Criterion 1

Maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles

INDICATOR 1.1

Area of forest and other wooded land, classified by forest type and by availability for wood supply

Landuse	1993		1998		2003		1993-2003
	x1,000 ha	%	x1,000 ha	%	x1,000 ha	%	Annual variation annuel
Forest (incl. poplar plantations)	**14,811**	**27.0%**	**15,220**	**27.7%**	**15.408**	**28.1%**	**0.4%**
Broadleaved	9,466	63.9%	9,715	63.8%	9.852	63.9%	0.4%
Conifers	4,052	27.4%	4,122	27.1%	4.090	26.5%	0.1%
Mixed	1,292	8.7%	1,384	9.1%	1.466	9.5%	1.3%
Other wooded land	**1,935**	**3.5%**	**1,825**	**3.3%**	**1.743**	**3.2%**	**-1.0%**
Thicked, hedges and scattered trees	**1,664**	**3.0%**	**1,563**	**2.8%**	**1.517**	**2.8%**	**-0.9%**
Total Wooded lands and other lands with tree cover	**18,410**	**33.5%**	**18,608**	**33.9%**	**18,668**	**34.0%**	**0.1%**
Others	36,509	66.5%	36,311	66.1%	36,251	66.0%	-0.1%
Total	**54,919**	**100.0%**	**54,919**	**100.0%**	**54,919**	**100.0%**	**0.0%**

(Source: SCEES/Teruti 1993, 1998 and 2003; forests excluding poplar plantations correspond to codes 18-21, poplar plantations to codes 24 and 25; FAO's other wooded land category corresponds to heathland-maquis-garrigues in the Teruti survey, code 70 ; thickets, hedges and scattered trees correspond to codes 22, 72, 23 and 26)

Commentary: the forest area in France has expanded to the current level of 15.4 million ha, i.e. 28.1% of the total area. The increase noted from 1993 to 1998 continued thereafter, but at a slower pace, decreasing from 82,000 to 38,000 ha per year. This downturn is mainly due to a decline in the afforestation of heath, fallow and farm lands. It is also associated with the decrease in agricultural abandonment and in subsidies that were provided to promote farmland afforestation within the framework of post-storm forest rehabilitation programmes (cf. § 1.1.1). Afforestation rates have been greatest in some of the least forested regions (Bretagne, Pays-de-la-Loire), as well as in the Mediterranean region, where the forest cover is already above 30% (Maps 1 and 2).

The percentage of broadleaved stands has remained steady (64%), whereas mixed stands have been increasing regularly. The conifer forest area seems to have levelled off at about 4.1 million ha.

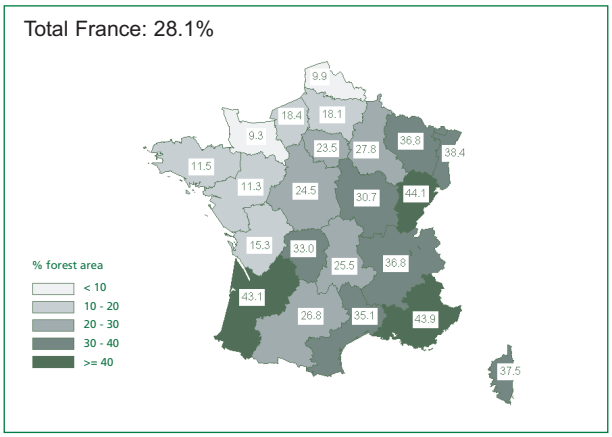
France ranks 3rd amongst the 25 EU countries in terms of forest area, surpassed only by Sweden (27.1 million ha) and Finland (21.9 million ha).

In France, the FAO classification "other wooded lands" corresponds to the "heathland-maquis-garrigue" category in the Teruti survey conducted by the French Service central des enquêtes et études statistiques (SCEES) and to most of the same Inventaire forestier national (IFN) categories. Contrary to its forest inventory data, IFN has not recorded any dendrometric data relevant to other wooded lands. These formations account for only 3.2% of the forest area in France, and they regressed at a rate of 16,000 ha per year between 1998 and 2003, as compared to 22,000 ha per year during the 5 preceding years. This is clearly in line with the preceding trend, i.e. heathland afforestation was already under way, but at a slower pace, along with a shift from heathland to farmland.

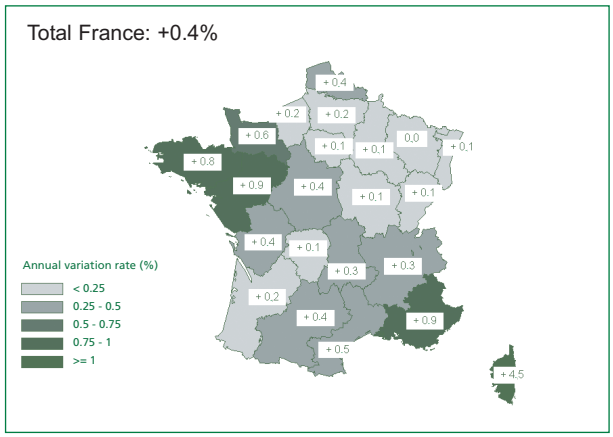
Areas with thickets and scattered trees also decreased from 1998 to 2003, but to a lesser extent than during the previous period. However, the overall trend shows an increase in afforestation in these lands, which has increased the forest area (cf. § 1.1.1).

Wooded lands and "other lands with tree cover" currently account for 18.7 million ha, or 34% of metropolitan France.

Finally, a comparison with the last two IFN inventories shows that planned afforestation accounted for just 16% of newly forested areas on average during the 1984-96 period, while a rate of 13% was recorded for a more recent period (1992-2002) in the Teruti survey conducted by SCEES. This indicates that the expansion of French forests has mainly been due to natural afforestation of heathland and fallows.



Map 1: Percentage forest area by administrative region in 2003 (source: SCEES/Teruti)



Map 2: Annual variation rate in forest area by administrative region from 1993 to 2003 (source: SCEES/Teruti)

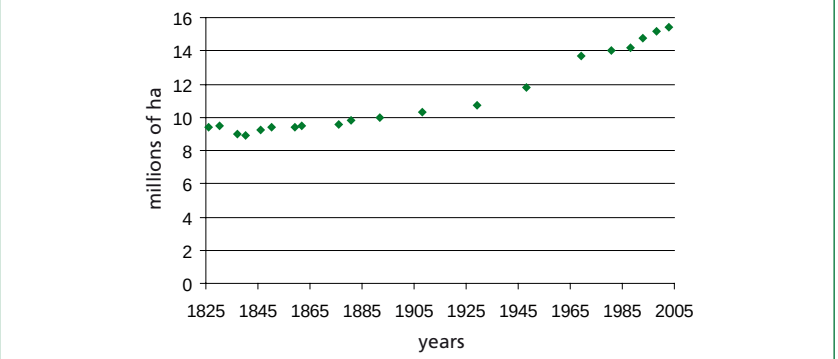


Figure 1: Variations in forest area over the last 2 centuries (source: Cinotti, based on a multi-source compilation for the pre-1980 period; SCEES/Teruti for the post-1980 period)

⇨Note : even though the direction of the trend is beyond doubt, the different values plotted on the graph should be considered with caution since, until 1960, they are based on estimates from varied sources, often drawn from the land register. This register is above all a fiscal instrument that often underestimates forest areas. From certain surveys, it can be estimated that in slack periods of afforestation the land register's underestimate is usually around 20%, but that in periods of intense afforestation the underestimate may be as much as 50% for some localities. The land register figures have nevertheless become much more reliable in recent years. From the 1960s, new statistical methods using aerial photography (Teruti survey of the Service central des enquêtes et études statistiques (SCEES) of the French Ministry of Agriculture, and the permanent inventory of forest resources conducted by the Inventaire forestier national (IFN), have improved the assessment of forest areas.

Box 1: Variations in forest area over the last 2 centuries

The area of land under forest has increased markedly since the early 19th century–it seems to have virtually expanded by two-thirds in nearly 2 centuries.
This situation, which is common to most European countries, is especially the upshot of higher agricultural yields and the reduced need for land for food production in the 19th and 20th centuries. It has also led to planned and natural reforestation of marginal land that had been cleared and cultivated as a result of population pressure. This has simplified erosion and flood control initiatives within the framework of national policies. The growth of forest areas is a very positive trend, since public opinion, the scientific community and legislators are unanimous in acknowledging the great economic, ecological and social value of forests. This sharp rise in forest coverage over 2 centuries should, however, not detract from the fact that land is still being cleared as a result of urban growth and infrastructural development, particularly around large built-up areas, and that some very unique forest environments, such as alluvial forests, are dwindling because of major projects undertaken to modify the course of large rivers.

Forest stands available for wood supply (including poplar plantations)

Forest type	1993		1998		2003		1993-2003
	x1,000 ha	% available /total	x1,000 ha	% available /total	x1,000 ha	% available /total	Annual variation rate
Broadleaved	9,062	95.7%	9,272	95.4%	9,344	94.8%	0.3%
Conifers	3,875	95.6%	3,929	95.3%	3,874	94.7%	0.0%
Mixed	1,236	95.6%	1,319	95.3%	1,388	94.7%	1.2%
Total	**14,172**	**95.7%**	**14,520**	**95.4%**	**14,605**	**94.8%**	**0.3%**

(Source : SCEES/Teruti 1993, 1998 and 2003 and IFN 1994, 1999 and 2004 to estimate the share available for wood supply represented by production forest stands that can be accessed for wood supply, including non-inventoried stands and poplar plantations).

Commentary: IFN considers that forest stands available for wood supply include all production forests that can be accessed for wood supply, along with poplar plantations. This is currently estimated to represent 95% of the total wooded area, or 14.6 million ha. This percentage applies equally to broad-leaved, conifer and mixed forests. It decreases slightly over time because the forest area not available for wood supply is expanding at a faster pace than production forests (2.6% versus 0.3% per year).

INDICATOR 1.1.1
Forest area gains and losses

Commentary: the transition matrix obtained in the Teruti survey conducted by the Service central des enquêtes et études statistiques (SCEES) enables a detailed analysis of the different patterns leading to the observed expansion of forest area. This matrix covers the 1997-2003 period, which overlaps the periods discussed in § 1.1, thus explaining the slight differences in the data presented.
Over the 1997-2003 period, the forest area increased by +40,200 ha per year on average as the result of two contrasting trends–a gain in forest area of 84,700 ha per year and a loss of 44 500 ha per year.

