Criterion 2

Maintenance
of forest ecosystem health
and vitality

INDICATOR 2.1

Deposition of air pollutants on forest and other wooded land, classified by N, S and base cations

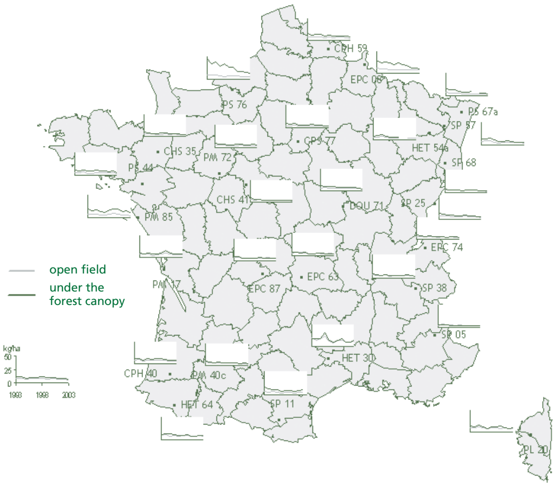
1) Estimate of atmospheric deposition under the forest canopy (throughfall) in the RENECOFOR network - 1999-2003 averages*

Plot	Mean annual deposition												Mean precipitation under the forest canopy
	H+	Cl	S-SO4	N-NO3	Na	N-NH4	K	Mg	Ca	Fe	Al	Mn	
	g/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	g/ha	g/ha	g/ha	mm
CHP 40	12.1	55.6	9.0	2.4	28.6	4.2	39.3	5.7	12.1	105	93	443	811
CHP 59	30.1	22.9	9.5	2.9	10.6	11.9	43.3	4.2	9.9	120	96	1,229	850
CHS 35	8.8	32.6	5.1	2.4	15.7	7.0	24.7	3.2	6.2	95	58	1,473	637
CHS 41	13.5	16.0	3.7	2.8	7.2	3.5	18.8	2.2	7.9	74	59	1,226	634
CPS 77	10.3	15.9	4.7	3.1	6.3	5.1	19.6	2.9	11.3	126	107	1,937	552
DOU 71	76.6	22.3	6.9	9.0	12.9	5.4	12.4	3.2	8.0	77	160	827	1,122
EPC 08	158.5	29.2	14.3	10.3	15.7	9.2	23.8	2.9	9.4	164	484	1,846	1,108
EPC 63	29.2	16.0	4.2	4.4	8.1	2.6	12.9	2.6	6.9	103	236	570	508
EPC 74	72.6	7.5	5.0	7.3	3.0	5.3	13.2	1.5	10.8	127	201	208	1,004
EPC 87	24.6	27.7	6.2	5.3	14.0	4.4	26.5	3.1	7.0	90	212	351	784
HET 30	130.7	32.4	12.8	8.5	19.0	7.4	17.3	3.6	19.7	149	176	607	2 036
HET 64	19.1	27.7	9.1	5.0	13.9	4.3	19.0	2.8	10.7	54	74	384	914
PL 20	51.8	99.1	10.5	3.9	56.0	0.8	12.7	8.7	21.2	124	598	340	1,059
PM 17	97.1	142.6	10.0	3.6	78.6	2.3	7.5	10.7	11.4	55	95	133	717
PM 40c	60.6	39.2	5.3	2.8	19.4	2.4	13.2	5.0	10.5	71	238	91	629
PM 72	22.6	35.1	6.1	6.1	18.3	9.2	12.4	3.3	6.9	68	114	433	730
PM 85	66.2	239.0	15.3	4.4	133.4	3.7	15.7	17.8	12.9	77	71	112	591
PS 44	73.5	80.9	8.4	3.5	43.5	6.5	19.2	6.1	6.4	74	219	219	701
PS 67a	95.2	12.2	6.2	6.8	5.7	10.4	11.9	1.4	6.3	68	176	868	589
PS 76	282.1	63.1	17.9	6.2	35.4	7.4	14.6	5.3	10.1	84	344	1,262	692
SP 05	2.9	5.4	3.9	0.7	1.6	0.8	31.4	2.3	14.0	72	236	106	611
SP 11	27.1	26.4	9.1	3.6	13.2	2.2	36.9	2.9	13.6	137	259	255	827
SP 25	110.6	14.9	7.0	6.9	7.2	4.6	19.1	2.1	12.6	143	147	378	1,523
SP 38	32.3	5.8	5.3	1.7	1.8	1.9	19.5	1.5	8.3	87	162	1,147	1,107
SP 57	91.4	12.6	6.9	5.3	5.5	3.7	19.0	1.4	7.2	95	151	2,369	811
SP 68	53.2	8.6	4.4	6.0	4.0	3.6	17.4	1.4	5.8	69	190	247	755
Mean 1999-2003	63.6	41.9	8.0	4.8	22.3	5.0	20.1	4.1	10.3	96	191	733	858
Mean 1993-1998	113.0	43.6	11.0	4.8	23.0	4.8	21.5	4.2	11.3	63	235	854	813
Absolute variation	-49.4	-1.6	-3.0	0.0	-0.7	0.2	-1.4	-0.1	-1.0	34	-44	-121	-45
Relative variation	-43.7%	-3.7%	-27.4%	0.0%	-3.0%	3.2%	-6.7%	-1.9%	-9.1%	53.6%	-18.8%	-14.1%	-5.6%

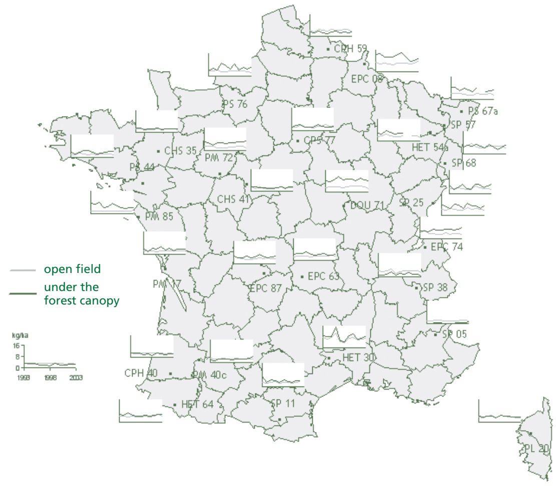
* except for PS 67a : 1999-2003 (not 2000) and SP 11 : 1999-2002

(Source : ONF (mean 1999-2003*), manager of the French RENECOFOR network (Réseau National de suivi à long terme des Ecosystèmes Forestiers) and the CATAENAT sub-network (Charge Acide Totale d'origine Atmosphérique dans les Ecosystèmes Naturels Terrestres) ; the plots are identified by their predominant species (CHS for sessile oak, CHP for pedunculate oak, CPS for pedunculate oak and sessile oak cumbined, HET for beech, EPC for Norway spruce, PS for Scots pine, PM for maritime pine, PL for Corsican pine, DOU for Douglas fir, SP for silver fir), followed by the department number of the plot)

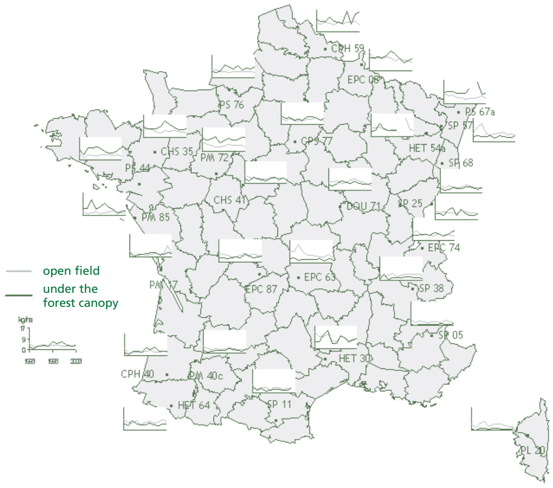
RENECOFOR - CATAENAT
Variations in *open field and throughfall deposition* of sulfate ($S\text{-}SO_4$) from 1993 to 2003



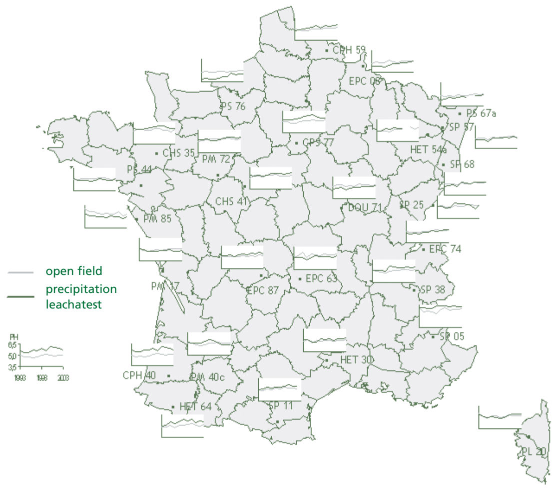
RENECOFOR - CATAENAT
Variations in *open field and throughfall deposition* of nitrate ($N\text{-}NO_3$) from 1993 to 2003



RENECOFOR - CATAENAT
Variations in *open field and throughfall deposition* of ammonium ($N\text{-}NH_4$) from 1993 to 2003



RENECOFOR - CATAENAT
Variations in *pH* in open field precipitation and throughfall from 1993 to 2003



(Source: ONF (1993-2003 averages), manager of the French RENECOFOR network (Réseau National de suivi à long terme des Ecosystèmes Forestiers) and the CATAENAT sub-network (Charge acide totale d'origine atmosphérique dans les écosystèmes naturels terrestres); the plots are identified by their predominant species (CHS for sessile oak, CHP for pedunculate oak, CPS for pedunculate oak and sessile oak combined, HET for beech, EPC for Norway spruce, PS for Scots pine, PM for maritime pine, PL for Corsican pine, DOU for Douglas fir, SP for silver fir), followed by the department number of the plot)

Map 8: Variations in open field and throughfall deposition of sulfate, nitrate, ammonium and associated precipitation pH from 1993 to 2003 - CATAENAT sub-network (source: ONF)

Commentary: the main purpose of the CATAENAT network, set up by the French Office national des forêts (ONF) in late 1992, is to quantify atmospheric deposition on forests. The network consists of 27 sites in open fields and 26 sites within forests located throughout metropolitan France, varying in terms of both the predominant species in the stand and its geographical location, without claiming to be statistically representative. A time-series of 11 years of annual precipitation and atmospheric deposition in the open field and under the forest canopy (throughfall deposition) is available for the 1993-2003 period (Map 8). As an in-depth specialised analysis of these results will soon be published, only the main trends reported in ONF scientific reports are discussed here.
Details on the 1993-98 and 1999-2003 comparisons are given in Appendix 11.

