and forest management. In addition to maintaining healthy forests and with the least amount of forest fuels, sustainable forest management should contribute in the increment of biomass production and improvement of the carbon sequestration capacity by the soil and conserve biodiversity. This has to be done addressing all the ecological, economic and social demands that the different stakeholders are asking to be provided by forest resources. In this case, fertilization and thinning are important as young forest stands have greater storage capacity than mature ones. In addition if these forest products are using instead of other non renewable materials, reductions levels of GHG will be even higher. Because after processing timber, CO_2 can be stored for longer periods as part of forest products.
- Use of wood as bio-fuel. Biomass removed from forests can be used as bio-fuels without releasing stored carbon during geological time. This fact will reduce the levels of GHG in the atmosphere.

i. Regional Strategy for Future Climate Change in Castilla y León from 2009 to 2012 and 2013 - 2020.

Castilla y León has developed various policies that have contributed to control GHG emissions and the study of adaptation options to climate change. The following are plans and actions taken from this administration that relate with mitigation of climate change:

- Control Strategy of Air Quality of Castilla y León 2001-2010. This strategy can be considered the first strategic initiative driven control of emissions from the regional administration and was approved by the regional government of Castilla y León in 2,002. This control strategy of air quality is an effective framework to prevent air pollution by managing air quality, designed to ensure protection health and conservation of environment and heritage in the autonomous community of Castilla y León. The implementation will be carried out by establishing a battery of measures whose implementation has helped to reduce both emissions of 17 air pollutants like GHGs by promotion of public transport, promotion of clean technologies and renewable energies, among other measures.

- Environmental Education Strategy 2002-2010. It was approved by the regional government of Castilla y León on 2 January 2003 and it establishes a process of communication, compromises and consensus among different stakeholders in the area of environmental education in the region. This plan is a working tool, that is helping to address the environmental challenges at global and local levels. This strategy details a number of recommendations and cross-cutting themes relate to energy uses for being applying to various fields of production like transport, consumption, air pollution, traffic and transportation, industry, urban and regional planning, land and people.

- Creation of the Instituto Tecnologico Agrario de Castilla y León (ITACyL). Since its inception in 2002 as a public entity governed primarily by private law, is committed to set itself as an efficient instrument to initiate the agricultural sector through the development of new technologies, research and transfer of scientific advances, promoting coordination and collaboration with other public and private organizations. The agency has developed various projects directly related to climate change in areas such as conservation agriculture, the study of agricultural carbon sinks, adaptation to climate change consequences, good agricultural practices, agricultural waste management and livestock, among others.

- The Forest Plan of Castilla y León, This is the policy framework for actions in the forestry sector at the regional level. It is made up of 19 thematic programs either vertical (focusing on a specific need or function of the natural resources) and transverse (affecting complement and inform the entire business to develop in the natural environment). The programs involve reforestation, improved forest and silvo-pastoral management measures, that will make a significant contribution to the harvesting of CO_2 from the atmosphere. This measures will contribute to improve the state of natural resources in Castilla y León.

- Regional Waste Strategy 2001-2010. This strategy sets the general policy frame on waste management in the Autonomous Community of Castilla y León, promoting the principle of prevention and measures for reuse and recycling. Includes all wastes considered in Act 18 10/1998 Waste and concrete action plans and targets for achieving during the period 2001-2010, and also establishing a general framework for further development of regional plans in the case of special waste requiring it. Among these, by their impact on climate change include the Regional Plan for Urban Waste Sectored Scope and Packaging Waste of Castilla y León 2004-2010. This document defines the policy followed in the management of municipal waste and packaging, updating the previous Urban Waste Regional Plan in order to comply with new EU and national policies. There is a serie of actions directly related to the control of GHG emissions, as landfill gas freeing or development of biogas production facilities.

35 17 Demonstration Plan and Incentive Measures for Sustainable Development and the Fight Against Climate Change 2008. This strategy against climate change, has developed a process of internal detection and planning for a setting specific actions in the area of control GHG emissions for demonstration purposes. These actions reflect the firm intention of the Government of Castilla y León for achieving a sustainable development and the fight against climate change. The plan has been approved through the agreement made in 21 July 2008 which includes actions for improving administrative operations and procedures, promoting clean energy and energy efficiency, improving transport and mobility or promotion of production and consumption patterns more sustainable.

Finally, it should be stressed that the recent reform of the Statute of Autonomy of Castilla y León, instruct that under the provisions of the Constitution and relevant laws of the State, the regional administration as an exclusive competence assumes the development of additional standards environmental protection and landscape and with particular attention to developing policies to help mitigate climate change.

ii. Plan of Mitigation for the Forestry Sector in Castilla y León.

Even that current socio-economic system keeps a much richer and healthier society than at any other moment of our history. This system has increased the share of regional land populated by forest. For this reason, during the last fifty years, Castilla y León has been an extraordinary resettlement policy that has managed to consolidate more than 500,000 ha. of new forests.

Currently, Castilla y León is the Spanish region with the greatest amount of CO_2 stored in their forests. In 40 years the current CO_2 values will be doubled. In fact, it has increased by 2.5 times in between 1970 and 2005.

The Forest Plan does not include a specific program on forests and climate change, but the new coming version of this plan will include a Program on Forests and Climate Change. The main lines of this plan are described below:

A)Policy framework

The plans and programs related to this plan are:

• The Spanish Forest Plan (approved by Consejo de Ministros on July 5, 2002).

• Forest Strategy of Castilla y León. Approved by Decree 115/1999 of 3 June, by approves the Community Forestry Strategy of Castilla y León.

• Forest Plan of Castilla y León from 2002 to 2027.

• Rural Development Program of Castilla y León.

B)Aims

• Increasing atmospheric CO_2 capture by increasing the biomass present at all sinks associated with forest sector in Castilla y León: aboveground biomass, forest soils, forest products, etc..

• Preservation and protection of forests against fire and other threats, reducing the release of CO_2 caused by forest fires and maintaining plant health of forest stands.

• Applying the principles of multifunctional and sustainable development of forestry systems.

• Initial value of the externalities generated by forest systems of Castilla y León, especially its contribution to mitigating climate change.

• Increased awareness and sensitivity by the society of Castilla y León towards the social, environmental and economic management of their forests.

• Promoting research and development in the forestry sector in relationship to their contribution to climate change and adaptation needs to future climate changes.

C) Programs and Measures

The Plan is divided into four programs, which includes a total of 11 measures, structured as follows:

PROGRAM 1: ENHANCEMENT OF CARBON SEQUESTRATION

This program will increase carbon sequestration levels at all sinks associated with forest system in Castilla y León. From this point of view, two basic parameters that define the contribution of a territory to the mitigation of climate change:

• The average supply of wood per hectare and its variation during the period of comparison.

• The level of timber harvesting per hectare and retention in sinks such as furniture, buildings, The forests of Castilla y León accumulate approximately 50 cubic meters of wood per hectare, but can surely achieve equilibrium levels between 125 and 150 cubic meters. At the same time, the level of cut is 1.25 cubic meters per hectare and year, half the value offered by other central European and Scandinavian countries, that our natural conditions would clearly overcome. The reality is that the degree of utilization of forests in Castilla y León did not reach 20% so that, in order to increase these numbers this Strategy establishes the following measures:

Measure 1: Forestation and Reforestation of Land Dismasted

The simplest and most direct way to increase the amount of carbon sequestered is to increase forest surface of Castilla y León.

During the next 25 years, will be reforested 446,310 hectares of treeless land, entailing an increase of 14.3% of the forested area in the region. Annually, 16,500 hectares of land incorporated trees, so that in the period 2009-2012 will be reforested 66,000 hectares.

It should be noted that along with the activities directly related to stocking, the Ministry of Environment developed over the coming years, two complementary lines of action:

- Collection of forest reproductive material needed for reforestation.
- Definition of the conditions of implementation and monitoring of reforestation.

Measure 2: Densification of forest stands

This measure has increased biomass in forests of Castilla y León through the generation of denser vegetation. The biomass growth of these systems will capture CO_2 in the atmosphere, contributing to mitigating climate change impacts.

The key activities included in these measures are:

- Promotion of forest management to maximize the presence of forest biomass in the mountains of Castilla y León.
- Development of forest planning for increasing carbon capture and sequestration at treeless or sparsely wooded systems.
- Grants and subsidies for increasing the sink capacity of forest and agro-forestry systems.
- Funding resources for promoting the increase of current stocking values of forests.
- Supporting sustainable management of private owned forests.
- Aids for restoring forestry potential and introducing prevention actions.

Measure 3: Development of a Forestry maximizing carbon sequestration

Traditional forestry is oriented to mainly production of wood, so as to obtain economic returns of conservation and forest management.

This measure will modify silvicultural practices developed in the mountains of Castilla y León with the aim of increasing carbon sequestration of forests in the region. This establishes the following:

- Intensification of forestry by encouraging the extension of turns and increasing the performances of short rotation systems and tending operations.
- Diversify woodlands with the objective of increasing its production, social and environmental value and reduce their vulnerability to climate change.
- Promote and preserve the capacity of carbon storage in forest soils, reducing its release during extraction tasks.
- Track fuller forest stands, detecting early so the necessary action to ensure their long-term sustainability.

Measure 4: Promoting Sustainable Forest Management

Sustainable management practices, enhances the increased vitality of forests and strengthens its ability to capture and sequestrate atmospheric CO_2. At the same time, chain of custody schemes allow that wood stemming from these chains will have a higher value when these products are coming to the consumers. Thus, certification is a way to generate demand for practice of sustainable forest management of Castilla y León.

Therefore, this move raises the increase in certified forest area by increasing the demand of certified products and for encouraging all logging companies of Castilla y León benefiting from the chain of custody certification of its products.

For them raises the following actions:

- Launching awareness campaigns about the environmental benefits of the acquisition of timber products from forest to forest certification.
- Conducting lectures and seminars to raise awareness of the strategic importance of forestry in the economy of Castilla y León and the revitalization of rural areas.
- Better training of foresters and forest owners on sustainable forest management.
- Increased subsidies for companies that come to the certification of the chain of custody of their products.

