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CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION
INTERNATIONAL CO-OPERATIVE PROGRAMME ON ASSESSMENT AND MONITORING
OF AIR POLLUTION EFFECTS ON FORESTS
and
EUROPEAN UNION SCHEME
ON THE PROTECTION OF FORESTS AGAINST ATMOSPHERIC POLLUTION

United Nations
Economic Commission
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Forest Condition in Europe

Results of the 2001 Large-scale Survey

2002 Technical Report

Prepared by:

Federal Research Centre
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CONTENTS

PREFACE

Two decades ago Europe was alarmed by reports on air pollution causing widespread forest death. The scene has changed after 20 years of forest damage research and more than 15 years of monitoring forest condition in Europe. Today there is even some evidence that forests are in a better shape than ever before. The true extent, development and causes of forest damage in Europe can only be ascertained by means of long-term systematic and intensive monitoring of forest condition.

Forest condition has been monitored by the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) under the Convention on Long-range Transboundary Air Pollution (CLRTAP) of the United Nations Economic Commission for Europe (UNECE) since 1986. In the same year, the European Union (EU) adopted its European Union Scheme on the Protection of Forests against Atmospheric Pollution. Since then, ICP Forests and EU have been monitoring forest condition in close cooperation. Today, 39 countries including all EU-Member States, Canada and the United States of America are participating.

The monitoring aims to assess the large-scale spatial and temporal variation of forest condition on a European-wide grid (Level I) and at the identification of cause-effect relationships at the ecosystem scale by means of intensive monitoring on permanent observation plots (Level II). At Level I, crown condition is assessed annually on a transnational (16 x 16 km) grid and on national grids of individual densities. On the transnational grid soil condition and foliage chemistry have also been assessed. At Level II, besides crown condition, soil condition and foliage chemistry, also increment, ground vegetation, air quality, deposition, soil solution, meteorology and the phenology of tree crowns are assessed.

Faced with the continuing threatening of forest condition by long-range transboundary air pollution and corresponding to the complex interrelations between the multitude of natural and anthropogenic factors involved, the programme has over the years grown up into one of the largest biomonitoring networks of the world. Today, the programme no longer contributes solely to the scientific basis of air pollution control policies of UNECE and the European Commission (EC). Beyond that, its well established infrastructure, its multidisciplinary monitoring approach and its comprehensive database permit significant contributions to other processes of international environmental policies. It pursues the objectives of three Resolutions and provides information on three indicators for sustainable forest management of the Ministerial Conference on the Protection of Forests in Europe (MCPFE). In addition, the soil data of the programme are expected to contribute to the assessment of carbon sinks as a input of the European Union to the Kyoto Protocol under the Framework Convention on Climatic Change (FCCC). The programme also cooperates with the Acid Deposition Monitoring Network in East Asia (EANET) and contributes to global forest policies such as the United Nations Forum on Forests (UNFF).

The monitoring results of each year are summarized in annual Executive Reports. The methodological background and detailed results of the individual surveys are described in Technical Reports. The present Technical Report on Forest Condition in Europe refers to the results of the large-scale transnational survey of the year 2001. It is the eleventh in the series published annually jointly by ICP Forests and EC. The contributions to the report made by the participating countries are gratefully acknowledged.

SUMMARY

Forest condition in Europe has been surveyed on large scale for 16 years under the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) of the United Nations Economic Commission for Europe (UNECE) and under the Scheme on the Protection of Forests against Atmospheric Pollution of the European Union (EU). In the year 2001, crown condition was assessed on 5 942 plots, constituting a transnational grid of 16 x 16 km in 30 countries. On these plots, defoliation of 132 350 sample trees was assessed for the calculation of results at the European scale. The transnational plots constitute a subsample of 340 903 plots from denser national grids of 34 countries.

The mean defoliation of the 2001 transnational tree sample was 20.1%. Of the main species, *Quercus robur* and *Q. petraea* had by far the highest mean defoliation (24.9%), followed by *Fagus sylvatica* (20.7%), *Picea abies* (19.4%) and *Pinus sylvestris* (19.1%). The development of defoliation has been traced on subsamples of those trees continuously observed since 1989. This reveals increasing defoliation for the most common six species with a high spatial variation.

The participating countries reported different causes for important changes in defoliation. The recovery of *Pinus sylvestris* is attributed to a decrease of acid deposition, but insect attacks or fungi infestations are responsible for regional increases in defoliation. The constant increase in defoliation of *Picea abies* is attributed to storms and subsequent insect attacks. The defoliation of *Quercus robur* and *Q. petraea* remained almost unchanged. *Fagus sylvatica* in 2001 showed the highest increase in defoliation among the main species, which was particularly pronounced in the Mountainous (south) region and partly explained by hailstorms. Over the total period of observation *Quercus ilex* and *Q. rotundifolia* and *Pinus pinaster* experienced the most severe deterioration of crown condition, which was attributed mainly to summer heat and drought.

Crown condition data of *Pinus sylvestris* and *Fagus sylvatica* were evaluated in relation to biotic agents, soil condition, deposition and meteorology. The results confirm that defoliation varies with stand age and geographic region. Besides this variation there is a small but statistically significant relationship between sulphur deposition and defoliation. High defoliation figures are found in areas with high sulphur deposition and a decrease in defoliation is observed in areas where successful abatement strategies have reduced sulphur deposition. The correlations between nitrogen inputs and forest condition are not statistically significant and reveal ambiguous conditions. This might confirm current knowledge that nitrogen inputs on one hand fertilise forest ecosystems, but on the other may have acidifying and thus damaging effects. The analysis of the spatial variation of defoliation for *Fagus sylvatica* showed a statistically significant positive correlation with the index for fungi infestations. The index for insect pests was positively correlated with defoliation for both tree species. Only in the case of spatial variation of defoliation for *Pinus sylvestris* was this correlation statistically significant. Defoliation was correlated to the interaction between precipitation and soil properties indicating a benefit of precipitation on soils with limited water availability.

Particular emphasis is being laid upon data quality assurance. Intercalibration exercises among the soil laboratories revealed the need for higher data quality for elements of low

concentrations. In contrast, the results for nitrogen, organic carbon, base saturation, pH and base cation exchange capacity showed high degrees of confidence. According to ring tests among the foliage laboratories, the comparability of trace elements needs to be enhanced, whilst the overall quality of the foliage data has improved considerably. Despite the undeniable success in the harmonisation of crown condition assessment, international intercalibration courses revealed relationships between the defoliation scores and the countries of the assessment teams. These relationships varied with site quality and stand age. Good quality photos were shown to be suitable for quality assurance in crown condition assessment.

1 INTRODUCTION

The large-scale transnational survey aims to gain knowledge on the European-wide spatial and temporal variation of forest condition in Europe in relation to natural and anthropogenic factors, particularly air pollution. For this purpose, crown condition has been assessed annually for 16 years on approximately 6 000 sample plots. In addition, soil condition was surveyed on about 5 300 and foliage chemistry was assessed on about 1 400 of these plots. The monitoring results are subjected to integrative evaluations, also together with large-scale data of other programmes.

The present report documents the results of the large-scale crown condition survey of the year 2001 and the development of crown condition over 16 years of monitoring. Moreover, statistical relationships between crown condition as dependent variable and site quality, precipitation, biotic agents and atmospheric deposition as predictor variables are presented. These statistical analyses compensate for stand age and for differences between the methods of crown condition assessments applied in different countries. International consistency of the methods and standards applied is crucial to the data quality of all surveys of the programme, not only of the crown condition assessment. Therefore, quality assurance for the transnational surveys on crown condition, soil condition and foliage chemistry is also described in the report. The report is outlined as follows:

Chapter 2 provides an overview of the parameters and methods of the large-scale transnational surveys on crown condition, soil condition and foliage chemistry. For these three surveys, measures and results on data quality assurance are presented. Furthermore, the methods of the statistical evaluations are described.

Chapter 3 presents the results of the crown condition survey of the year 2001. Crown condition and its development are described with regard to several species, regions and identified damage types.

Chapter 4 provides maps on crown condition and its temporal development based on a geostatistical approach. The spatial and temporal variation of crown condition are then explained by means of site quality, precipitation, biotic agents and atmospheric deposition, accounting for stand age and methodological differences between countries.

Chapter 5 comprises the national reports on forest condition as provided by the countries.

Chapter 6 interprets the results of the transnational and national surveys.

Maps, graphs and tables concerning the transnational and national results are provided in Annexes I and II. Annex III provides a list of tree species with their botanical names and their names in the official UNECE and EU languages. The statistical procedures used in the evaluations are described in Annex IV. Annex V provides a list of addresses.

2 METHODS OF THE SURVEYS IN 2001

2.1 Background

The methods of the transnational survey are described in the "Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests" (UNECE, 1998) and in Commission Regulation (EEC) No. 1996/87 and its amendments (EU, 1987). In the following sections, the selection of sample plots, the assessment of stand and site characteristics and the assessment of parameters on crown condition, soil condition and foliage chemistry are described. Also described are measures and results on data quality assurance as well as the evaluation and presentation of the survey results.

2.2 Selection of sample plots

2.2.1 The transnational survey

The transnational survey aims to assess the spatial development of forest condition at the European level. This is achieved by means of large-scale monitoring on a 16 x 16 km transnational grid of sample plots. In several countries, the plots of the transnational grid are a subsample of a denser national grid (Chapter 2.2.2).

The coordinates of the transnational grid were calculated and provided to the participating countries by EC. If a country had already established plots, the existing ones were accepted, provided that the mean plot density resembled that of a 16 x 16 km grid, and that the assessment methods corresponded to those of the ICP Forests Manual and the relevant Commission Regulations. The fact that the grid is less dense in parts of the boreal forests can be shown to be of negligible influence due to the homogeneity of these forests.

The transnational survey of the year 2001 comprised 5 942 plots assessed in 30 countries Table 2.2.1-1 presents the numbers of plots for each participating country for the last 13 years. Cyprus started its participation in ICP Forests with 15 plots and submitted crown condition data for the first time. In addition, 6 plots were assessed on the Azores and 13 plots on the Canary Islands, but excluded from the transnational evaluation as they are not located in those geoclimatic regions according to which all other plots were assigned (Annex I-1). These plots, however, are shown in the respective maps. The figures in Table 2.2.1-1 are not necessarily identical to those published in previous reports. Consistency checks and subsequent data corrections as well as new data submitted by countries may have caused rearward changes in the data base. For example, in 2000 Belarus submitted new data which dated back to 1997. Italy and Spain completed their plot sample by establishing additional plots. The Czech Republic reduced from 1998 onwards the number of its plots in order to avoid an overrepresentation of its results in the transnational data base.

Figure 2.2.1-1 shows the spatial distribution of the plots assessed in 2001. For a range of observations the plot sample is stratified according to geoclimatic regions adapted from those by WALTER et al. (1975), and WALTER and LIETH (1967). For an explanation of these regions see Annex I–1. Percentages of plots in the 10 different regions are given in Table 2.2.1-2.

Table 2.2.1-1: Number of sample plots from 1989 to 2001 according to the current database.

Country	Number of sample plots												
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Austria		72	79	77	76	76	76	130	130	130	130	130	130
Belgium	33	29	29	29	29	29	29	29	29	29	30	29	29
Denmark	25	25	25	25	25	25	24	23	22	23	23	21	21
Finland			359	413	405	382	455	455	460	459	457	453	454
France	509	514	513	505	506	534	543	540	540	537	544	516	519
Germany	297	410	411	414	412	417	417	421	421	421	433	444	446
Greece	104	101	101	98	96	96	95	95	94	93	93	93	92
Ireland	22	22	22	22	22	21	21	21	21	21	20	20	20
Italy	204	204	206	202	212	209	207	207	181	177	239	255	265
Luxembourg	4	4	4	4	4	4	4	4	4	4	4	4	
The Netherlands	14	14	14	14	13	13	13	12	11	11	11	11	11
Portugal	152	152	151	149	143	147	141	142	144	143	143	143	144
Spain	457	447	436	462	460	444	454	447	449	452	598	607	607
Sweden	60	38	45	67	59	340	726	766	758	764	764	769	770
United Kingdom	74	74	74	72	69	66	63	79	82	88	85	89	86
EU	1955	2106	2469	2553	2531	2803	3268	3371	3346	3352	3574	3584	3594
Belarus									416	416	408	408	408
Bulgaria						109	120	120	120	135	115	108	109
Croatia					84	88	82	83	86	89	84	83	81
Cyprus													15
Czech Republic		93	362	156	178	205	199	196	196	116	139	139	139
Estonia					88	90	90	91	91	91	91	90	89
Hungary		67	66	65	65	62	63	60	58	59	62	63	63
Latvia		80	101	100	101	94	94	99	96	97	98	94	97
Lithuania				73	74	73	73	67	67	67	67	67	66
Moldova					12	12	11	10	10	10	10	10	10
Norway				387	390	384	386	387	386	386	381	382	408
Poland		474	476	476	476	441	432	431	431	431	431	431	431
Romania				215	167	199	241	224	237	235	238	235	232
Russian Fed.						7	134						
Slovak Republic	111	111	111	111	111	111	111	110	110	109	110	111	110
Slovenia					34	34	42	42	42	41	41	41	41
Switzerland		45	45	45	45	45	47	49	49	49	49	49	49
Total Europe	2066	2976	3630	4181	4356	4757	5393	5340	5741	5844	6051	6047	5942

Table 2.2.1-2: Distribution of the 2001 sample plots over the climatic regions.