Throughfall deposition is usually quite different from open field deposition. Several factors of differing significance are involved, i.e. the type of local or regional pollution, tree species, presence of mist or cloud droplets, stemflow and canopy exchange (absorption or leaching of elements). All of these factors generally lead to a net increase in throughfall deposition, except for nitrogen compounds (especially ammonia) which tend to diminish in regions where nitrogen deposition is low due to canopy uptake. Cation exchange on leaf surfaces can also reduce proton deposition under the canopy.
Furthermore, throughfall deposition is often greater under conifers–except for larch–than under broadleaved species in the same forest area owing to the persistence of conifer foliage in winter.

a) Acid deposition induced by **protons** in open field precipitation and throughfall is mostly low, i.e. in all plots they are under 1 kg (Keq)/ha/year. The maxima obtained in throughfall occur in Seine-Maritime (PS76), Ardennes (EPC08) and at Mont Aigoual (HET30). Apart from Jura (SP 25), where proton deposition increased by 10%, all the other sites showed a clear decrease in direct acid deposition between the two periods 1993-98 and 1999-2003. This decline generally ranged from 33 to 55%. The sharpest decrease was noted in Seine-Maritime (PS 76), in the Brotonne forest, located midway between Le Havre and Rouen.

b) During the 1993-98 period, **sulphur** was the main acidic compound at half of the sites, whereas during the 1999-2003 period it was the main acidic compound at 30% of the sites. This pattern was marked by two contrasting trends. First, sulphur depositions following the massive reduction in emissions declined at almost all of the sites (except PM17, in Charente-Maritime, near the coast) and, secondly, total mineral nitrogen (N-NO_3+N-NH_4) depositions increased at 14 out of 26 sites, while levels remained steady at three sites and decreased at nine sites. Nitrogen is thus slowly becoming the predominant acidic compound. Depending on the prevailing soil fertility, forest soil acidification can rise substantially when sulfate depositions surpass 4-16 kg/ha/year. The progress made in SO_2 emission reductions from 1980 onwards now seems to be having a marked impact.
With a few exceptions, throughfall sulphur deposition is always higher than open field sulphur deposition, thus perfectly demonstrating the filtering effect of the canopy. Two plots situated close to an industrial site or region (PS76 and EPC08) showed high deposition loads in throughfall which are likely to upset the balance of the forest ecosystem, even though they can to some extent be offset by calcium inputs. The Vendée site (PM 85), where sulphur deposition is also high, is close to the Atlantic coast and thus also benefits from depositions of marine sulphur and other neutralising compounds (potassium, calcium, magnesium).

c) **Ammonium** deposition (precipitation leachates and not total deposition in modelled forests) varies considerably between regions. An increase was noted at 17 out of 26 sites. In the northwestern quarter (PM85 to CHP59) and Alsace (PS67a), throughfall ammonium fluxes are high because of nearby intensive farming (livestock breeding and fertilisation).
The highest nitrate deposition rates are found in the northeastern quarter of France, ranging from 7 to 10 kg/ha/year, where throughfall fluxes are up to twice the open field deposition fluxes (EPC08, PS67a, DOU71). Mont Aigoual (HET 30), which receives exceptional precipitation, has a high nitrogen deposition level which can eventually lead to ecosystem degradation due to soil eutrophication. An increase in nitrate deposition of 5 to 41% was observed at 11 sites, with a decrease of 0.4 to 32% noted at 15 sites.

d) Average total mineral **nitrogen** (N-NO_3+N-NH_4) deposition is quite high, i.e. 10 kg/ha/year (range 4-20 kg/ha/year). These inputs increased at 14 sites (from 2 to 37%), decreased at 9 sites (from 2 to 40%) and remained steady at three sites.

e) Deposition loads of **sodium** and **chloride**, when elevated (PL20, PM17, PM85), are essentially derived from the sea, with trees subjected to extreme salinity conditions.

f) Considerable **aluminium** deposition is generally related to the proximity of polluting industries (PS76, PS67a). For plot PL20, the probable cause is more contingent (road traffic or soil erosion).

g) Of the **heavy metals**, manganese deposits represent the highest levels, particularly in plots SP57, PS76 and EPC08. Additional analyses are currently under way to confirm the link between these deposits and nutritional deficiency in conifer stands.

The nitrogen and sulphur deposition patterns suggest that poor to moderately poor soils are subjected to accelerated acidification and that all ecosystems with high nitrogen inputs will likely undergo eutrophication. Analyses of soils of plots in the RENECOFOR network are to be replicated 10 years after the initial analysis (1993/95)–these analyses should reveal the actual impact of these deposits on forest ecosystems.

2) Variations in overall precipitation quality <u>in open fields</u> in the CATAENAT sub-network from 1993 to 2003 (mean national concentrations weighted by the precipitation)
Units: per mm of precipitation in mg/mm, with pH and protons in g/l

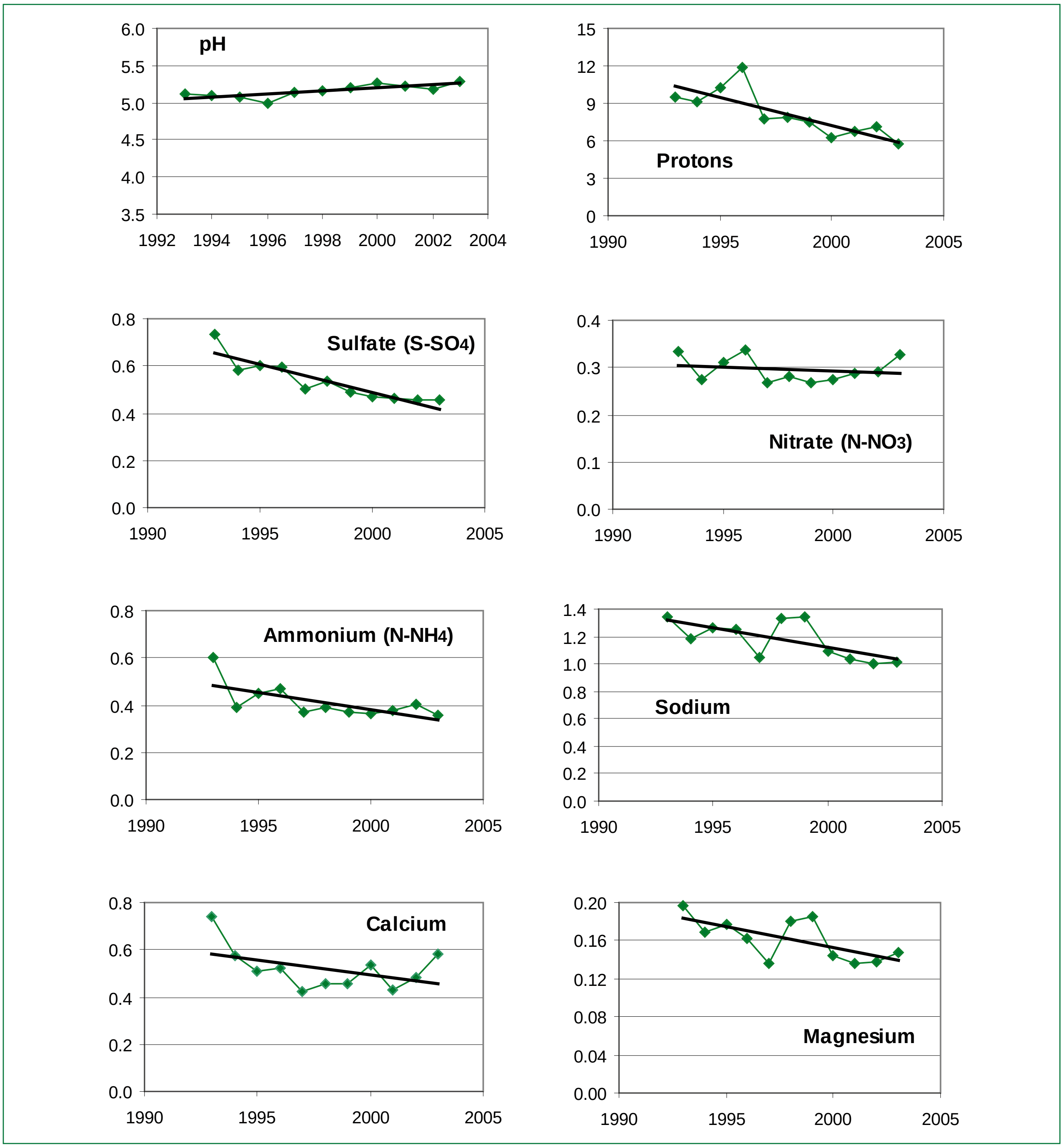
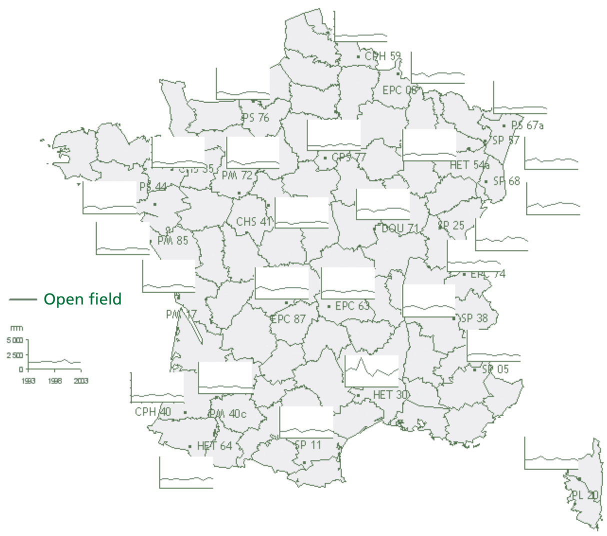


Figure 8: Variations in overall precipitation quality in open fields in the CATAENAT sub-network from 1993 to 2003 (source: ONF)

Commentary: indicators of the mean overall precipitation quality in France can be calculated simply by dividing the sum of annual depositions at all sites by the sum of their precipitations. The result is the mean annual concentration per mm of precipitation for all 27 sites located in the open field. From a scientific standpoint, this is the only national indicator for monitoring long-term precipitation quality trends (Figure 8 and Map 9).

The mean precipitation acidity has decreased over the last 10 years–the mean pH has been steadily rising since 1993, with a decrease of 43% in the proton concentration within 11 years. This could be partially explained by the 36% decrease in sulfate concentrations during the same period. Nitrate concentrations have unfortunately levelled off, while ammonium levels have been dropping, but this trend will have to be confirmed in the coming years. Annual variations in other ions are still much too marked to be able to accurately determine the trends.

RENECOFOR - CATAENAT
Variations in open field *precipitation* from 1993 to 2003



(Source: ONF, manager of the French RENECOFOR network (Réseau National de suivi à long terme des Ecosystèmes Forestiers) and the CATAENAT sub-network (Charge acide totale d'origine atmosphérique dans les écosystèmes naturels terrestres); the plots are identified by their predominant species (CHS for sessile oak, CHP for pedunculate oak, CPS for pedunculate oak and sessile oak combined, HET for beech, EPC for Norway spruce, PS for Scots pine, PM for maritime pine, PL for Corsican pine, DOU for Douglas fir, SP for silver fir), followed by the department number of the plot))

Map 9: Variations in open field precipitation from 1993 to 2003 - CATAENAT sub-network (source: ONF)

INDICATOR 2.1.1
Atmospheric pollutant emission patterns

Commentary: atmospheric pollutants are among the factors that contribute to forest damage. Sulphur dioxide (SO_2) is an acidifying factor (sulphuric acid). Nitrogen oxide (NO_x) contributes to acidification (nitric acid) and eutrophication (nitrogen enrichment); it also contributes to the production of ozone (O_3), through reactions with non-methane volatile organic compounds (NMVOC). Ammonia (NH_3) contributes to nitrogen deposition and acidification of soils.