Origin and allocation of forested area	Changes in forested area from 1997 to 2003 (ha/year)		
	Forested area gains	Forested area losses	Balance
water and wetlands	1,100	-1,100	0
soil with outcropping parent rock	2,900	-1,200	1,700
farmland in use	23,300	-12,200	11,100
thickets and scattered trees	13,600	-7,300	6,300
hedges	1,300	-1,500	-200
hathland-maquis-garrigues and fallows	38,800	-13,500	25,300
grassland, trails and ornamental gardens	1,200	-2,000	-800
man-made areas +/- structures, prohibited areas	2,600	-5,800	-3,200
total	**84,700**	**-44,500**	**40,200**
% of total in France	0.15%	-0.08%	0.07%

(Source : SCEES/Teruti, see transition matrix for 1997/2003 in appendix ; forested area encompasses woodlands and forests (18 to 21) and poplar plantations (24, 25))

These gains in forest coverage concerned heathland and fallows (46%), farmland (28%) and thickets and scattered trees (18%). Forest losses also concerned these three categories, but the balance is largely in favour of forests (estimated at +42,700 ha/year). The main negative category is man-made areas–infrastructures and urban areas–with an estimated balance of – 3,200 ha per year.

An in-depth analysis of the 1997-2003 transition matrix sheds greater light on these trends (cf. Appendix 11):

➢ the variations in heathland and fallows are in line with typical transitions that occur in periods ofagricultural abandonment: farmland ⇨ fallows ⇨ heathland ⇨ forest. The result of these transitions is that farmlands turn into heathlands and fallow lands at a rate of +10,900 ha/year and heathlands and fallows are transformed into forest at +25,300 ha/year. The rates estimated for the 1993-98 period are +26,600 and +47,600 ha/year, respectively, thus confirming the hypothesed correlation between diminishing agricultural abandonment and forest expansion.

➢ there is a positive shift from thickets and scattered trees to forest (+6 300 ha/year), which is due to two contrasting trends–thickets gradually become denser and expand to more than 50 ares, i.e. the threshold of the forest classification, at a rate of 13,600 ha/year, while forests are fragmenting into thickets at a rate of 7,300 ha/year.

➢ the situation differs markedly for hedges as the balance relative to forests is virtually null. Hedges have increased by +800 ha/year but this is offset by substantial reverse trends. The increase mainly involves thickets and scattered trees, which is hard to explain and possibly related to a confusion in the definition. The loss of hedges is mainly to the benefit of agriculture (–900 ha/year), but this rate is better than that estimated for the 1993-98 period (–3,200 ha/year).

INDICATOR 1.1.2
Forest area by biogeographical area and elevation class

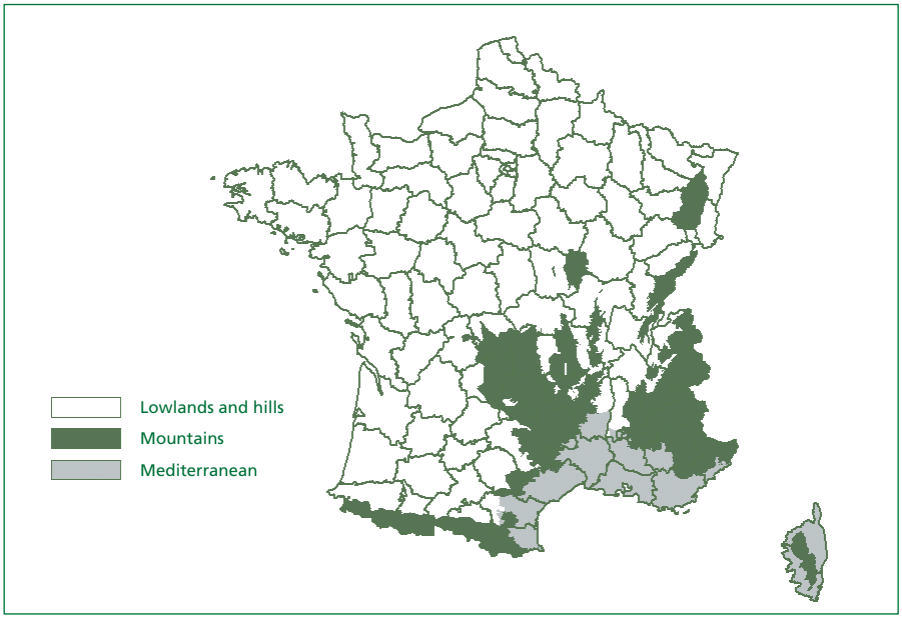
Forests (including poplar plantations)

Biogeographical area	1989		1994		1999		2004		1994-2004
	x1,000 ha	%	x1,000 ha	%	x1,000 ha	%	x1,000 ha	%	Annual variation rate
Lowland and hill forests	8,924	63.1%	8,989	62.4%	9,152	62.0%	9,338	61.8%	0.4%
Mountain forests	4,040	28.6%	4,171	29.0%	4,274	29.0%	4,403	29.2%	0.5%
Mediterranean forests	1,175	8.3%	1,234	8.6%	1,327	9.0%	1,357	9.0%	1.0%
Total	**14,139**	**100.0%**	**14,394**	**100.0%**	**14,753**	**100.0%**	**15,098**	**100.0%**	**0.5%**

(Source : IFN, for all forests including poplar plantations; the three biogeographical areas together form a series of IFN forest regions corresponding to the boundaries featured in the Atlas des forêts de France - Published by de Monza - 1991, p. 39)

Commentary: the 1994-2004 Inventaire forestier national (IFN) data correspond to an average for the 1986-1996 period because national inventories are currently only conducted every 10-12 years. These data therefore cannot be directly compared to the Teruti 1993-2003 survey data of the Service central des enquêtes et études statistiques (SCEES) mentioned in § 1.1.1 (cf. cautionary note).

Lowland and hill forests still represent over 60% of French forests, although this proportion continues to fall slightly in favour of the other categories. Mediterranean forests have recorded the highest rate of increase (+1% per year), mainly owing to the natural afforestation of heathland and fallow land by Aleppo pine, pubescent oak and holm oak. Mountain forests are expanding at a fair rate (+0.5% per year)–their proportion is now close to 30% of the total area.



Map 3: Biogeographical areas in France (source: IFN)

Commentary: two-thirds of French forests are lowland forests below 500 m elevation. Those located above 750 m represent over 20% of the total forest area, covering 3.3 million ha, and require management that is tailored to their specific climatic constraints. The percentage mapped forest area is increasing for all elevation classes, but at a higher pace at lower elevations, which is in line with the rate of increase of Mediterranean forests that are mainly located in lowland areas. The percentage mapped forest area is 57% within the 750-1,500 m elevation range.

Forests (including poplar plantations)

Elevation range	1999			2004			1999-2004
	Mapped area		% mapped forest area	Mapped area		% mapped forest area	Annual variation rate of mapped area
	x1,000 ha	%		x1,000 ha	%		
0 - 250 m	6,456	41.2%	19.5%	6,630	41.4%	20.0%	0.5%
250 - 500 m	3,913	25.0%	35.5%	4,005	25.0%	36.3%	0.5%
500 - 750 m	2,024	12.9%	49.9%	2,069	12.9%	51.0%	0.4%
750 - 1,000 m	1,375	8.8%	52.3%	1,404	8.8%	53.4%	0.4%
1000 - 1,500 m	1,437	9.2%	59.6%	1,455	9.1%	60.4%	0.2%
above 1,500 m	454	2.9%	27.1%	459	2.9%	27.4%	0.2%
Total	**15,659**	**100.0%**	**28.5%**	**16,023**	**100.0%**	**29.2%**	**0.5%**

(Source : IFN 1999 and 2004, for all forests of over 4 ha (including poplar plantations) based on the IFN cartographic database and the IGN Alti database (50 m elevation intervals). The areas monitored are larger than those derived from statistical data, i.e. 14,753 Kha for 1999 and 15,098 Kha for 2004, because they are based on cartographic processing data - cf. Appendix 4).

INDICATOR 1.1.3
Forest area by IFN forest structure

Forest stands available for wood supply (including poplar plantations)

Forest structure (excluding poplar plantations)	1989		1994		1999		2004		1994-2004
	x1,000 ha	%	x1,000 ha	%	x1,000 ha	%	x1,000 ha	%	Annual variation rate
regular high forest	5,753	43.1%	6,021	44.8%	6,423	47.2%	6,768	49.0%	1.2%
irregular high forest	729	5.5%	707	5.3%	671	4.9%	639	4.6%	-1.0%
coppice	2,393	17.9%	2,258	16.8%	2,124	15.6%	2,098	15.2%	-0.7%
mixed coppice/broadleaved high forest	3 685	27.6%	3,581	26.6%	3,494	25.7%	3,437	24.9%	-0.4%
mixed coppice/conifer high forest	683	5.1%	741	5.5%	747	5.5%	764	5.5%	0.3%
temporarily unstocked*	93	0.7%	137	1.0%	139	1.0%	115	0.8%	-1.7%
Subtotal	**13,337**	**100%**	**13,444**	**100%**	**13,597**	**100%**	**13,821**	**100%**	**0.3%**
unspecified	0		127		270		270		7.8%
Total	**13,337**		**13,571**		**13,867**		**14,091**		**0.4%**

* clear cutting or accident less than 5 years previously

Poplar plantations : regular high forest	**202**	**202**	**207**	**220**	**0.9%**

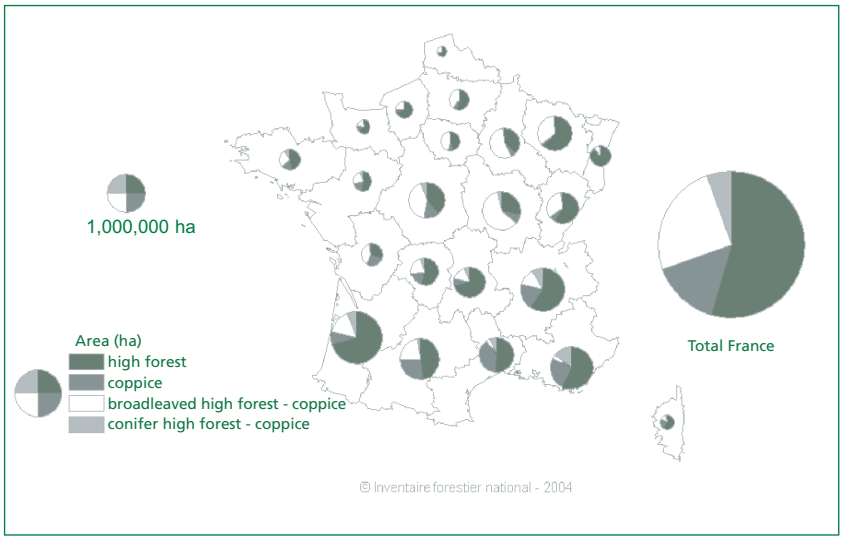
(Source : IFN, criterion established only for the inventoried forests available for wood supply and poplar plantations (landuse 5))

Commentary: silvicuture based on regular high forest has developed considerably in France over the past 2 centuries. High forest now represents 53% of the inventoried forest area compared with 32% in the estimates of the Daubrée statistics of 1908-1913 (excluding Alsace-Lorraine departments).