Measure 5: Promoting the Use of Wood and Forest Products.

Encouraging the use of wood instead of other substitute materials is an interesting strategy to support increased atmospheric carbon capture. Because doing so would not only retain the carbon in it, but it is also streamlining the forest sector and encouraging their contribution combating climate change.

In this sense, the actions to be undertaken will include:

- Characterization and regulation of regional forest raw materials and products thereof.
- Promotion of business cooperation channels in the marketing of products derived from regional forest resources.
- Construction of demonstration examples of regional wood use in infrastructure dependent on regional administration.
- Prioritization of furniture, furnishings and decorative objects made of wood as a criterion for acquisition of property by the regional government of Castilla y León.

PROGRAM 2: PRESERVATION AND PROTECTION OF FOREST STANDS

Deforestation and forest degradation are the causes and result of climate change. In normal activity, forests act as sinks to absorb atmospheric CO_2 , when there are perturbed by different biological and non biological agents, they can release large amounts of CO_2 into the atmosphere, becoming a source of GHG. That is why this program main objective is to reduce emissions from the forests of Castilla y León by reducing forest fires and pests.

Measure 6: Improving plant health conditions of forest stands

The measure, in line with the Forest Plan of Castilla y León establishes a series of actions to improve the health status of the stands, a situation that will increase carbon sequestration and reduce atmospheric carbon release associated with the loss of biomass caused by pests. The most noteworthy actions include:

- Evaluation of the plant health of forests.
- Strengthening of regional diagnostic laboratories.
- Implementation of phytosanitary treatments in woodland managed by the Ministry of Environment.
- Establishment of forest phytosanitary treatments grants to local organizations and individuals.
- Phytosanitary treatment of elms and chestnuts.
- Phytosanitary control of remarkable trees.

Measure 7: Fight against Wildfire

Fighting fires is one of the pillars of the Junta de Castilla y León in the field of environmental protection, considering the continuity of the policy currently under way, and develop policies that enhance and complement.

During the period 2009 - 2012 the planned actions are:

- Definition of policy and technical framework for protection against forest fires.
- Strengthening prevention activities. At this point we will work to change the traditional use of agro-livestock-fire, take forward the actions to prevent fires profit and intensify research into the causes of it.
- Improved prevention activities indirectly. Forestry will be developed preventive and auxiliary network will improve (ground equipment).
- Optimizing operational detection and extinguishing forest fires.
- Getting started of a regional centre for defence against fire.
- Strengthening of environmental education on forests, forest fires and sustainable forest management. In short terms, will be developed, within the Agenda 42 and Plan EDUFORES, a specific campaign aimed at schools in the Autonomous Region, which will have an impact on the values of sustainable forest management, the importance of forests in Castilla y León and preventing forest fires.

PROGRAM 3: RESEARCH, ASSESSMENT AND MONITORING

The forest sector, like all other sectors, has an intrinsic need to enhance and improve knowledge while progressing in line with the technical and social progress happen over time.

The Spanish Forest Strategy sets the responsibility for identifying needs and promoting action on research and forest development.

It is necessary to develop a system of evaluation and monitoring of forest stands allowing a deeper analysis of the situation in the mountains of Castilla y León and the same time assessing the efficacy of the measures proposed in the various plans and programs that directly affect the forest resources of the region.

Measure 8: Promotion of research and development related to forestry

The measure's main objective is the promotion of research in relation to the forestry sector in Castilla y León. This raises the internal reorganization of the resources of the Environmental Council and the maintenance of research infrastructure and defining the means to carry out research. Likewise, define and plan the needs for research, for which they form the Research Advisory Committee on forest and prepare the annual plan of action in forestry.

The Forest Plan establishes the need for spreading the results of researcher projects, as well of the right organization and dissemination of bibliographic materials and other relevant documents. This will encourage communication between managers, researchers and the forest sector in general.

The measure will be implemented in three concrete actions:

- Administrative reorganization of forestry research in the Ministry of Environment.
- Defining the needs and development of research projects.
- Communication and dissemination of results of research and development carried out in the forestry sector.

Measure 9: Evaluation and Monitoring of forest stands

Castilla y León is awarded of the necessity of a better knowledge of forest stands along the region. For that reason, there is a growing necessity in increasing the number of available databases of environmental variables. The strategy raises the following actions:

- Increased number of studies on generation scenarios, anticipating change and impacts and risk assessment of forests and natural habitats.
- Creating a network for monitoring the environment. This network is constituted by a forest meteorological network, a network of soil inventory, a network of health of forests, a network of forest inventory, stock inventory and identification of indicator species of change.
- Analysis and evaluation of the content of CO_2 in the sinks.

PROGRAM 4: POLICIES IN FAVOR OF FOREST SYSTEMS.

Kyoto Protocol is the main legal international instrument that aims to mitigate the effects of climate change, but it is given little importance to the role forests as carbon sinks. For this reason, it is necessary to act at the political level, so the new coming legal agreements can recognize this role of forest resources.

In this context, the Castilla y León believes necessarily to develop an effective policy for forest systems, both locally and regionally, nationally and internationally that enhance the environmental benefits.

Measure 10: Institutional Action Generating Policies in Support of Forest Systems

The Junta of Castilla y León is making a significant effort for preserving and protecting their forests. Because it is a region with high forest area, but with low population density and average income level. The combination of these factors makes every inhabitant of Castilla y León to pay 54 euros in taxes to cover their costs for forest conservation and management, the highest rate of all Spanish regions, whose average is 16.3 euros.

Thus, it should articulate new ways to generate, recognition of the global role of forests and subsequently to provide greater resources to develop actions that increase its contribution to mitigating climate change.

The actions to be taken are as follows:

- Analyse and quantify the environmental contribution of forests, especially its contribution to all aspects of climate change.
- Support and propose policies and income-generating activities in the forestry sector as a result of the externalities generated.
- Advocate for an increase in the amount of National Forest Fund from the current 200M€ to 400M€.
- Participate and encourage the international agencies that are traded on the policies to combat climate change wider recognition of the role of forests as carbon sinks.

Measure 11: International Partnerships in the Sustainable Forestry Exploitation

The Junta of Castilla y León considers as a part of its forest policy through the promotion of global operating model of forest ecosystems to contribute for mitigation of climate change, reducing carbon leakage and provide benefits to global society. To do this, the Ministry of Environment participates in a number of international projects such as the Mediterranean Network of Model Forests and Argentinian Forest Plan among others.

Therefore, and as a continuation of the policy developed above, during the period 2009-2020, the Junta of Castilla y León promote the signing and development of agreements and protocols with other governments for sustainable exploitation of forests.

Concrete actions will be developed in the framework of these instruments are:

- Exchange of forestry professionals and researchers.
- Exchange of technical information and experiences aimed at the implementation of environmental protection measures and mitigation of climate change.
- Collaboration in research and publications.
- Implementation and participation in seminars, conferences, fairs or exhibitions.
- Design and development of instruments for regulating the sector.
- Development, promotion and funding of international networks to promote sustainable forest management.
- Development and implementation of educational programs related to the forest world.

5.d Basque Country

The importance of the problem of climate change prompted the autonomous government of the Basque Country to create the Basque Office for Climate Change in January 2006 as the core co-ordinator of the different departments involved in the fight against climate change. Its mission is to energise and co-ordinate public policies for the Basque Country for reduction of greenhouse gases emission (GGE), and to comply with the objectives established in the Kyoto protocol. Also, from the perspective of adaptation to the consequences of climate change, it attempts to minimise the effects due to climate transformation.

It comprises representatives of the Departments of Land Use and the Environment (DMAOT), Industry, Trade and Tourism (DICT); Transport and Public Works (DTOP), Education, Universities and Research (DEUI), Agriculture Fisheries and Food (DAPA), and Housing and Social Affairs (DVAS) Directed by an Interdepartmental Policy Committee, the Department of Land Use and the Environment is responsible for technical management, which co-ordinates a technical group composed of experts from each of the previously mentioned departments.

It developed the Basque Plan Against Climate Change 2008-2012 with the goal being that by 2020, the Basque Government will have made irreversible steps towards the consolidation of a socio-economic model less dependant on carbon, minimising its vulnerability in the face of climate change. For this, strategic targets to be met by 2012 were fixed as follows:

- Limiting the emissions of greenhouse gases (GGE) to +14% with respect to the base year
- Increasing the absorption capacity of carbon sinks to 1% of emissions of the base year
- Minimising the risk to natural resources
- Minimising the risk to people's health, urban habitat quality and socio-economic systems.

To achieve these strategic objectives, the Plan established 4 programmes that spread out into 14 lines of action, which include 120 concrete actions.

The total public resources invested on this Plan added up to 630 million euros, of which 79.5 million euros are resources that will need to be additionally provided to the general Basque government budgets after 2008.

i. EXECUTION OF THE PLAN.

Programme 1. Less Carbon

The objective of this programme is to produce and consume using cleaner energies and less carbon, and to manage sinks.

Six action sectors are distinguished: energy, industry, transport, residential and services, agriculture and forestry and management of wastes.

For the agriculture and forestry sector, the following action lines are proposed:

- Promotion of renewable energies. This includes actions that promote the use of agricultural and forestry biomass as combustibles.
- Reduction of non-energy greenhouse gases emissions (GGE.) Pursuing the reduction of methane produced by intensive farming by utilising it for energy.
- Management of carbon sinks. Attempts will be made to maintain the current carbon sinks and to increase the absorption of carbon in the different sectors (forestry, agriculture, pasture) until reaching a level that represents 1% of emissions of the base year.

Within this programme, concrete steps are already being taken in the forestry sector with the awarding of a research project to IKT, which will attempt, amongst other objectives, to undertake a study of the cost/effectiveness of forestry measures designed to maintain and expand carbon sinks.