Climatic region	Number of plots	Percentage of plots
Boreal	993	16.7
Boreal (temperate)	945	15.9
Atlantic (north)	338	5.7
Atlantic (South)	289	4.9
Sub-atlantic	1113	18.7
Continental	255	4.3
Mountainous (north)	269	4.5
Atlantic (south)	724	12.2
Mediterranean (higher)	404	6.8
Mediterranean (lower)	612	10.3
All regions	5942	100.0

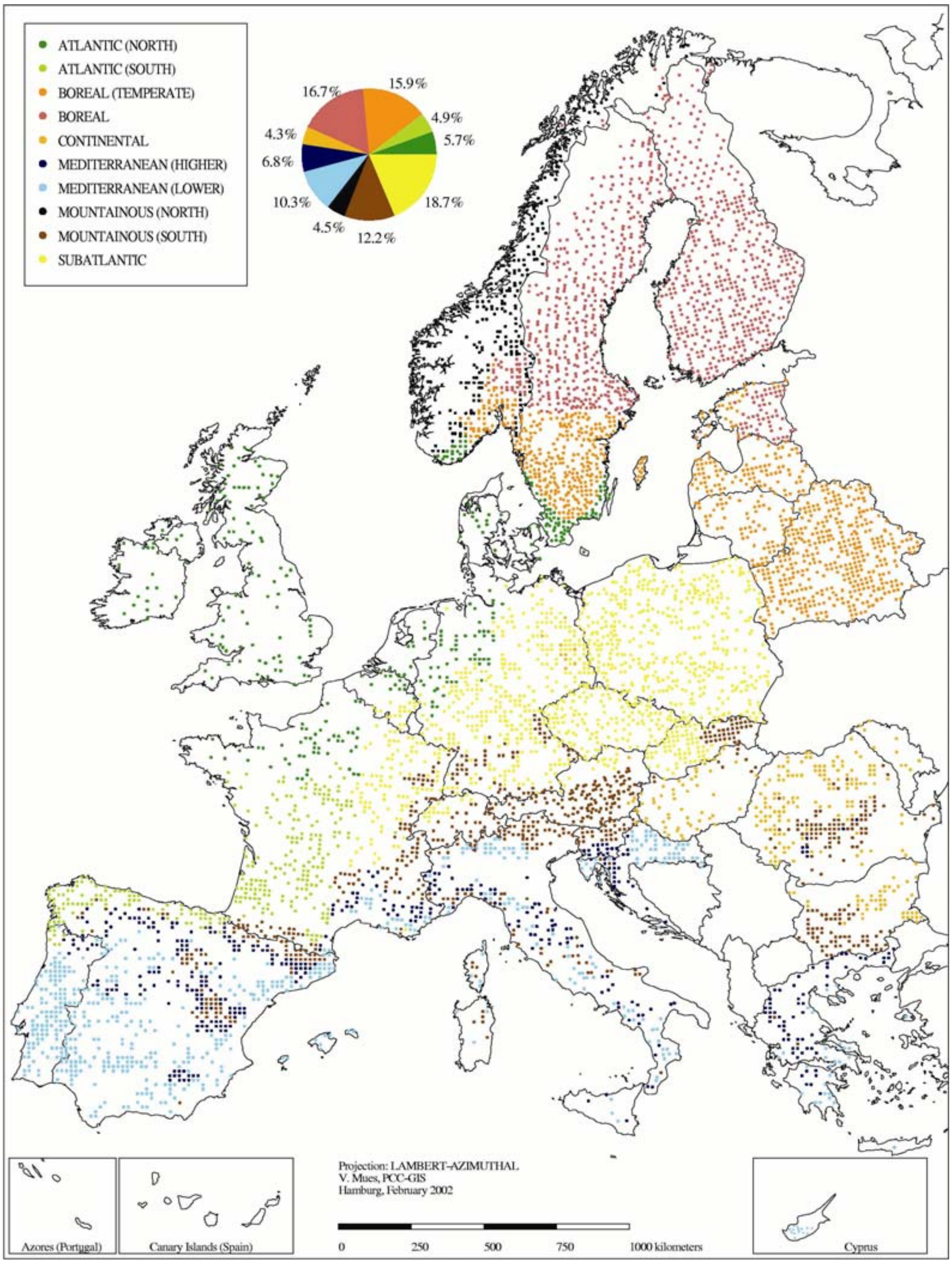

Figure 2.2.1-1: Plots according to climatic regions (2001).

2.2.2 National surveys

Besides the transnational survey, national surveys are conducted in many countries. These aim at the documentation of forest condition and its development in the respective country. Therefore, the national surveys are conducted on national grids. Since 1986, densities of national grids with resolutions between 1 x 1 km and 32 x 32 km have been applied due to differences in the size of forest area, in the structure of forests and in forest policies. Results of crown condition assessments on the national grids are tabulated in Annexes II-1 to II-7 and are displayed graphically in Annex II-8. The national reports of Chapter 5 are based on these data. Any comparisons between the national surveys of different countries should be made with great care because of differences in species composition, site conditions and methods applied.

2.3 Assessment parameters

2.3.1 Stand and site characteristics

On the plots of the transnational survey, the following plot and tree parameters are reported in addition to defoliation and discolouration:

Country, plot number, plot coordinates, altitude, aspect, water availability, humus type, soil type (optional), mean age of dominant storey, tree numbers, tree species, identified damage types and date of observation (Table 2.3.1-1).

Table 2.3.1-1: Stand and site parameters given within the crown data base.

Registry and location	country	state in which the plot is assessed [code number]
	plot number	identification of each plot
	plot coordinates	latitude and longitude [degrees, minutes, seconds] (geographic)
	date	day, month and year of observation
Physiography	altitude [m a.s.l.]	elevation above sea level, in 50 m steps
	aspect [°]	aspect at the plot, direction of strongest decrease of altitude in 8 classes (N, NE, ... , NW) and "flat"
Soil	water availability	three classes: insufficient, sufficient, excessive water availability to principal species
	humus type	mull, moder, mor, anmor, peat or other
	soil type	optional, according to FAO (1990)
Climate	climatic region	10 climatic regions according to WALTER et al. (1975)
Stand related data	mean age of dominant storey	classified age; class size 20 years; class 1: 0-20 years, ..., class 7: 121-140 years, class 8 irregular stands
Additional tree related data	tree number	number of tree, allows the identification of each particular tree over all observation years
	tree species	species of the observed tree [code]
	identified damage types	treewise observations concerning damage caused by game and grazing, insects, fungi, abiotic agents, direct action of man, fire, known regional pollution, and other factors

Nearly all countries submitted data on water availability, humus type, altitude, aspect, and mean age. The numbers of plots for which these site parameters were reported increased distinctively in recent years (Table 2.3.1-2). The data set is now almost complete for the EU-Member States. One EU-Member State did not report soil type.

Table 2.3.1-2: Number of sample plots and plots per site parameter.

Country	Number of plots	Number of plots per site parameter					
		Water	Humus	Altitude	Aspect	Age	Soil
Austria	130	130	128	130	130	130	130
Belgium	29	29	29	29	29	29	10
Denmark	21	21	21	21	21	21	21
Finland	454	454	454	454	454	454	454
France	519	519	519	519	519	519	519
Germany	446	446	446	446	446	446	410
Greece	92	92	92	92	92	92	92
Ireland	20	20	20	20	20	20	19
Italy	265	265	265	265	265	265	
Luxembourg	4	4	4	4	4	4	4
The Netherlands	11	11	11	11	11	11	11
Portugal	144	144	144	144	144	144	137
Spain	607	607	607	607	607	607	431
Sweden	770	686	756	770	770	770	569
United Kingdom	86	86	86	86	86	86	86
EU	3594	3510	3576	3594	3594	3594	2889
Percent of EU plot sample		97.7	99.5	100.0	100.0	100.0	80.4
Belarus	408	407			408	408	
Bulgaria	109	109		109	109	109	109
Croatia	81	81	81	81	81	81	56
Cyprus	15	15	15	15	15	15	
Czech Republic	139	139	59	139	139	139	59
Estonia	89	89	89	89	89	89	89
Hungary	63	63	41	63	63	63	63
Latvia	97	97	97	97	97	97	97
Lithuania	66	66	1	66	66	66	66
Rep. of Moldova	10	10	10	10	10	10	
Norway	408		368	408	408	408	364
Poland	431	431	11	431	431	431	12
Romania	232	232	232	232	232	232	224
Slovak Republic	110		110	110	110	110	110
Slovenia	41	41	41	41	41	41	41
Switzerland	49	46	46	49	49	49	46
Total Europe	5942	5336	4777	5534	5942	5942	4225
Percent of total plot sample		89.8	80.4	93.1	100.0	100.0	71.1

2.3.2 Soil parameters and their assessment

Soil data on chemical and some physical properties of the solid phase as well as soil types according to FAO (1990) are available from 5 289 plots in 28 countries. Some of the inventories at the Level I plots date back to 1985 and some were collected as late as 1998, but most were surveyed in the years from 1993 to 1995 (2 498 plots). An overview is given in Table 2.3.2-1.

Table 2.3.2-1: Availability of soil data from participating countries.

Country	from	to	Number of plots
Austria	1987	1998	131
Belgium	1993	1994	31
Denmark	1994	1994	25
Finland	1987	1995	442
France	1992	1994	517
Germany	1987	1993	416
Greece	1994	1994	15
Ireland	1995	1995	22
Italy	1995	1996	70
Luxembourg	1994	1994	4
The Netherlands	1995	1995	11
Portugal	1995	1995	157
Spain	1993	1995	464 1)
Sweden	1985	1995	1249
United Kingdom	1993	1995	67
Bulgaria	1990	1994	176
Croatia	1993	1995	87
Czech Republic	1995	1995	100
Estonia	1990	1994	91
Hungary	1994	1994	67
Latvia	1991	1991	76
Lithuania	1992	1992	74
Norway	1988	1992	440
Poland	1995	1995	122
Romania	1993	1995	242
Slovak Republic	1993	1993	111
Slovenia	1994	1995	34
Switzerland	1993	1993	48
Total Europe	1985	1998	5289

1) 12 of them belonging to Canary islands

For plots on which the soil survey was conducted, the following general parameters are reported:

- country – nation [code] in which the plot is situated
- plot number – identification of each plot
- plot coordinates – geographic latitude and longitude [°, ', "]
- date – day, month and year of observation
- altitude – elevation above sea level, in 50 m steps.
- soil unit – soil classification name according to FAO (1990); > 200 types.

As well as general information the database also contains data on the chemical soil condition of the organic and mineral soil layers (VANMECHELEN et al., 1997). The surface mineral soil layer is generally subdivided into two layers. The surface layer covers depths between 0-5 cm, 0-10 cm and in a few cases 0-20 cm. The samples of the subsurface mineral soil layer are taken in depths between 10 and 20 cm, and - deviant from the Manual (UNECE, 1998) - between 10 and 30 cm. Resulting codes together with those for the organic layer are listed in Table 2.3.2-2. Combinations of the listed layers are often grouped country-wise. Deviations of sampling depths occur due to national approaches, which have been performed before the manual has been adopted.

Table 2.3.2-2: Layer codes used within soil survey (according to VANMECHELEN et al., 1997).

Layer	Description	Thickness
H	organic layer saturated with water	
O	organic layer not saturated with water	
M05	mineral layer 0-5 cm (advised)	5
M01	mineral layer 0-10 cm (mandatory)	10
M51	mineral layer 5-10 cm (advised)	5
M12	mineral layer 10-20 cm (mandatory)	10

On the majority of plots $pH_{(CaCl2)}$ values, concentrations of organic carbon and total nitrogen are available for both mineral soil layers and the organic layer (see Table 2.3.2-3). Concentrations of P, K, Ca, and Mg are mandatorily given for the organic layer. Total concentrations of Na, Al, Fe, Cr, Ni, Mn, Zn, Cu, Pb, Cd, and cation exchange properties were less frequently reported. Informations on soil parent material and some physical properties (texture, coarse fragments and bulk density) were - on a voluntary basis - scarcely provided. However, the reference methods (UNECE, 1998) were not used in all cases. Therefore different methodological deviatiations are to be expected.

Systematic differences between the participating laboratories were tested and estimated by ring tests. The resulting mean errors for the most relevant parameters are 23% for pH, 10% for total N, and 10% for base saturation. These mean errors could be surmounted considerably by the errors of individual laboratories. Furthermore, reported data violating one or more integrity rules outlined in VANMECHELEN et al. (1997), were flagged and cross-checked by the National Focal Centres.

Table 2.3.2-3: Soil parameters reported for Level I plots (according to VANMECHELEN et al., 1997).