The increase in regular high forest noted 5 years ago is still under way, and mainly concerns broadleaved stands–it derives principally from the active or passive (by ageing) conversion of coppices and mixed coppice/high forest stands which are in sharp decline, and to a lesser extent from natural afforestation. This process is very clear in the eastern and northeastern regions (Alsace, Lorraine, Champagne-Ardenne, Franche-Comté and Rhône-Alpes) of France, as well as in Normandie and Pays de la Loire (cf. Appendix 11).
Coppices and mixed coppice/high forest stands still represent around 2/3 of broadleaved stands, which is a phenomenon specific to France, in contrast with countries following the German silviculture tradition and Scandinavian countries.

Areas classified as irregular high forest are also still declining. This trend mainly concerns the Rhône-Alpes, Auvergne and Limousin regions, where recent inventories have highlighted a clear reduction in irregular high forest to the benefit of regular high forest. When interpreting the low level attained by irregular high forest structures (4.6%), it should be kept in mind that the forest structure observed by IFN represents an objective recording of the state of the stand–essentially in terms of the vertical structure–and not a reflection of the work done by the owner. Aged or regularised selection high forests, particularly in the Jura and Pyrénées regions, are classified by IFN as regular high forest, even though current silviculture programmes are aimed at restoring selection.

The overall temporarily unstocked land area does not exceed 1% of the total inventoried forest area.
The increase in temporarily unstocked area resulting from the 1999 storms could only be partially taken into account since the survey data in the IFN database currently just covers 22 administrative departments (cf. list of survey dates and departments in Appendix 3). Paradoxically, a decrease in unstocked area is noted in the 2004 data because the area deforested by storms in Gironde and Landes was not taken into account. The 1994 and 1999 data integrate the damage inflicted by the frost of 1985 on maritime pine in these two departments, which sharply increased the unstocked area relative to the 1989 situation. IFN's new annual survey method should overcome this problem in future.



Map 4: Forest area by administrative region and IFN forest structure (source: IFN, 2004)

INDICATOR 1.1.4
Forest area by main tree species

Forest stands available for wood supply (excluding poplar plantations)

Main tree species	1989		1994		1999		2004		1994-2004
	x1,000 ha	% of total area	x1,000 ha	% of total area	x1,000 ha	% of total area	x1,000 ha	% of total area	Annual variation annuel
pedunculate oak	2,382	17.9%	2,424	17.9%	2,333	16.9%	2,200	15.7%	ND
sessile oak	1,762	13.2%	1,777	13.2%	1,868	13.6%	1,835	13.1%	ND
undifferentiated oak*	0		0		0		148	1.1%	ND
maritime pine**	1,398	10.5%	1,383	10.2%	1,381	10.0%	1,365	9.8%	-0.1%
beech	1,231	9.2%	1,255	9.3%	1,291	9.4%	1,301	9.3%	0.4%
Scots pine	1,179	8.8%	1,154	8.5%	1,122	8.2%	1,127	8.0%	-0.2%
pubescent oak**	846	6.3%	860	6.4%	920	6.7%	981	7.0%	ND
common spruce	717	5.4%	744	5.5%	740	5.4%	718	5.1%	-0.4%
silver fir	544	4.1%	554	4.1%	566	4.1%	572	4.1%	0.3%
chestnut**	515	3.9%	488	3.6%	492	3.6%	496	3.5%	0.2%
holm oak**	367	2.8%	390	2.9%	432	3.1%	432	3.1%	1.0%
ash	271	2.0%	309	2.3%	359	2.6%	398	2.8%	2.6%
Douglas fir	231	1.7%	296	2.2%	332	2.4%	368	2.6%	2.2%
Aleppo pine	232	1.7%	236	1.7%	241	1.8%	254	1.8%	0.8%
hornbeam	202	1.5%	197	1.5%	198	1.4%	204	1.5%	0.3%
Austrian pine	183	1.4%	188	1.4%	179	1.3%	194	1.4%	0.3%
birch	199	1.5%	163	1.2%	156	1,1%	164	1.2%	0,0%
Corsican pine	92	0.7%	109	0.8%	133	1.0%	153	1.1%	3.4%
false acacia	136	1.0%	134	1.0%	131	0.9%	131	0.9%	-0.2%
larch	95	0.7%	94	0.7%	96	0.7%	109	0.8%	1.4%
large alder	94	0.7%	85	0.6%	82	0.6%	83	0.6%	-0.2%
cork oak**	72	0.5%	79	0.6%	79	0.6%	79	0.6%	0.1%
willow	57	0.4%	52	0.4%	61	0.4%	71	0.5%	3.1%
aspen	60	0.5%	60	0.4%	61	0.4%	63	0.5%	0.5%
large maple	27	0.2%	33	0.2%	38	0.3%	57	0.4%	5.8%
mountain pine	55	0.4%	56	0.4%	55	0.4%	56	0.4%	0.0%
other broadleaved species	264	2.0%	245	1.8%	268	1.9%	290	2.1%	1.7%
other conifer species	118	0.9%	139	1.0%	153	1.1%	148	1.1%	0.6%
total broadleaved**	**8,484**	**63.7%**	**8,552**	**63.3%**	**8,769**	**63.7%**	**8,935**	**63.8%**	**0.4%**
total conifers**	**4,845**	**36.3%**	**4,953**	**36.7%**	**4,999**	**36.3%**	**5,063**	**36.2%**	**0.2%**
subtotal**	**13,329**	**100.0%**	**13,505**	**100.0%**	**13,768**	**100.0%**	**13,998**	**100.0%**	**0.4%**
unspecified	8		66		99		93		
Total	**13,337**		**13,571**		**13,867**		**14,091**		**0.4%**

* pedunculate, sessile and pubescent oak

** including estimated area in different formations of the Mediterranean region not inventoried in 1994, 1999 and 2004

(Source : IFN, apart from poplar plantations, a criterion set only for forests available for wood supply where the tree species is regarded as predominant. The variation rate of the area under pedunculate, sessile and pubescent oak could not be calculated because these three oaks were aggregated in 2004 when doubt was raised as to the species determinations)

Commentary: French forests are very diversified, with 136 species represented, including 176 broadleaved and 60 conifer species. Amongst these, 65 species or groups of species are sufficiently represented for the Inventaire forestier national (IFN) to include them in its forest dendrometric surveys (cf. Appendices 5 and 6).

Predominantly broadleaved stands are still in the majority, covering 64% of the forest area, or 8.9 million ha (Figure 3). Their annual rate of increase is now above that of conifer stands (+0.4% versus +0.2%). The different species of oak now represent more than 40% of the forest area of metropolitan France. Of these, sessile and pedunculate oaks cover 4.2 million ha, an area that has remained relatively steady over the last 10 years (Figure 2).

The main species that have expanded in the past decade are ash, pubescent oak, holm oak, beech, sessile oak, Corsican pine, Douglas fir, Aleppo pine and silver fir. Of these, pioneer species whose expansion can be explained by natural afforestation dynamics (ash, pubescent oak, Aleppo pine, holm oak) can be distinguished from species commonly utilised in silviculture programmes, for: afforestation and reforestation (Douglas fir, Corsican pine, silver fir), conversion to regular high forests (beech, sessile oak), and stand management (sessile oak, beech, ash, silver fir). The different explanations are not mutually exclusive–the expansion of beech is probably linked to its natural spreading tendency, to the silvicultural practices which favour it, particularly in oak-beech forests on the limestone plateau of northeastern France, and to its low palatability for large ungulates. The slight expansion of chestnut is the result of two contrasting phenomena: first, chestnut is declining due to the abandonment of old sweet chestnut groves and to the intended substitution of species in certain stands, particularly in the Massif Central and the Mediterranean region; secondly, it often takes over as the main species in mixed stands with pedunculate oak when the management of this later species is gradually halted, such as in the Limousin region.

There are various possible explanations for the reduction in the areas of certain main species. Common spruce is declining at the fastest rate, i.e. -0.4% or 2,600 ha per year. This is evidence that common spruce is gradually being replaced by other reforestation species (Douglas fir, broadleaved species, etc.). The regions most affected are Limousin, Rhône-Alpes and Alsace.

The slighter decline of Scots pine is actually the result of expansion via natural colonisation in the regions of southern France, and of a reduction by the substitution of species during reforestation in the other regions (in favour of Douglas fir, Corsican pine, white conifers and broadleaved species). The reduction in the area under maritime pine should be analysed while taking the relevant inventory dates into account. This decline is mainly the outcome of pest and disease problems affecting this species in the Provence-Alpes-Côte d'Azur region and the hurricane that hit Bretagne in 1987.

Finally, many studies are under way to assess the impact of climate change on the future spatial distribution of forest species. This includes, for instance, one component of the CARBOFOR project (cf. § 1.4) entitled "Modelling and cartography of the potential climatic area of major forest tree species". This study, which was undertaken between 2002 and 2004 by the French Institut national de la recherche agronomique (INRA) in collaboration with IFN, focused on 67 species. The main conclusions indicated a possible expansion of the potential area of Atlantic and Mediterranean species and a reduction in the areas of mountain species.