	Units	1980	1985	1992	1997	2002	Annual variation rate 1992-2002
SO_2	x1,000 tonnes	3,214	1,497	1,261	806	537	-8.2%
NO_x	x1,000 tonnes	2,024	1,847	1,914	1,607	1,352	-3.4%
NH_3	x1,000 tonnes	795	799	765	783	778	0.2%
COVNM	x1,000 tonnes			2,424	1,947	1,542	-4,4%
acidification and eutrophication (SO_2, NO_x et NH_3)	in acid equivalent (Aeq)	191.3	133.9	126.0	106.1	91.9	-3.1%

(Source : Citepa/Coralie/Secten format - Update : 27 April 2004)

Over the past 10 years, considerable scientific research has been focused on "critical loads", i.e. deposition levels below which there is no adverse effect on susceptible components of the ecosystem. This has provided a basis for negotiation on all pollutants (SO_2, NO_x, COV, NH_3) in terms of their contribution to acidification, eutrophication and photochemical pollution (O_3). The resulting "multi-pollutants - multi-effects" protocol (Gothenburg Protocol, 1999) sets new pollutant reduction targets for 2010–it is more restrictive than existing protocols, and for the first time includes NH_3.

SO_2 emissions have dropped sharply since 1980, especially because of the closure of thermal power plants, the

desuphurisation of industrial emissions and the use of low-sulphur fuels. France has thus fulfilled its commitments of 1985 and 1994 under the "Convention on Long-Range Trans-boundary Air Pollution" (Geneva, 1979). The second protocol (Oslo, 1994) set its sights on a 74% reduction of 1980 levels by 2000, a target that has largely been met. This reduction trend should continue in coming years with the implementation of regulations aimed at more severely controlling the threshold emission limits for large-scale combustion plants, while also reducing the sulphur content in liquid fuel. This is in line with the quite restrictive targets for 2010, through the "National Emission Ceilings" directive, which is geared towards reducing emissions by around 40% relative to current levels.

The protocol on the reduction of nitrogen oxide emissions (NO_X) signed in Sofia in 1988 set two commitments: stabilisation of emissions at 1987 levels by 1994 and a 30% reduction of the 1980 levels by 1998. The first commitment has been fulfilled, but not the second. Road traffic represents the prime emitter (48% in 2002), even though its contribution has declined over the last 10 years owing to the fact that vehicles are progressively being fitted with catalytic converters. There should be further reductions in the near future as large-scale combustion plants are forced to comply with the directive.

The agriculture sector accounts for a major share of ammonia (NH_3) emissions, i.e. around 97% of total emissions in metropolitan France in 2002, with 78% just for livestock production. The emission fluctuations noted in recent years are related to variations in livestock numbers. The current emission level corresponds to the 2010 target under the National Emission Ceilings directive, i.e. 780 kilo-tonnes. Considering the predicted increase in some livestock herds in coming years, measures will be required to reduce agricultural ammonia emissions in order to be able to meet the national target.

Non-methane volatile organic compound (NMVOC) levels have dropped considerably since 1988, mainly in road transport and energy transformation (road vehicles fitted with catalytic converters, progress in storage and distribution of hydrocarbons). France's commitment to reduce emissions by 30% between 1988 and 1999 (Geneva Protocol, 1991) has been fulfilled. Further substantial progress is needed in the coming years to reach the target set by the National Emission Ceilings directive, i.e. 1050 kilo-tonnes.

The "acidification and eutrophication" indicator aims to assess the overall quantity of compounds released into the atmosphere which contribute to acidification and eutrophication phenomena. Deposition levels have dropped by around 50% since 1980 due to the marked reduction in SO2 emissions. Ammonia currently represents half of the contribution of this indicator, as compared to 24% in 1980.

INDICATOR 2.2

Chemical soil properties (pH, CEC, C/N, organic C, base saturation) on forest and other wooded land related to soil acidity and eutrophication, classified by main soil types

Commentary: forest soils were first analysed in 1993-1994 in plots of the European network for forest damage monitoring (European network level 1) that were set up throughout France on the basis of a 16 x 16 km square grid in 1989. This network is extended to non-forest areas through a soil quality measurement network, with plots set up as of 2001 according to the same square grid and managed by the "Sols" scientific interest group. Variations in soil quality, according to 2000 assessment points, are thus being monitored throughout France via these networks.

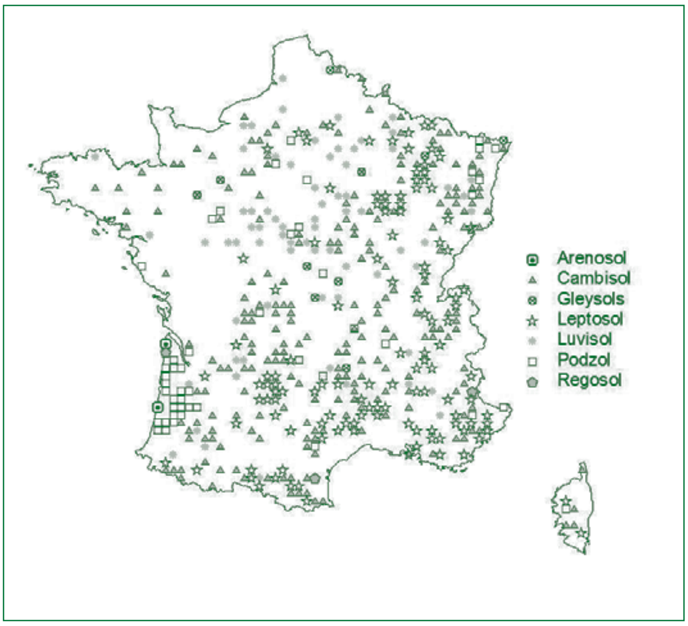
Soil type	Number of plots monitored	Water pH	Cation exchange capacity (CEC)	Base saturation rate	Organic carbon content	Carbon/nitrogen ratio (C/N)
Cambisol	222	5.5	11.5	57.6	36.0	14.9
Leptosol	123	7.0	27.0	93.5	47.1	14.1
Luvisol	72	4.8	5.6	47.6	27.5	16.5
Podzol	47	4.7	3.3	32.6	26.5	24.5
Gleysol	10	5.8	19.2	75.4	41.2	13.0
Regosol	3	6.7	13.6	82.6	37.3	17.8
Arenosol	2	5.3	1.4	60.1	12.5	25.5
Others	29	5.8	8.7	70.2	34.8	16.3

(Source : Département de la santé des forêts - inventaire des sols forestiers européens (16 km x 16 km) ; means for 1993-94 in the 0-20 cm horizon; Histosols were not found in the 508 monitored plots; an update will be available in 2006.)

The second forest network in France, i.e. the REseau National de suivi à long terme des ECOsystèmes FORestiers (RENECOFOR), managed by the Office national des forêts, aims to gain insight into changes in forest ecosystems based on intensive monitoring of around 100 sampling plots. This network is not statistically representative of the entire French forest, but studies on forest soils (also sampled between 1993 and 1995) will provide reliable data, especially on changes in acidic forest soils which are very prevalent in this network.

A second analysis of soils in plots of the European network for forest damage monitoring (level 1) is planned for 2006-2007. The date of the second resampling of soils of the RENECOFOR network has not yet been set. While awaiting these new inventory surveys, the main characteristics of French forest soils could be represented by the 1993-94 soil sampling results.

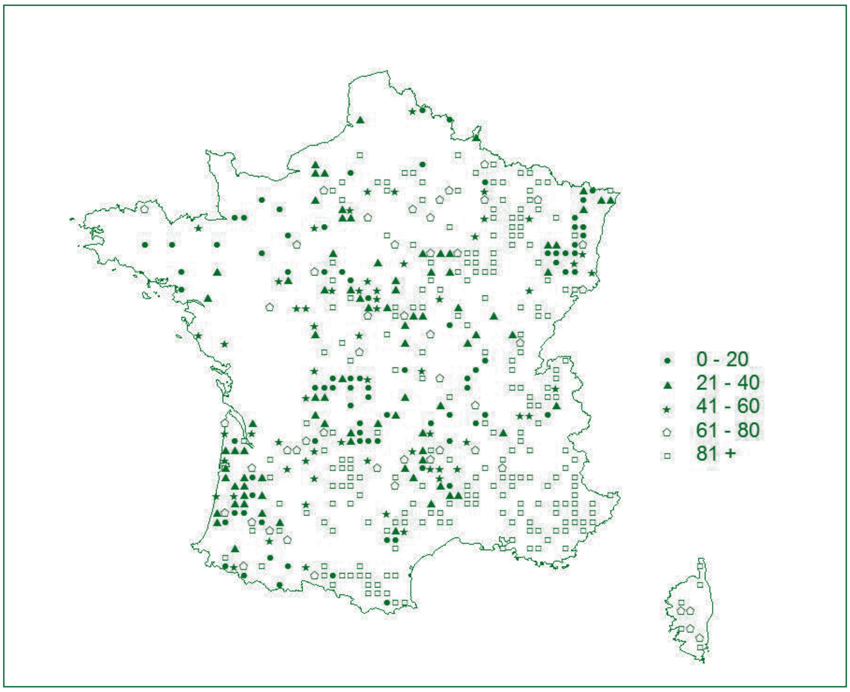
The distribution of types of forest soils sampled in the plots of the European network (level 1) is given in the table according to the 1999 FAO classification. The spatial distribution is also shown on Map 10. Cambisols and Leptosols predominate throughout France, accounting for two-thirds of the soils in the sampling plots. The chemical characteristics, which can change due to the impact of silviculture and atmospheric inputs, are also presented for each soil type. However, these mean values mask the very high heterogeneity within the same FAO class, e.g. the variation coefficient (CV) for the cation exchange capacity of Cambisols is above 100%. The base saturation rate and organic carbon content are also highly variable (CV over 50%). Although this variability is artificial and linked with the classification system used, it highlights that the spatial variability in soils must be carefully taken into account during the sampling phase. This spatial variability has to be substantially reduced during sampling within the monitoring network–where pedological characteristics are the main focus of investigation–in order to allow detection of fine temporal changes in the soils.
The historical data show that forest soils in northeastern France have become impoverished in recent decades, but there is not enough available data to quantify the extent of these trends in the various regions and for the different types of soil. The networks recently set up will make it possible to monitor future trends.



Map 10: Types of soil found in the plots of the European monitoring network over a 16 x 16 km grid (source: DSF, 1993-94)

Forest soils are much more acidic and unsaturated (low proportion of base cations in the cation exchange complex) than agricultural soils. The differences could be explained by the fact that forest stands often grow on barren soils (mountain, hydromorphic and superficial soils, etc.), without any inputs (fertilisers and other soil conditioners). Moreover, mineral losses regularly occur as a result of silvicultural nutrient export without subsequent mineral restoration, litter extraction, and increased leaching of minerals by acidic atmospheric depositions.

Map 11 highlights the spatial distribution in rates of nutrient (calcium, magnesium, potassium) saturation of the cation exchange complex within the 0-20 cm horizon in soils from sampling plots in the European monitoring network. 45% of these soils have a base saturation rate of over 80%, whereas 16% have a rate of less than 20%. No precise minimum thresholds have been set, below which forest trees would have mineral nutrition problems, but it is known that the risks increase considerably when the base saturation rate is under 10% (6% of soils). The most unsaturated soils are mainly found in Vosges, the northwestern regions (Normandie, Bretagne), Massif Central and the Landes massif.