Parameter	Unit	Reference method	Organic layer	Mineral layer
pH		extractant: 0.01M $CaCl_2$ measurement: pH-electrode	mandatory	mandatory
org. C	$g\ kg^{-1}$	dry combustion	mandatory	mandatory
total N	$g\ kg^{-1}$	dry combustion	mandatory	mandatory
P, K, Ca, Mg	$mg\ kg^{-1}$	digestion in aqua regia	mandatory	optional
$CaCO_3$	$g\ kg^{-1}$	calcimeter (if pH > 6)	optional	mandatory
weight of the organic layer	$kg\ m^{-2}$	volume (cylindrical) – dry weight	mandatory	
Na, Al, Fe, Cr, Ni, Mn, Zn, Cu, Pb, Cd	$mg\ kg^{-1}$	digestion in aqua regia	optional	
exchangeable acidity (AcExc)	$cmol(+)\ kg^{-1}$	titration of a 0.1M $BaCl_2$ extraction to pH 7.8		optional
acid exchangeable cations	$cmol(+)\ kg^{-1}$	sum of Al^{3+}, Fe^{2+}, Mn^{2+} and H^+ measured in a 0.1M $BaCl_2$ extraction		optional
basic exchangeable cations (BCE)	$cmol(+)\ kg^{-1}$	sum of Ca^{2+}, Mg^{2+}, K^+ and Na^+ measured in a 0.1M $BaCl_2$ extraction		optional
cation exchange capacity (CEC)	$cmol(+)\ kg^{-1}$	BCE + ACE or BCE + AcExc		optional
base saturation	%	100 x BCE/CEC		optional

2.3.3 Foliage chemistry parameters and their assessment

The foliar database contains information on 1 497 plots from 17 European countries (Table 2.3.3-1). Data from the foliage survey are available from 1987 to 1998 with highest frequency in the years from 1992 to 1997 (1 317 plots), and mainly in the years 1994 and 1995 (982 plots). For a series of plots especially from Austria and Finland time series are available (e.g. Austria: 813 observations on 87 plots over 10 years). On the plots of the foliar condition survey, the parameters listed in Tab. 2.2.3-2 are reported (STEFAN et al., 1997).

Table 2.3.3-1: Availability of foliage data from participating countries.

Country	from	to	Number of plots
Austria	1989	1998	87
Belgium	1995	1995	19
Finland	1987	1997	30
France	1996	1996	57
Germany	1987	1996	330
Ireland	1995	1995	21
Italy	1995	1997	67
Spain	1994	1995	337
United Kingdom	1995	1995	62
Bulgaria	1991	1995	178
Croatia	1994	1994	8
Czech Republic	1995	1995	40
Lithuania	1993	1995	64
Norway	1992	1992	20
Russia	1995	1995	27
Slovak Rep.	1995	1997	111
Slovenia	1995	1995	39
Total Europe	1987	1998	1497

Table 2.3.3-2: Parameters of the foliar data base.

Registry and location	country	state [code] where the plot is situated
	plot number	identification of each plot
	plot coordinates	latitude and longitude [degrees, minutes, seconds] (geographic)
	date	day, month and year of sampling
Physiography	altitude	elevation above sea level in 50 m steps
Tree species	tree name	species of the sampled tree (acc. Flora Europaea)
	tree species	species [code] of the sampled tree
	main species	main genera (oak, beech, spruce, pine, others)
Leaves	NJ	year when needles / leaves are provided
	leaves type	0=current, 1 = current + 1 year, 2 = current + 2 years
	year	year when leaves type 0 are provided
Parameters	N, S, P, Ca, Mg, K	element concentrations in dry mass [mg g^{-1}], mandatory parameters
	Na, Zn, Mn, Fe, Cu, Pb, Al, B	element concentrations in dry mass [mg kg^{-1}], optional parameters
	NG	dry mass of 1000 needles or 100 leaves [g]

2.3.4 Defoliation

2.3.4.1 Defoliation assessment

On each sampling point of the national and transnational grids situated in forest, at least 20 sample trees are selected according to standardised procedures. Predominant, dominant, and co-dominant trees (according to the system of KRAFT) of all species qualify as sample trees, provided that they have a minimum height of 60 cm and that they do not show significant mechanical damage. Trees removed by management operations or blown over by wind must be replaced by newly selected trees. Due to the small percentage of removed trees, this replacement does not distort the survey results, as has been shown by a special evaluation (UNECE, CEC, 1994).

The variation of crown condition is mainly the result of intrinsic factors, age and site conditions. Moreover, defoliation may be caused by a number of biotic and abiotic stressors. Defoliation assessment attempts to quantify foliage missing as an effect of stressors including air pollutants and not as an effect of long lasting site conditions. In order to compensate for site conditions, local reference trees are used, defined as the best tree with full foliage that could grow at the particular site. Alternatively, absolute references are used, defined as the best possible tree of a genus or a species, regardless of site conditions, tree age etc. depicted on regionally applicable photos, e.g. photo guides (UNECE, 1998, SANASILVA, 1986).

Changes in defoliation and discolouration attributable to air pollution cannot be differentiated from those caused by other factors. Consequently, defoliation due to factors other than air pollution is included in the assessment results. Trees showing mechanical damage are not included in the sample. Should mechanical damage occur to a sample tree, any resulting loss of foliage is not counted as defoliation. In this way, mechanical damage is ruled out as a cause as far as possible.

In principle, the transnational survey results for defoliation are assessed in 5% steps. The assessment down to the nearest 5 or 10% permits studies of the annual variation of defoliation with far greater accuracy than using the traditional system of only 5 classes of uneven width (Chapter 2.5). Discolouration is reported both in the transnational and in the national surveys using the traditional classification.

2.3.4.2 Defoliation assessment in 2001

The total numbers of trees assessed from 1988 to 2001 in each country are shown in Table 2.3.4.2-1. The figures are not necessarily identical to those published in previous reports for the same reasons explained in Chapter 2.2.1.

The 2001 tree sample represented 113 species. 63.9% of the plots were dominated by conifers, 35.8% by broad-leaves and 0.3% by maquis (Annex I-2). Plots in mixed stands were assigned to the species group which comprised the majority of the sample trees. Most abundant were *Pinus sylvestris* with 26.7% , followed by *Picea abies* with 19.9%, *Fagus sylvatica* with 8.9%, and *Quercus robur* with 3.7% of the total tree sample (Annex I-3).

Table 2.3.4.2-1: Number of sample trees from 1989 to 2001 according to the current database.

Country	Number of sample trees												
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Austria		2132	2244	2167	2121	2107	2101	3670	3604	3577	3535	3506	3451
Belgium	791	684	686	673	685	684	678	684	683	692	696	686	682
Denmark	600	600	600	600	600	600	576	552	528	552	552	504	504
Finland			3899	4545	4427	4261	8754	8732	8788	8758	8662	8576	8579
France	10170	10280	10255	10093	10118	10672	10851	10800	10800	10740	10883	10317	10373
Germany	7853	10558	10662	10767	10729	10866	10907	11002	10990	13178	13466	13722	13478
Greece	2463	2392	2392	2320	2272	2272	2248	2248	2224	2204	2192	2192	2168
Ireland	462	458	458	460	462	441	441	441	441	441	417	420	420
Italy	5635	5701	5741	5643	5884	5791	5703	5836	4873	4939	6710	7128	7350
Luxembourg	96	96	96	95	95	93	96	96	96	96	96	96	
The Netherlands	278	279	280	280	260	260	257	237	220	220	225	218	231
Portugal	4569	4563	4585	4508	4308	4414	4230	4260	4319	4290	4290	4290	4320
Spain	10968	10728	10462	11088	11040	10656	10896	10728	10776	10848	14352	14568	14568
Sweden	234	146	265	300	311	3989	10310	10925	10910	11044	11135	11361	11283
United Kingdom	1776	1776	1770	1728	1656	1584	1512	1896	1968	2112	2039	2136	2064
EU	45895	50393	54395	55267	54968	58690	69560	72107	71220	73691	79250	79720	79471
Belarus									9982	9904	9753	9771	9769
Bulgaria						4370	4812	4789	4788	5389	4379	4197	4209
Croatia					2016	2150	1970	1974	2030	2066	2015	1991	1941
Cyprus													360
Czech Rep		2325	8971	3882	4423	5087	4933	4853	4844	2899	3475	3475	3475
Estonia					2136	2159	2160	2184	2184	2184	2184	2160	2136
Hungary		1351	1371	1348	1361	1322	1342	1298	1257	1383	1470	1488	1469
Latvia		1920	2424	2396	2420	2257	2262	2368	2297	2326	2348	2256	2325
Lithuania				1768	1843	1760	1776	1643	1634	1616	1613	1609	1597
Moldova					288	288	263	236	253	234	259	234	234
Norway				4001	4016	3942	3905	3948	4028	4069	4052	4051	4304
Poland		9476	9520	9520	9520	8820	8640	8620	8620	8620	8620	8620	8620
Romania				5155	4004	4776	5688	5375	5687	5637	5712	5640	5568
Russian Fed.						183	3180						
Slovak Rep	5382	5333	5296	5251	5144	5115	5091	5018	5033	5094	5063	5157	5054
Slovenia					816	816	1008	1008	1008	984	984	984	984
Switzerland		479	487	488	500	509	824	854	880	868	857	855	834
Total Europe	51277	71277	82464	89076	93455	102244	117414	116275	125754	130970	135859	136008	132350

2.4 Data quality assurance

2.4.1 Soil data

In 1991, prior to the large-scale soil survey, the Forest Soil Expert Panel decided to conduct an intercalibration exercise for soil analysis aimed to assess the variation induced by different analytical methods. The resulting variation turned out to be high, and moreover, it was found that even laboratories using the same analysis method often recorded strongly different results. In 1993, the Forest Soil Expert Panel proposed to proceed with a second intercalibration exercise, using a set of two standard samples to be analysed together with the samples collected at the inventory plots. This allowed a quality control of the submitted data. Because the same methods were applied in the transnational surveys, the intercalibration provided information on the transnational comparability of the data. The variation among the reported standard sample results again illustrated the need for a better laboratory control/quality and a wider and more accurate use of reference methods. Lower concentrations of elements are apt to result in higher deviations of the individual analysis results from the average deviation. This was the case for Na, Cr, Ni, Cu and Pb. However, also for K and Mg high deviations from the average results were observed. For these macronutrients the use of different methods became a more important factor causing variability. N and organic carbon were available in high amounts in the representative standard sample, and base saturation, being calculated as a ratio, is less influenced by the methodologies used. For these parameters, as well as for pH and BCE, the intercalibration showed that transnational comparability is possible with a fairly high degree of confidence.

2.4.2 Foliage data

In preparation for the large-scale foliage survey, the first step to ensure a high and comparable laboratory standard was a European needle/leaf interlaboratory test on two certified standards (BCR 100 - beech leaves - and BCR 101 - spruce needles). The test was organised by France in 1993 with 24 laboratories from 21 countries participating. Since that time, three further tests were organised by Germany in 1995/1996, in 1997/1998 and in 1999/2000). Moreover, Germany is organising a fifth test which is currently ongoing. In the last (fourth) test, dried plant powder of *Picea abies* (from Austria and Norway), *Pinus sylvestris* (from Germany) and *Fagus sylvatica* (from Slovak Republic) were distributed to 52 laboratories in 29 countries. The mandatory elements to be analysed were N, S, P, Mg, Ca and K. Further elements could be analysed on a voluntary basis.

In comparison to previous tests, the fourth test shows a distinctive improvement and stabilisation of the quality of the analyses. This holds true in particular for the mandatory elements, but also for some of the optional elements. This improvement results, apart from a growing awareness of the importance of data quality assurance, especially from the increased use of elemental analysers and multi-element spectroscopes. Their use replaces the classical analytical methods more and more. The analysis of Na and Pb, however, remain as problematic as before.

The results of the fourth test permit conclusions for future tests, foliage analyses and for a revision of the respective part of the ICP Forests Manual. All national laboratories should participate in a test every two years. Of each laboratory, the results of future analyses of a given element are recommended to be accepted only in case that the test results for this element were among the tolerable limit in at least three out of the four tests. Despite the significant improvement of analytical quality, bigger efforts are necessary to improve especially the comparability of the results for trace elements.

For the foliage survey of Level I, only the first test in 1993 was of benefit. The subsequent tests were conducted in order to increase the quality of the Level II data. However, the progress in data quality assurance made by means of these courses will be of benefit for Level I, too, in case that foliage analyses will ever be repeated at the large scale.

Kommentar: Durrant: Ganzer Absatz raus, nützt nicht

2.4.3 Crown condition data

2.4.3.1 International Cross-calibration Courses

Quality assurance (QA) procedures applied within the transnational crown condition assessments have been described extensively in previous reports (e.g. UNECE, EC, 2001). Important QA tools until now were the International Intercalibration Courses. Three of these courses are normally offered per year, one in southern, one in central and one in northern Europe, assembling national teamleaders in the forests. The main benefit of previous courses consisted in preventing that methods deviated more and more between the countries over the years. The results of international intercalibration courses, however, were so far of limited use for quantifying country bias, as they were normally not designed for this purpose. Besides this point, the comparability between years could not be tested satisfactorily because of annually changing locations of the courses. Therefore, a reform of the system of the international courses is being strived for. A recently elaborated concept for future International Cross-calibration Courses (ICCs) aims to derive country specific differences from the scores of the participating national team leaders. The new concept is being tested and further developed. As part of the test phase, provisional ICCs were held in 2001 in Finland, Czech Republic and Portugal (SEIDLING, 2002). At these courses, participants were explicitly asked to use their national methods and not to communicate their estimates in the course of the assessments. Intensified data evaluations were applied afterwards. The main outcomes are given below:

- Country differences were in most cases significant, in addition there were significant differences between teams of the same countries.
- Tree species had an important effect on the assessment results. For Pinus sylvestris, the rankings of trees according to defoliation between countries is generally less consistent between the sites than for *Picea abies* and *Betula pendula*.
- Relations between age and defoliation vary considerably for different teams at changing plots. Teams that were in comparison to others overestimating stands of certain age classes were underestimating at other age classes. This shows that the „handling“ of the factor age during the assessments varies between countries. Adjustment functions have therefore to be country, age and defoliation specific.
- Results show changing assessment levels for the same teams. In addition to tree species and age, site and probably even stand characteristics influence the estimates. Teams that were in comparison to others overestimating on certain site types were underestimating at others. Adjustment factors should therefore also be site specific.
- The country wise results of the ICCs at the plot level were put into relation to the results of the regular forest condition survey, i.e. ICC results were regressed against the country-specific means calculated as medium-term averages over the years 1994 to 2000 (UNECE, CEC, 2001). Even though that the plots and teams of the national surveys are not directly comparable to those of the calibration courses, there was a low correlation for countries with close to the mean averages and a close correlation for the countries with extreme values. This suggests that differences in the overall country means are influenced additionally by differences in the assessment methods and supports the application of the preliminarily adjusted defoliation (PAD, see Chapter 4 and UNECE, CEC, 2001).