Programme 2. Anticipation

The objective of this programme is to anticipate climate change to preserve natural ecosystems, protect human health and adapt infrastructures and socio-economic systems.

Its action is centred in: (i) natural systems, (ii) health of people and the urban environment and (iii) economic activities.

It proposes the following action lines for natural systems:

- Systematic observation and learning. Directed at observation of the effects of climate change on various natural systems. This contains actions of monitoring and co-ordination to guarantee surveillance of species indicative of climate change and quantify possible effects.
- Definition of criteria and planning. Forecasting impacts from management and planning. Attempts to update planning guidelines for ¬natural resources and the instruments of planning
- Adaptation and availability of resources. To strengthen the integrity of the elements that make up the natural systems. Including actions to cushion the effects of climate change on the more vulnerable ecosystems of the Basque Country.

Programme 3. Knowledge

The objective of the programme is to observe nature, know the problems and create solutions. The work is centred in developing knowledge on climate change along three action lines:

- Basic research and co-operation. This has settled on the goal of having 150 researchers working along lines related to climate change. A BERC (Basic and

Excellence Research Centre) on climate change has been created, whose areas of specialisation are: (i) the atmospheric general circulation models (AGCMs), (ii) the integrated models of climate change (IMCC), (iii) the social and economic implications of climate change and (iv) the valuation of impact and vulnerability. The undertaking of a multi-disciplinary project of the ETORTEK (K-Egokitzen) programme has commenced. The UPV/EHU (University of the Basque Country), the Basque Meteorological Agency and various technology centres associated with Tecnalia are participating and it will generate new regionalised scenarios of climate change for the Basque Country. It will also study its possible impact and the adaptation to change in the urban, terrestrial, coastal and marine systems.

- Applied research. Participation of the private sector in research on climate change.
- Cross over resources. Participation of the Basque Technology Network and companies in international climate change research projects.

Programme 4. The Public and the Authorities

This involves the different Basque Government Departments, Regional Councils and Town Councils. Its action lines are:

- General activities and buying green
- Saving and efficiency at work, home and travelling
- Information and awareness
- Education and training

5.e Navarra

i. Navarran Action Plan for the Climate

It was approved in 2007 (September, 17th) by the Government of Navarra and it comprises from 2008 to 2012. It is elaborated by "Departamento de Desarrollo Rural y Medio Ambiente" (Gobierno de Navarra). This Plan aims to analyse and test different actions to change the current trend of greenhouse gases emissions (figure 44). So these actions are established to mitigate greenhouse gases and, later, they will be incorporated into this Plan, which will be able to define Navarran Climate Change policies in next years (2008-2012) and in early future (2012-2020).

	1990 (t CO_2-eq)	2007 (t CO_2-eq)	Incremento 1990-2007 (%)
Total emisiones	5.295.592	**7.287.227**	37,61%

Illustration 59: Greenhouse emissions (ton.CO_2) evolution during the period 1990-2007

Government of Navarra has analyzed different scenarios with or without taking preventive actions. At the scenario without taking any action, projections tell us that emissions in 2020 would increase more than 100% respect to 2006 and to 1990 logically (figure 55).

According to this scenario, industrial sector might be the main responsible for the increment of emissions in Navarra, and the transport system is occupying the second place. Taking into account actions, the scenario will be some different. In this case, emissions in 2020 would increase more than 100% respect 1990 and 84% respect 2006 (figure 56).

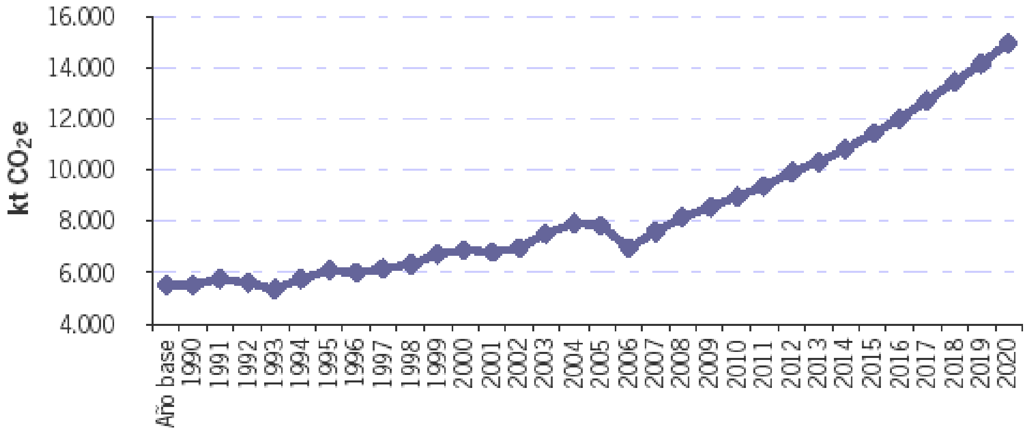

Illustration 60: Total emissions projection in Navarra to 2020 (without actions)

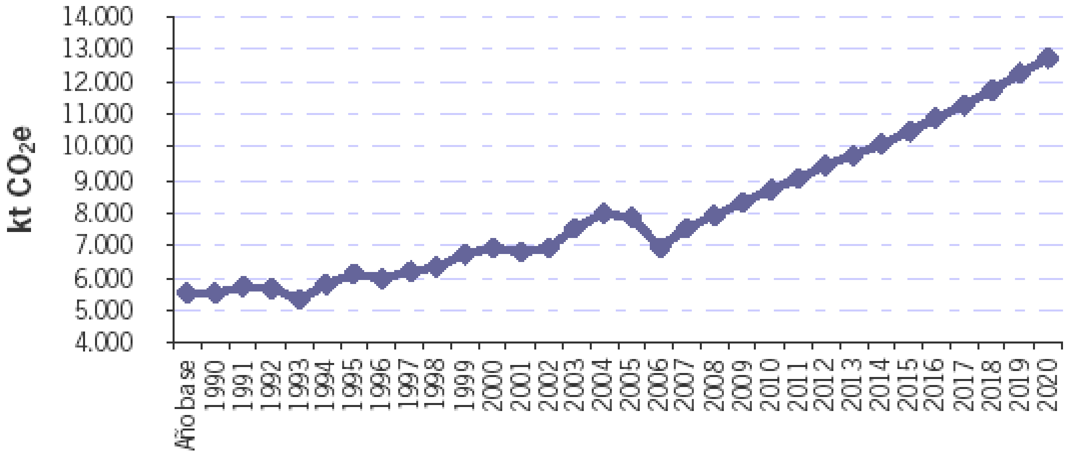

Illustration 61: Total emissions projection in Navarra to 2020 (with actions)

At this second option, industrial sector would be the main responsible for greenhouse gases emissions again. The design of the measure will be carried out in different stages.

➢ Identifying possible actions

Different actions will be taken to reduce greenhouse gases emissions in every sector, according to what different Spanish Regions and foreigner countries are doing. This first stage includes different consultation with social agents and other stakeholders involved.

➢ Limiting emissions

The potential of every action to reduce emissions in every sector will be tested until 2020.

➢ Assessing every action

Every action will be tested and assessed by people in charge (Navarran Government experts). Once experts have selected the most suitable and viable actions, these will be budgeted and a timescale will be established in order to start and to develop the Navarran Action Plan for the Climate (2009-2012).

➢ Final approval

Finally, the Government of Navarra will update the Navarran Action Plan. Main actions regarded in this Plan, and related to energy and forestry sectors, are:

Energy sector

- Improvement the efficiency of electric consumption efficiency in industrial sector, transport, agriculture, services and increasing social awareness
- Supporting renewable energies to get the Spanish requirements in 2010, so 29’4% of the electric production is coming from renewable sources.

- Implementation of political active actions in order to decrease CO_2 emissions

Forestry sector

Forest and other wooded lands (FOWL) cover 64% of Navarra. And this forest resources are sequestrated 25% of CO_2 total emissions generated by fossil combustibles consumption. This make forestry a very important sector for the Navarran society. For this reason different management and planning actions related to this sector are planned for the coming years. The most important action of these is: Forestry Plan of Navarra. Its main objectives are:

- Increasing forestry woodland surface, mainly with indigenous species. With this action CO_2 sinks are promoting and improving as the same time, by right silvicultural techniques
- Development of forest harvesting planned in order to get natural environment protection and profits. This issue can be got by increasing forestry fuels and firewood consumption, supporting wood use for building …
- Pooling forestry issues inside environmental education

5.f France

i. Institutional actions

In France, the national strategy had been defined in an institutional process called Grenelle de l'Environnement which started in 2007.

Two main objectives were defined:

- mitigation of Global warming below 2°C through a collective and sustained effort
- adaptation to Climate Change effects on economy, ecosystems, society.

The Ministry of Environment, Energy and Sustainable Development defines and implements the national policy about energy. There are two main objectives:

- control greenhouse gases and atmospheric pollutants emissions,
- enhance competitiveness and supply security.

The General Direction of Energy and Climate is in charge of developing actions in three main areas:

- Control of energy consumption and improvement of energetic efficiency
- Support of a sustainable transition toward a “less-carboned” economy and Development of renewable energies
- Assessment of Climate Changes impacts and their costs and development of adaptation strategies.

France has created and interministry task-force on the greenhouse effect (MIES) in order to coordinate sectorial actions in this area.

The Ministry in charge of Environment has also created a monitoring agency, the ONERC (Observatoire National sur les Effets du Réchauffement Climatique) which collects and develops meteorological information and assessment reports on several topics related to Climate Change.

The federating research programme ‘Management and Impacts of Climate Change’ (GICC - Gestion et Impacts du Changement Climatique) is one of the research programmes supported by the French Board for Economic Studies and Environmental Evaluation (D4E - Direction des études économiques et de l'évaluation environnementale).