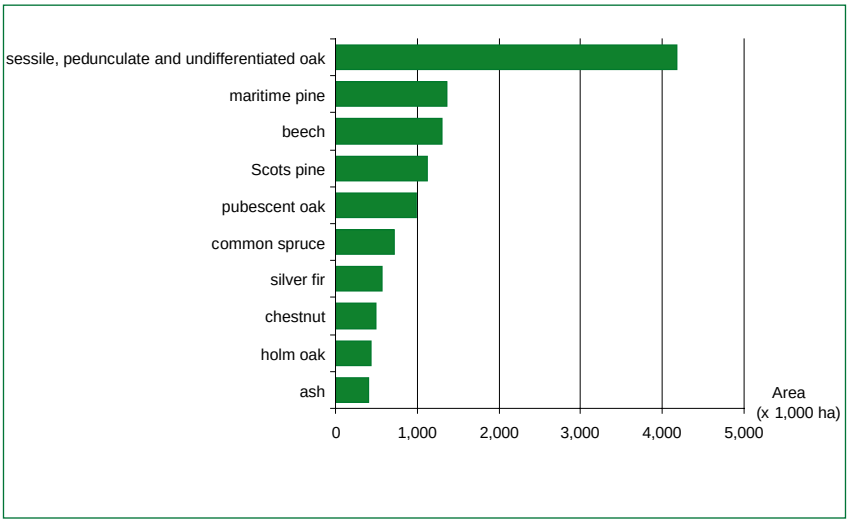
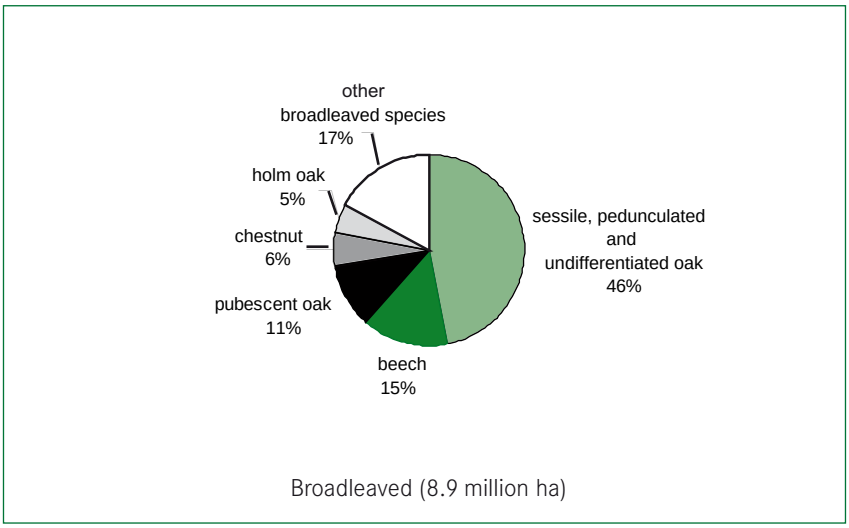


Figure 2: Forest areas of the top 10 tree species (source: IFN, 2004)



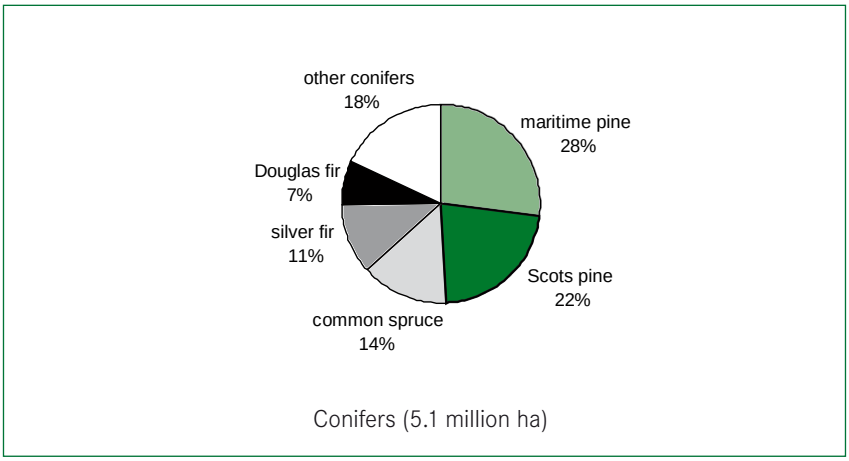


Figure 3: Forest area per main tree species (source: IFN, 2004)

INDICATOR 1.2

Growing stock on forest and other wooded land, classified by forest type and by availability for wood supply

Forest stands available for wood supply (excluding poplar plantations)

IFN stem volume (7 cm top diameter)

Forest type	1989		1994		1999		2004		1994-2004
	x 1,000 m³	%	x 1,000 m³	%	x 1,000 m³	%	x 1,000 m³	%	Annual variation rate
Broadleaved	1,003,991	58.3%	1,069,993	57.7%	1,147,815	57.7%	1,219,036	57.3%	1.3%
Conifers	558,873	32.4%	612,343	33.0%	648,956	32.6%	696,938	32.8%	1.3%
Mixed	159,687	9.3%	171,394	9.2%	194,093	9.7%	211,226	9.9%	2.1%
Total	**1,722,550**	**100%**	**1,853,730**	**100%**	**1,990,864**	**100%**	**2,127,201**	**100%**	**1.4%**

	m³/ha	m³/ha	m³/ha	m³/ha	%
Broadleaved	119	126	133	139	1.0%
Conifers	150	163	172	184	1.2%
Mixed	137	145	158	164	1.2%
Total	**129**	**138**	**146**	**154**	**1.1%**

(Source : IFN, apart from poplar plantations, for inventoried forests available for wood supply, based on overbark stem volumes to a 7 cm top diameter limit for stems with a diameter greater than 7.5 cm at breast height (1.30 m))

The increase in broadleaved growing stock is also associated with an increase in broadleaved stand area and with the aging of some stands, especially in the Centre, Midi-Pyrénées and Rhône-Alpes regions.

Cultivated poplar plantations were considered separately since the growing stock had only been estimated in the main departments involved, so this is an underestimation (cf. § 1.2.1).

Commentary: growing stock inventoried in production forests, excluding poplar plantations, is currently 2.1 billion m³ (expressed in IFN stem volume). The annual rate of increase is +1.4%, which is much higher than that of forest area–the average growing stock per ha is now 154 m³/ha, as compared to 138 m³/ha 10 years ago, and the capitalisation of standing wood noted in 1999 is ongoing.

This trend also applies to most other highly forested European countries. It is the result of a lower felling rate relative to the increment, and the overall increase in yield capacity of forest stands noted elsewhere (cf. § 3.1).

Broadleaved stands account for 57% of the growing stock, while conifer stands represent a third and mixed stands 10% (Figure 4). Despite this pattern, the greatest increase in growing stock concerns mixed stands (+2.1% per year). This phenomenon is associated with the rate of expansion of mixed stand area and with the high capitalisation rate, especially in mountain regions (Alps, Jura et Pyrenees).

Conifer stands have the highest growing stock per ha (currently 184 m³/ha). This trend is sharply increasing since many afforested and reforested areas are becoming productive, in addition to the capitalisation of some old mountain stands.

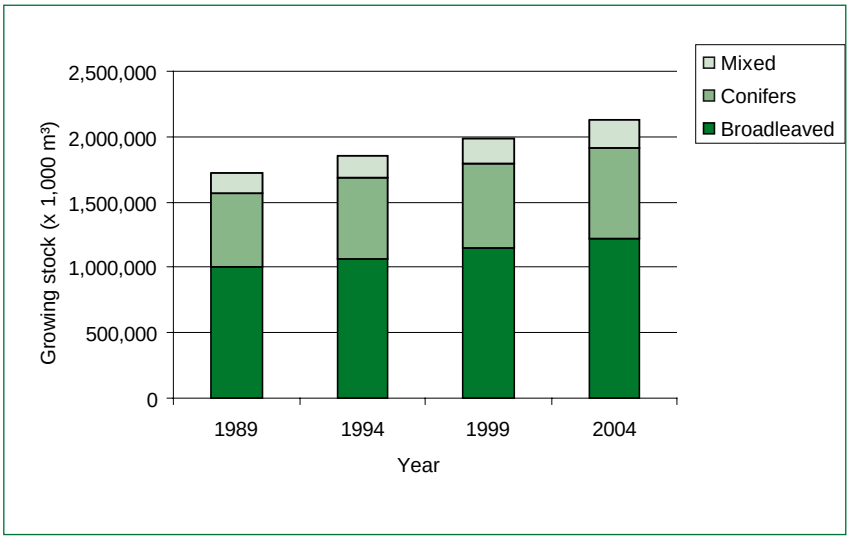


Figure 4: Growing stock patterns per forest type (source: IFN)

INDICATOR 1.2.1
Growing stock by IFN forest structure

Forest stands available for wood supply (including poplar plantations)

IFN stem volume (7 cm top diameter)

Forest structure (excluding poplar plantations)	Year	Volume (x 1,000 m³)	% volume	Volume per ha (m³/ha)	Annual variation rate Total volume 1994-2004
regular high forest	1989	932,260	54.1%	162	
	1994	1,046,411	56.4%	174	
	1999	1,163,922	58.5%	181	
	2004	1,285,378	60.4%	190	2.1%
irregular high forest	1989	108,661	6.3%	149	
	1994	108,891	5.9%	154	
	1999	111,892	5.6%	167	
	2004	107,198	5.0%	168	-0.2%
coppice	1989	138,463	8.0%	58	
	1994	137,194	7.4%	61	
	1999	137,725	6.9%	65	
	2004	139,865	6.6%	67	0.2%
mixed coppice/broadleaved high forest	1989	475,119	27.6%	129	
	1994	483,897	26.1%	135	
	1999	496,214	24.9%	142	
	2004	509,338	23.9%	148	0.5%
mixed coppice/ conifer high forest	1989	68,047	4.0%	100	
	1994	77,337	4.2%	104	
	1999	81,111	4.1%	109	
	2004	85,422	4.0%	112	1.0%
Total	**1989**	**1,722,550**		**129**	
	1994	**1,853,730**		**138**	
	1999	**1,990,864**		**146**	
	2004	**2,127,201**		**154**	**1.4%**

(Source : IFN, apart from poplar plantations, for inventoried forests available for wood supply, based on overbark stem volumes to a 7 cm top diameter limit for stems with a diameter greater than 7.5 cm at breast height (1.30 m))

pure poplar plantations	**1994**	**22,761**		149	
	1999	**20,592**		137	
	2004	**18,273**		121	-2.2%

(Source : IFN, special inventory of pure poplar plantations limited to the main departments concerned, based on overbark stem volumes to a 7 cm top diameter limit for stems with a diameter greater than 7.5 cm at breast height (1.30 m), it is not possible to recreate the 1989 situation)

Commentary: the capitalisation phenomenon under way in French forests involves all stand types, but especially regular high forests, which currently have a growing stock of 190 m³/ha. The conversion of mixed coppice/high forest stands has prompted a substantial increase in growing stock in favour of regular high forest. Moreover, when afforested and reforested areas become productive, there is a subsequent boom in growing stock, especially Douglas fir (+6.8% per year in regular high forest stands). There has also been a rise of 1% per year in conifer growing stock in mixed coppice stands. Despite conversion operations, standing timber in mixed coppice/broadleaved high forest and coppice stands is still being capitalised. These coppice stands currently have a growing stock of 67 m³/ha.