- It was difficult to derive general results from the courses, as the sample sizes and numbers of plots per tree species were still too small and did not allow for calculations of species, age and site specific adjustment factors.

2.4.3.2 Photo techniques

Recent developments in photo techniques using digital imagery, storage and analysis now offer an additional QA method that can help to document changes over time. At the three International Intercalibration Courses in 2001, participants were asked to assess trees both in the field and on photographs and the results were analysed. A digital scoring system (CROCO) was used in some cases and additional information (e.g. assessable crown depth) was documented.

The ad hoc sub group on Photo QA was set up in order to investigate the subject in the light of new developments in photographic equipment and image analysis now available. The aims and objectives are:

- To document and analyse changes over time and between regions.
- To obtain an objective tool to quantify actual scores of crown condition between regions and countries over time.
- To develop and document quality assurance methods.

The objectives, which were derived from these aims for the work of future Photo QA are:

1) To produce sets of photographic records of ‘trees’ by country and species over time.
2) To obtain an objective tool in order to compare and quantify actual scores of crown condition trees over time to allow more meaningful comparisons between regions and countries.
3) To set up a structure to co-ordinate this information on regional, national and pan-European scale.
4) To test the validity of using photographic methods for national training courses and for international cross-calibration courses.
5) To develop and document quality assurance methods for use in national training and intercalibration using photographs.
6) To produce a manual describing methods for photographing and documenting the range of crown condition scores for the major species used in the pan-European forest health survey at a national and regional level.

During 2001 pilot trials assessing trees by using photographs took place at all three intercalibration courses in order to obtain information on objectives 4 and 5 (above).

Photos of *Picea abies*, *Quercus robur* and *Fagus sylvatica* were taken near the sample plots selected for standard field assessment. The “assessable crown” was not marked on the photos but the participants were asked to assess only part of the crown that was not shaded by neighbours. The field assessment of the photographed trees was by standard field-method from the same position where the photo was taken.

The analysis of the tree crowns (using CROCO) was carried out in Switzerland. The CROCO-system overestimated the defoliation level compared to the field assessment results both for conifers and broad-leaves. However there were only a small number of photographs available for analysis on the broad-leaved trees compared to the spruce so these results must be interpreted with care. In addition, the analysis was conducted on a slightly overexposed set of photographs to the ones used in the field trial and this will also have an effect. A re-analysis on the actual photo set used in the field is being conducted.

Pinus pinaster and *Quercus suber* were assessed from photographs and in the field. The pines were photographed in similar light conditions to the field assessment, but the oak trees had to be photographed at a different time of day. These practical problems do not differ from the field assessment situation and may influence the results.

In order to document differences between countries on the interpretation of assessable crown, a scale was marked on the photographs and participants were asked to record the number that was closest to their interpretation of assessable crown depth. The variation in assessment between countries for photos was similar to that obtained by the conventional field assessment.

The northern intercalibration course was held in Finland. Test trees were selected in the vicinity of the ICC plots trying to ensure good visibility for both the surveyors and the camera but only a few freestanding trees were available with no overlapping crowns or trees in the field of view behind the sample tree. This is the normal situation in most forests, but in spite of that some high quality photographs were obtained. To overcome the visibility problem the assessable part of the crown was marked on the photograph so that everyone could assess the same crown area. All trees were then assessed from the same position as the photos. There was very close agreement between the photos and the field assessments.

Conclusions and Recommendations

The results show that good quality photos can be used for QA/QC purposes. In many cases the agreement with field scores was high. The better the photo quality, the smaller the likely bias when assessing crown condition. As with normal field assessment, direction of view and weather conditions can also affect the scores. It is clear that some changes need to be made before the 2002 courses but they are fairly minor.

The problems encountered when taking and assessing photos are similar to those of normal field assessments. Using the correct methods will overcome most of these. Good documentation is essential and a manual with specific instructions has to be developed. In the 2002 Intercalibration exercises a first test will be done using the photos from last year to verify the inter-annual comparability. At the same time new photos should be taken and assessed. National teams are encouraged to carry out similar exercises in their national training courses.

Implementation of the QA/QC using photos has proved to be possible. When accompanied by sufficient documented information on the subject tree, these photographic exercises will begin to build up a picture of the variation that may exist between (or within) countries and can provide the necessary quality assurance over time.

2.5 Evaluation and presentation of the survey results

Crown condition assessments reflect the current state of scientific knowledge. Though this has set high standards in data quality, the interpretation of the assessment results has to take into account the following limitations:

Defoliation has a variety of causes. It would therefore be inappropriate to attribute it to a single factor such as air pollution without additional evidence. As the true influence of site conditions and the share of tolerable defoliation can not be precisely quantified, damaged trees can not be distinguished from healthy ones only by means of a certain defoliation threshold. Consequently, the 25% threshold for defoliation does not necessarily identify trees damaged in a physiological sense. Some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of trends over time.

Natural factors strongly influence crown condition. However, in many countries the natural growing conditions are most favourable in those areas receiving the highest depositions of air pollution. As also stated by many participating countries, air pollution is thought to interact with natural stressors as a predisposing or accompanying factor, particularly in areas where deposition may exceed critical loads for acidification (CHAPPELKA and FREER-SMITH, 1995, CRONAN and GRIGAL, 1995, FREER-SMITH, 1998).

It has been suggested that the severity of forest damage has been underestimated as a result of the replacement of dead trees by living trees. However, detailed statistical analyses of the results of 10 monitoring years have revealed that the number of dead trees has remained so small that their replacement has not influenced the results notably (UNECE, CEC, 1994).

2.5.1 Classification of defoliation data

The tree and plot data of the transnational survey are submitted in digital format via EC or directly to PCC of ICP Forests for screening, storage and evaluation. PCC carries out these tasks on behalf of ICP Forests and the European Commission. The national survey results are submitted to PCC as country related mean values, classified according to species and age classes. These data sets are accompanied by national reports providing explanations and interpretations. All tree species are referred to by their botanical names, the most frequent of them listed in 11 languages in Annex III.

Table 2.5.1-1: Defoliation and discolouration classes according to UNECE and EU classification

Defoliation class	needle/leaf loss	degree of defoliation
0	up to 10 %	none
1	> 10 - 25 %	slight (warning stage)
2	> 25 - 60 %	moderate
3	> 60 - < 100 %	severe
4	100 %	dead
Discolouration class	foliage discoloured	degree of discolouration
0	up to 10 %	none
1	> 10 - 25 %	slight
2	> 25 - 60 %	moderate
3	> 60 %	severe
4		dead

The survey results are preferably presented in terms of mean plot defoliation or the percentages of the trees falling into 5%-defoliation steps. However, in order to ensure comparability with previous presentations of survey results, partly the traditional classification of both defoliation and discolouration has been retained for comparative purposes, although it is considered arbitrary by some countries. This classification (Table 2.5.1-1) is a practical convention, as real physiological thresholds cannot be defined.

In order to discount background perturbations which might be considered minor, a defoliation of >10-25% is considered a warning stage, and a defoliation > 25% is taken as a threshold for damage. Therefore, in the present report a distinction has sometimes only been made between defoliation classes 0 and 1 (0-25% defoliation) on the one hand, and classes 2, 3 and 4 (defoliation > 25%) on the other hand.

Classically, trees in classes 2, 3 and 4 are referred to as "damaged", as they represent trees of considerable defoliation. In the same way, the sample points are referred to as "damaged" if the mean defoliation of their trees (expressed as percentages) falls into class 2 or higher. Otherwise the sample point is considered as "undamaged".

Attention must be paid to the fact that *Quercus ilex* and *Quercus rotundifolia* are evaluated together and noted as "*Quercus ilex* and *Q. rotundifolia*". For this reason the present results are not fully comparable with the corresponding ones from the last reports.

The most important results have been tabulated separately for all countries having participated (called "total Europe") and for those 15 countries being EU-Member States in the survey year 2001.

2.5.2 Mean defoliation and temporal development

For all evaluations related to the tree species a criterion had to be set up to be able to decide if a given plot represents this species or not. The number of trees with species being evaluated had to be three and more per plot ($N \geq 3$).

The plot wise mean defoliation was calculated as the mean of defoliation values of the trees on the respective plot. Accordingly, a country wise mean defoliation was calculated as mean of the defoliation values of the trees in the respective country.

The temporal development of defoliation is expressed on maps as the slope, or regression coefficient respectively, of a linear regression of mean defoliation against year of observation. It can be interpreted as the mean annual change in defoliation. A value of 3% means an increase by 3% defoliation per year on average. These slopes are called "significant" if there was less than 5% probability that they are different from zero from random variation only. In case of the comparison of the assessments in 2001 with those in 2000 (Annex I-8) changes in mean defoliation per plot are called "significant" only if both,

- the change ranges above the assessment accuracy, i.e. is higher than 5%,
- and the significance at the 95% probability level was proven in a statistical test.

For detailed information on the respective calculation method for the change from 2000 to 2001 see Annex IV.

2.5.3 Integrative evaluations

The integrative evaluation of last year’s report (UNECE, CEC, 2001) used statistical and geostatistical methods to analyse the spatial variation of crown condition (medium-term mean defoliation 1994 to 2000). The aim of the integrative studies in the present report is to analyse in addition the temporal variation of defoliation.

Spatial variation describes the diversity of values at different locations. The last years' integrative evaluations showed that for nearly all of the evaluated tree species (*Pinus sylvestris*, *Picea abies*, *Pinus pinaster*, *Fagus sylvatica*, *Quercus robur* and *Q. petraea*, and *Quercus ilex*) a country-wise age-effect could explain a part of the spatial variation. It was expressed by linear regression that locations ("plots") with older trees – on average – take higher defoliation values than those with younger ones (UNECE, CEC, 2001). Differences of the medium-term (1994 to 1999) mean plot defoliation to those country-wise linear regressions of defoliation over stand age are called preliminarily adjusted defoliation (PAD) and maps of this parameter are used in chapter 4 to depict the spatial variation of defoliation. It can be interpreted as the mean deviation of the mean plot defoliation from that model value which is expected for a stand of the respective age in the respective country. Additionally indices for fungal and insect infestations could explain some part of the spatial variation of medium-term mean defoliation. The expansion of the database by the integration of precipitation data of the Global Precipitation Climatology Centre (GPCC) and of deposition data of the Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP) enables a more detailed analysis to examine supposed cause-effect relationships. The aim of the analyses concerning spatial variation is to explain the differences in defoliation at varying locations.

Kommentar: Hier könnte Berechnung von PAD noch einmal in einem Satz erklärt werden (Differenz von mmdi zu country specific age-Modell

In addition and as a basis for detailed analyses of the *spatial* variation, the description of the *temporal* variation of defoliation is in the focus of this years' integrative evaluations. Questions to be answered are:

- Why is defoliation higher (lower) in year t+n than in year t?
- Is there a temporal trend in the data, maybe changing with location?
- Are there any correlations of defoliation values over time with predictor variables?
- Do these correlations with time varying variables confirm hypotheses derived from former studies and evaluations?

Although only a low part of temporal variation could be explained within earlier case studies, they showed that temporal variation of defoliation is influenced by biotic, meteorological and deposition factors. These factors themselves are varying over time in contrast to other factors, which are more or less constant over time (e.g. soil type). For the years 1993 to 1999 EMEP-data could be used for the estimation of the deposition rates at the Level I plots for sulphur (SO_x-S) and nitrogen (NO_x-N as well as NH_x-N). Additionally the monthly precipitation could be quantified for the Level I plots using digital information layers from the Global Precipitation Climatology Centre (GPCC, 1986 to 2000). Because of the temporal limitations of the auxiliary database (EMEP) and due to the fact that a substantial increase in transnational Level I plots was observed before 1994, the evaluation period was fixed from 1994 to 1999. Due to changes in methodology, data from France and Italy could not be integrated in these evaluations.

Regression techniques are used to detect those time-varying predictor variables, which are influencing the temporal development of defoliation.