It was launched in 1999 by the ministry concerned, now called the Ministry of Ecology, Energy, Sustainable Development and Seas (MEEDM). Several other organisms also contributed to the programme: the interministry task-force on the greenhouse effect (MIES), the Ministry of Agriculture, the Environment and Energy Conservation Agency (ADEME), the National Climate Warming Effects Monitoring Agency (ONERC), the French Biodiversity Institute, etc.

The stated objectives of the programme have always been to develop knowledge to back public policies, considering climate changes from the perspective of their impacts as well as from that of greenhouse gas limitation measures and climate change adaptation measures. This requires the mustering of research teams from a wide range of academic fields: on the one hand, the physical and biological sciences for a better knowledge of the impacts and, on the other, social studies to explore mitigation and adaptation possibilities.

Scientific knowledge is steadily progressing within this multidisciplinary and interdisciplinary approach. The Scientific Council is careful to take into account the validated research results as well as the societal concerns voiced by the Steering Committee to define the major orientations of each oncoming CRP. Research activities on climate change undertaken at the European level are also taken into account. The French Ministry of Ecology, for example, is involved in the European programme ERA-NET CIRCLE that aims to coordinate the funding agencies of national research in Europe, thus facilitating links between this type of programme and GICC.

The GICC programme operates through yearly Calls for Research Proposals (CRPs). CRPs were issued in 1999, 2000, 2001, 2002, 2003, 2005 and 2008, as was a joint call for tenders with the French Biodiversity Institute (IFB) on the theme of ‘biodiversity and global change’.

The research projects selected as a result of these CRPs cover several years (3 years), so the different programmes overlap in time. CRP 2008, now under way will last until the beginning of 2011, when CRP 2010 will take over.

The programme is managed by two committees, a scientific council and a steering committee, and coordinated by GIP ECOFOR (Groupement d'Intérêt Public ECOsystèmes FORestiers).

Exemples of projects funded by the GICC and related to forestry were:

APR 1999

Effects of silviculture on carbon storage in forest soils – Parameter validation for model of trends in carbon stocks

APR 2000

Carbon and water balances in South-West France: recent history, present state and scenarios for the future – Comparing climatic and anthropic pressures

Dendro-ecological indicators of the effects of environmental changes on the wood characteristics and growth of major forest species

Incentive actions for carbon sequestration in privately-owned forests

APR 2001

CARBOFOR Project: Carbon sequestration in large forest ecosystems in France. Quantification, spatialization and impact of various climatic and management scenarios

Global changes and biodiversity: Relative performances of introduced and indigenous species and simulation of distributional changes

APR 2003

Response of French Mediterranean Forests to Climate Change

As for forest policy and adaptation to Climate Change, a technical report, the ROMAN-AMAT report (december, 2007), defined actions for the future.

It was made on a command from Ministry in charge of Agriculture and Ministry in charge of Environment.

It proposes a balance of climate change predictions and their impact on forest ecosystems.

It gives a set of possible actions for the future : R&D, risks, public policies about production forests, biodiversity, public governance.

ii. Observatory of forest ecosystems and climate change in Picardie

The CRPF Nord Pas-de-Calais Picardie puts up a regional observatory of forest ecosystems (OREF), to permanently monitor developments of climate change in the regional forests and provide guidance and advice to forest management suitable to the owners. Funded by the Conseil Régional Nord Pas-de-Calais Picardie and the European InterregIIIa, the OREF was developed in partnership or in coordination with research organizations (INRA, IDF), forestry professionals and environmental (NFB, NFI, Conservatoire Botanique National de Bailleul, Conservatories sites ...) and local naturalists. This operation inserts the Observatory within national observation devices and will allow for synergies between regional organizations.

Two lines of work were put in place a network of permanent trials on the one hand and regional overviews of 6 major types of indicators belonging to various disciplines (phenology, tree growth, tree health, climate, vegetation, ornithology).

The network of trials was established from observation networks already exist, including the network Experimentation and Development of CRPF, which has existed for over 20 years. Besides taking advantage of prior steps, this choice reflects the desire to create an observatory that values of existing devices and is inexpensive to follow.

The development of the protocol and the first observations took place in 2006. An initial assessment of observation has been conducted in 2007 and prepares the initial state of forest ecosystems of Nord Pas-de-Calais Picardie.

iii. DRYADES: Vulnerability of forests to climate change [1]

The research project Dryade aims to understand the current forest declines distinguishing the components climatic, biotic and forestry.

The scientific consensus on the intensity and speed of climate change and the longevity of trees make it necessary to anticipate potential risks that could threaten the survival or productivity of some forests in France.

A consortium of researchers and managers

An interdisciplinary program to understand and anticipate the failures of forests, involving a consortium of managers and researchers in ecology, ecophysiology, remote sensing, soil science, genetics, entomology and forest pathology is supported by the "Vulnerability: Environment and Climate of the National Research Agency (ANR), Nathalie Breda (INRA Nancy) as coordinator.

One of the original project is to bring together within a consortium comprising 12 partners:

- Researchers in ecology, ecophysiology, genetics, entomology, forest pathology
- Forest managers of private and public
- Two bodies monitoring and evaluation of the French forest.

From observing networks National and European species 5 and a model host-aggressor

This program will study at different levels (individual, population, massive, region, area bioclimatic) vulnerabilities to change and / or climatic five major tree species (sessile and pedunculate oak, beech, fir and Douglas fir) and their production. The main climatic hazard is considered drought.

A retrospective of tree growth in relation to the environment and climate, and declines mapping from the ground and by remote sensing will allow the prioritization of

1 http://www.inra.fr/dryade

vulnerabilities.

The spatial analysis by GIS soil, mineral and water constraints stands, field surveys and epidemiological complete knowledge of water stress.

The analysis of environmental databases and dendrometric of the National Forest Inventory refine the mapping of the area of petrol Biogeographic considered.

The models incorporate an explicit interactions with pests, defoliating insects, and fungi in cortical, or as the primary factor increasing the vulnerability of trees to climatic events, or as an aggravating factor after climatic. A model host / parasite, the typographer, an insect in cortical, regularly cause major damage to spruce plantations.

However, the risks storms / fire or related to air pollution are beyond the scope of the project.

Recommendations to managers

The project was finally completed very vocation in terms of recommendations for planning and rational management of forests to climate change announced. It will be proposed maps of vulnerability to impacts and adaptive management strategies (including management of populations in crisis) or anticipation: planning for the diagnosis of water balance, the choice of species and varieties, improved the resilience of the people, by an adaptation of forestry to mitigation of stresses.

This program started in 2007 continued until 2010. The questions many foresters have required a year of formalization. The local private, highly reactive, and solicited regularly feed a continuous and constructive dialogue. The mobilization of many organizations and researchers will provide the long-awaited answers.

iv. AFORCE Network for Forest response to climate change [1]

AFORCE is a Mixed Network Technology (RMT) forest response to climate change, introduced in autumn 2008, with support from the Ministry of Agriculture and Fisheries. It brings together 12 partners in the forest, among the research organizations (ENGREF, INRA, Cemagref, FCBA, IFN), development (ECOFOR Gip, CNPPF / IDF, IEFC, Chambre d'Agriculture de la Sarthe), management (NFB , SFCDC) Education and Training (School of Forest Meymac).

It is coordinated by the "Institut pour le Développement Forestier".

Its objective is to provide short-term results in the form of operational tools, used directly by forest managers.

The RMT enables the synergy of different networks of competence. It facilitates the

1 http://www.foretpriveefrancaise.com/accueil-161899.html

assessment of concerns and needs of managers.

Five major themes of work are distinguished for better coordination and better disseminate information:

- Soil and climate environment,
- Vulnerabilities of populations,
- Exploitation and conservation of genetic resources,
- Growth and forestry,
- The economic consequences for forest production.

It works by calls for annual projects.

The issues and objectives are:

- coalesce into networks of expertise to be able to :I) to best respond to new issues of foresters, II) to consolidate and build on the results already obtained, III) to optimize the acquisition and dissemination of new knowledge,
- Mobilizing the information, structure and circulate to the professionals,
- Coordinate initiatives and promote the emergence of common projects,
- Delivering tools for decision support for managers: fact sheets, benchmarks, practical guides, software, articles, training materials.

v. Factors of decline of pedunculate and sessile oaks in Atlantic

All indigenous oaks in France are affected by dieback. The Evergreen oak seems to be with the most affected followed by pedunculate oak and sessile oak..

The aim is to establish the dieback of oak Atlantic to assess its capacity to respond, now and the future, and monitor his health status to anticipate the consequences of climate change on oak. The issue is important because the oak is very current in north-west of France.

The study consists of 4 main parts:

- Situation in "Poitou-Charentes" and "Pays de la Loire" : in 2009, on these two regions, an assessment and mapping rate of decline of different species of oak will be made.
- A diagnostic for identifying oaks can better resist stress, by combining the protocols DEPEFEU (% leaf loss) and Archie (architectural analysis of trees). This work is planned for 2010
- Set the threshold of the water balance from which the oak away: the aim is to highlight the ecological parameters that influence the risk of oak decline and set the threshold value of the water balance from which the oaks are dying . A key to determining risk soil condition will be established. The ultimate goal is to define where it's possible to

continue to produce timber oak or not. This work is planned for 2010 -2011.

- Evaluate the quality of pubescent oak wood, a acceptable candidate to replace the pedunculate or sessile oak in the very dying plots: this evaluation is a comparison of technicals characteristics of pubescent oak wood with sessile oak by mechanical tests (densities, modulus of elasticity, Brinell hardness, ...). This work is planned for 2010.

This study will be conducted between 2009 and 2012 by the IDF and the CRPF Pays de la Loire, Bretagne, Ile de France - Centre, Poitou-Charentes and Normandie.

vi. **Tracking declines result of climate change.**[1]

Following the drought of 2003, significant declines have been observed in conifer plantations of the South Massif Central. They have resulted in high mortality. We can consider that thousands of hectares of public and private forests have been affected.