Map 11: Base saturation rates recorded in plots of the European monitoring network over a 16 x 16 km grid (source: DSF, 1993-94)

INDICATOR 2.3

Defoliation of one or more main tree species on forest and other wooded land in each of the defoliation classes: "moderate", "severe" and "dead"

Defoliation class	Species	Proportion of trees affected							
		1997	1998	1999	2000	2001	2002	2003	2004
moderate (25% to 60%)	Broadleaved	27.5%	25.0%	21.7%	20.3%	21.8%	23.8%	30.0%	34.1%
	Conifers	14.2%	15.4%	13.2%	10.7%	12.8%	13.8%	16.8%	15.8%
	All species	**22.9%**	**21.6%**	**18.7%**	**17.0%**	**18.7%**	**20.3%**	**25.4%**	**27.7%**
severe (over 60%)	Broadleaved	2.2%	1.7%	1.0%	1.2%	1.6%	1.5%	3.3%	4.1%
	Conifers	1.7%	1.3%	0.8%	1.0%	1.1%	1.2%	1.9%	1.5%
	All species	**2.1%**	**1.6%**	**0.9%**	**1.1%**	**1.4%**	**1.4%**	**2.8%**	**3.2%**
dead trees	Broadleaved	0.2%	0.2%	0.1%	0.1%	0.1%	0.2%	0.2%	0.5%
	Conifers	0.3%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	1.3%
	All species	**0.2%**	**0.2%**	**0.1%**	**0.1%**	**0.2%**	**0.2%**	**0.2%**	**0.8%**
Total : over 25% defoliation	Broadleaved	29.9%	26.9%	22.8%	21.6%	23.6%	25.4%	33.4%	38.7%
	Résineux	16.2%	16.8%	14.2%	12.0%	14.1%	15.1%	19.0%	18.6%
	All species	**25.2%**	**23.3%**	**19.7%**	**18.3%**	**20.3%**	**21.9%**	**28.4%**	**31.7%**

(Source : Département de la santé des forêts - European network for forest damage monitoring. Due to a change of method during the 1995-1997 period, data recorded before 1994 cannot be compared with those recorded after 1997, so the results presented here were recorded as of 1997. Defoliation of a tree was assessed relative to a reference tree (nul defoliation). The references are defined for each species, region and stand. Comparisons between species or main categories (broadleaved, conifers) are thus difficult. When considering the data presented on the table, it is important to focus on relative defoliation trends for a given species rather than on absolute values.)

➪ *Note : the European network for forest damage monitoring is a network of permanent plots, each consisting of 20 trees installed on a systematic 16 x 16 km grid. There are potentially 558 plots in the French part of this network (which involves around 30 countries). Recordings are only done on plots with a stand that has grown to a certain height (over 60 cm). Since the 1999 storms, just over 40 plots have been temporarily suspended until a new stand meets the monitoring criteria. Hence, just over 510 plots have been monitored since year 2000. They are surveyed every summer by a team of two pest and disease specialists. The state of the tree crowns is visually assessed and potential causes of damage are determined when possible.*

Commentary: the defoliation status generally reflects the vitality of the tree, and is the result of various factors: tree age, silvicultural history, pest insects, pathogenic fungi, climatic stress, atmospheric pollution, mineral deficiency, etc. It is, however, often hard to assess theextent of impact of these factors.

Two major climatic events affected forest stands in France during the 2000-2004 period–the 1999 storms and the 2003 drought-heat wave.
The severe storms in December 1999 caused major damage to French forests. In the European network for forest damage monitoring, stands on 41 plots were decimated by more than 50% and 23 of them were completely destroyed. Windfall and broken trees began being replaced in the summer of year 2000 when possible in the stands. However, sampling on 29 plots was suspended (impossible to obtain a suitable sample within a 40 m radius). For the other plots, 1,051 trees of the 1999 sampling were replaced, i.e. about 10% of the total 1999 sample. No major crown degradation was noted during the years following the storms since branches broken by the storms were not recorded as defoliation elements.

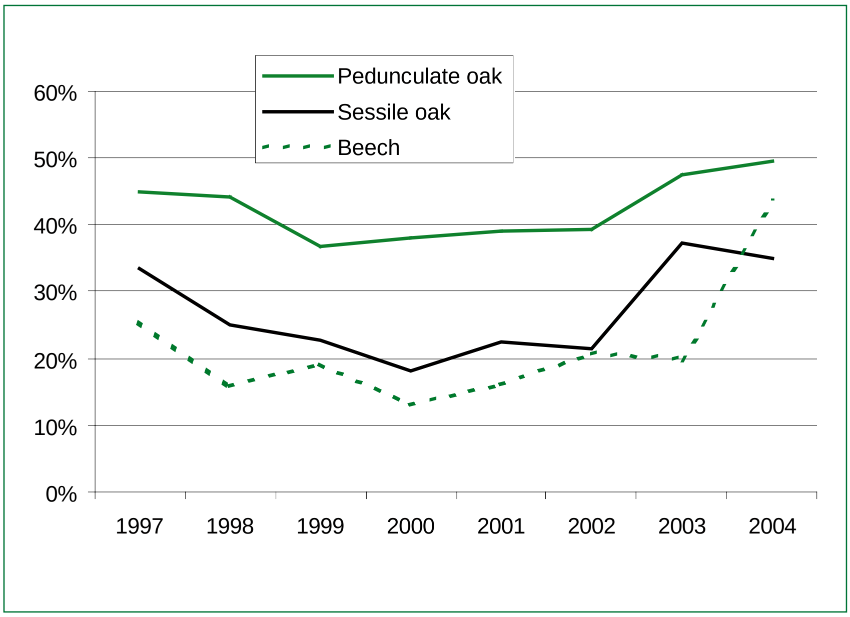


Figure 9: Variations in the percentage of broadleaved trees with a defoliation rate above 25% from 1997 to 2004 (source: DSF)

Overall, there was a steady improvement in most species from 1997 to 2002, but this trend was more substantial in broadleaved species than in conifers, except for maritime pine and Scots pine whose defoliation rates began increasing as early as 2000 (Figures 9 and 10). Of the broadleaved species, oaks–especially pedunculate and pubescent oaks–had very high defoliation rates. Fir and spruce, which were in an alarming state in the 1980s, remained stable during this 1997-2002 period.

In 2003, the drought and heat wave had a major impact on tree crowns, as early as 2003 for some species (sessile oak, pedunculate oak, birch, etc.), but for most species the effects were noted as of 2004 (beech, spruce, etc.).

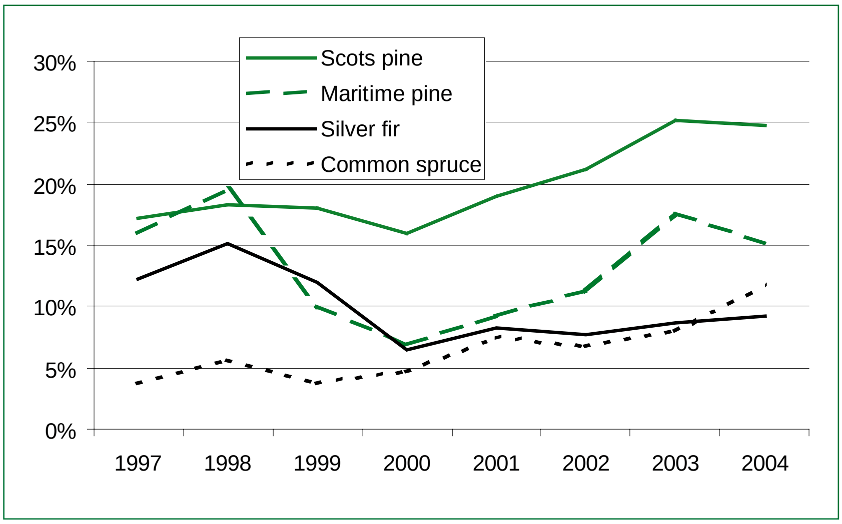


Figure 10: Variations in the percentage of conifer trees with a defoliation rate above 25% from 1997 to 2004 (source: DSF)

Number of trees monitored

Species	1997	1998	1999	2000	2001	2002	2003	2004
Sessile oak	1,212	1,229	1,237	1,233	1,236	1,243	1,246	1,248
Pedunculate oak	1,218	1,219	1,185	1,196	1,178	1,179	1,170	1,170
Holm oak	407	388	386	386	380	362	362	359
Pubescent oak	858	843	845	834	844	845	807	811
Beech	1,039	1,010	1,135	1,060	1,093	1,094	1,100	1,104
Maple	169	164	152	139	139	140	138	139
Birch	243	209	200	175	181	180	177	162
Hornbeam	281	281	279	281	269	264	269	266
Chestnut	531	523	510	481	476	477	467	463
Ash	306	295	298	291	292	290	286	288
Poplar	203	174	171	140	142	142	139	139
Wild cherry	130	132	131	110	112	113	109	105
Other broadleaved	477	464	457	428	425	422	425	421
Total broadleaved	**7,074**	**6,931**	**6,986**	**6,754**	**6,767**	**6,751**	**6,695**	**6,675**
Common spruce	597	603	584	548	550	546	547	519
Silver fir	512	501	520	464	464	481	482	486
Scots pine	761	748	745	633	633	635	632	631
Maritime pine	970	974	961	907	927	906	906	887
Austrian pine	278	280	278	231	235	235	235	236
Aleppo pine	105	125	226	226	222	226	226	226
Douglas fir	243	318	319	320	341	341	341	325
Larch	140	141	141	142	142	142	142	143
Other conifers	120	119	119	92	92	92	92	91
Total conifers	**3,726**	**3,809**	**3,893**	**3,563**	**3,606**	**3,604**	**3,603**	**3,544**
Total all species	**10,800**	**10,740**	**10,879**	**10,317**	**10,373**	**10,355**	**10,298**	**10,219**

Moderate defoliation (25% to 60%)

Species	1997	1998	1999	2000	2001	2002	2003	2004
Sessile oak	32.0%	24.1%	22.3%	17.8%	21.9%	20.8%	34.9%	32.5%
Pedunculate oak	42.0%	41.3%	35.3%	36.1%	36.5%	36.8%	43.7%	44.4%
Holm oak	20.9%	26.5%	25.6%	28.2%	30.8%	32.6%	49.2%	39.6%
Pubescent oak	40.2%	41.9%	28.6%	31.4%	28.6%	35.3%	37.8%	38.7%
Beech	21.8%	15.2%	19.0%	13.1%	16.0%	20.0%	19.0%	39.5%
Maple	9.5%	14.0%	9.2%	6.5%	7.2%	11.4%	25.4%	31.7%
Birch	21.8%	15.8%	20.5%	9.7%	17.7%	15.6%	24.3%	29.0%
Hornbeam	15.7%	18.1%	5.7%	3.2%	7.8%	11.4%	15.6%	33.1%
Chestnut	10.9%	7.8%	8.4%	6.2%	5.7%	6.1%	9.0%	15.1%
Ash	16.3%	13.6%	10.4%	11.0%	13.7%	16.2%	23.1%	21.9%
Poplar	25.1%	19.5%	22.2%	27.1%	18.3%	20.4%	20.9%	28.8%
Wild cherry	32.3%	35.6%	26.0%	20.0%	22.3%	24.8%	24.8%	28.6%
Other broadleaved	16.1%	11.2%	10.5%	12.6%	14.6%	16.4%	20.2%	17.8%
Total broadleaved	**27.5%**	**25.0%**	**21.7%**	**20.3%**	**21.8%**	**23.8%**	**30.0%**	**34.1%**
Common spruce	3.0%	4.8%	3.3%	4.2%	6.9%	6.2%	7.1%	6.9%
Silver fir	11.3%	14.0%	11.3%	5.6%	7.3%	6.7%	6.6%	8.0%
Scots pine	14.5%	16.8%	16.5%	13.6%	16.4%	18.0%	22.2%	20.3%
Maritime pine	14.7%	17.9%	9.3%	6.2%	8.8%	10.7%	16.4%	13.8%
Austrian pine	8.6%	8.9%	11.2%	12.1%	14.5%	17.4%	19.6%	20.8%
Aleppo pine	47.6%	41.6%	38.1%	37.6%	36.5%	42.0%	54.4%	43.8%
Douglas fir	25.1%	17.9%	17.6%	11.9%	11.1%	11.4%	15.2%	15.4%
Larch	38.6%	33.3%	27.7%	21.8%	28.9%	24.6%	12.0%	20.3%
Other conifers	8.3%	5.9%	10.9%	9.8%	10.9%	9.8%	9.8%	8.8%
Total conifers	**14.2%**	**15.4%**	**13.2%**	**10.7%**	**12.8%**	**13.8%**	**16.8%**	**15.8%**
Total all species	**22.9%**	**21.6%**	**18.7%**	**17.0%**	**18.7%**	**20.3%**	**25.4%**	**27.7%**