Predictor variables and the dependent variable defoliation are basically transformed to differences to the plot means which were calculated over the evaluation period (1994 to 1999) from the annual values. These transformed variables are called "referenced" values. The value of this referenced variable ref(X) for location i and year j is calculated for the years 1994 to 1999 and the n locations as described in the following equation:

$$\mathrm{ref}(X)_{ij} = X_{ij} - \overline{X}_i = X_{ij} - \frac{\sum_{j=1994}^{1999} X_{ij}}{6} \qquad (1)$$

i = 1, 2, 3, … n ; n = number of locations
j = year of observation

The benefit of this referencing procedure is the separation of spatial and temporal variation. Thus, e.g. the medium-term mean defoliation ($\mathrm{MMD}_i = \overline{X}_i$ of defoliation) was already used in the last year's integrative evaluation (UNECE, CEC, 2001) for quantifying the spatial variation of defoliation. The MMD_i is the mean level of defoliation at each survey plot (location). Annually changing deviations from this mean level comprise the temporal variation at the respective plot.

For the 1 313 plots which were available for *Pinus sylvestris*, 1 313 mean values were calculated. The 7 878 (= 1 313 * 6 years) differences from the respective 1 313 plot-wise mean values are the observations for the evaluation of temporal variation. Figure 2.5.3-1 and Figure 2.5.3-2 show an example for one plot location with 6 defoliation observations from 1994 to 1999. The temporal variation remains the same when expressed by the referenced values, which are the differences between the six observed values and the mean values 22%, and 1996.5 years respectively. Linear regressions over the predictor variable and over its referenced values lead to identical regression coefficients ("slopes") in both cases. When calculating with referenced predictor variables, the additional component (intercept) is always the plot-wise mean defoliation (MMD).

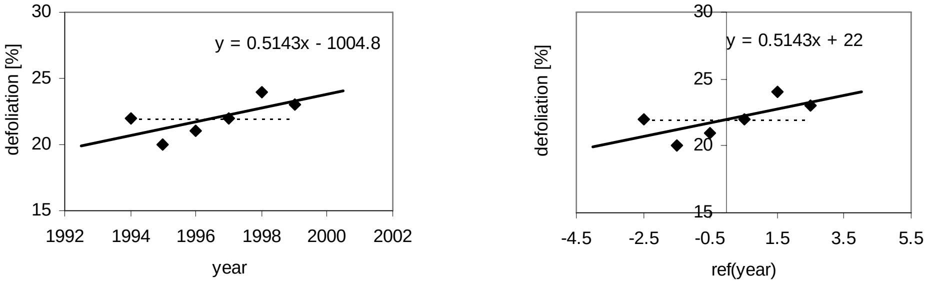

Figure 2.5.3-1: Linear trend of defoliation vs. year (untransformed)

Figure 2.5.3-2: Linear trend of defoliation vs. referenced year, ref(year)

The model, which is used in the example of Figure 2.5.3-2 (only one of many plots is shown there) is a simplified case of equation 2b without meteorological or deposition predictor variables. Equation 2b can be derived from a pure model, in which referenced defoliation is explained by referenced predictor variables:

$$\begin{aligned} ref(D)_{ij} = {} & \beta_1\, ref(dSOx)_{ij} + \beta_2\, ref(dNOx)_{ij} + \beta_3\, ref(dNHy)_{ij} \\ & + \beta_4\, ref(precind)_{ij} + \beta_{5i}\, ref(year)_{ij} + \varepsilon_{ij} \end{aligned} \qquad (2)$$

D_{ij} – defoliation in year j at location i

$dSOx_{ij}$ – deposition of SOx in year j at location i ; analogue for NOx and NHy

$precind_{ij}$ – precipitation index in year j at location i

$year_{ij}$ – year j of observation at location i

ε_{ij} – residuum (unexplained error) in year j at location i

By analogy to equation 1, equation 2 can be transformed on the left side to 2a:

$$\begin{aligned} D_{ij} - MMD_i = {} & \beta_1\, ref(dSOx)_{ij} + \beta_2\, ref(dNOx)_{ij} + \beta_3\, ref(dNHy)_{ij} \\ & + \beta_4\, ref(precind)_{ij} + \beta_{5i}\, ref(year)_{ij} + \varepsilon_{ij} \end{aligned} \qquad (2a)$$

MMD_i – medium-term mean defoliation (1994-1999)

Taking the medium-term mean defoliation MMDi to the right side results in equation 2b:

$$\begin{aligned} D_{ij} = {} & MMD_i + \beta_1\, ref(dSOx)_{ij} + \beta_2\, ref(dNOx)_{ij} + \beta_3\, ref(dNHy)_{ij} \\ & + \beta_4\, ref(precind)_{ij} + \beta_{5i}\, ref(year)_{ij} + \varepsilon_{ij} \end{aligned} \qquad (2b)$$

In equation 2b the plot-wise medium-term mean defoliation MMD_i as time-constant spatial variation is used to "explain" a part of the variation of defoliation. The part, which is explained by the plot-wise variable medium-term mean defoliation, was used in a modification of split-plot analyses to test the significance of the other predictor variables (compare DIGGLE et al., 1994). The same statistical test was used by HENDRIKS et al. (2000) for a similar analysis of data from The Netherlands for the period 1984 to 1994. This error model was used to allow for repeated measures data (i.e. the defoliation assessments in the same plots over years). However, the probably existing temporal autocorrelation, the dependence of an observation x in year t from the observed value x_{t-n} of former years is not evaluated by this method. This component of time series analyses should be evaluated as soon as longer time series become available for a sufficient number of plots. A pilot evaluation of explorative character (not depicted) showed no temporal autocorrelation for the period 1994 to 2000. Perhaps, this is caused by the shortness of the evaluation period. Autocorrelative effects can also be overlaid by other effects, which are influencing the temporal variation.

The regression coefficients β_1 to β_5 can be interpreted as gradients for the respective predictor variable describing the amount of defoliation changing with an increase of one unit of the predictor variable. Maps of the plot-wise calculated regression coefficients of the referenced observation year, β_{5i}, are used in chapter 4 to describe the temporal trend of defoliation.

For the evaluation of temporal variation as well as that of spatial variation a model with all possible predictors was calculated first. From the precipitation indexes with plausible (negative) regression coefficients only that was used, which showed the highest explanation power, or the highest Type III sum of squares respectively. Thus, the first model includes the following predictors: Sums of precipitation, fungi index(1), insect

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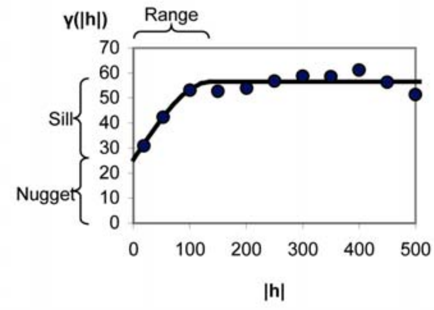
(1) share of plot trees with identified damage due to fungi or insects, respectively (s. Table 2.3.1-1)

index[1)], deposition of sulphur, oxidised and reduced nitrogen, the year of observation and the medium-term mean defoliation. The next step was to reduce the model by the predictors with implausible regression coefficients. From the resulting model, which includes all plausible predictors, the predictor variable with the lowest explanation potential was rejected stepwise until only statistically significant predictor variables were remaining in the model. Additionally the model, which is built by the only predictor variable YEAR of observation was calculated and used for a descriptive mapping of the temporal development of defoliation.

The plot-wise results were mapped to get an overview of the spatial distribution. Additionally, the results were interpolated with geostatistical kriging following the methodology described in the last year's technical report (UNECE, CEC, 2001). The fundamental assumption of geostatistics is, that a regionalised variable may consist of a deterministic, a correlative and a random component (RIPLEY, 1981; see also SCHALL, 1999). The deterministic component, the "drift", can be described e.g. by regression or covariance models. The correlative component means, that points located close together show smaller differences concerning the value of the regionalised variable than points with a large spatial distance. Because this is a spatial correlation of values from **one** variable, it is called spatial (intravariable) autocorrelation. This component can be used, to calculate weights for an interpolation by the data themselves instead of those subjectively chosen, like e.g. inverse squared distance weighted interpolations.

The spatial autocorrelation of the regionalised variable (e.g. plot-wise slope of linear temporal trend of defoliation) can be described by an empirical semivariogram which expresses the dissimilarity increasing with distance h between (sample) points x_i and $x_i + h$ (Figure 2.5.3-3). Each point in the empirical semivariogram is calculated using equation (3) for the particular distance or class (lag) of distance h. The semivariance is the mean squared difference between i pairs of values of the regionalised variable from i pairs of points/locations within the spatial distance h.



$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(x_i) - z(x_i + h)]^2 \quad (3)$$

$N(h)$ – number of point pairs with distance h

$z(x_i)$ – regionalized variable at sample point x_i

Figure 2.5.3-3: Experimental semivariogram of average dissimilarities over spatial distance |h| [m] and a modelled spherical semivariogram: nugget: 25.5 sill: 31.0 range: 136 km.

Three parameters are usually used to describe the shape of the semivariogram: nugget, sill and range. The nugget is the semivariance, which is observed for the distance h = 0. It can be interpreted as the random component of the regionalised variable. Mainly two conditions lead to a nugget value greater than zero:

- The underlying measurement gridnet has a too low density, so that the spatial structure/autocorrelation could not be detected completely.

- The underlying spatial structures are hidden by inaccuracies of data assessment or other "noise".

The sill is quantifying the autocorrelative component of the regionalised variable. The range is the distance in which spatial autocorrelation is observed. The closer a plot is lying to an estimation (target) point x_i, the lower is the particular value of the semivariogram $\gamma(h)$ and the higher is – in general – the (kriging-) weight of this plot for the interpolation (kriging) of the regionalised variable at any estimation point $z^*(x_i)$.

The kriged maps allow a quicker overview. Only for those points a value of the regionalised variable was estimated, for which at least 12 Level I plot values are available in a radius of 400 km and for which at least 4 plot values are available within a radius of 100 km. The latter precondition was defined in order to reduce the area of extrapolation beyond the sample area. For the calculation of the kriging values however plots within the 400 km radius were used.

3 Results of the transnational survey in 2001

3.1 Crown condition in 2001

3.1.1 Defoliation and discolouration by region and species

In the transnational survey of the year 2001, 132 350 sample trees on 5 942 sample plots were assessed for defoliation. Of 22.4% of the total tree sample the defoliation exceeded 25%, i.e. were rated as “damaged” (Table 3.1.1-1). The share of damaged broad-leaves was with 24.4% clearly larger than the share of damaged conifers with 21.0%. In the EU-Member States the share of damaged trees (18.9%) was lower than in total Europe, because areas with higher defoliation are mainly located in the non-EU countries, namely in parts of central and eastern Europe. Also in the EU-Member States the share of the damaged broad-leaves (23.4%) was markedly higher than that of the conifers (15.9%).

Table 3.1.1-1: Percentages of trees in defoliation classes and mean defoliation for broad-leaves, conifers and all species.

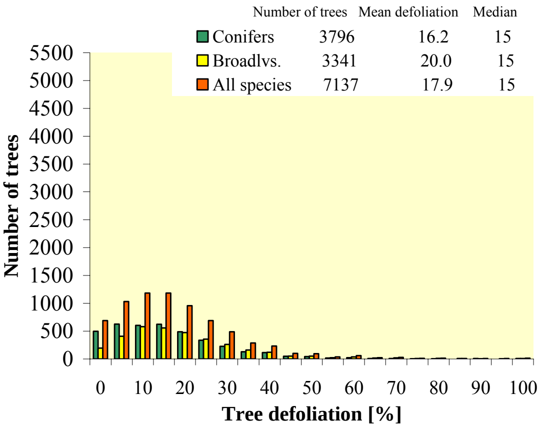
	Species	Percentage of trees in defoliation class							Defoliation		No. of
	type	0-10%	>10-25%	0-25%	>25-60%	>60%	dead	>25%	Mean	Median	trees
EU	Broad-leaves	31.8	44.8	76.6	20.5	2.0	0.9	23.4	20.8	15	32403
	Conifers	45.3	38.8	84.1	14.2	1.2	0.5	15.9	16.8	15	47068
	All species	39.8	41.3	81.1	16.7	1.5	0.7	18.9	18.4	15	79471
Total Europe	*Fagus sylv.*	32.0	42.8	74.8	22.9	1.6	0.7	25.2	20.7	20	11780
	Quercus robur + Q. petraea	19.7	46.4	66.1	30.6	2.1	1.2	33.9	24.9	20	8514
	Broad-leaves	31.0	44.6	75.6	21.4	2.0	1.0	24.4	21.1	20	53514
	Picea abies	38.7	35.5	74.2	23.6	1.9	0.3	25.8	19.4	15	26322
	Pinus sylv.	32.2	50.0	82.2	16.1	1.0	0.7	17.8	19.1	15	35321
	Conifers	35.3	43.7	79.0	18.8	1.4	0.8	21.0	19.3	15	78836
	All species	33.6	44.0	77.6	19.9	1.6	0.9	22.4	20.1	15	132350

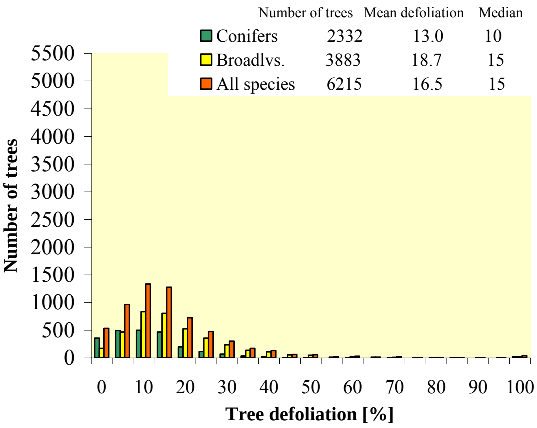
The map in Annex I-4 shows the percentage of damaged trees for each plot. Plots with a share of damaged trees larger than 25% occur throughout Europe, but are more concentrated in central and eastern Europe. Plots with a share of damaged trees higher than 50% are abundant in the Czech Republic, in the Slovak Republic, in the mountainous parts of Romania and Bulgaria, in Italy, Norway, northern Sweden, southern Poland and in central Germany. Regions with small shares of damaged trees are situated in Austria, Belarus, southern Sweden, southern Finland, eastern Germany, the Baltic states and in several parts of the Iberian Peninsula.