A report on this decline was made in 2004 and 2005 by two forest organisation (CRPF and ONF) with the help of Forest Department of Health and the remote sensing laboratory at the Ecole Supérieure d'Agriculture de Purpan.. The analysis, using remote sensing techniques and the Normalized Difference Vegetation Index (NDVI), focused primarily on the Douglas Fir (*Pseudostuga menziesii*), Grant Fir *(Abies grandis*) and Norway (*Picea abies*) and Sitka spruce (*Picea sitchensis*)

Climatological data obtained revealed recurrent droughts since 2003 whose effect was cumulative to the 2003 heatwave. This in a general increase in aridity for 12 years.

The declines observed appeared related to water stress caused by these phenomena, followed by attacks by secondary pests and pathogens for Grant fir, spruce and Douglas.

vii. **A Monitor Seasons (ODS = "observatoire des saisons")**[1]

ODS is based on the observation of seasonal rhythms, ie the phenology of plants, trees, birds, insects. It takes place throughout the year. Studying phenology is the study of plant or animal according to the seasons and climate.

Climatologists have shown that climate change is taking place throughout our planet.

In the context of national and international concerns around climate change, ODS offers to contribute to scientific research on the impacts of climate change on vegetation and animals.

With a simple protocol established by researchers and mediators scientific, you can make

1 http://www.crpf-midi-pyrenees.com/datas/pdf/dep_reb_resx_1_rapport.pdf

1http://www.obs-saisons.fr

statements on the flora and fauna.

To participate in this project it's necessary to be register in the web site, to participate in section and observe regularly (2 times per week) species selected. Once your observations you enter them in the web site database.

Private foresters are planning to join this observatory and participate in monitoring the phenology of forest trees.

viii. **CARBOFOR project (2002-2005)**[1]

Research project Gip Ecofor GICC 2001, coordination by D. LOUSTAU (EPHYSE – INRA)

INRA – IFN – CIRAD – METEO France – CNRS – Université Paris-Sud 11 – ENGREF – Université d’Orléans

Main issues:

•Carbon fixation by major forest ecosystems France.

•Quantification, spatialization, vulnerability and impacts of different climatic and sylvicultural scenarii

ix. **CARBOEUROPE-IP (2004-2009)** [2]

CarboEurope-IP aims to understand and quantify the present terrestrial carbon balance of Europe and the associated uncertainty at local, regional and continental scale. This means to

- determine the European carbon balance with its spatial and temporal patterns
- understand the controlling processes and mechanisms of carbon cycling in European ecosystems and how these are affected by climate change and variability and human management
- develop an observation system to detect changes in atmospheric CO2 concentrations and ecosystem carbon stocks related to the European commitments under the Kyoto Protocol.

CarboEurope emerged as a cluster of European projects in 2000. Since then, it consolidated an interdisciplinary research community in the fields of different ecosystems, atmosphere, measurements and modelling. The CarboEurope-IP bundles and expands on these earlier projects and allows for the first time a harmonised and consistent gathering of data and integration of space and time scales.

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1 www.pierroton.inra.fr/carbofor/index.htm

2 www.carboeurope.org

The consortium consists of 61 Contractor Institutes from 17 European countries, plus about 30 Associated Partners within Europe and further Collaborating Institutes outside Europe . The Max-Planck-Institute for Biogeochemistry , Germany , is project co-ordinator. CarboEurope-IP is open to associate further partners.

INRA is associated in this project. The project is supported by the European Commission, Directorate-General Research, Sixth Framework Programme, Priority 1.1.6.3 Global Change and Ecosystem, Contract No. GOCE-CT-2003-505572. The budget consists of 16.3 million Euro from the European Commission and about 30 million Euro from national funding.

x. EVOLTREE (2006 – 2010)[1]

European research project « Réseau d'Excellence », coordination by A. KREMER (BIOGECO – INRA)

25 research groups from 15 european countries.

Main issues:

- Analyse the impact of climate change from an evolutionary point of view
- Evaluate the adaptation capability of tree species by genetical diversity using predictive methods including modelization and simulation
- Support for defining forest genetical resources conservation and management policies

xi. BACCARA (2009-2012)[2]

European research project 7th « PCRD », coordination by H. JACTEL (BIOGECO – INRA)

15 research teams in Europe and China.

Main issues:

- 3D Risk analysis linking climatic changes, functional diversity and forest primary production:
- Effect of climatic changes on forest biodiversity
- Relationship between biodiversity and forest primary production
- Prediction of forest productivity loss, taking into account climatic events frequency, diversity modification and influence of diversity on productivity

1 www.evoltree.org

2 http://www.baccara-project.eu/

xii. **CDC Strategy (2009 – 2011)** [1]

The Forest Society of Caisse des Dépôts et Consignations manages 230 000 ha in France

Objective:

Adaptation strategy of forest management. Can be revised every 3 years.

Main issues:

- Opportunities and risks
- Risks mapping: sensitivity of forest areas and answers (stands modification and/or sylvicultural changes)
- Development of tools and trials (soil water resources, soil compacting, transition species of broadleaved and coniferous)

xiii. GIS Pin maritime du futur Breeding program and climate change

Objective: Preparing future

- To select polyvalent varieties, stable ones, adapted to a large rank of site conditions, to begin research program on defining "adaptation" selection criteria.

  On the other hand, to select specialized varieties
- To shorten production cycles and quickly renew varieties according to the appearance of changes.
- To move selection areas with multiple populations, anticipating CC.
- To use selection assisted by markers technology yet in tree nursery

Main issues:

Strategy for maritime pine: adaptation of existing varieties

- Evaluation network of varieties that we must extend south
- Multiple-site evaluation of parents and choice of polyvalent and stable varieties
- if necessary, genetical clearing in tree orchards on the basis of breeding tests

xiv. CLIMAQ : anticipating and foreseeing A R+D program in Aquitaine (2008 – 2011)

Common program for Aquitaine forest organizations of research, development and cooperatives FCBA, INRA, CRPF-CPFA-IDF, CAFSA, ETFA, DRAF& EPFA

Program proposal consistent with national research projects and actions (particularly IDF)

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1 www.foret-et-climat.fr

and other regional projects (SYLVOGENE of IPMF)

Main issues:

Climaq project is organized in four articulated parts:

A) Compilation of installed trials: identifying potentially adapted species in existing network.

- To compile and summarize installed trials
- To Integrate the results in a common database
- To Classify species that are able to resist CC from an homogeneous analysis grid

Action leader : CRPF

Partners: CRPF, FCBA, CAFSA, INRA

B) To install new trials: experiment and early-development of new species adapted to Climate Change

To install new field trials with selected species that may be able to adapt to CC

B1 - To test new species (20 sp., 6 field trials, 2ha/trial)

B2 - To install a reference network (9 field trials, 6 sp., 3ha/trial)

B3 - To experiment new origins for Pinus taeda

C) To experiment and develop specialized stands (coppice and coniferous) for biomass production: developing renewable energies.

C1 To experiment specialized stands (short-term coppice, coniferous stands)

C2 To help developing specialized stands

C3 To evaluate different scenarii (technical, economical and environmental criteria)

C4 To create eucalypts varieties adapted to regional context

D) Communication et knowledge transfer

5.g United Kingdom.

England, Scotland and Wales are developing information and guidance on the impacts of climate change and forestry for their respective countries. General information on climate change and British woodland is contained available on line[2], with specific guidance for Scotland[3] and Wales[4]. Similar information for the whole of England is not currently available, though regional assessments have been published, e.g. for south-west England[1]

Research on forests and climate change is primarily undertaken by Forest Research (FR), the UK Forestry Commission's research agency. FR's programme of climate change-related research is wide-ranging, covering impact assessment and monitoring, adaptation and mitigation. The scope of the research includes forest management, biosecurity, the management of woodland for biodiversity and the services that trees and woodlands provide to society. The Forestry Commission spends about a quarter of its research budget with FR on climate change and related programmes, either directly on projects specifically on climate change, including:

- Climate change impacts on forest function
- Ecological site classification (ESC) for climate change
- Forestry as an instrument for mitigating climate change
- Silvicultural impacts on carbon
- Biosecurity in a changing climate
- Tree stability and climate
- Process modelling
- Woodfuel research

or as elements in other research programmes, such as:

- Hydrology
- Seed biology
- Economic research
- Genetic conservation
- Provenance and species choice

2http://www.forestresearch.gov.uk/pdf/fcin069.pdf/$FILE/fcin069.pdf

3http://www.forestresearch.gov.uk/fr/INFD-79RD4S

4http://www.forestresearch.gov.uk/fr/INFD-7FXBYQ

1http://www.forestry.gov.uk/pdf/cchg_SW_climate_change.pdf/
$FILE/cchg_SW_climate_change.pdf

- Long-term experiments
- Landscape ecology and spatial planning
- National inventory of Woodland and Trees
- Land regeneration, urban greening and social research

[2]Further details of FR's research on climate change can be found on line.

6 Existing inventories and databases related to trials and experiments

6.a Portugal

There is no National database on existing trials and experiments. These experiments are maintained by Public Institutions, belonging to the Ministry of Agriculture and Universities, and also Pulp Companies. ISA (Instituto Superior de Agronomia) is compiling information about these trials and experiments, for the REINFFORCE database.

An important tool for forest management is the Inventario Forestal Nacional (National Forest Inventory), performed with an average 10 year periodicity by the National forestry services since 1964. The Forest Inventory supplies statistical information about:

- Portuguese Land coverage
- Forest stands structural analysis
- Assessment on Forestry production, wood and non-wood products
- Sanity and vitality of forest stands monitoring
- Time analysis on forest changes.