Severe defoliation (> 60%)

Species	1997	1998	1999	2000	2001	2002	2003	2004
Sessile oak	1.2%	0.8%	0.2%	0.2%	0.5%	0.6%	2.2%	2.4%
Pedunculate oak	2.8%	2.3%	1.5%	1.8%	2.4%	2.4%	3.8%	5.0%
Holm oak	1.2%	1.5%	0.8%	1.0%	4.5%	3.9%	1.4%	7.0%
Pubescent oak	2.3%	3.0%	1.3%	1.9%	2.4%	1.8%	4.7%	3.8%
Beech	3.8%	0.6%	0.2%	0.0%	0.2%	0.5%	0.5%	2.8%
Maple	0.0%	0.6%	0.0%	0.7%	0.0%	0.0%	0.0%	3.6%
Birch	0.4%	1.0%	0.0%	0.0%	0.6%	0.0%	1.7%	2.5%
Hornbeam	0.0%	2.5%	0.4%	0.0%	0.0%	0.4%	4.1%	16.9%
Chestnut	3.6%	3.3%	2.7%	3.3%	2.5%	2.1%	7.9%	4.8%
Ash	1.3%	0.3%	0.7%	0.7%	0.7%	0.3%	1.0%	0.7%
Poplar	1.0%	1.1%	1.2%	0.7%	6.3%	5.6%	6.5%	5.0%
Wild cherry	6.2%	2.3%	4.6%	10.0%	4.5%	3.5%	17.4%	7.6%
Other broadleaved	2.3%	2.4%	2.2%	1.4%	2.1%	1.4%	4.0%	1.7%
Total broadleaved	**2.2%**	**1.7%**	**1.0%**	**1.2%**	**1.6%**	**1.5%**	**3.3%**	**4.1%**
Common spruce	0.7%	0.7%	0.3%	0.5%	0.5%	0.4%	0.7%	1.3%
Silver fir	1.0%	1.0%	0.4%	0.9%	0.9%	0.8%	1.9%	0.4%
Scots pine	2.0%	1.5%	1.2%	2.1%	1.9%	2.7%	2.5%	3.3%
Maritime pine	1.0%	1.5%	0.6%	0.2%	0.1%	0.6%	0.9%	0.7%
Austrian pine	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%	5.5%	1.7%
Aleppo pine	3.8%	3.2%	2.2%	4.9%	5.9%	4.9%	6.6%	2.7%
Douglas fir	8.2%	2.5%	1.9%	0.9%	0.3%	0.3%	0.3%	1.2%
Larch	5.0%	0.7%	0.0%	0.0%	1.4%	0.0%	0.0%	0.0%
Other conifers	0.0%	0.8%	0.8%	1.1%	1.1%	2.2%	2.2%	3.3%
Total conifers	**1.7%**	**1.3%**	**0.8%**	**1.0%**	**1.1%**	**1.2%**	**1.9%**	**1.5%**
Total all species	**2.1%**	**1.6%**	**0.9%**	**1.1%**	**1.4%**	**1.4%**	**2.8%**	**3.2%**

Percentage of dead trees

Species	1997	1998	1999	2000	2001	2002	2003	2004
Sessile oak	0.2%	0.0%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%
Pedunculate oak	0.1%	0.4%	0.1%	0.3%	0.1%	0.2%	0.1%	0.1%
Holm oak	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.3%	0.0%
Pubescent oak	0.1%	0.1%	0.0%	0.0%	0.1%	0.2%	0.0%	0.4%
Beech	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.3%	1.0%
Maple	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Birch	1.2%	1.0%	0.5%	0.0%	0.0%	0.6%	0.0%	3.7%
Hornbeam	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Chestnut	0.0%	0.4%	0.2%	0.2%	0.2%	0.6%	0.6%	1.9%
Ash	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Poplar	0.0%	2.3%	1.2%	0.7%	1.4%	0.7%	0.0%	1.4%
Wild cherry	0.8%	0.0%	0.0%	0.0%	0.9%	0.0%	0.0%	1.9%
Other broadleaved	1.0%	0.2%	0.2%	0.2%	0.7%	0.2%	0.7%	0.0%
Total broadleaved	**0.2%**	**0.2%**	**0.1%**	**0.1%**	**0.1%**	**0.2%**	**0.2%**	**0.5%**
Common spruce	0.0%	0.2%	0.2%	0.0%	0.0%	0.2%	0.2%	3.5%
Silver fir	0.0%	0.2%	0.2%	0.0%	0.0%	0.2%	0.2%	0.8%
Scots pine	0.8%	0.0%	0.3%	0.3%	0.6%	0.6%	0.5%	1.1%
Maritime pine	0.2%	0.1%	0.1%	0.6%	0.3%	0.0%	0.3%	0.7%
Austrian pine	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.0%
Aleppo pine	1.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%	0.9%
Douglas fir	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%
Larch	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other conifers	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total conifers	**0.3%**	**0.1%**	**0.1%**	**0.2%**	**0.2%**	**0.2%**	**0.2%**	**1.3%**
Total all species	**0.2%**	**0.2%**	**0.1%**	**0.1%**	**0.2%**	**0.2%**	**0.2%**	**0.8%**

(Source : Département de la santé des forêts - European network for forest damage monitoring)

Mortality trends

Species	Mean mortality rate		
	1990-94	1995-99	2000-04
Sessile oak	0.03%	0.06%	0.03%
Pedunculate oak	0.15%	0.20%	0.14%
Holm oak	0.17%	0.00%	0.16%
Pubescent oak	0.08%	0.12%	0.14%
Beech	0.00%	0.10%	0.29%
Maple	0.13%	0.00%	0.00%
Birch	1.34%	0.63%	0.80%
Hornbeam	0.21%	0.35%	0.00%
Chestnut	0.43%	0.51%	0.72%
Ash	0.08%	0.00%	0.00%
Poplar	1.78%	1.01%	0.85%
Wild cherry	0.17%	0.19%	0.55%
Other broadleaved	0.89%	0.58%	0.38%
Total broadleaved	**0.28%**	**0.22%**	**0.23%**
Common spruce	0.00%	0.04%	0.74%
Silver fir	0.21%	0.05%	0.25%
Scots pine	0.29%	0.33%	0.63%
Maritime pine	0.43%	0.18%	0.38%
Austrian pine	0.00%	0.09%	0.60%
Aleppo pine	0.19%	0.95%	0.36%
Douglas fir	0.25%	0.10%	0.18%
Larch	0.00%	0.00%	0.00%
Other conifers	0.00%	0.21%	0.00%
Total conifers	**0.23%**	**0.17%**	**0.43%**
Total all species	**0.26%**	**0.20%**	**0.30%**

(Source : Département de la santé des forêts - European network for forest damage monitoring)

➪*Note : changes in the methods of assessing damage to crowns from 1994-97 have not affected the counting of dead trees. Tree mortality is assessed by the observers during their summer visit. It applies only to predominant and co-dominant trees (the only ones assessed in the European network). Windfalls from the 1999 storms were not integrated in this dead tree count. The real rate is probably (slightly) higher, since dead trees have already been felled before the summer assessment and the observers cannot always determine if the trees have been felled for thinning or sanitation purposes. While it is true that silvicultural intensity (removal frequency) has remained constant overall since the founding of the network in 1989 (though probably not everywhere), this "annual mortality rate" is still a relevant criterion for assessing the health of the forest.*

Commentary: overall, after a slight mortality peak in the early 1990s resulting from the 1989-91 drought, the mortality rate generally levelled off at an annual rate of 0.2% until 2003. This established mortality rate is much lower than the removal rates, estimated for the same network at 1-3% per year, i.e. 5-fold higher. However, there was a subsequent mortality peak in 2004 in both broadleaved and conifer stands, with some species being harder hit (common spruce, birch). This mortality peak was directly related to the 2003 drought-heat wave.

INDICATOR 2.4

Forest and other wooded land with damage, classified by primary damaging agents (abiotic, biotic and human induced) and by forest type

Cause of damage	Main species	Area (ha/an)			Number of damaged plots (%)		Number of damaged trees (%)	
		1985-94	1995-99	2000-04	1995-99	2000-04	1995-99	2000-04
Pest insects	Broadleaved	ND	ND	ND	40.3%	39.9%	17.9%	18.0%
	Conifers	ND	ND	ND	9.5%	8.6%	3.4%	1.8%
	All species	**ND**	**ND**	**ND**	**34.7%**	**34.2%**	**12.8%**	**12.3%**
Fungal diseases	Broadleaved	ND	ND	ND	13.4%	13.0%	3.7%	3.6%
	Conifers	ND	ND	ND	9.3%	14.6%	4.5%	7.3%
	All species	**ND**	**ND**	**ND**	**14.2%**	**16.0%**	**4.0%**	**4.9%**
Climatic stress	Broadleaved	ND	ND	ND	15.4%	10.3%	5.6%	3.8%
	Conifers	ND	ND	ND	8.2%	8.1%	4.5%	2.3%
	All species	**ND**	**ND**	**ND**	**15.1%**	**10.5%**	**5.2%**	**3.3%**
Fire	**All species**	**34,660**	**17,220**	**32,330**	-	-	-	-
Storms	**All species**	**9,300**	**231,000**	**0**	-	-	-	-

(Source : see details per topic below)

Note : Concerning the first three categories on the table, an assessment was conducted for the first two editions of the present report (1995 and 2000) based on the main pest and disease events reported during the 5 previous years and by using a multiplicative correction factor to account for non-inventoried situations. This is the only method that can be used with currently available data. However, considering the error level, it did not seem useful to conduct a new assessment for the 2000-2004 period. It is not possible to clearly determine exactly how the areas would have changed relative to the previous period.

It is hard to set up a reliable system for monitoring this indicator because of several factors:

- *damage symptoms due to pest insects (e.g. defoliators) and fungal diseases are often temporally limited and thus a suitable statistical system has to be available to be able to quantify the damage at the right time;*
- *some pathogenic fungi (e.g. conifer polypores) are very hard to detect if there is no mortality in the affected trees or if they are not logged;*
- *relations between the extent of symptoms and the extent of increment losses are often unknown;*
- *trees can die several months or even years after being damaged by pest insects or fungal diseases. These trees are often scattered throughout the stands and the mortality threshold beyond which the stand may be rehabilitated can vary markedly depending on the forest manager's priorities.*

Commentary: national data are available on damage caused by pest insects, fungal diseases, climatic stress, fires and storms. For the first three factors, the reliable available data can only be expressed according to the number of plots and trees affected, but not in terms of area, contrary to the fire and storm damage data (cf. note). An in-depth analysis of this damage is provided hereafter.