Finally, only cultivated poplar plantations have shown a decline in both total volume and per-hectare volume. This situation is associated with a recent renewal of cultivated poplar plantations, which has seriously imbalanced the age class distribution (cf. § 3.1). It also corresponds to a decrease in forest area, especially in Champagne-Ardenne, Centre and Picardie regions, where a total of 6,000 ha was lost in 10 years. Of course, the expansion of forest area noted in other regions just slightly boosts the growing stock. Note again that the dendrometric data recorded on cultivated poplar plantations involved only the most representative French administrative departments.

INDICATOR 1.2.2
Growing stock by tree species

Forest stands available for wood supply (excluding poplar plantations)

IFN stem volume (7 cm top diameter)

Tree species	1989		1994		1999		2004		1994-2004
	total growing stock (x1,000 m³)	% total volume	total growing stock (x1,000 m³)	% total volume	total growing stock (x1,000 m³)	% total volume	total growing stock (x1,000 m³)	% total volume	annual variation rate
sessile & pedunculate oak	434,356	25.0%	467,151	25.2%	499,795	25.0%	524,989	24.6%	1.2%
beech	214,044	12.4%	222,683	12.0%	234,972	11.8%	241,727	11.3%	0.8%
maritime pine*	164,565	9.6%	186,395	10.0%	188,855	9.5%	200,267	9.4%	0.7%
silver fir	145,114	8.4%	147,789	8.0%	156,560	7.8%	164,737	7.7%	1.1%
common spruce	124,454	7.2%	137,649	7.4%	152,197	7.6%	164,380	7.7%	1.8%
Scots pine	136,376	7.9%	137,574	7.4%	140,467	7.0%	142,736	6.7%	0.4%
chestnut*	85,911	5.0%	90,150	4.9%	97,622	4.9%	101,091	4.7%	1.2%
hombeam	61,620	3.6%	67,575	3.6%	75,801	3.8%	81,917	3.8%	1.9%
pubescent oak*	40,955	2.4%	46,230	2.5%	54,340	2.7%	67,937	3.2%	3.9%
ash	40,875	2.4%	45,663	2.5%	51,764	2.6%	57,556	2.7%	2.3%
Douglas fir	15,454	0.9%	27,974	1.5%	41,256	2.1%	53,619	2.5%	6.7%
birch	38,555	2.2%	39,103	2.1%	39,524	2.0%	38,561	1.8%	-0.1%
Austrian pine	21,927	1.3%	23,369	1.3%	23,629	1.2%	25,609	1.2%	0.9%
aspen	21,210	1.2%	22,054	1.2%	22,443	1.1%	22,328	1.0%	0.1%
Corsican pine	12,021	0.7%	15,274	0.8%	18,877	0.9%	21,738	1.0%	3.6%
false acacia	16,789	1.0%	17,788	1.0%	18,190	0.9%	20,281	1.0%	1.3%
larch	15,542	0.9%	15,309	0.8%	15,265	0.8%	19,740	0.9%	2.6%
large alder	17,002	1.0%	17,151	0.9%	17,452	0.9%	19,464	0.9%	1.3%
large maple	10,024	0.6%	11,433	0.6%	13,367	0.7%	16,074	0.8%	3.5%
cherry or wild cherry	10,875	0.6%	12,482	0.7%	14,223	0.7%	15,796	0.7%	2.4%
holm oak*	10,714	0.6%	13,019	0.7%	14,421	0.7%	15,734	0.7%	1.9%
small maple	10,568	0.6%	11,298	0.6%	13,004	0.7%	14,770	0.7%	2.7%
Aleppo pine	10,464	0.6%	10,976	0.6%	11,181	0.6%	13,543	0.6%	2.1%
linden	9,797	0.6%	10,992	0.6%	12,083	0.6%	12,931	0.6%	1.6%
other broadleaved	39,172	2.3%	38,540	2.1%	41,807	2.1%	45,424	2.1%	1.7%
other conifers	14,166	0.8%	20,944	1.1%	27,247	1.4%	29,732	1.4%	3.6%
total broadleaved*	**1,062,468**	**61.7%**	**1,133,311**	**61.0%**	**1,220,810**	**61.2%**	**1,296,580**	**60.8%**	**1.4%**
total conifers*	**660,082**	**38.3%**	**723,253**	**39.0%**	**775,533**	**38.8%**	**836,101**	**39.2%**	**1.5%**
Total*	**1,722,550**	**100.0%**	**1,856,564**	**100.0%**	**1,996,343**	**100.0%**	**2,132,680**	**100.0%**	**1.4%**

* including estimated growing stock in the types of formations not inventoried in 1994, 1999 and 2004

(Source : IFN, apart from poplar plantations, for inventoried forests available for wood supply, based on overbark stem volumes to a 7 cm top diameter limit for stems with a diameter greater than 7.5 cm at breast height (1.30 m)).

Commentary: the 1999 storms were only partially taken into account in the 2004 figures, which is also the case for other IFN data (cf. list of survey dates and departments in Appendix 3). However, these events could have significantly modified the growing stock of some species, especially beech and maritime pine.

Broadleaved species account for more than 60% of the growing stock (1.3 billion m³), representing the majority species in most French regions, except for Aquitaine, Rhône-Alpes, Auvergne, Languedoc-Roussillon and Provence-Alpes-Côte d'Azur (Map 5).

The top 10 species represent over 80% of the growing stock in France (Figure 5), with sessile and pedunculate oak accounting for a quarter of the total, i.e. 525 million m³.

The growing stock of almost all species has increased over the last decade, even species whose area has declined, such as common spruce, Scots pine and maritime pine.

In conifers, the most spectacular increase was noted in Douglas fir (+6.7% per year) and Corsican pine (+3.6%), with reforested stands of saplings now in full growth. The growing stock of common spruce has also significantly increased, i.e. currently 187 m³/ha as compared to 152 m³/ha 10 years ago. Old spruce stands are thus being

capitalised. The low increase in silver fir recorded in 2000 was not confirmed in the latest update, i.e. the per-hectare growing stock has been steadily rising to the current level of 239 m³/ha.

Maritime pine is still the top conifer species in French forests, with more than 200 million m³ of standing timber. The increase in this species' growing stock is directly linked with the fact that the highest yielding stands derived from intensive silviculture in the Landes massif are reaching maturity.

The broadleaved growing stock has also increased significantly over the last decade, by an annual rate of 16 million m³, including 6 million m³ for sessile and pedunculate oak alone. As the areas of these two species have remained relatively steady, this phenomenon simply corresponds to capitalisation associated with the conversion into high forest stands and coppice aging. The growing stock of sessile and pedunculate oak stands has risen from 96 to 103 m³/ha in 10 years. The sharp increase in pubescent oak growing stock (+3.9% per year) seems to be associated with coppice aging and natural afforestation.

A different pattern applies for species such as beech and ash as their total growing stock is rising faster than their per-hectare growing stock, respectively increasing from 131 to 136 m³/ha and from 75 to 76 m³/ha in 10 years. It is quite likely that the growing stock has increased most significantly in stands in which beech and ash are secondary species.

Forest stands available for wood supply (excluding poplar plantations)

main tree species	growing stock per ha of main species (m³/ha)			
	1989	1994	1999	2004
sessile & pedunculate oak	90	96	102	103
beech	130	131	134	136
maritime pine	113	130	132	142
silver fir	228	226	230	239
common spruce	141	152	170	187
Scots pine	99	101	105	105
chestnut	87	89	99	100
hornbeam	55	57	64	67
pubescent oak	41	46	50	56
ash	73	75	76	76
Douglas fir	54	82	109	129
birch	46	47	49	51
Austrian pine	108	110	116	117
aspen	64	65	69	68
Corsican pine	119	124	127	129
false acacia	64	71	73	78
larch	129	128	127	146
large alder	95	98	104	115
large maple	53	56	60	66
cherry or wild cherry	35	37	35	38
holm oak	23	26	28	30
small maple	30	28	28	27
Aleppo pine	42	44	44	51
linden	71	74	75	83
other broadleaved	45	48	48	48
other conifers	63	84	104	116
total broadleaved	**83**	**88**	**93**	**94**
total conifers	**119**	**128**	**135**	**143**
Total	**96**	**102**	**108**	**112**

(Source : IFN, apart from poplar plantations, for inventoried forests available for wood supply, based on overbark stem volumes to a 7 cm top diameter limit for stems with a diameter greater than 7.5 cm at breast height (1.30 m). Only the growing stock of the main species is considered and correlated with the inventoried area of this species.)

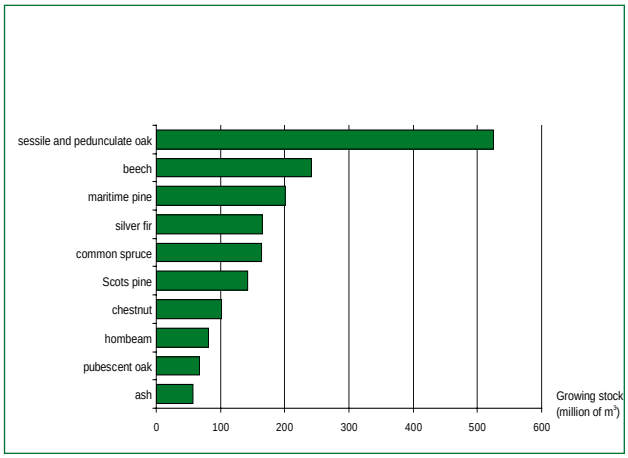
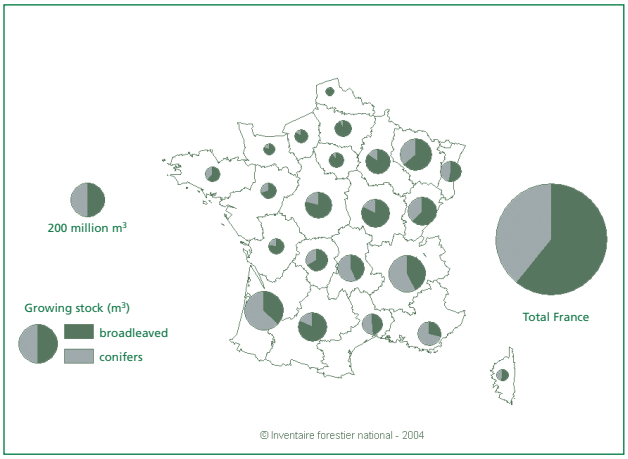


Figure 5: Growing stock of the top 10 species (source: IFN, 2004)



Map 5: Growing stock by administrative region and species group (source: IFN, 2004)

INDICATOR 1.3

Age structure and/or diameter distribution of forest and other wooded land, classified by forest type and by availability for wood supply

Forest stands available for wood supply (excluding poplar plantations)

Age distribution of regular high forest stands

Commentary: over half of regular high forests are now less than 60 years old, and the 20-40 year age category is the most represented, covering 20% of the area.