6.b Galicia

CIF-Lourizán maintains databases of records of forestry experiments carried out since the 1940s. The data stored there includes information from locations both inside and outside Galicia. These databases contain records on silvicultural and forest-fire experiments, species, provenance trials and seed-orchards, for species such as *Pinus pinaster, P. radiata, Pseudotsuga menziesii, Sequoia sepmpervirens, Eucalyptus globulus, Castanea sativa, Quercus robur, Prunus avium* and *Juglans regia*. Several demonstration trials are also being performed at locations all around Galicia. At this point in time, we are attempting to unify data from our files. Other databases, containing contain records on silvicultural and tree growth, are maintained by the Sustainable Forest Management Unit

[2] http://www.forestresearch.gov.uk/fr/INFD-7K9DFZ

of the Higher Polytechnic School of Lugo (Rojo Alboreca et *al*., 2004).

6.c Castilla y León

In Castilla y León there is no experimental data base on forestry at regional level. But the Agricultural Engineering Faculty of Palencia (University of Valladolid) has installed a network of plots and experiments for research sustainable forest management, because the lack of forestry research data are usually the limiting element. Therefore, this research group is working intensively for installing a complete network systems experimental forest in central and northern Spain filling the lack of this type of infrastructure in this area of the Iberian Peninsula. At these sites different sort of plots have been installed, temporary and permanent, and with the help of experimental devices, the main ecological aspects of forest are recorded. The whole network is divided into 5 plots and 3 types of experimental devices. This is shown in (Figure 58). Actually, this network is composed by the following subnets:

- Plots of growth and yield in natural stands of conifers.
- Plots of growth and production in conifer reforestation.
- Plots for developing temporary of crown relations and study of the forest structure.
- Plots for the study of sampling methods.
- Plots of coniferous forest regeneration.
- Testing of natural regeneration.
- Tests for species plantations producing quality wood.

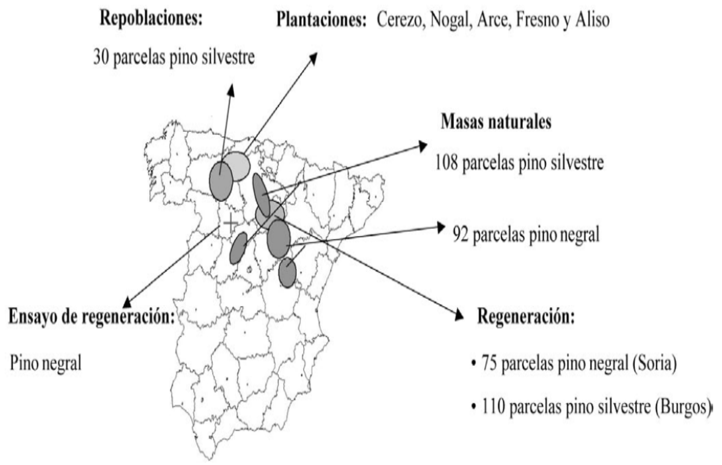

Figura 1. Parcelas y experimentos más relevantes de la Red del Grupo de Investigación sobre Gestión Forestal Sostenible (Dept. Prod. Vegetal y Recursos Forestales, ETS de Ing. Agrarias de Palencia-Universidad de Valladolid)

Illustration 62: Plots Network of the Research Group of Sustainable Forest Management of the Agricultural Engineering Faculty of Palencia (University of Valladolid) Source personal comunication

6.d Basque Country

Trials whose data are found compiled in IKT:

- Trials of Forestry Experimentation for *Pinus radiata* by silviculturists in the Historical Territory of Bizkaia (last undertaken in 2003.)
- Network of Experimental Forestry plots (thinning regimes) in MUP for *Pinus nigra* (last undertaken in 2006) and *Pseudotsuga menziesii* (last undertaken in 2004) in Gipuzkoa.
- Network of Experimental Forestry Plots (thinning regimes and of pruning) by silviculturists for *Pinus nigra* and *Pseudotsuga meziesii* in Gipuzkoa (last undertaken in 2003)

Trials whose data are found compiled in NEIKER:

- Network of trials of progeny selection of *Pinus radiata* by half siblings and full siblings
- Network of trials of provenances of *Pinus radiata*.
- Network of trials of sources of *Quercus robur* and *Q. petraea*.

Monitoring plots whose data are available from IKT

- Network of Forest Inventory Plots of the Basque country: undertaken in 1996 and 2005 (some 3,900 plots in total following the UTM 1*1 grid.)
- Basonet Plots Network: 428 parcels, sub-sample 3*3 km of the forest inventory of the Basque Country, which includes soils' analysis (undertaken in 2001).

Known plots whose data are unavailable

- Network of Plots of Introduced Conifer Species of the IFIE-INIA, 1966-1983. This deals with various parcels of experimental plantations in state owned mountainous land in Bizkaia and Gipuzkoa.
- Network of Plots of sources for *Pseudotsuga menziesii* and *Fagus sylvatica* (Araba) installed by the Lourizán Institute.
- Trial Plot of resistant *Castanea sativa* (Laukiz, Bizkaia) installed by the Lourizán Institute.
- Eucalyptus provenances assays for *Eucalyptus spp* (Bizkaia) installed by ENCE
- Trials of application of iron slag LD and fertiliser NPK in agrarian systems with *Pinus radiata* in the Historical Territory of Bizkaia (last undertaken by silviculturists in 2000)

6.e Navarra

Experimental plots in Navarra depending on Sección de Gestión Forestal del Departamento de Desarrollo Rural y Medio Ambiente.

- Network of silvicultural (thinning regimes) trials with different species: *Fagus sylvatica L.* (Txangoa, Legua Acotada, Aralar); *Pinus nigra Arn.* (Oloriz, Zúñiga); *Pinus sylvestris L*. (Garde, Aspurz -monitoring plot-).
- Network of provenance trials of *Pseudotsuga menziesii*, *Sequoia sempervirens* and *Fagus sylvatica.*
- Plots at different stands for forest management plans data.
- Data from *Inventario forestal nacional* (national forest inventory) plots.
- European plots net (Level 1): 18 plots
- European plots net (Level 2): 1 plot, located in Burguete.

6.f France

As in many other countries, the first forest monitoring network in France was the National Forest Inventory (IFN). It was created in 1958 and effectively implemented all over France during the sixties and the seventies. Later on, it was very useful to account for carbon sequestration, together with the national Land Survey (TERUTI). At the end of the seventies and the beginning of the eighties, deteriorations of forest health were observed in many sites (see introduction and paragraph 1.1.2.4). These events induced the implementation of monitoring system of forest health at the national and European levels (1986 regulation).

As a result, the current permanent forest monitoring network can be represented by the graph below:

LEVEL 3

F-ORE-T: 9 instrumented plots

LEVEL 2

RENECOFOR: 102 plots

LEVEL 1

16X16 km European network: 500 French plots

LEVEL 0

IFN and DSF observations

7 of the 9 sites of F-ORE-T network (Survey for Environment Research on Forest Ecosystem Functioning) are located in metropolitan France (the 2 others are in French Guiana and in Côte d'Ivoire). They represent the different kinds of French forests: plain, Mediterranean, artificial and tropical forests. Functioning and quantification of carbon fluxes are determined, with nutrient balances 12 . Those data were utilized in CARBOFOR project (2004).

For level 2, meteorological, dendrometric and dendrochronologic parameters are assessed. Atmospheric inputs are also assessed for only 27 plots and soil solutions for 17. Some new objectives are set up for this network and particularly to study forest ecosystems evolution under climate change.

For level 1, in an European perspective and since 1989, some permanent plots have been set up. 20 trees per plot are assessed every year in order to study forestry health.

For level 0, IFN (National Forest Inventory) carries out permanent survey on more than 7.000 temporary plots a year (one plot per 2000 ha of forest). Dendrological, ecological (plants and soil) and environmental data are collected using remote sensing techniques and field measurement. At last, all these networks are completed by non systematic observations realized by DSF (Forest Health Department).

Regarding biodiversity, the National Museum (Muséum National d'Histoire Naturelle, MNHN) coordinates a national network, with regional sub-networks. The aim is to follow the state of nature condition by observation of biodiversity indicators groups: birds, butterflies, bats and coming soon plants and amphibians. Most of the observations are carried out by voluntary naturalists' networks, utilizing simple scientific protocols 13.

6.g United Kingdom

Forest Research maintains databases of records of forest experiments that have been set up since the 1920s. For historical reasons, the information is stored in two separate databases: one at the Northern Research Station holds information on silvicultural and genetics experiments that have been set up in Scotland, Wales and Northern Britain, while the other at Alice Holt Research Station contains records of experiments set up in lowland England. It is intended to merge the two databases together, and make the information available on-line.

Both databases contain records on species and provenance trials. A subset of existing experiments, which also includes many species and provenance trials, has been identified for long-term retention, and information on these can be accessed from the NoLTFoX website [1]which also contains records on experiments from other northern European countries.

7 Existing results on climate change adaptation

7.a Portugal

Since the National Strategic Plan for the Climate Change hasn't been implemented yet, there is little information on forest adaptation to climate change.

The known publications on this matter are listed below:

F. D. Santos, K. Forbes, and R. Moita (2002). Climate Change in Portugal. Scenarios, Impacts and Adaptation Measures - SIAM Project. Gradiva, Lisbon, Portugal (456 pp).

Pereira JS, Correia AV, Correia AC, Ferreira T, Godinho N, Onofre N, Freitas H. (2005). Florestas e Biodiversidade in Santos FD, Miranda P, eds. Alterações Climáticas em Portugal. Cenários, Impactes e Medidas de Adaptação. Lisboa. Gradiva

1 http://noltfox.metla.fi

7.b Galicia

Most climate change research in forestry has focused on its impacts and mitigation; in comparison, there has been little systematic research on the adaptation of forest management to climate change. Much of the mitigation work is focused on the important contribution that forestry makes to carbon budgets, including developing carbon inventories, developing forest management guidelines to promote carbon sequestration, and forestry as source of bio-energy.