Only partial surveys have focused on damage caused by large ungulates, but it is possible to monitor annual changes in areas protected from game within regenerating stand plots (cf. § 2.4.1). No national surveys have been conducted so far to assess logging damage. A European Life project, entitled "Demonstration of methods to monitor sustainable forestry" was conducted by the French Institut pour le développement forestier (IDF) and Cemagref from 1999 to 2002. Within the framework of this project, a logging damage assessment method was tested in plots visited by the Inventaire forestier national.

1) Damage caused by pest insects, fungal diseases and abiotic stress

Damage caused by pest insects, fungal diseases and abiotic stress, such as spring frost and summer drought, varies widely from year to year–it can be limited to 1 year or fluctuate over several years, depending on the specific dynamics of these pest populations, and in interaction with the climatic stress factors (particularly water stress). Mortality is often the ultimate stage of progressive weakening (aging, root rot fungi, etc.). Tree death can occasionally become more frequent due to a combination of unfavourable factors (e.g. drought and insect defoliators) or outbreaks of bark beetles after storms or droughts.

Because of the lack of an operational measurement instrument capable of supplying reliable quantitative data at the national level on the impact of different biotic and abiotic factors, the question is covered here from three complementary angles:

- **the proportion of trees and plots in the European network affected by "known causes"**: the sampling density is sufficient to reflect major health problems, but probably not more localised problems. Moreover, the summer rating underestimates the damage symptoms and causes because the factors of spring stress (insects, frosts, etc.) are not always identifiable in summer and certain problems (e.g. root problems) are difficult to diagnose. The recent data cannot be compared to those for the initial 1990-1994 period because observer training levels have been raised considerably.

- **assessment of the severity of serious pest and disease problems on the basis of observations made by the correspondents-observers of the Département santé des forêts** (several thousand observations per year): these problems have been documented, but the proportion of stands affected in a given region is unknown. The observations collected enable us to monitor fluctuations in the main pests affecting French forests.

a) damage of known origin in the European network for forest damage monitoring (mean frequencies of problems linked with attacks by pest insects and fungal diseases and with climatic stress)

• Number of plots

Species	number of plots with at least one tree of the species	number of plots in which insect pests were reported		number of plots in which pathogenic fungi were reported		number of plots in which damage due to a climatic factor was reported	
	mean 2000-2004	mean 2000-2004	%	mean 2000-2004	%	mean 2000-2004	%
Sessile oak	130.8	44.6	34.1%	10.2	7.8%	5.0	3.8%
Pedunculate oak	153.0	63.6	41.6%	22.6	14.8%	8.4	5.5%
Holm oak	27.6	9.2	33.3%	0.4	1.4%	4.0	14.5%
Pubescent oak	67.4	30.4	45.1%	5.4	8.0%	10.2	15.1%
Beech	131.6	26.0	19.8%	2.2	1.7%	8.6	6.5%
Maple	60.4	5.2	8.6%	1.0	1.7%	2.6	4.3%
Birch	44.0	5.4	12.3%	0.0	0.0%	2.0	4.5%
Hornbeam	56.2	11.2	19.9%	0.2	0.4%	3.2	5.7%
Chestnut	60.4	3.8	6.3%	8.6	14.2%	3.2	5.3%
Ash	64.0	12.0	18.8%	0.0	0.0%	3.8	5.9%
Poplar	30.6	6.0	19.6%	0.4	1.3%	2.6	8.5%
Wild cherry	45.2	11.2	24.8%	4.8	10.6%	2.2	4.9%
Other broadleaved	89.0	15.8	17.8%	3.8	4.3%	5.2	5.8%
Total broadleaved	**395.0**	**157.6**	**39.9%**	**51.2**	**13.0%**	**40.8**	**10.3%**
Common spruce	49.4	2.4	4.9%	0.8	1.6%	2.0	4.0%
Silver fir	48.4	2.6	5.4%	10.4	21.5%	3.2	6.6%
Scots pine	66.4	6.0	9.0%	10.2	15.4%	4.4	6.6%
Maritime pine	54.0	7.0	13.0%	1.2	2.2%	2.8	5.2%
Austrian pine	22.8	0.8	3.5%	1.8	7.9%	1.6	7.0%
Aleppo pine	15.0	0.4	2.7%	6.6	44.0%	2.6	17.3%
Douglas fir	22.6	1.0	4.4%	2.8	12.4%	1.6	7.1%
Larch	12.2	0.6	4.9%	0.0	0.0%	1.2	9.8%
Other conifers	10.0	0.4	4.0%	0.0	0.0%	0.4	4.0%
Total conifers	**238.4**	**20.6**	**8.6%**	**34.8**	**14.6%**	**19.4**	**8.1%**
Total all species	**515.8**	**176.4**	**34.2%**	**82.6**	**16.0%**	**54.0**	**10.5%**

(Source : Département de la santé des forêts - European network for forest damage monitoring. Current methods do not allow us to estimate errors due to low sampling rates. The figures are probably acceptable only for well-represented species (e.g. > 50 plots and > 300 trees). The values for "other broadleaved", "total broadleaved", "other conifers", "total conifers" and "total all species" are calculated for each of these collective samples and do not represent the weighted average of the figures by species. This explains why the values for these collective samples may be higher than the average value for each species.)

Commentary: for all species, the three most frequent stress factors during the 2000-2004 period are:

- pest insect attacks: 34% of plots and 12% of trees

- attacks by pathogenic fungi: 16% of plots and 5% of trees

- climatic stress: 10% of plots and 3% of trees

The degree of damage is difficult to interpret, as it can be both overestimated (detected damage is variable and often of low severity) and underestimated (trees sometimes have partially replaced their foliage by the time of the summer observations).

It can, however, be noted that the hierarchy of factors over the most recent period is the same as that of the previous period. The rates are also within the same range between the two consecutive periods, except for climatic stress, which seems to be lower for the most recent period.

Broadleaved species are generally much more severely affected by pest insect attacks than conifers, while there is less of a difference for fungal diseases.

Of the broadleaved species, pedunculate and sessile oaks, i.e. the most

• **Number of trees**

Species	number of trees	number of trees on which insect pests were reported		number of trees on which pathogenic fungi were reported		number of trees on which damage due to a climatic factor was reported	
	mean 2000-2004	mean 2000-2004	%	mean 2000-2004	%	mean 2000-2004	%
Sessile oak	1,241.2	282.0	22.7%	34.6	2.8%	40.3	3.2%
Pedunculate oak	1,178.6	347.4	29.5%	100.4	8.5%	34.0	2.9%
Holm oak	369.8	43.2	11.7%	22.0	5.9%	29.6	8.0%
Pubescent oak	828.2	155.2	18.7%	25.0	3.0%	51.4	6.2%
Beech	1,090.2	155.0	14.2%	12.0	1.1%	45.4	4.2%
Maple	139.0	8.6	6.2%	1.3	0.9%	4.2	3.0%
Birch	175.0	11.6	6.6%	0.0	0.0%	7.2	4.1%
Hornbeam	269.8	50.4	18.7%	1.0	0.4%	14.0	5.2%
Chestnut	472.8	6.2	1.3%	41.4	8.8%	14.6	3.1%
Ash	289.4	48.6	16.8%	0.0	0.0%	8.4	2.9%
Poplar	140.4	18.2	13.0%	24.0	17.1%	10.0	7.1%
Wild cherry	109.8	21.2	19.3%	17.7	16.1%	5.5	5.0%
Other broadleaved	424.2	61.2	14.4%	16.7	3.9%	17.5	4.1%
Total broadleaved	**6,728.4**	**1,208.8**	**18.0%**	**244.4**	**3.6%**	**257.8**	**3.8%**
Common spruce	542.0	7.0	1.3%	4.3	0.8%	5.0	0.9%
Silver fir	475.4	7.0	1.5%	37.2	7.8%	15.4	3.2%
Scots pine	632.8	19.4	3.1%	75.6	11.9%	19.6	3.1%
Maritime pine	906.6	21.2	2.3%	2.7	0.3%	8.3	0.9%
Austrian pine	234.4	1.0	0.4%	7.6	3.2%	4.3	1.8%
Aleppo pine	225.2	3.5	1.6%	117.3	52.1%	11.8	5.2%
Douglas fir	333.6	6.3	1.9%	44.0	13.2%	12.5	3.7%
Larch	142.2	3.5	2.5%	0.0	0.0%	14.3	10.1%
Other conifers	91.8	2.0	2.2%	0.0	0.0%	2.5	2.7%
Total conifers	**3,584.0**	**62.8**	**1.8%**	**262.4**	**7.3%**	**81.4**	**2.3%**
Total all species	**10,312.4**	**1,271.6**	**12.3%**	**506.8**	**4.9%**	**339.2**	**3.3%**

(Source : Département de la santé des forêts - European network for forest damage monitoring. Current methods do not allow us to estimate errors due to low sampling rates. The figures are probably acceptable only for well-represented species (e.g. > 50 plots and > 300 trees). The values for “other broadleaved”, “total broadleaved”, “other conifers”, “total conifers” and “total all species” are calculated for each of these collective samples and do not represent the weighted average of the figures by species. This explains why the values for these collective samples may be higher than the average value for each species.)

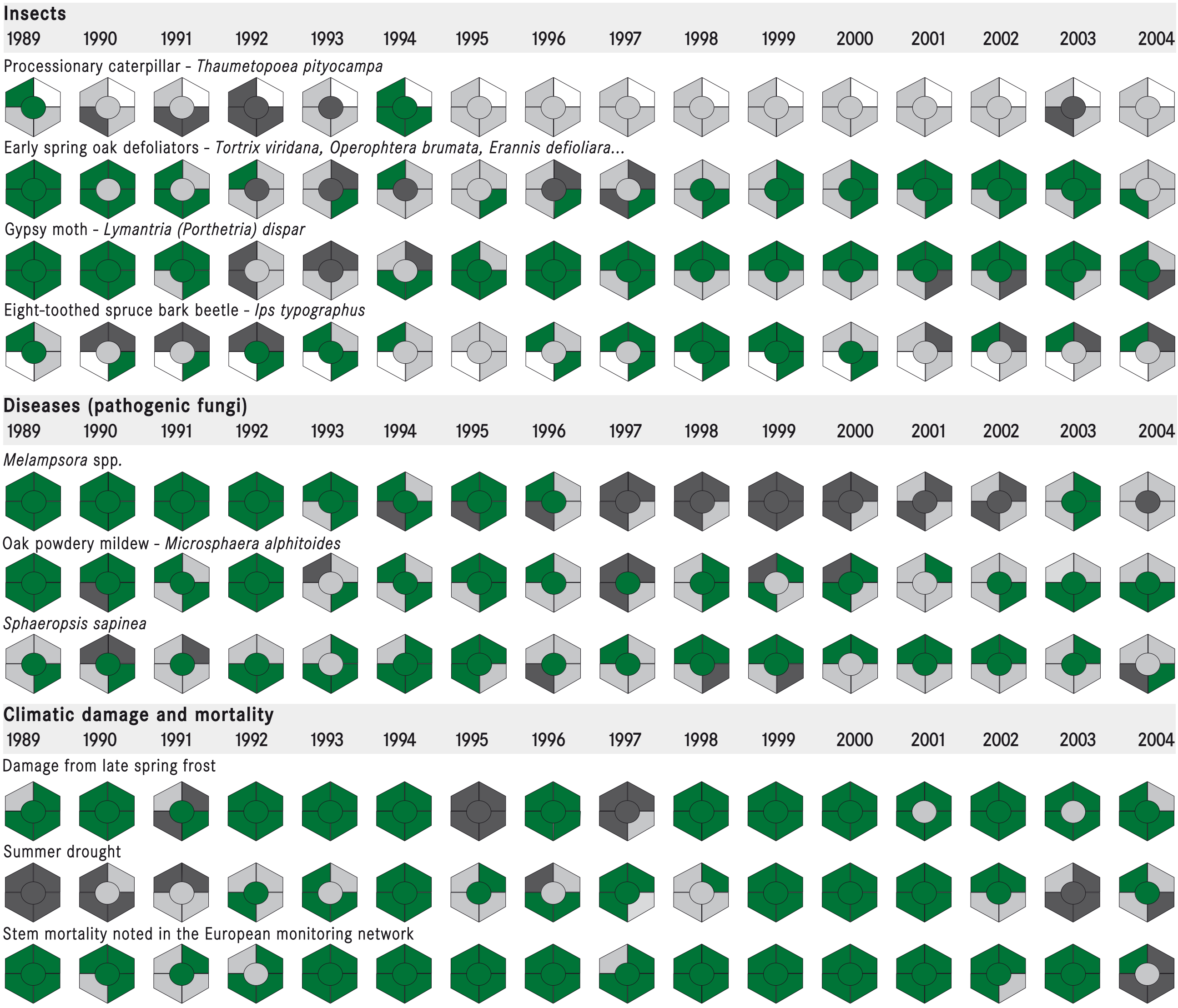
abundant French species, are stillmost frequently attacked by pest insects (especially defoliating insects).