The table confirms the trends already recorded in 1999, i.e. a reduction in the area of stands less than 20 years old and over 180 years old, and an expansion of those in the 20-180 year age range. These trends, as expressed in proportions (Figure 6), are more manifest for young stands, which declined from 20% to 16.5% of the total area in 15 years, and for old stands as their share began diminishing as of 140 years old.

A breakdown of these results by species group shows a contrasting situation for broadleaved and conifer species. The reduction in the 0-20 age category applies only to conifers and reflects a slowdown in the pace of afforestation and reforestation, essentially in spruce and Scots pine. In contrast, the expansion of young broadleaved stands is probably due as much to regeneration and conversion as to natural afforestation.

The expansion of the 20-180 year categories cannot be explained solely by natural flows between age categories. It is obviously linked with the conversion of coppices and mixed coppice/high forest stands to regular high forests observed in § 1.1.3, which represents a considerable contribution, particularly in the 40-120 year category for sessile and pedunculate oaks.
Finally, the decline in high forests aged over 180 applies above all to pedunculate oak, beech and chestnut (cf. § 4.3.1).

Age class (years)	1989		1994		1999		2004		1994-2004
	x1,000 ha	%	x1,000 ha	%	x1,000 ha	%	x1,000 ha	%	annual variation rate
0-19	1,163	20.2%	1,133	18.8%	1,105	17.2%	1,118	16.5%	-0.1%
20-39	1,152	20.0%	1,190	19.8%	1,356	21.1%	1,351	20.0%	1.3%
40-59	881	15.3%	930	15.4%	1,001	15.6%	1,134	16.8%	2.0%
60-79	753	13.1%	817	13.6%	882	13.7%	956	14.1%	1.6%
80-99	585	10.2%	644	10.7%	715	11.1%	779	11.5%	1.9%
100-119	397	6.9%	432	7.2%	468	7.3%	519	7.7%	1.9%
120-139	330	5.7%	363	6.0%	383	6.0%	395	5.8%	0.8%
140-159	292	5.1%	309	5.1%	308	4.8%	313	4.6%	0.1%
160-179	61	1.1%	69	1.1%	76	1.2%	71	1.0%	0.3%
180-199	47	0.8%	48	0.8%	48	0.7%	46	0.7%	-0.4%
200-219	36	0.6%	34	0.6%	33	0.5%	35	0.5%	0.3%
220-239	36	0.6%	34	0.6%	33	0.5%	35	0.5%	0.3%
240 and over	18	0.3%	18	0.3%	15	0.2%	16	0.2%	-1.2%
unspecified	2	0.0%	0	0.0%	0	0.0%	0	0.0%	
Total	**5,753**	**100.0%**	**6,021**	**100.0%**	**6,423**	**100.0%**	**6,768**	**100.0%**	**1.2%**

(Source : IFN, apart from poplar plantations, only for regular high forests of inventoried forests available for wood supply, based on measurement of 20 year age classes in regular even-aged stands and by 30-80 year age classes in regular uneven-aged stands)

In conclusion, it should be borne in mind that regular high forests represent only 49% of the inventoried area and that this survey requires additional breakdown by diameter category in order to reach beyond the forest structures.

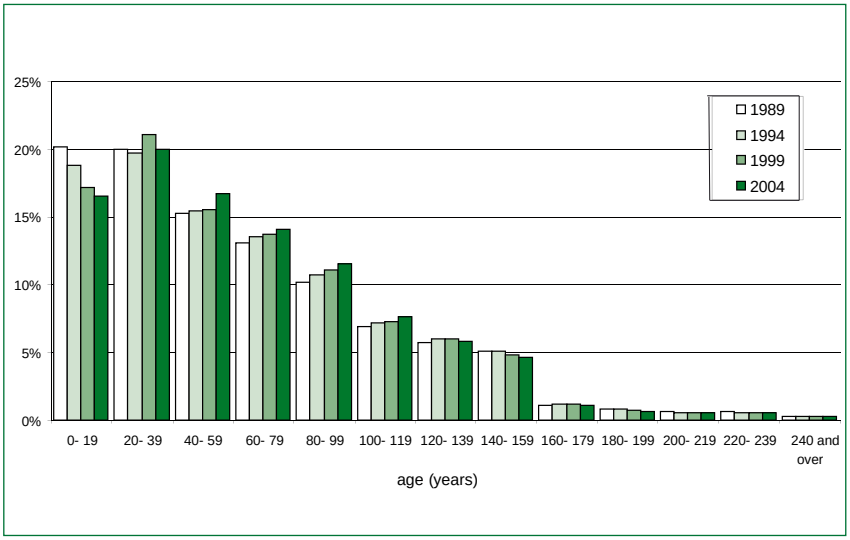


Figure 6: Variations in regular high forest by age class (source: IFN, total for France)

Tree diameter classes (for all structures combined)

IFN stem volume (7 cm top diameter)

Forest type	diameter class	1989		1994		1999		2004		1994-2004
		volume (x1,000 m³)	% volume	volume (x1,000 m³)	% volume	volume (x1,000 m³)	% volume	volume (x1,000 m³)	% volume	annual variation rate
Broad-leaved	10-25 cm	467,329	46.6%	489,208	45.7%	515,941	45.0%	536,165	44.0%	0.9%
	30-55 cm	431,611	43.0%	466,916	43.6%	503,265	43.9%	540,050	44.3%	1.5%
	60-85 cm	93,970	9.4%	103,093	9.6%	116,886	10.2%	130,445	10.7%	2.4%
	90-115 cm	8,946	0.9%	9,005	0.8%	9,759	0.9%	10,637	0.9%	1.7%
	120 cm and over	1,872	0.2%	1,615	0.2%	1,833	0.2%	1,738	0.1%	0.7%
Total broadleaved		**1,003,728**	**100.0%**	**1,069,836**	**100.0%**	**1,147,684**	**100.0%**	**1,219,034**	**100.0%**	**1.3%**
Conifers	10-25 cm	211,842	37.9%	233,798	38.2%	253,056	39.0%	256,946	36.9%	0.9%
	30-55 cm	307,865	55.1%	336,007	54.9%	352,144	54.3%	390,584	56.0%	1.5%
	60-85 cm	36,807	6.6%	39,971	6.5%	41,004	6.3%	47,004	6.7%	1.6%
	90-115 cm	2,038	0.4%	2,100	0.3%	2,321	0.4%	2,320	0.3%	1.0%
	120 cm and over	147	0.0%	116	0.0%	86	0.0%	85	0.0%	-3.1%
Total conifers		**558,699**	**100.0%**	**611,993**	**100.0%**	**648,611**	**100.0%**	**696,938**	**100.0%**	**1.3%**
Mixed	10-25 cm	61,811	38.7%	65,613	38.3%	74,365	38.4%	79,980	37.9%	2.0%
	30-55 cm	83,376	52.2%	89,417	52.2%	100,449	51.8%	109,299	51.7%	2.0%
	60-85 cm	13,377	8.4%	14,780	8.6%	17,456	9.0%	20,468	9.7%	3.3%
	90-115 cm	824	0.5%	1,129	0.7%	1,419	0.7%	1,321	0.6%	1.6%
	120 cm and over	259	0.2%	234	0.1%	186	0.1%	158	0.1%	-3.9%
Total Mixed		**159,647**	**100.0%**	**171,174**	**100.0%**	**193,875**	**100.0%**	**211,226**	**100.0%**	**2.1%**
All types	10-25 cm	740,983	43.0%	788,620	42.6%	843,362	42.4%	873,090	41.0%	1.0%
	30-55 cm	822,852	47.8%	892,339	48.2%	955,858	48.0%	1,039,933	48.9%	1.5%
	60-85 cm	144,153	8.4%	157,844	8.5%	175,346	8.8%	197,916	9.3%	2.3%
	90-115 cm	11,808	0.7%	12,234	0.7%	13,500	0.7%	14,277	0.7%	1.6%
	120 cm and over	2,278	0.1%	1,966	0.1%	2,104	0.1%	1,981	0.1%	0.1%
Subtotal		**1,722,074**	**100.0%**	**1,853,003**	**100.0%**	**1,990,171**	**100.0%**	**2,127,198**	**100.0%**	**1.4%**
unspecified		476		727		693		3		
Total		**1,722,550**		**1,853,730**		**1,990,864**		**2,127,201**		**1.4%**

(Source : IFN, apart from poplar plantations, for inventoried forests available for wood supply, based on overbark stem volumes to a 7 cm top diameter limit for stems with a diameter greater than 7.5 cm at breast height (1.30 m); the A diameter class refers to trees with a diameter ranging from A-2.5 cm to A+2.5 cm)

Commentary: the 1999 storms were only partially taken into account in the 2004 inventory update. However, the diameter class distribution could have been substantially modified since various studies have demonstrated that the storms had the greatest impact in forests with large diameter trees.

The increase in growing stock affected all diameter classes except the 10 cm class, which declined, and the 120 cm class and over, which remained virtually steady (Figure 7).
Despite the decrease in the number of 10 cm diameter trees, the growing stock of small diameter trees (10-25 cm) increased in all types of forest. The breakdown by species shows that this rise mainly involved Douglas fir, white conifers and broadleaved species other than oak and beech (cf. Appendix 11). The growing stock of medium diameter trees (30-55 cm) also increased, especially Douglas fir and other broadleaved species.