7.c Castilla y León

i. Analysis of recent climatic variations in Castilla y León (Spain)

This paper reports the results of the analysis of annual mean temperature and precipitation series from 171 meteorological stations distributed over Castilla y León in Spain on monthly, seasonal and annual time-scales for a 37-year study period (1961–1997). Various statistical tools were used to detect and characterize significant changes in these series. The magnitude of the trends was derived from the slopes of the regression lines using the least squares method, and the statistical significance was determined by means of nonparametric tests. Positive trends of about 0.33 ºC in the annual mean temperature were found for the whole period. Mean temperatures increased in spring and winter, the winter trend being statistically significant. The months of December and March also showed significant trends. Decreases in rainfall were found for three seasons (winter, spring and autumn), with statistically significant trends in March. Summer precipitation showed slight increases over the 37-year period. On this basis, the authors consider that the increase in summer precipitation and the decrease in the range of average temperatures between the warmest and the coldest months of the year (continentally), point towards a trend to a more oceanic climate in Castilla y León.

ii. Variability of Mediterranean Stone pine cone production: Yield loss as response to climate change

Cones are harvested from Mediterranean Stone pine *Pinus pinea* L. for their edible kernels, pine nuts, which have been used as a food item in the region since Palaeolithic times. At present, cone yields render higher incomes to the owners of these pine forests than any other forest products. The large annual variation of cone yields is an important issue for forest management planning, which requires further research in order to establish its causes. One of the simplest explanations given for masting habits in polycarpic plants is that of weather tracking. Many plant ecologists, however, consider that this theory is insufficient and that further causes should be investigated. In this context, the present study analyses historical weather and yield registers over 41 years in one of the world's main Stone pine areas, the Northern Inland Plateau of Spain. Significant relationships found between rainfall and temperatures at certain key periods during the 4-year cone development period allowed for a multiple linear regression model for the log-transformed annual cone yield to be set up. This also included a negative autocorrelation with the ripening cone load during strobili induction. The model accounts for 75% of total variance between years. The observed trend of cone-yield reduction from 180 to less than 100 kg /ha in the last 40 years was slightly overestimated by the predicted effects of the co-variables that show significant tendencies to a warmer and drier climate.

iii. Influence of climatic variables on crown condition in pine forests of Northern Spain: current state and climate change scenarios

The high frequency of climatic perturbations and natural disasters driven by pollution and greenhouse gases, suggests that a global climate change is likely occurring, a fact now widely accepted by scientific community. Changes in land use and other emissions are causes of atmosphere saturation by particles, increasing greenhouse effect, thus leading to the warming of atmospheric lower layers. Current mitigation policies derived from Kyoto Protocol follow two main ways, reduction of gas emissions and implementation of a sustainable development assuring persistence of carbon sinks, mainly forest lands. Sustainable forest management is an essential tool to assure the permanence of our forests and to maintain properly their ecological functioning, and it is promoted by Kyoto Protocol too.

The role of forest as a CO2 drain is influenced by the presence of forest pests and diseases, causing tree defoliation and crown reduction. Live crown condition is closely related to forest health, and also the contribution of each individual tree on CO2 sequestration depends on crown development. In addition, forest health is greatly determined by the management applied. The objective of this study is to search for relationship between, defoliation or crown transparency, an evident forest health parameter, and climatic variables, as temperature, rainfall and solar radiation, aimed to determine how this influence is and which are the effects in a future climate change scenario.

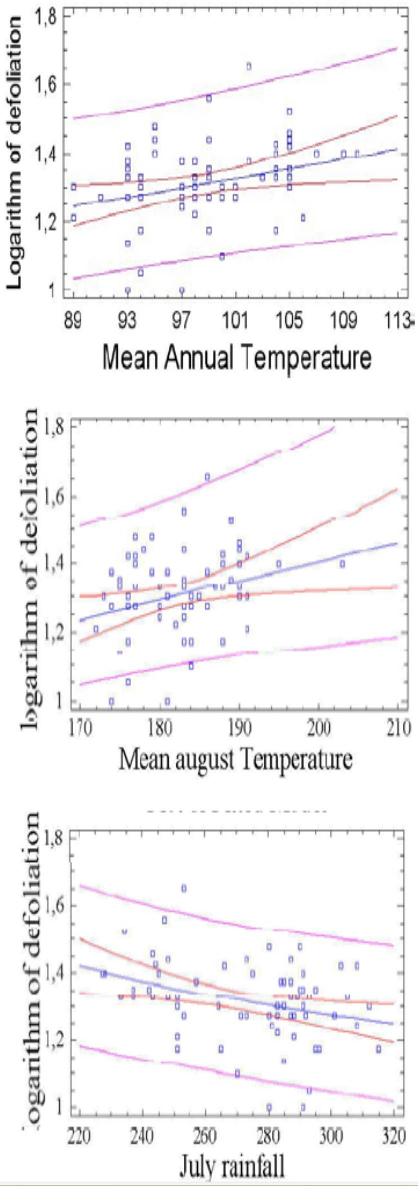

Illustration 63: Regression models for defoliation and climatic parameters. Exponential regression model related to mean annual temperature [Plot defoliation = exp(-0.244452 + 0.0052147 Mean annual temperature)] (left). Double reciprocal model related to mean August temperature [Plot defoliation = 1 / 0.155929 + 111.238 / August temperature] (Right). Reciprocal-X regression model related to July rainfall [Plot defoliation = 0.872209 + 120.684 / July rainfall] (Center).*

Defoliation was estimated following methods of the European Programme for the Intensive Monitoring of Forest Ecosystems, level I, in 68 plots included in the Second National Forest Inventory (38 of *Pinus sylvestris*, 22 of *P. nigra* and 9 of *P. pinaster*), located in Palencia province (Castilla y León, Spain). These plots were selected from systematic sampling, in a 2 Km grid. Meteorological variables for each stand were obtained from the Digital Climatic Atlas of the Iberian Peninsula.

Statistical analysis showed differences in mean plot defoliation among levels of mean annual temperature, August temperature, and July rainfall. Defoliation was significantly higher in plots with higher levels of mean annual temperatures and August temperature, and lower levels of July rainfall. The analysis showed that changes in these variables may produce a significant increase of defoliation. Thus, these meteorological variables may act as key factors in forest condition, and their future variation could be a major cause of forest damage, and an important issue to take into account the forest management under climate change scenarios.

iv. **Assessing Pine Wilt Disease Risk under a Climate Change Scenario in Northwestern Spain.**

Forest ecosystems are characterized by their structural complexity and biodiversity and trophic relationships within them commonly involve several levels. Functioning of these systems is likely to be perturbed in many ways if significant warming predicted eventually occurs. Among the interactions to be shifted by temperature increments in the Mediterranean region, these between forest pest and host trees are highly relevant to forest conservation and management, since perturbations may result in many cases in a reduced probability of tree or stand survival.

In this chapter, we defined a risk rating model to establish distinct risk levels for development of pine wilt disease in Castilla y León Autonomous Community determined: firstly, current forest areas were these levels occurred and secondly, expected changes in risk areas if global warming raised main air temperature of July by 2°C. The potential introduction of the pine wood nematode poses a serious threat to many pine forest in Europe, thus, even though the study presented is within a regional scope, the procedure here developed would be of interest for application to most of the European regions were *Monochamus galloprovinciallis* and susceptible hosts occur.

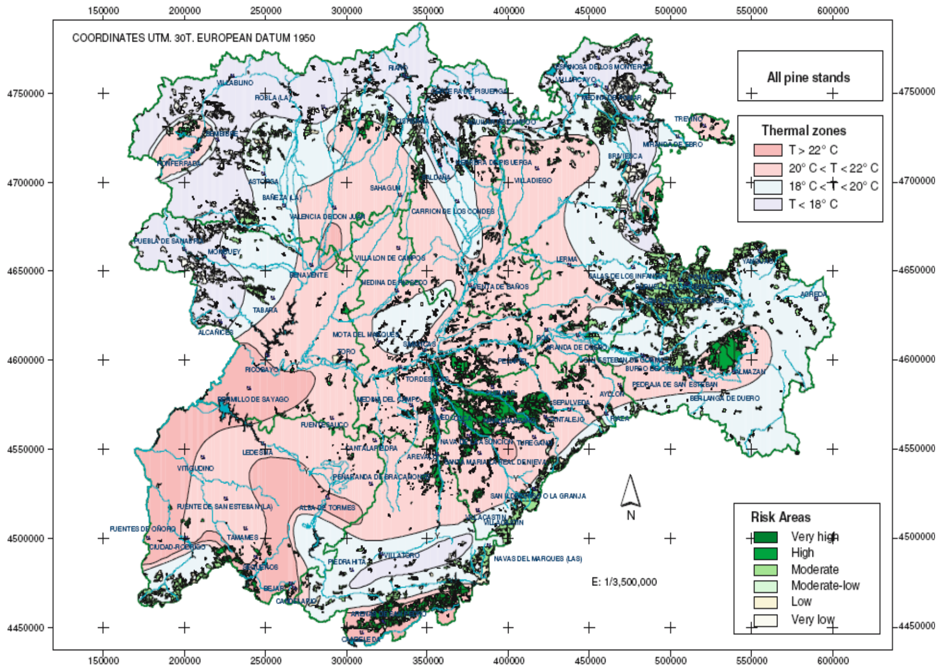

Fig. 3 Current risk levels of pine wilt disease in all pine stands in Castile and Leon

Illustration 64: Risk level of pine wilt disease in Castilla y León

7.d Basque Country

At this point, and surely due to the lack of a Basque Plan Against Climate Change, the author/s is aware of only a small list of publications on the adaptation of forest systems to climate change:

Garcia-Plazaola, Jose Ignacio, Esteban R, Hormaetxe K, Fernandez-Marin B1, Becerril JM- 2008. Photoprotective responses of Mediterranean and Atlantic trees to the extreme heat-wave of summer 2003 in Southwestern Europe. Trees-Structure and Function: 22: 3. 385-392

Loidi, Javier, Ortubay, A. 2001. Cambio climático: Predicción de su influencia en la distribución de especies arbóreas en el País Vasco. En: Vegetación y cambios climáticos / coord. por Francisco Gómez Mercado, Juan Francisco Mota Poveda, ISBN 84-8240-493-8, p. 165-176.