Because of the uneven width of the classical defoliation classes, frequency distributions in 5%-defoliation steps were produced. The frequency distributions for the broad-leaved trees, the coniferous trees and the total of all trees are shown in Figures 3.1.1-1a and 3.1.1-1b for each climatic region as well as for the total of all regions. The number of trees, the mean defoliation and the median are also given. The maps in Figures 3.1.1-2 to 3.1.1-5 show mean plot defoliation for *Pinus sylvestris*, *Picea abies*, *Fagus sylvatica*, and *Quercus robur* and *Q. petraea*. Plots qualified for inclusion into a map whenever the number of trees of the given species on them was at least three.

Atlantic (north)

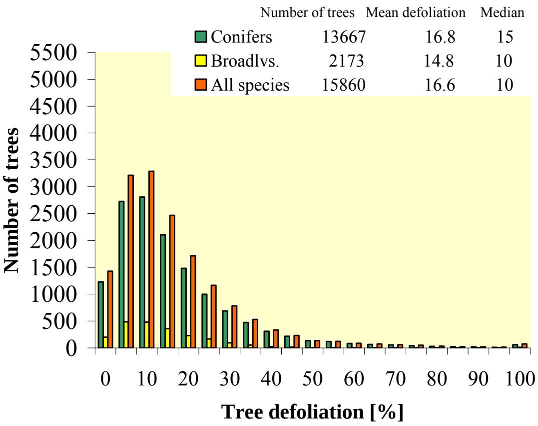
Atlantic (south)

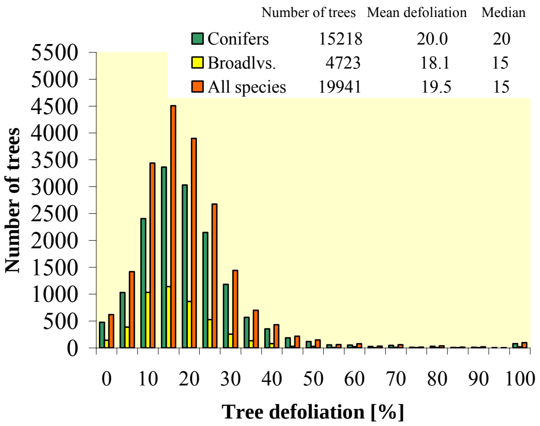




Boreal

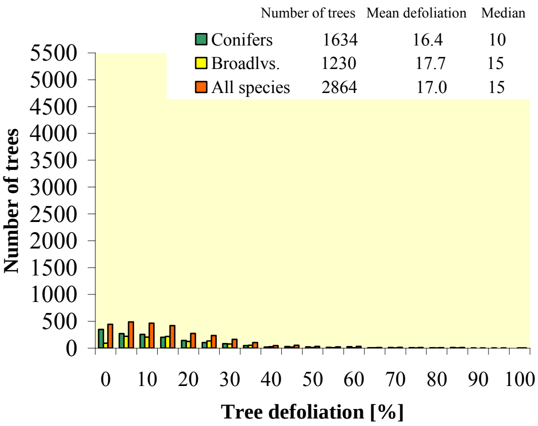
Boreal (temperate)





Mountainous (north)

Mountainous (south)



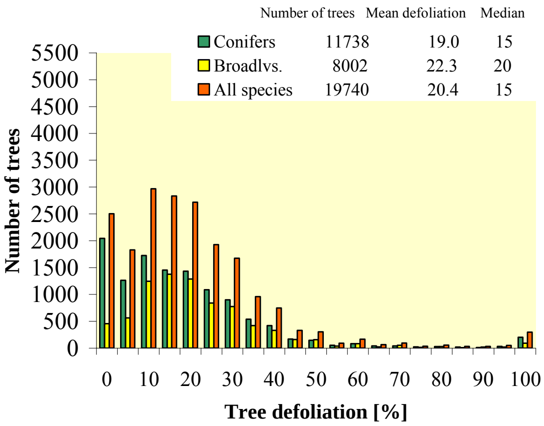
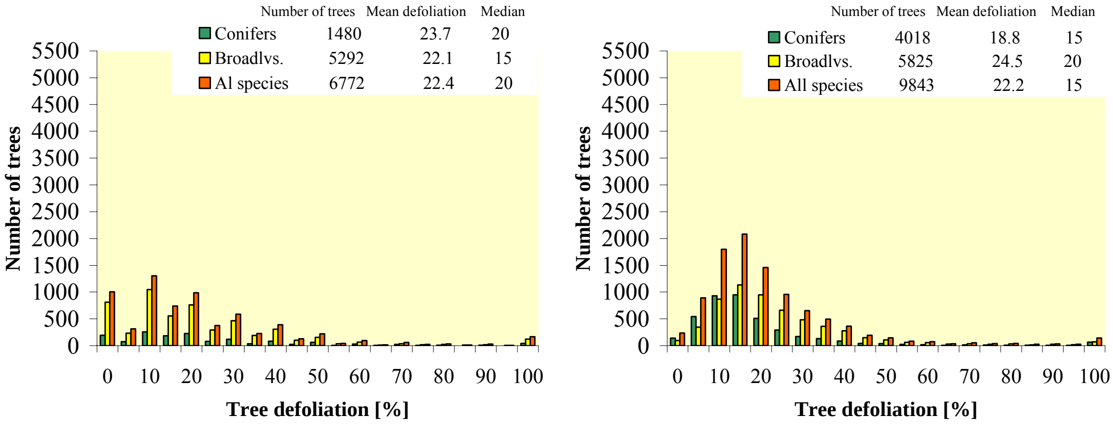


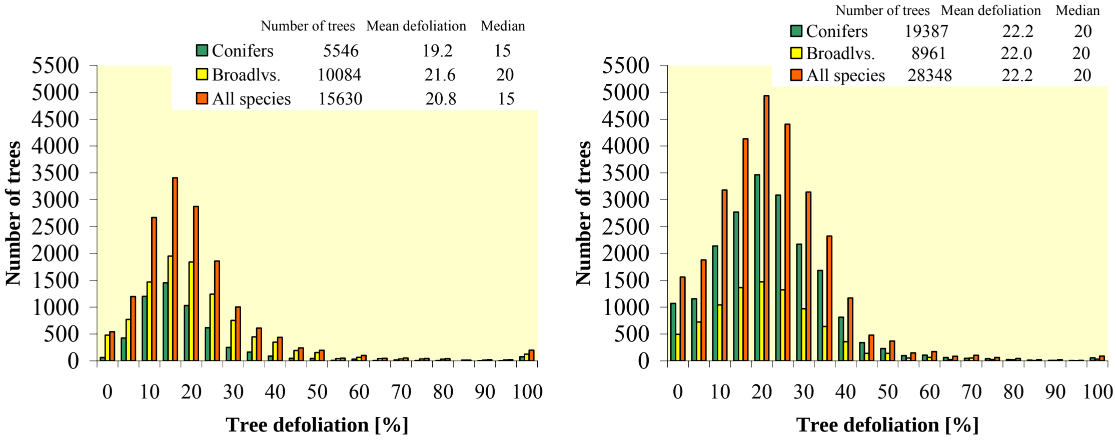
Figure 3.1.1-1a: Frequency distribution of trees in 5%-defoliation steps.

Continental

Mediterranean (higher)



Mediterranean (lower) **Sub-atlantic**



All regions

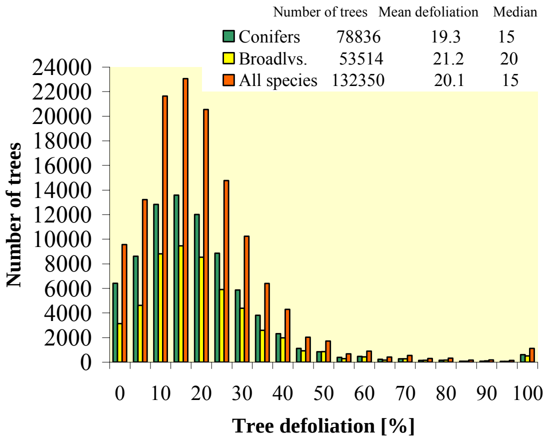


Figure 3.1.1-1b: Frequency distribution of trees in 5%-defoliation steps.

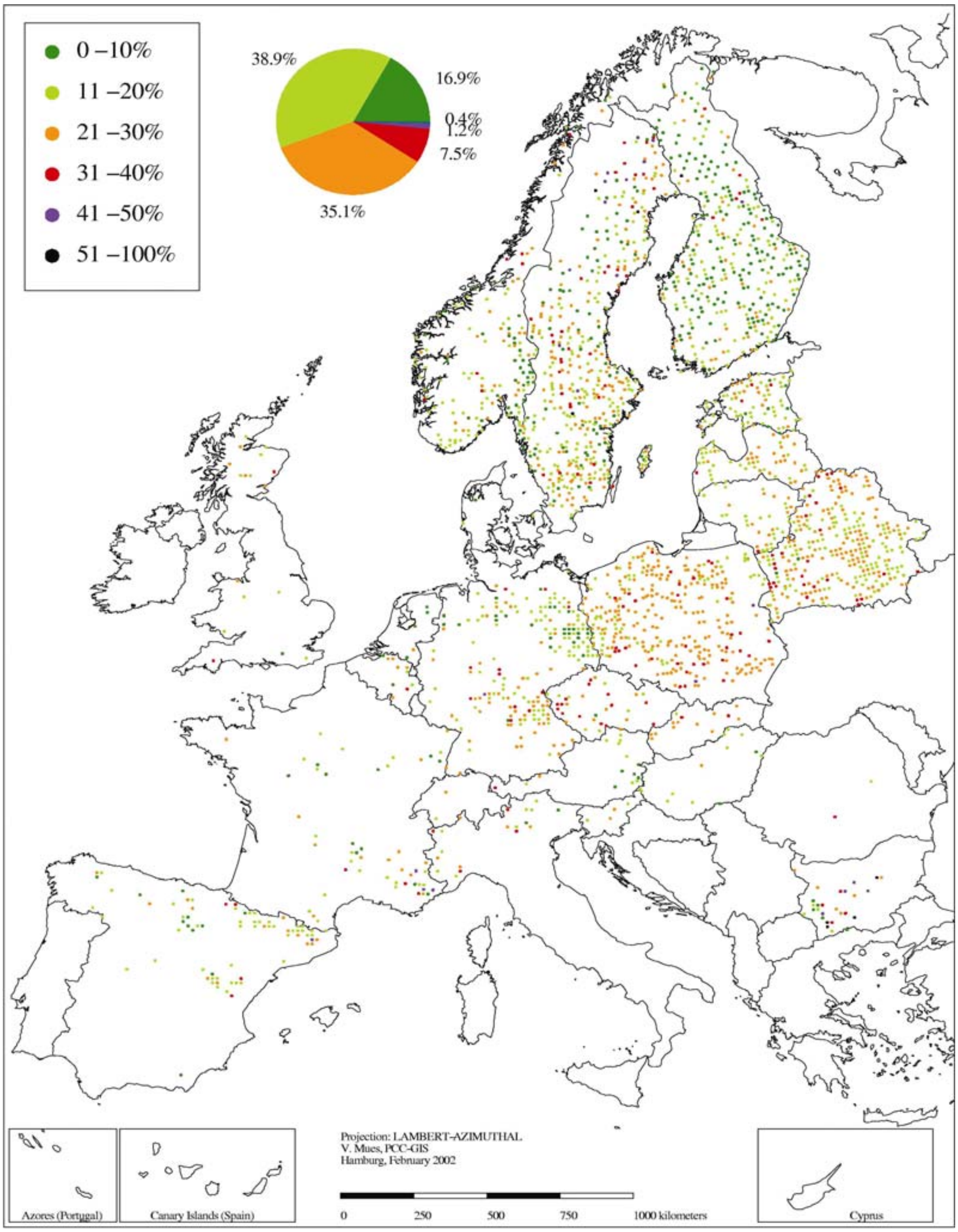


Figure 3.1.1-2: Mean plot defoliation of *Pinus sylvestris*.

Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used.