However, during the recent period (2000-2004), poplars and wild cherry trees were the broadleaved species most attacked by pathogenic fungi.

For conifer species, maritime and Scots pines were also the most affected by insect attacks (especially the pine processionary caterpillar). Allepo pine is regularly hampered by fungal diseases.

The results on climatic stress are not very reliable because the symptoms of some major stresses, especially water stress, are usually not very specific. Moreover, the 2000-2004 period was very heterogeneous, with substantial rainfall at the beginning of the period (2000-2002) and exceptionally dry weather at the end (2003-2004). Mean values for the 2000-2004 period are therefore not very representative.

b) severity of the 10 major pest and disease problems affecting French forests from 1989 to 2004 (source: DSF)



The hexagons represent France:
Northwest Northeast
Massif Central
Southwest Southeast

Severity of problems:
Green: absence, trace, slight, endemic
Light grey: moderate
Dark grey: marked, epidemic

The white part of some hexagons indicates that the pest mentioned was absent from the concerned regions.

Commentary: windfalls due to the 1999 storms had a marked impact at the beginning of the 2000-2004 period. Outbreaks of subcortical insects were noted in pine stands, especially in the Landes region, and in spruce stands in eastern France (Vosges, Jura, northern Alps). Bark beetles caused considerable damage (several million m³). Apart from the storms, following the severe frost in November 1998, spectacular infestations of xylophagous beetles were noted in beech stands in northeastern France (mainly in the Ardennes massif) from 2000 to 2002. As a result of the 2003 drought-heat wave, new subcortical insect outbreaks occurred, especially on silver fir in medium mountain regions.
Populations of early spring defoliators of broadleaved species generally remained at a low level, but at the end of the period they seemed to increase again in many regions.
High poplar rust infestations that began in 1997 continued until 2002, and then considerably declined as a result of the 2003 drought. In conifers, during the 2000-2004 period, pine stands sometimes presented symptoms of intense red stain due to the presence of red band disease, especially in the eastern regions.

The overall forest decline observed in the early 1990 has clearly slowed down. However, during the 2000-2004 period, beech stands were found to be declining in many regions. These trends could be explained by many factors, such as destructuring of stands by the 1999 storms, soil compaction due to windfall logging, and the extreme climatic conditions in 2003. The effects of the 2003 drought-heat wave were still partially evident in 2004, including high mortality in Douglas fir and birch stands, etc., along with the onset of the decline in pedunculate oak, silver fir, etc.

2) Fires observed in forests and other wooded lands

Année	Area destroyed by fire (ha)				Number of fires
	Outside of Mediterranean region	Mediterranean region (1)		Total	
1979	6,376	53,351	89%	59,727	ND
1980	5,988	16,188	73%	22,176	ND
1981	4,233	23,478	85%	27,711	ND
1982	6,486	48,659	88%	55,145	ND
1983	5,239	48,490	90%	53,729	ND
1984	12,507	14,696	54%	27,203	ND
1985	9,861	47,507	83%	57,368	ND
1986	4,460	47,400	91%	51,860	ND
1987	3,714	10,395	74%	14,109	ND
1988	1,494	5,208	78%	6,702	ND
1989	18,695	56,871	75%	75,566	6,743
1990	18,728	53,897	74%	72,625	5,881
1991	3,581	6,549	65%	10,130	3,888
1992	3,828	12,765	77%	16,593	4,002
1993	4,797	11,901	71%	16,698	4,769
1994	2,390	22,605	90%	24,995	4,618
1995	8,149	9,988	55%	18,137	6,563
1996	8,281	3,119	27%	11,400	6,401
1997	9,331	12,250	57%	21,581	8,005
1998	7,837	11,243	59%	19,080	6,288
1999	3,123	12,782	80%	15,905	4,960
2000	5,162	18,864	79%	24,026	4,553
2001	2,502	17,970	88%	20,472	4,260
2002	23,860	6,299	21%	30,159	4,097
2003	11,771	61,507	84%	73,278	7,023
2004	3,114	10,596	77%	13,710	3,767

(1) Languedoc-Roussillon, Provence-Alpes-Côte d'Azur, Corsica, Drôme, Ardèche

mean 1980-84 (ha/an)	6,891	30,302	81%	37,193	
% total area				*0.23%*	
mean 1985-89 (ha/an)	7,645	33,476	81%	41,121	
% total area				*0.25%*	
mean 1990-94 (ha/an)	6,665	21,543	76%	28,208	4,632
% total area	*0.05%*	*0.63%*		*0.18%*	
mean 1995-99 (ha/an)	7,344	9,876	57%	17,221	6,443
% total area	*0.06%*	*0.24%*		*0.10%*	
mean 2000-2004 (ha/an)	9,282	23,047	71%	32,329	4,740
% total area	*0.07%*	*0.54%*		*0.19%*	

(Source : French Ministry of Agriculture and Fisheries and Ministry of the Interior, based on the Prométhée files for the Mediterranean region and statements by DRAF and DDAF for the other regions. Burnt areas are relative to forest areas and other wooded lands from the Teruti survey of SCEES.)

Commentary: from 1991 to 2002, the area affected by fires in France ranged from 10,000 to 30,000 ha per year, which differed markedly from the trend of the previous decade (Figure 11). These encouraging results were upset by the drought-heat wave of 2003, when there was a record number of more than 7,000 fires, with 73,300 ha burnt. The Mediterranean region was especially affected, with more than 60,000 ha burnt in 2003, including 27,400 ha in Corsica and 18,800 in the Var region, thus surpassing the scores of 1989 and 1990. The mean burnt area per fire was more than 10 ha throughout France, as was also the case in 1989 and 1990. These mean results conceal the marked variations between regions, with the largest forest fires recorded in the Mediterranean region.

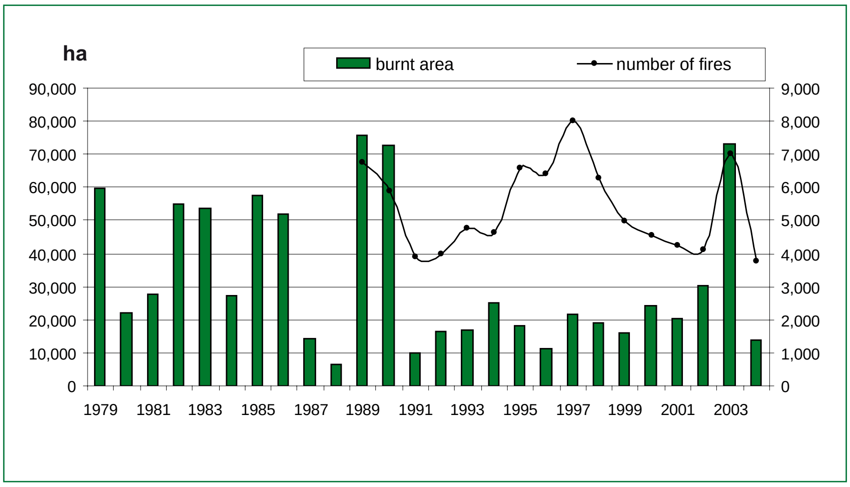


Figure 11: Variations in the number of fires and burnt areas in forests and other wooded lands from 1979 to 2003 (sources: French Ministry of Agriculture and Fisheries, and Ministry of the Interior)

Another unique feature in recent years concerns the peak in burnt areas recorded in 2002 outside of the Mediterranean area, corresponding to very large forest fires that occurred in the Aquitaine and Midi-Pyrénées regions. The situation returned to normal in 2004, with less than 14,000 ha burnt throughout France.

Experimental findings after the 2003 fires highlighted the following points:
- the extreme climatic conditions of 2003 considerably depleted the soil water reserves and transformed the Mediterranean vegetation into a virtual tinder box;
- the brush infestation of rural areas, resulting from agricultural abandonment and poor maintenance, increased the combustible area and inflammability level, especially between wooded massifs and inhabited zones. Fire fighting resources were focused around inhabited areas because of the lack of maintenance around houses, which meant that these resources were no longer available for fighting forest fires. Moreover, this brush infestation phenomenon was ironically boosted by the low level of fires recorded during the previous decade;
- the quantity of combustible biomass increased sharply during the previous decade because of the low forest fire rate;
- the good results recorded between 1991 and 2002 could have led to a reduction in forest fire prevention resources (funding, enforcement of regulations, forest-fire experience, equipment maintenance, etc.).

Several recommendations were put forward on the basis of these points, including:
- better adaptation of the system to extreme climatic conditions;
- effectively controlling urbanisation in forest areas and better self-protection of homes;
- regular clearing maintenance in collaboration with crop and livestock farmers when possible;
- more effective coordination of stakeholders;
- enhanced public awareness on forest fire prevention.

3) Storms

	1965-74	1975-84	1985-94	1995-2004
volume in state-owned forest	3 M m³	3.6 M m³	9.7 M m³	61.7 M m³
volume in private forest	0.7 M m³	12 M m³	6.5 M m³	115.4 M m³
total volume	3.7 M m³	15.6 M m³	16.2 M m³	177.1 M m³
% of growing stock	0.23%	0.95%	0.87%	8.3%
% of production of the corresponding period	-	2.58%	2.16%	20.0%
mean volume per ha of metropolitan forest per year	0.026 m³/ha/year	0.111 m³/ha/year	0.114 m³/ha/year	1.149 m³/ha/year
from 1965 to 1998: area-equivalent of volumes destroyed; 1999: IFN estimation of stand areas in which more than 10% of the cover is destroyed	approx. 2,500 ha/year	approx. 9,800 ha/year	approx. 9,300 ha/year	approx. 115,300 ha/year

(Source: from 1965 to 1998: ONF and MAP, only for exceptional windfalls, thus not taking into account windfall volumes regularly removed in mountains at the end of winter; for private forests, most of the figures come from M. Doll's thesis "Disastrous Meterorological Events in Forests", 1988; the area-equivalent of the volumes destroyed per year is calculated from the mean volume per hectare of regular high forest, the type of stand most often affected by windfalls. For the 1999 storms, IFN estimations were based on analyses of aerial photos and field surveys after the storms (see details below); the exceptional windfall volume between year 2000 and 2004 was null)

Commentary: the storms of December 1999 had a very damaging impact on French forests. These storms hit many regions from southwestern to northeastern France (Map 12), contrary to storms during previous periods that mainly just affected single regions (Massif Central, 1982; northeastern France, 1984; Bretagne, 1987; northern France, 1990). The extent of the damage boosted the damage indicators 10-fold for the last decade relative to the previous ones. The proportion of destroyed growing stock rose to 8.3% (1.1 m³/ha/year) from the maximum level of 1% over the previous 30 years (0.1 m³/ha/year). The proportion of current production destroyed was 20% as compared to a maximum of 2.6% for the previous period.