Ortubai, Amelia 2000. Repercusión de la hipótesis de cambio climático en la vegetación del País Vasco. En: El Campo de las ciencias y las artes. - N. 137, p. 261-278-

Silván Beraza, Fran, Ortubay, A. 2001. Caracterización climática del hábitat potencial y actual de tres especies arbóreas en los valles de Ayala y Orduña (País Vasco) En: Vegetación y cambios climáticos / coord. por Francisco Gómez Mercado, Juan Francisco Mota Poveda, ISBN 84-8240-493-8, p. 177-188.

Eusko Jaurlaritza 2005. Inventario Forestal de la Comunidad Autónoma del País Vasco 2.005. [1]

7.e Navarra

There are no trials (known or found) within the topic of forest adaptation to climate change. But some key references about forest and management in Navarra are enclosed:

- Camarero, J.J. & E. Gutiérrez (2004): Pace and pattern of recent treeline dynamics: response of ecotones to climatic variability in the Spanish Pyrenees. Climate Change 63:

- Castillo, F. J., Imbert, J. B., Blanco, J. A., Traver, C. y Puertas, F. 2003. Gestión forestal sostenible de masas de pino silvestre en el Pirineo Navarro. Ecosistemas 2003/3 [2]

- Iriarte, A, Puertas F. 2003. Site of thinning experience in Pinus s*ylvestris* L. Aspurz. Silviculture and sustainable management in mountain forests in the western Pyrenees. IUFRO (Units 1.05.14; 1.05.15 & 4.00.00) Navarra, Spain, September 15-19, 2003.

- Iriarte, A, Puertas F. 2003.Thinning experiment in a stand of Pinus nigra in Oloriz. Silviculture and sustainable management in mountain forests in the western Pyrenees. IUFRO (Units 1.05.14; 1.05.15 & 4.00.00) Navarra, Spain, September 15-19, 2003.

- Traver M. C. ; Puertas, F. 2003. Beech (Fagus Sylvatica L.) Provenances Experimental Trial Site. Burguete – Navarra (Spain) Silviculture and sustainable management in mountain forests in the western Pyrenees. IUFRO (Units 1.05.14; 1.05.15 & 4.00.00) Navarra, Spain, September 15-19, 2003.

1http://www.nasdap.ejgv.euskadi.net/r50-15135/es/contenidos/informacion/inventario_forestal_index/es_dapa/inventario_forestal_index.html

2 http://www.aeet.org/ecosistemas/033/investigacion3.html

$^{35}_{17}$ Vega G. et al.: Pacific Douglas fir: 15 year performance in Ochagavia common-garden test, the pyrenees, Navarra, Spain. IUFRO 1995.

$^{35}_{17}$ Zavala MA, Zamora R, Pulido F, Blanco JA, Imbert JB, Marañón T, Castillo FJ, Valladares F Nuevas perspectivas en la conservación, restauración y gestión sostenible del bosque mediterráneo. En “Ecología del bosque mediterráneo en un mundo cambiante” Valladares, F. (ed.). pp. 509-529, Ministerio de Medio Ambiente, EGRAF,
S.A. Madrid, 2004. ISBN: 84-8014-552-8.

$^{35}_{17}$ Web pages:
The Spanish Nacional Climate Change Adaptation Plan
http://www.presidencia.gub.uy/_web/cambio_climatico/Plan_Nal_Espana.pdf
http://www.mma.es/secciones/cambio_climatico/documentacion_cc/divulgacion/pdf/pnacc_ing.pdf

7.f France

Most of research projects dealing with climate change impacts (current or expected) give some direct and practical advice for forest adaptation. The guidelines previously quoted for ONF and SFCDC are some examples. For instance, from the climate forecast and various modelling, CARBOFOR project (Loustau, 2004) led to recommendations. Where climate change effects are beneficial to forest functions, in northern temperate, continental and boreal forests, the results suggest that optimising forest management should aim at reducing the effects of limiting factors, for instance through fertilisation. Conversely, where detrimental effects of the future climate are expected through increased water deficit, e.g. in southern temperate and Mediterranean forests, enhancing the ecosystems resistance to drought and fire using species substitution, understory control, site preparation and reductions in the maximal value of leaf area index could be appropriate strategies to adopt.

Since climate change is provoking a continuous -but not monotonous- change in site productivity, the forest management must be revised dynamically along its life course. At the southern margin of geographical areas, a management aiming at an optimal adaptation of forests should be considered, favouring, for example, multi-age and mixed forest stands including pre-existing species and their southern variants and maximising the intra-specific diversity.

The institution in charge of private forestry (CNPPF) has developed general information of forest owners on the physical bases of climate change, on the present and actual effects and on possible future effects. Then many questions have been raised (“what must I plant?”...) and their answers have still to be elaborated by the scientists. All these questions were compiled in 5 thematic sheets published in a professional newspaper (Riou-Nivert, 2008):

- stand management: how to diagnose stands to know their potential? do we have to develop new silvicultures and what kind? do we have to get techniques for stand establishment in progress?

- forest reproductive material: how to choose the species? what about genetic improvement and conservation of genetic resources?...

- forest sites: how to take into account water balance? how to determine the sites which present higher risks for the strands in regard to climate change? what is precise species autecology?...;

- risk management: how to take into account the direct and indirect effects of climate change (dryness, hot wave, storm, fire, disease...) in silvicultural management? how to manage the risks? wood production and harvest: what are the quantitative and qualitative evolutions of harvest?

Specific researches are carried out in order to answer these questions:

- predictive mapping for forest sites, using three main ecological factors (soil nutrient content, soil moisture and bioclimate which integrates temperature and water balance) (Gegout and al., 2008); in Champagne-Ardenne (North-Eastern France) forest managers took also into account climate change in their forest sites types and they defined new guides (Gaudin, 2007);

- the DRYADE project (cf. chapter 1.1.3.2), in progress, will lead to recommendations for forest managers to take into account the drought and its consequences on forest diebacks, threw an anticipating management plan (species and varieties, objectives, stand resilience improvement) or an attenuation of constraints (adapted silviculture, fight against diseases and parasites);

- within the scientific platform about the “maritime pine of the future”, which gathers together FCBA, INRA, CRPF and ONF in Aquitaine, genetic improvements of maritime pine (Pinus pinaster) are carried out; one of the new criterion for this improvement is the adaptation of current or new varieties to dryness (Alazard, 2006).

With all the uncertainties concerning climate forecast, natural species adaptiveness and forest inertia, forest owners and managers are still prudent by implementing “no regret” or reversible strategies (shorter turnaround times, mix of species...). Strategies to manage uncertainties are needed and should be based on various scenarios more or less pessimistic. They would explore all the possible futures, by analyzing and evaluating all the possible actions at different scales and mainly at local scale to be more adapted (Legay and al., in press). As long as deterministic techniques are no more entirely appropriate and decision methods under uncertainty are not yet tailored to forest management, the feeling of vulnerability will still be reinforced.

7.g United Kingdom

Most of the emphasis of climate change research in forestry has focussed on impacts and mitigation, in comparison there has been little systematic research on adaptation of forest management to climate change. Much of the mitigation work is focussed on the important contribution that forestry makes to carbon budgets, including developing carbon inventories, developing forest management guidelines to promote carbon sequestration, and forestry as source of bio-energy. Full details on mitigation[1]. Other relevant programmes include research on biosecurtiy in a changing climate[2] and tree stability and climate[3]

Potential impacts of the projected changes in climatic factors on plantations and native woodlands have been assessed using Ecological Site Classification (ESC), which is a decision support system that assesses species suitability based on climatic and edaphic factors (Pyatt, Ray and Fletcher, 2001). This provides an objective way of assessing how projected changes under different CO_2 emission scenarios might affect species suitability in different regions of Britain (Ray, Pyatt and Broadmeadow, 2002). For example, beech is relatively drought intolerant, and the warmer and drier climate projected for southern England would reduce its suitability, confining it to more moisture retentive sites; whereas its suitability in more northern and western parts of Britain might increase (Figure 42). Further information on impacts on other species can be found in Ray, Pyatt and Broadmeadow (2002)[4], and maps of predicted yields of ash (*Fraxinus excelsior*), downy and silver birch (*Betula pubescens* and *B. pendula*), sessile and pedunculate oak (*Quercus petraea* and *Q. robur*), sweet chestnut (*Castanea sativa*), sycamore (*Acer pseudoplatanus*), Corsican pine (*Pinus nigra* ssp. *laricio*), Scots pine (*Pinus sylvestris*), Douglas-fir (*Pseudotsuga menziesii*) and Sitka spruce (*Picea sitchensis*)

Knowledge gained from work assessing potential impacts of the projected changes on species suitability, together with past work on species and provenance trialling, help inform the development of guidance that suggests the use of more southerly provenances selected on the basis of climate matching (Broadmeadow, Ray and Samuel, 2005; Hubert and Cottrell, 2007), and other strategies such as promoting more frequent natural regeneration cycles to maintain high genetic variation, and planting mixtures of local and non-local provenances (Hubert and Cottrell, 2007).

Currently, new research initiatives are being developed on adaptation strategies to climate changes that include trialling of species that might be suited to the projected future climate of Britain, particularly in southern Britain where the impacts of projected changes are likely to be greatest. Such work is also driven by the need to source alternative species to

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1http://www.forestresearch.gov.uk/website/forestresearch.nsf/ByUnique/INFD-62HCJH

2http://www.forestresearch.gov.uk/fr/INFD-5STC8A

3 http://www.forestresearch.gov.uk/fr/INFD-639A92

4http://www.forestresearch.gov.uk/website/forestresearch.nsf/ByUnique/INFD-5ZXFSD

Corsican pine (*Pinus nigra* ssp. *laricio*) which is very susceptible to red band needle blight (*Dothistroma septosporum*) that has recently spread to the UK (Brown and Webber, 2008).

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8.a Portugal

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