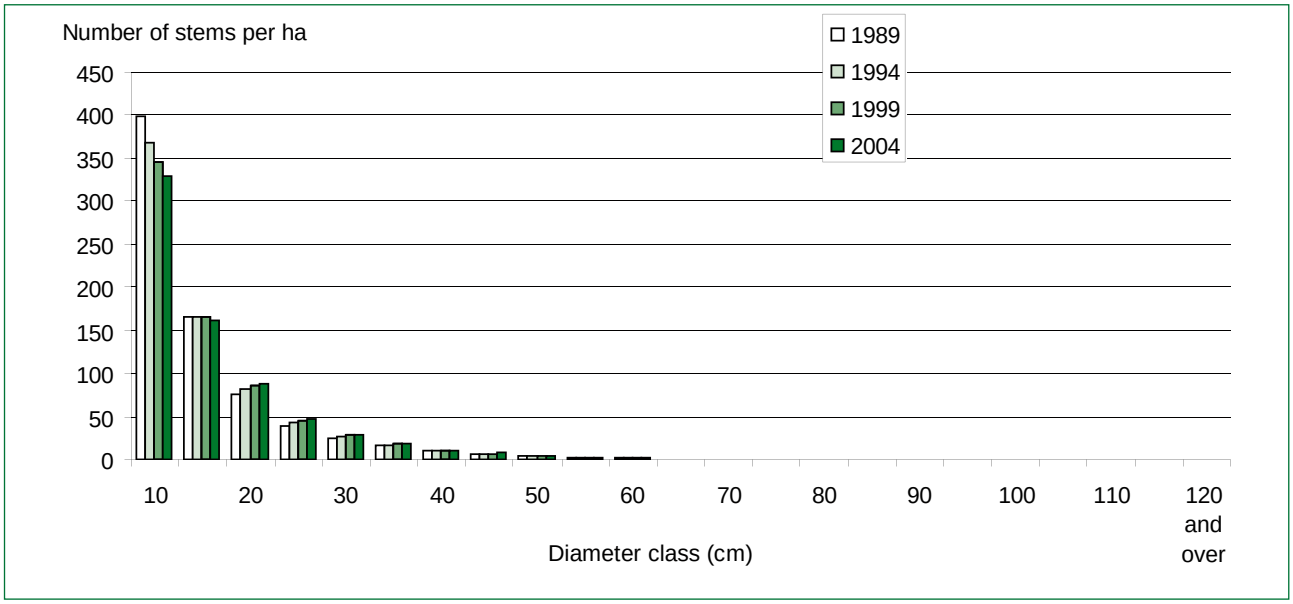
The stock of large diameter trees (60-85 cm) also increased, particularly in broadleaved stands, notably oak, and mixed stands. Growing stock of trees in the 120 cm and higher diameter classes declined in conifer and mixed stands, but these data are not very accurate due to the low volumes assessed.

Relative to the total growing stock, these results indicate that capitalisation has mainly been focused on medium diameter trees, which currently represent around 50% of the total growing stock, and on large diameter trees, whose stock has risen from 8.5% to 9.3% in 10 years. The share of capitalised very large diameter trees (90 cm and over) has levelled off.

Conversely, the proportion (in both number and stock) of small diameter trees continues to decrease. This

phenomenon is noted especially in sessile and pedunculate oak stands, with the number of 10 cm diameter trees dropping by 25% in 10 years. In view of the expansion of young age classes in regular high forest, it seems that this trend could mainly be attributed to coppice-with-standards management–their conversion into high forest has led to a sharp decline in oak and hornbeam coppice trees.

The extent of growing stock and density variations seems to differ within the same diameter class as a result of an increase in the mean tree stock, which in turn is mainly linked to an increase in mean tree height. It is, however, not clear whether silviculture or yield increases could have an impact on tree shape. A more in-depth analysis would now be required since the Inventaire forestier national (IFN) has changed its tree diameter calculation method, which could have slightly biased the results.



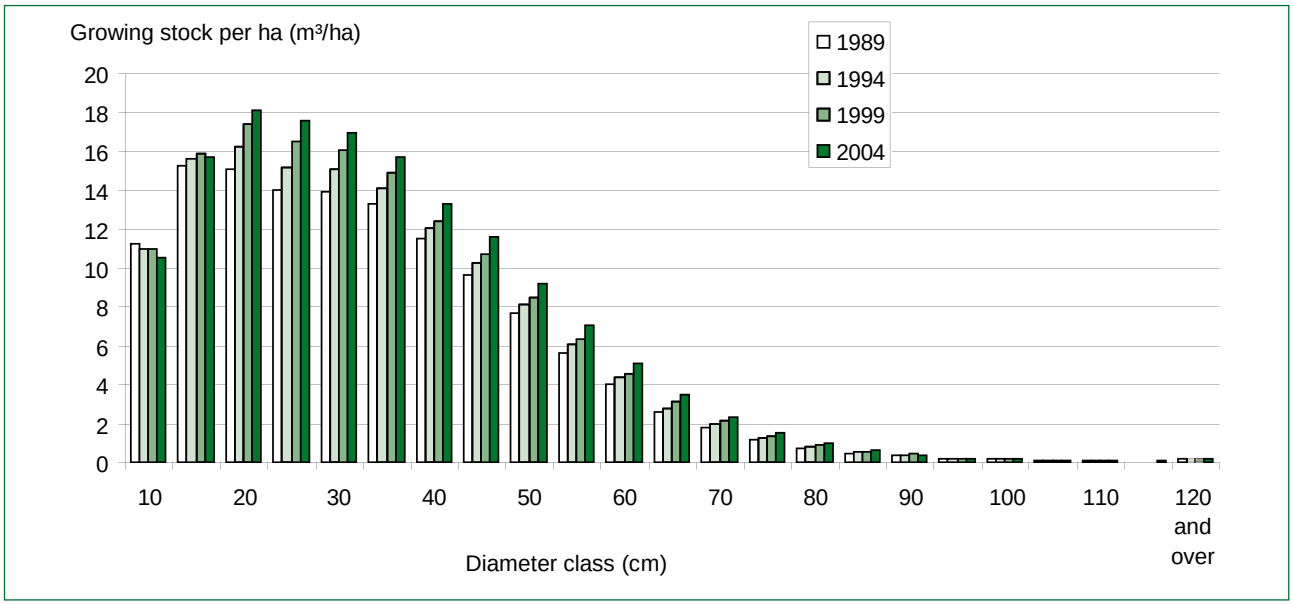


Figure 7: Variations in the number of stems and growing stock per ha and diameter class (source: IFN, total for France)

INDICATOR 1.4

Carbon stock of woody biomass and of soils on forest and other wooded land

Forest stands available for wood supply (excluding poplar plantations)

Compartment	Carbon stock (million t)				Carbone sink (million t/year)
	1989	1994	1999	2004	1994-2004
Tree above-ground biomass	603	654	714	765	11.1
Tree below-ground biomass	172	187	204	219	3.2
Subtotal forest biomass	**775**	**841**	**917**	**984**	**14.3**
per ha (t C/ha)	**58**	**63**	**67**	**71**	**0.9**
Forest soils (including litter)	ND	ND	1,074	1,074	ND
Total	ND	ND	**1,991**	**2,058**	ND
per ha (t C/ha)	ND	ND	**146**	**149**	ND

(Source : IFN, for inventoried forests available for wood supply, excluding poplar plantations, using LERFOB volume tables and the "root biomass expansion factor", "wood density" and "carbon content" coefficients given in the 2004 final report of the CARBOFOR France project; DSF 1993-94 was used to estimate carbon stocks in forest soils from the European network for forest damage monitoring (540 plots); the estimation includes carbon stored in the litter and in the 0-30 cm soil horizon; the 1999 value was retained for 2004 since the update will not be available until 2006).

⇨ *Note : this table is based on a physical approach which does not go against the recording rules which apply within the framework of France's commitments under the Kyoto Protocol.*

Commentary: forests represent the most important carbon storage ecosystem in the world and are thus a key lever in policies designed to reduce greenhouse gas emissions.

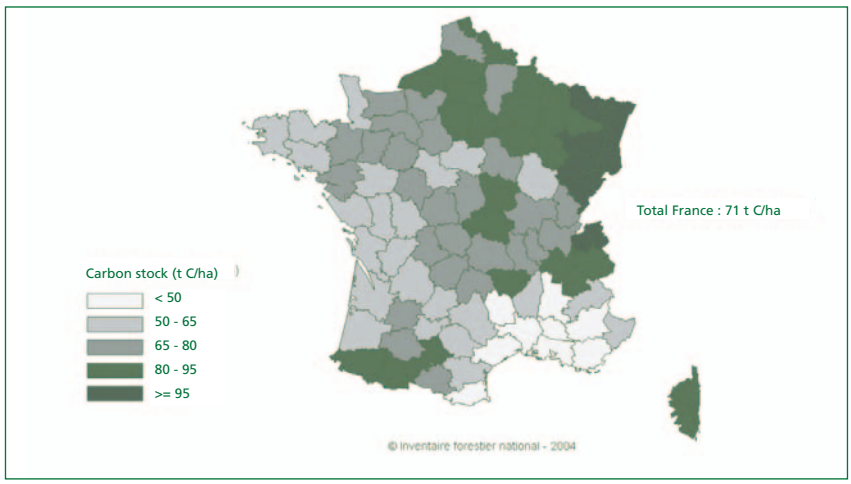
In forests, carbon is mainly stored in soilborne organic matter and tree biomass.

In 1993-94, the carbon stock in forest soils was assessed in 540 plots of the European network for forest damage monitoring (cf. § 2.3). This soil carbon stock was estimated to be 79 t/ha, or 54% of the total forest carbon stock. This proportion is slightly lower than that estimated in 1999 (60%) since the re-evaluation indicated a higher level of carbon stored in tree biomass. As these data are to be updated in 2006, temporal variations in this stock are still unknown. It seems certain that soilborne carbon increases with the tree age in new stands (natural colonisation or afforestation of farmland and heathland), but the patterns are less clear in long-established forests. Moreover, a network for soil quality measurement has been set up to assess soil carbon stocks and flows in other wooded lands (cf. § 2.2).

Carbon contained in tree biomass is increasing steadily, like the growing stock, and now amounts to 984 million t in inventoried production forest (excluding poplar plantations), or 71 t/ha. Below-ground tree biomass accounts for more than 20% of this total amount. The net annual carbon storage, or "sink", is estimated at 14.3 million t per year for the 1986-96 period (1994-2004 available data). This sink represents 13% of gross CO_2 emissions, without taking land-use, land-use changes and forestry into account (cf. §1.4.1).