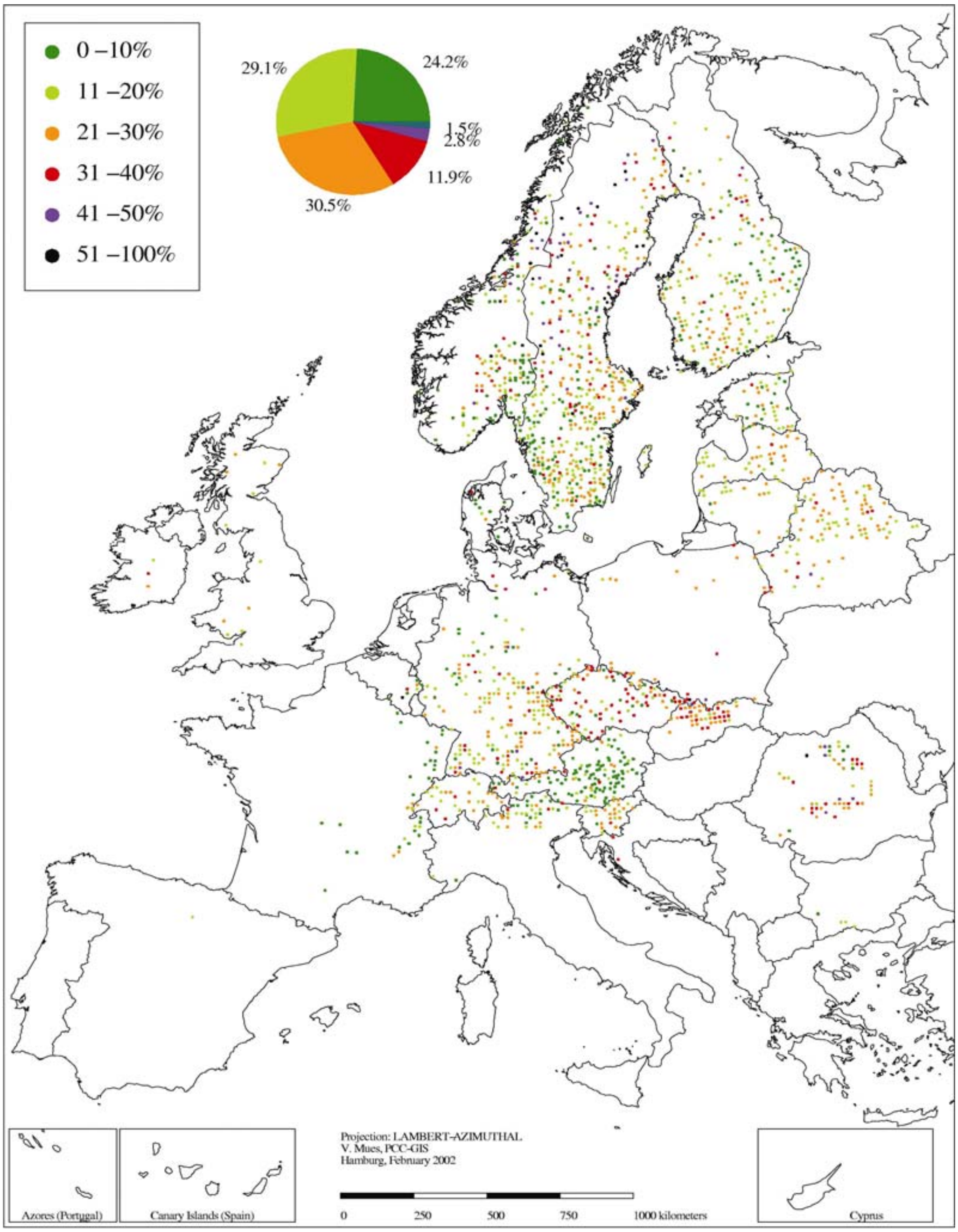


Figure 3.1.1-3: Mean plot defoliation of *Picea abies.*

Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used.

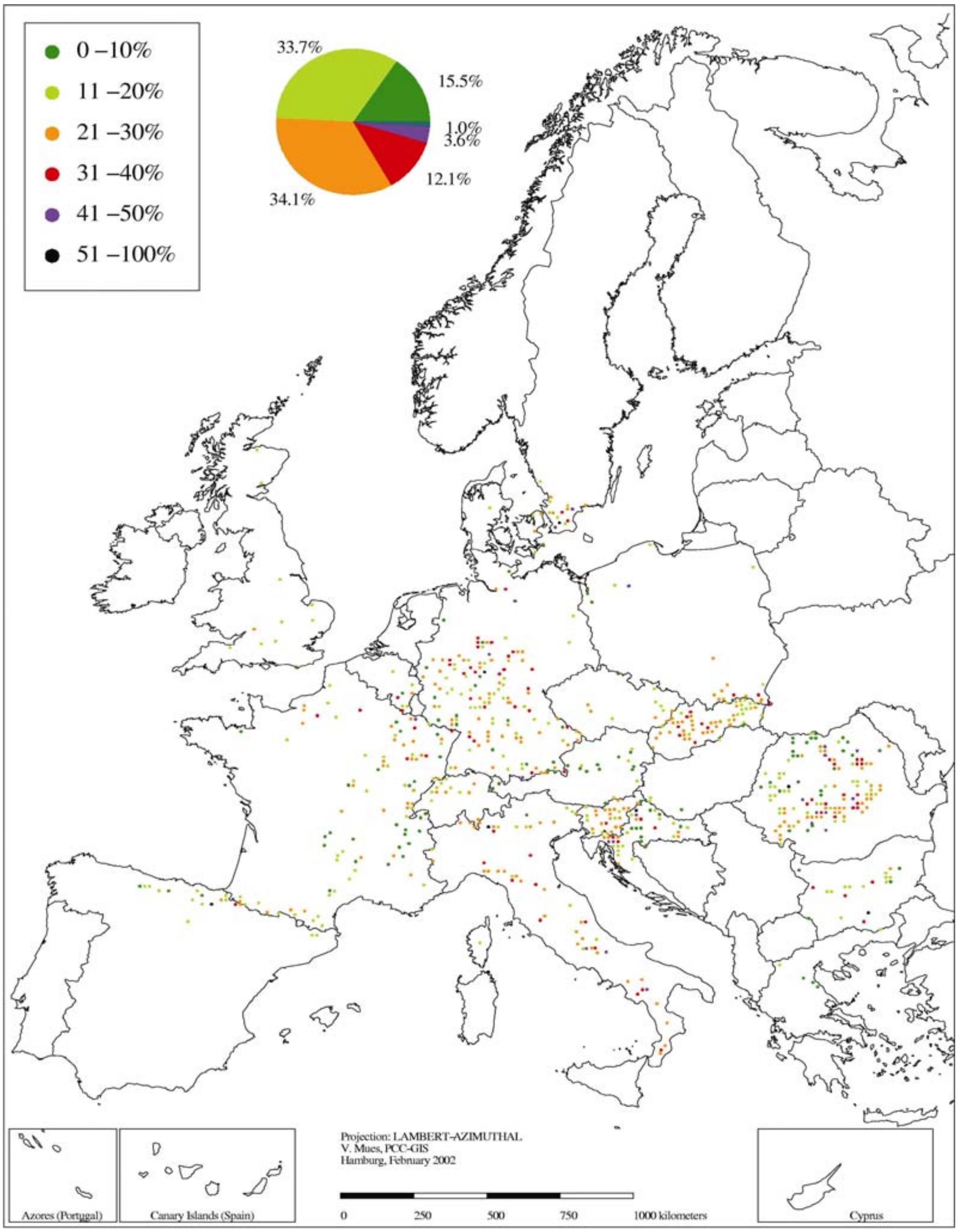


Figure 3.1.1-4: Mean plot defoliation of *Fagus sylvatica.*

Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used.

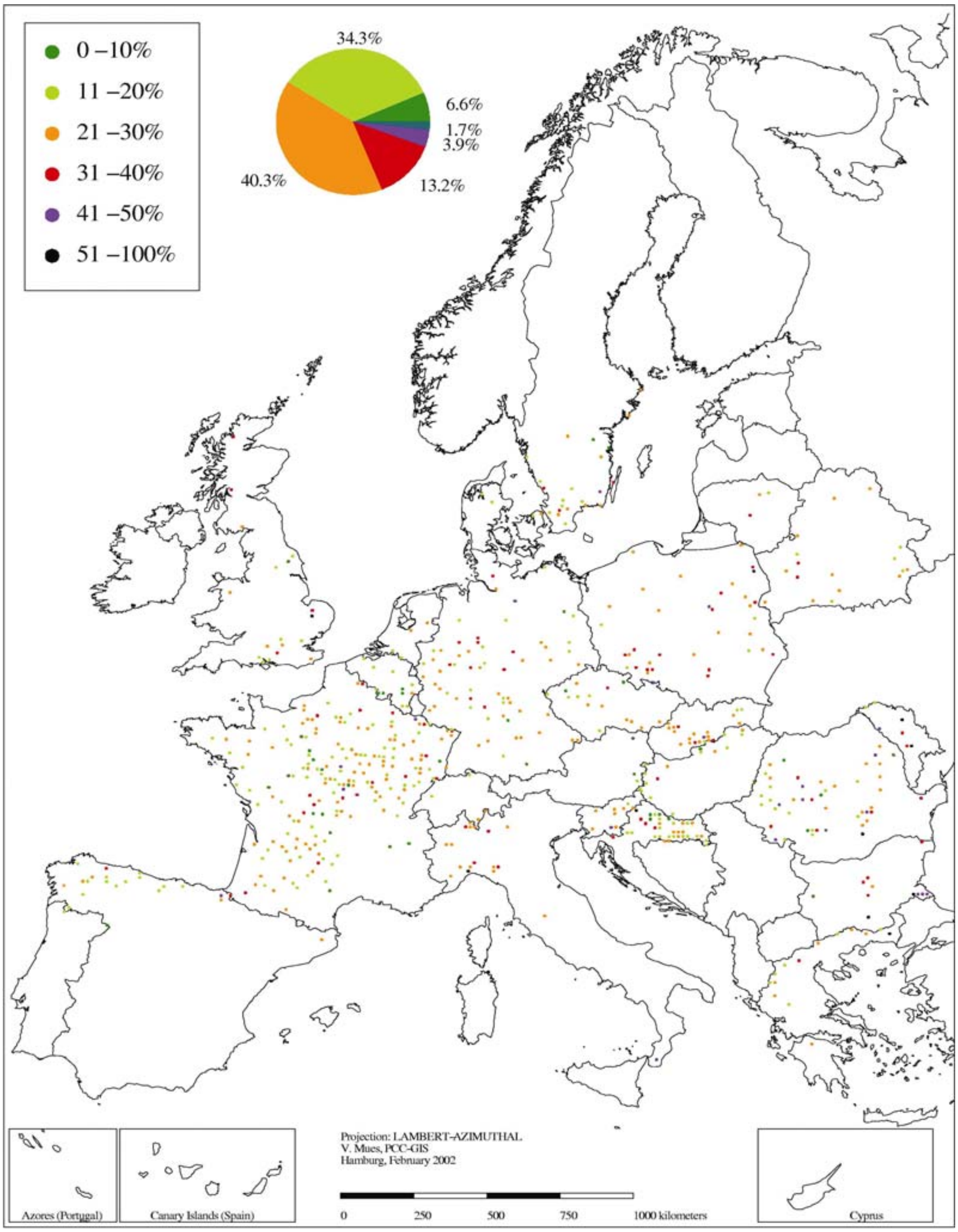


Figure 3.1.1-5: Mean plot defoliation of *Quercus robur* and *Q. petraea.*

Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used.

Figures 3.1.1-2 to 3.1.1-5 reflect the mean defoliation given for each species in Table 3.1.1-1. The two main coniferous species, *Pinus sylvestris* and *Picea abies* show high mean plot defoliation in some regions, whilst in other regions defoliation is low. This yields smaller shares of highly defoliated plots for the two coniferous species than for the two broad-leaved species (see pie diagrams in the maps), the latter showing highly defoliated plots throughout their habitat. Mean defoliation for the total of all regions is 20.1%. A map of mean plot defoliation of all species is given in Annex I-5.

The share of the discoloured trees (i.e. trees of discolouration greater than 10%) of all species in total Europe was 7.6% (Table 3.1.1-2). Plot discolouration is mapped in Annex I-6.

Table 3.1.1-2: Percentages of trees in discolouration classes for broad-leaves, conifers and all species.

	Species type	Discolouration						No. of trees
		0-10%	>10-25%	>25-60%	>60%	dead	>10%	
EU	Broad-leaves	92.4	4.8	1.4	0.5	0.9	7.6	32403
	Conifers	94.1	4.1	1.1	0.2	0.5	5.9	47068
	All species	93.3	4.4	1.3	0.3	0.7	6.7	79471
Total Europe	Broad-leaves	92.3	5.0	1.5	0.3	0.9	7.7	53514
	Conifers	92.5	4.7	1.9	0.2	0.7	7.5	78836
	All species	92.4	4.8	1.7	0.3	0.8	7.6	132350

3.1.2 Defoliation and identified damage types

The presence of the following eight different damage types on the trees is reported, though without any information on the intensity of the damage:

- game and grazing
- presence or traces of an excessive number of insects
- fungi
- abiotic agents (wind, drought, snow)
- direct action of men (poor silvicultural practises, logging, etc.)
- fire
- air pollution from known local or regional sources
- other types of damage.