Finally, the damaged area increased from less than 10,000 ha per year to more than 115,000 ha per year between 1995 and 2004. These latter results should, however, be considered in the light of the fact that the assessment results for previous decades (based on area equivalents) were likely underestimated, i.e. if this area-equivalent method were to be used to evaluate the 1999 data, only stands damaged by more than 50% would have been taken into account.

The total volume destroyed over the last decade is estimated at 177.1 million m³, including 175.9 million m³ just for 1999 and 1.2 million m³ in 1996 in the private Landes massif. Two-thirds of the volumes destroyed were located in private forests.

Storms of December 1999

Damage class	Area per main species				Windfall volume per species				Windfall volume per ha
	Broadleaved	Conifers	Total		Broadleaved	Conifers	Total		Total
	x 1,000 ha			%	x 1,000 m³			%	m³/ha
0-10%	8,140	4,440	12,580	91.7%	32,452	20,185	52,638	29.9%	4
10-50%	341	353	694	5.1%	21,037	19,346	40,383	23.0%	58
50-90%	133	167	299	2.2%	21,345	25,041	46,386	26.4%	155
90-100%	49	103	153	1.1%	12,342	24,125	36,466	20.7%	239
Total	**8,664**	**5,062**	**13,726**	**100.0%**	**87,176**	**88,697**	**175,873**	**100.0%**	**13**
> 10%	523	623	1,146	**8.3%**	54,724	68,511	**123,236**	70.1%	108
> 50%	182	270	452	**3.3%**	33,687	49,166	**82,852**	47.1%	183

(Source : IFN 2002, based on damage recorded at each IFN plot. The damage rate was calculated according to fiels survey data - including departments normally monitored after storms - or on the basis of a cartographic analysis of damage noted on aerial photographs. The windfall volume for the 0-10% class was difficult to determine in departments where no field surveys had been conducted because the proportion of destroyed volume was highly variable.)

Commentary: The Inventaire forestier national (IFN) was assigned to evaluate the damage caused by the 1999 storms. Forest damage was mainly assessed by cartographic procedures using aerial photographs and satellite images and via field surveys in a few departments. In some 30 administrative departments, this assessment was supplemented with data from the current update of inventories under-taken since year 2000. In this new update, for each sampling plot of the last inventory, IFN allocated a damage rate according to four classes:

- sparse damage: 0-10%
- substantial damage: 10%-50%
- severe damage: 50-90%
- massive damage: more than 90%

The results indicated that 1.1 million ha of forest were damaged by more than 10%, i.e. 8.3% of the inventoried area. This includes an estimated 450,000 ha of stands that had been damaged by more than 50%–conifer stands were the hardest hit, representing 60% of the severe and massive damage classes in terms of both area and volume. Lorraine, Limousin and Aquitaine were the most affected regions, with a mean estimated area damage rate of 30%, 22% and 20%, respectively (Map 12), followed by Basse-Normandie (18%), Champagne-Ardenne (15%), Poitou-Charentes (14%) and Alsace (12%). More than half of the stands affected in Limousin and Poitou-Charentes suffered severe to massive damage, and the damage rate was also high in Lorraine, Aquitaine and Alsace.

The total volume destroyed is estimated at 176 million m³, including 30% in stands with sparse damage (0-10% class).

The actual volume destroyed in this 0-10% class is hard to determine, especially for departments that were only assessed cartographically. A few hypotheses were thus put forward on the actual rates of damage in these stands. However, this 30% estimate does not seem excessive compared to the mean 50% destroyed volume recorded in the five departments where field surveys had been conducted. The Service central des enquêtes et études statistiques (SCEES) also estimated that 119 million m³ of windfalls have been logged, including self-consumption. These data were converted into overbark volumes, including logging losses, and the results indicated that 140 million m³ have been logged, as compared to 176 million m³ estimated by IFN, which means that the non-utilised windfall volume left in the forest was 20%.

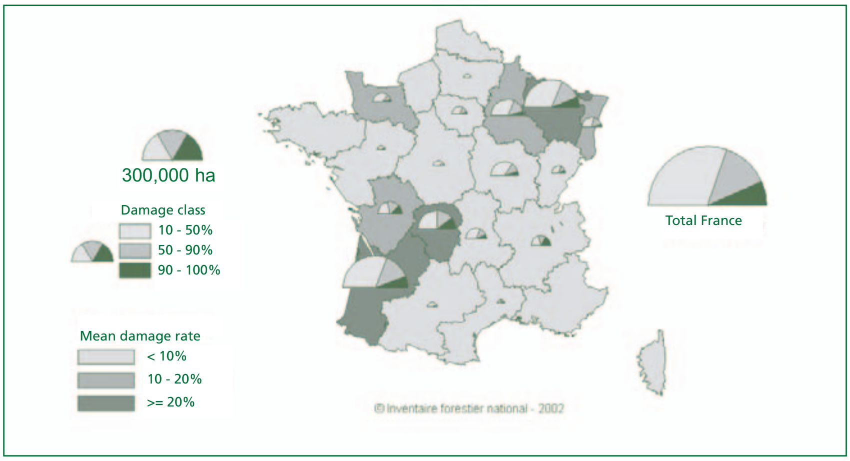
IFN's difficulties in evaluating the storm damage was one of the reasons for the adoption of a new method in 2005–the switch to a systematic annual method should enable IFN to respond quicker and more reliably in assessing damage caused by extreme events in the future.

The total volume destroyed represents 8% of the growing stock, 2-fold the current production and 3- to 4-fold the annual fellings over the 1995-99 period, irrespective of whether self-consumption is considered or not. France was the European country most severely affected by the 1999 storms, especially as compared to Switzerland (2.8-fold the annual removals) and Germany (0.8-fold).

This situation prompted the French ministry for forests to assess the impact of these storms on the conifer availability for wood supply in France up until 2015. This assessment was carried out by IFN and the Association forêt-cellulose (AFOCEL). The conclusions indicated that the overall loss of conifer availability for wood supply will be limited, i.e. 700,000 m³ per year over the next 5 years, but with a major impact on the regions most affected by the storms.

A national research programme entitled "Forests, winds and risks" was initiated in year 2000 and coordinated by the ECOsystèmes FORestiers (ECOFOR) public interest group. The research results presented in 2005 enhanced awareness on the vulnerability of French forest ecosystems and on ways to stabilise them.

Finally, many issues have yet to be investigated concerning the rehabilitation of plot stands after the 1999 storms. The Laboratoire d'études des ressources forêt-bois (LERFOB), the Institut pour le développement forestier (IDF) and the Office national des forêts (ONF) thus initiated a national observatory on post-storm vegetation dynamics in 2002. The overall aim is to monitor changes in herbaceous vegetation and tree regrowth in a network of permanent plots that are representative of relatively unknown but highly problematic situations. The sites will thus be periodically monitored over a 10-15 year period on the basis of different characteristics: soil, tree regrowth, herbaceous vegetation, lying wood, holdover trees and the surrounding stand.

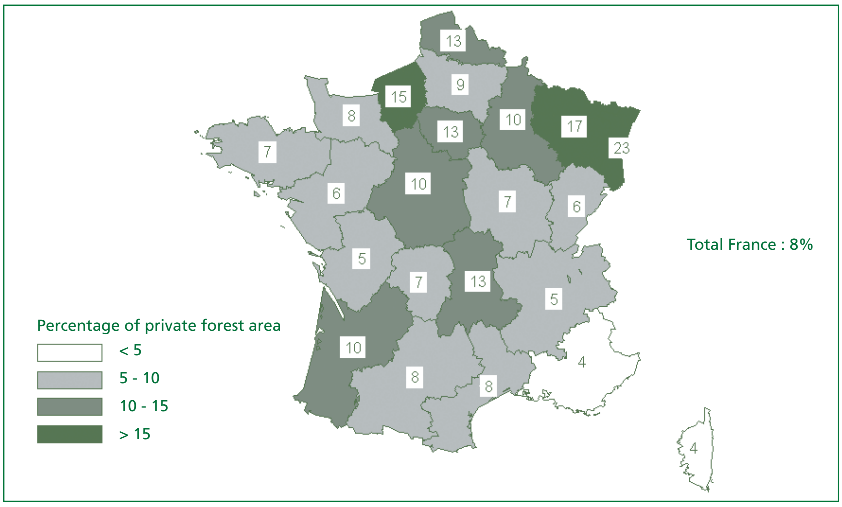


Map 12: Area of stands damaged by more than 10%, ranked by damage class and mean damage rate per administrative region (source: IFN, 2002)

INDICATOR 2.4.1
Regenerations protected from damage by large ungulates

Forest category	Area protected from large ungulates (ha/an)	
	1998-99	2002-03
State-owned forest	4,220	3,000
Other public forests governed by forest regulations	4,320	2,850
Total public forests	**8,540**	**5,850**

(Source : ONF, working database)



Map 13: Proportion of private forest area in administrative regions damaged by game according to forest owners' declarations (source: SCEES, 1999)

Commentary: initiatives to protect regenerated stands from large ungulates are aimed at avoiding three types of damage, i.e. browsing, rubbing and debarking, by fencing in the plots or by installing individual plastic sleeves around tree trunks.
6,000 ha per year are currently protected in this way in state-owned forests, but this figure has dropped by 30% in the last 5 years because of the high protection cost.

A survey on private forest structures conducted by the Service central des enquêtes et études statistiques (SCEES) in 1999 assessed how private forest owners view this problem. 13% of these owners declared that they had noted serious damage incurred on 8% of their private forest area. Alsace, Lorraine and Haute-Normandie were the regions most affected by this problem in terms of area (Map 13), while very little impact was noted in Corsica and Provence-Alpes-Côte d'Azur.

The increase in deer populations to the current level of 0.7 red deer and 10 roe deer per 100 forested ha (cf. § 4.9.1) has substantially increased forest owners' management expenditures.

It is generally considered that protection against roe deer can double plantation costs, while anti-red deer protection can quadruple them. It is thus essential to ensure the silviculture-hunting balance by implementing hunting plans.

The Observatoire national des dégâts de cervidés et du plan de chasse published a highly informative study on this topic that was conducted in five test departments (Landes, Oise, Sarthe, Tarn and Vosges) in 2003.

The main recommendations are:

- to establish a cartographic system for forecasting damage risks through the creation of regularly updated departmental databases on susceptible stands;
- to regularly monitor damage in susceptible stands;

- to enhance the efficacy of hunting programmes;

- to increase the involvement of concerned stakeholders, especially forest owners.

Finally, this study highlighted the advantages of tailoring silvicultural techniques to the presence of deer and the importance of analysing the relations between irregular forest management and damage.