These estimates are substantially higher than those published in the 2000 edition of the present report–the carbon stock that was estimated at 51 and 55 t/ha for 1994 and 1999 have now been re-evaluated at 63 and 67 t/ha, respectively. This adjustment is based on the conclusions of the final report of the CARBOFOR project, published in 2004, which modified the proportions of branches and roots allocated to the IFN volumes (Box 2).

The highest carbon stocks are found in northeastern France (Alsace, Lorraine, Franche-Comté), the northern Alps and western Pyrenees (Map 6), while the lowest levels are found in the Mediterranean region. These results are linked with the stem volumes (IFN volumes) and the proportion of branches. Broadleaved stands thus have a higher per-hectare carbon stock than conifer stands even though their per-hectare IFN volume is lower (76 t C/ha versus 62 t C/ha for conifers).

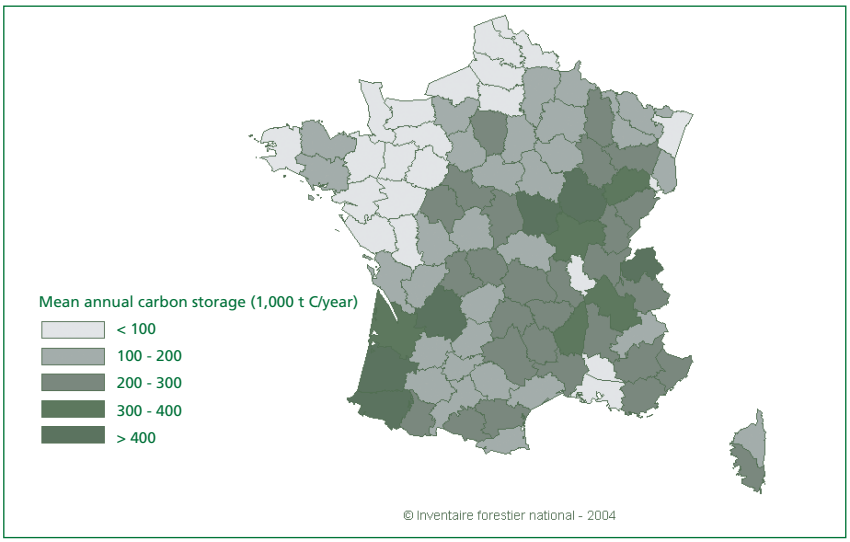


Map 6: Mean carbon stock per ha in forest biomass by department in the last inventory (source: IFN, 2004)

The greatest carbon sinks are located along a broad diagonal line tracking from the southwest to the northeast, especially in the Aquitaine and Bourgogne regions (Map 7). This situation was likely modified by the 1999 storms, but their impact was only partially taken into account in 2004–most departmental inventories after year 2000 were conducted in regions that were largely unaffected by the storms. These estimations will soon be updated via the new annual inventory method.
The results obtained in Aquitaine should be analysed with caution since they could be linked with the sharp rise in maritime pine yield capacity. Moreover, it should also be checked whether the change in tree diameter measurement method has had an effect (impact on tree volume table used). These results are at variance with the fact that Landes and Gironde departments have a high timber removal rate.

These estimates only concern inventoried production forests, excluding poplar plantations, for which reliable data are available. Other compartments could not be taken into account in this indicator due to the lack of reliable elements: deadwood and living biomass formed by woody and non-woody undergrowth and foliage. Substantial work is thus still required for a full assessment of carbon storage in forests by compartment:
- living biomass: other wooded lands, poplar plantations and other wooded areas (heathlands) to be taken into account; non-inventoried stems, shrubs, non-woody vegetation and foliage in all formations to be taken into account
- deadwood: to be taken into account in all formations
- soils and ground litter: poplar and other wooded areas (heathlands) to be taken into account.

Forests contribute to curbing the greenhouse effect, but this contribution not only involves their carbon stock. The use of timber produced by forests from atmospheric CO2 increases the carbon sustainably stored in forest products (buildings, constructions), while also reducing fossil fuel consumption. In addition to using fuelwood as an alternative to fossil fuel, timber use–at equivalent performance–consumes less energy than other competing raw materials (steel, concrete, PVC, etc.). This contribution is, however, hard to quantify.



Map 7: Annual variations in forest biomass carbon stock by department between the last two inventories (source: IFN, 2004)

Box 2: CARBOFOR project

The CARBOFOR project on carbon sequestration in large-scale forest ecosystems in France was jointly conducted from 2002 to 2004 by many partners and funded by the French Ministry of Ecology and Sustainable Development (MEDD) and the Forestry Ministry (MAP) via the ECOFOR public interest group. This research project compared ecosystem responses to a regionalised climatic scenario (1960-2100) with respect to the carbon cycle, biogeography and susceptibility to major pests and diseases.
The French Institut national de la recherche agronomique (INRA), Inventaire forestier national (IFN) and the Laboratoire d'études des ressources forêt-bois (LERFOB) have developed a new method for calculating carbon stocks in tree biomass on a national scale. The modifications relative to the method outlined in the year 2000 edition of the present report are as follows:
- the total above-ground carbon volume of trees is based on volume tables drawn up by LERFOB from French forest research archival data, so the mean branch biomass expansion factor is 1.61 for broadleaved species and 1.33 for conifers, as compared to 1.40 and 1.30, respectively (FAO/UNECE mean coefficients);
- the root biomass expansion factor, wood density and carbon content were modified on the basis of a bibliographical analysis. The root biomass expansion factors were readjusted from 1.14 to 1.28 for broadleaved species and 1.15 to 1.30 for conifers. The wood density was upgraded from 0.53 to 0.55 for broadleaved species and from 0.39 to 0.44 for conifers. Finally, the carbon content was reset at 0.475 instead of 0.5.
These modifications resulted in an overall ratio (t C/m³ IFN) of 0.53 for broadleaved species and 0.36 for conifers, as compared to 0.42 and 0.30, respectively, in the year 2000 report. The difference generally concerns the use of the LERFOB volume tables per main species types. These new results will have to be confirmed, but they already seem more suitable than the previous overall broadleaved/conifer coefficients.

INDICATOR 1.4.1
Annual carbon emission levels

Commentary: carbon dioxide (CO2) is a major greenhouse gas which contributed to more than 70% of the net global warming potential of France in 2002. This proposed indicator highlights the role of forests and land-use in overall carbon emissions in France.
Gross annual carbon emissions were estimated at 107 million t in 2002, excluding flows associated with land-use, land-use changes, and forestry (LULUCF).
These emissions are mainly linked with fossil fuel consumption, so the data are highly sensitive to climatic variations. Road transport, residential/service industries, industrial manufacturing and energy conversion are the main sectors involved.

	Units	1990	1992	1997	2002	Annual variation rate 1992-2002
gross annual CO_2 emission excluding land-use, land-use changes and forestry (LULUCF)	million t of carbon equivalent	106	110	107	107	-0.3%
net CO_2 sink (LULUCF : land-use, land-use changes and forestry)	million t of carbon equivalent	7	7	11	13	6.4%
net annual **CO_2 emission**	million t of carbon equivalent	99	103	96	94	-0.9%
	t of carbon equivalent per capita	1.75	1.79	1.64	1.58	-1.3%

(Source : Citepa/Coralie/UNFCCC format - metropolitan France - updated 19/12/2003 and INSEE/national population census; the net CO_2 sink is the balance between carbon destocking (emission) and storage (gross sink) noted during land-use changes and forest operations (LULUCF); the main emission concerns timber fellings in forests and trees out of forests; conversely, tree biomass volume increment represents most of the gross carbon sink, the difference between gross carbon emissions excluding LULUCF and the net carbon sink represents the net emission).

A comparison with 1990–the Kyoto Protocol reference year–revealed that gross CO2 emissions, excluding LULUCF, have remained relatively steady in metropolitan France. This phenomenon is tied closely with the increase in road transport, which offsets the advances achieved in other areas such as energy conversion.
Net carbon emissions have markedly decreased, with 94 million t recorded in 2002. In relation to the French population, they represented 1.58 t per capita in 2002 versus 1.75 in 1990. These results highlight the importance of taking forest carbon sinks into consideration in policies geared towards reducing greenhouse gas emissions in France. The net carbon sink has increased from 7 to 13 million t since 1990 and progressed by 2 million t over the last 5 years. This clear trend could be explained by the differential between increment and timber fellings in forests, which increased during this period. It could also, in some situations, be reversed when large-scale accidental events such as the 1999 storms occur. It is probable that such events could reoccur considering the present climate change setting.
These data cannot be directly compared with those presented in § 1.4 because the methods implemented and the fields concerned are not exactly the same (cf. Box 3).
The measures to be implemented to curb CO2 emissions in France were described in the Plan Climat 2004, which are aimed at saving 54 million t of CO2 equivalent yearly by 2010, or 15 million t of carbon equivalent. For the forestry sector, the main measures concern the effective use of biomass-derived products (fuelwood and timber) and increasing forest carbon sinks.

Box 3: CITEPA estimation of net carbon sinks

The carbon sink associated with land-use, land-use changes and forestry (LULUCF) is estimated annually by the Centre interprofessionnel technique d'études de la pollution atmosphérique (CITEPA). It is based on different estimations:

- **variations in forest carbon stocks are calculated through:**
  - **an assessment of forest and non-forest tree biomass increment based on Inventaire forestier national (IFN) data; this provides a gross carbon sink estimate**
  - **an assessment of fellings based on data from the Service central des enquêtes et études statistiques (SCEES) for commercial fellings, and from the Observatoire de l'Energie for self-consumption. The total fellings represent the gross carbon emission**
- **deforestation (gross carbon emission)**
- **variations in carbon stock due to land-use changes: conversion of grassland and uncultivated farmland into forests, and grassland into uncultivated farmland (carbon sink), and conversion of forests and grassland into farmland (carbon source). The balance is negative, thus inducing net carbon emission.**

Concerning variations in forest carbon stocks, carbon flows in forests (increment and fellings) can be estimated directly using the CITEPA method. It thus differs from the method outlined in § 1.4, which is based on a comparison of carbon stocks at different dates and is limited to production forests inventoried by IFN. The expansion coefficients used by CITEPA to correct increment are not the same as those used by IFN in § 1.4. Finally, net soil carbon emissions that occur for 15-30 years after intensive cutting or clearcutting are currently not taken into account.