Table 3.1.2-1 provides the shares of trees for which each particular damage type was assessed. The trees assessed are divided into those on which the respective damage type was present and those on which it was not present. The damage type most frequently recorded was insects, with 9.9% of the sample trees in total Europe being affected. Second largest was the share of trees showing fungi (6.6%), followed by abiotic agents recorded on 5.6% of the total sample.

Table 3.1.2-1: Percentages of trees assessed for each damage type, based on both the total tree sample and the tree sample of the EU.

Damage type	Total Europe			EU		
	not assessed	assessed and not present	assessed and present	not assessed	assessed and not present	assessed and present
Game/grazing	57.1	42.0	0.9	39.0	59.8	1.2
Insects	45.4	44.7	9.9	34.0	53.6	12.4
Fungi	46.0	47.4	6.6	35.7	57.6	6.7
Abiotic agents	46.6	47.8	5.6	35.4	57.6	7.0
Action of man	46.9	49.3	3.8	36.1	60.1	3.8
Fire	49.0	50.6	0.4	37.6	62.0	0.4
Known air pollution	59.9	37.7	2.4	59.8	40.2	-
Other	45.3	47.5	7.2	36.2	56.8	7.0

Table 3.1.2-2 shows the percentage of damaged (defoliation >25%) and discoloured (discolouration >10%) individuals among those trees showing a particular damage type. As shown in Table 3.1.2-1, for 2.4% of all sample trees air pollution was identified as a cause of damage. Of these trees, 41.0% had a defoliation greater 25% (Table 3.1.2-2).

The assessment of identified damage type is important because defoliation and discolouration are triggered by various factors. Some of these are known to interact. However, confidence of the results between individual observers differs greatly, partly due to different assessment criteria. Previous evaluations (UNECE, EC, 1997) show that currently different thresholds are applied above which e.g. insect attack is rated as damage. As long as these methodological problems remain unsolved, interpretation of the results will remain difficult.

Table 3.1.2-2: Percentages of trees of defoliation >25% and discolouration >10% of those trees showing a particular damage type.

Damage type	Defoliation (>25%)		Discolouration (>10%)	
	Total Europe	EU	Total Europe	EU
Game/grazing	22.2	19.1	6.3	5.5
Insects	34.8	33.5	12.8	12.9
Fungi	32.8	33.7	14.4	16.2
Abiotic agents	37.7	37.4	13.0	13.3
Action of man	32.7	25.5	13.9	11.6
Fire	47.0	49.3	20.0	24.1
Known air pollution	41.0	-	3.0	75.0
Other	29.4	29.7	7.2	9.2
Total tree sample	22.4	18.9	7.6	6.7

3.2 Development of defoliation

3.2.1 The common samples

Development of defoliation is traced by means of those sample trees having been monitored continuously over a certain period. These trees are common to the surveys of all years and are therefore referred to as “Common Sample Trees” (CSTs). The size of a sample of CSTs depends on the starting year of the period chosen, because the total plot sample increased over the years. Later starting years yield larger sample sizes, however, to the disadvantage of the length of the period.

Aimed at a short-term comparison with a maximum number of CSTs, the sample “$CSTs_{00}$” (2000-2001) was chosen. For the analysis of the mid-term development a sample “$CSTs_{94}$” (1994-2001) was selected. This mid-term time series had to be confined to the years 1997-2001 in some areas because of changes in the assessment methods between 1994 and 1997. A sample “$CSTs_{88}$” (1988-2001) was chosen in order to analyse the long-term development. The spatial coverage of the samples representing the time series is mapped in Annex I-7.

For the $CSTs_{00}$ differences in mean plot defoliation between 2000 and 2001 were calculated, checked for their statistical significance and mapped in Annex I-8. The sample size of 126 390 $CSTs_{00}$ corresponds to 95.5% of the total tree sample. The sample size for the $CSTs_{94}$ amounted to 61 390 trees (46.4% of the total tree sample). The $CSTs_{88}$ comprised 21 037 trees (15.9% of the total tree sample). Tables 3.2.1-1 and 3.2.1-2 indicate the sample sizes of the six most frequent tree species and their distribution over the climatic regions. For these six species the development of defoliation is presented individually in Chapters 3.2.2-3.2.7. In each chapter the development of the shares of the $CSTs_{88}$ and the $CSTs_{94}$ of defoliation class 0 and defoliation classes 2 and higher are plotted in two graphs. One graph represents the development of defoliation over all regions. The other graph represents a region in which a peculiar development was noted. The numerical basis for the graphs is provided in Annex I-9 and Annex I-10. They also contain the respective information for *Abies alba* and *Picea sitchensis* because of their ecological and economical importance in some regions. Also in Chapters 3.2.2-3.2.7, the trends in mean defoliation between 1994 and 2001 are mapped for each plot.

Table 3.2.1-1: Number of trees common to the surveys from 1988 to 2001 ($CSTs_{88}$) by species and climatic region. Italy and France are not included due to changes in the methodology.

Climatic region	*Picea abies*	*Pinus sylvestris*	*Pinus pinaster*	*Fagus sylvatica*	*Quercus ilex + Q. rotundifolia*	*Quercus petraea + Q. robur*
Atlantic (north)	147	447	0	223	0	183
Atlantic (South)	0	74	230	29	24	75
Mediterranean (higher)	0	369	196	80	467	188
Mediterranean (lower)	0	72	903	33	1732	3
Atlantic (south)	920	480	45	765	31	87
Sub-Atlantic	1945	1090	0	1463	0	679
All regions	3012	2532	1374	2593	2254	1215
Percent of all common trees 1988-2001	14.3	12.0	6.5	12.3	10.7	5.8

Table 3.2.1-2: Number of trees common to the surveys from 1994 to 2001 ($CSTs_{94}$) by species and climatic region. Italy and France are not included due to changes in the methodology.

Climatic region	*Picea abies*	*Pinus sylvestris*	*Pinus pinaster*	*Fagus sylvatica*	*Quercus ilex* + Q. *rotundifolia*	*Quercus petraea* + Q. *robur*
Atlantic (north)	679	762	0	669	0	640
Atlantic (South)	0	75	341	40	24	168
Boreal	2081	3030	0	0	0	2
Boreal (temperate)	1723	3023	0	2	0	47
Continental	255	187	0	747	1	618
Mediterranean (higher)	53	490	310	277	620	229
Mediterranean (lower)	16	80	1222	144	2196	280
Mountainous (north)	623	771	0	0	0	0
Atlantic (south)	2838	1143	45	1918	35	312
Sub-Atlantic	4010	7537	0	2086	0	1344
All regions	12278	17098	1918	5883	2876	3640
Percent of all common trees 1994-2001	20.0	27.9	3.1	9.6	4.7	5.9

The plotwise trends in defoliation between 1994 and 2001 for all species are mapped in Figure 3.2.2-1. A statistically significant increase in defoliation (deterioration) occurred on 13.5% of the plots. These plots are scattered all over Europe, but show concentrations in southern Finland, Estonia and Latvia, western Germany, the Czech Republic, Slovenia, Romania, easternmost Bulgaria and Portugal. Defoliation decreased significantly (improvement) on 11.4% of the plots, these plots being clearly concentrated in Estonia, Poland and northern Romania.

The development of mean defoliation of the $CSTs_{88}$ and the $CSTs_{94}$ is plotted for the six most frequent species over all regions in Figures 3.2.2-2 and 3.2.2-3, respectively. The Mediterranean species *Pinus pinaster* and *Quercus ilex* and *Q. rotundifolia* show the steepest increase in defoliation since 1988. For the remaining species the increase is only minor, with obvious phases of recovery in *Pinus sylvestris* (after 1994) and *Quercus robur* and *Q. petraea* (after 1998).

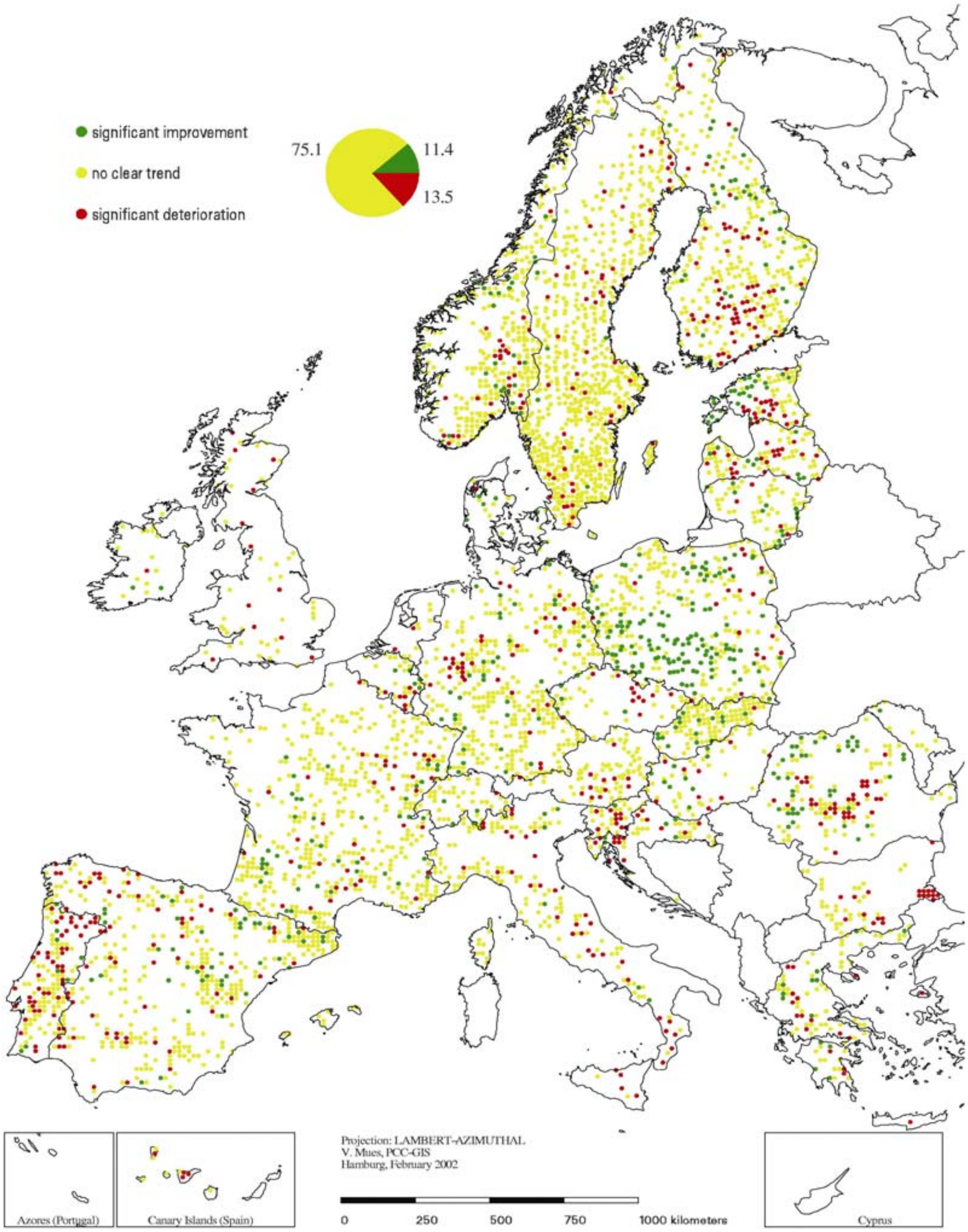


Figure 3.2.1-1: Trend of mean plot defoliation (slope of linear regression) of all species over the years 1994 to 2001 (1997 to 2001 for France and Italy due to changes in the assessment methodology and for Sweden due to changes in the sampling).

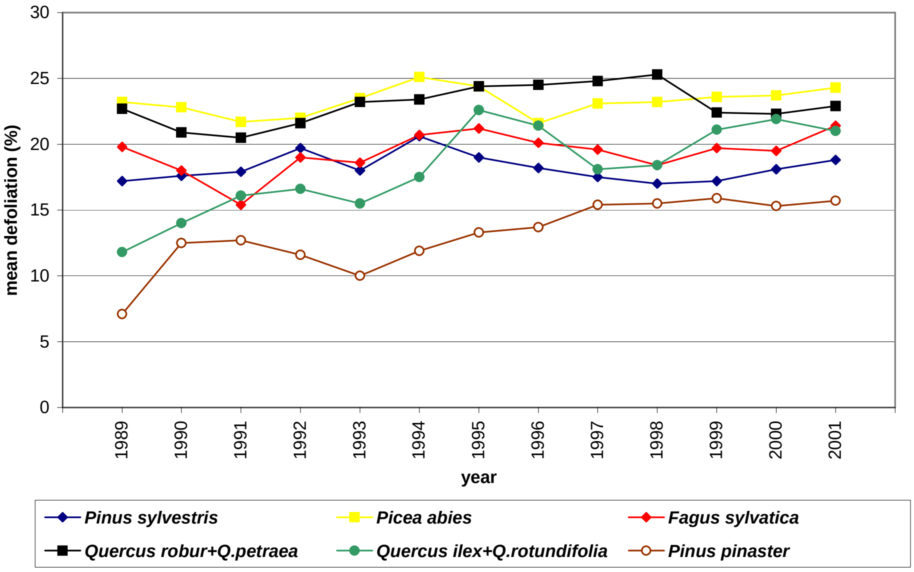


Figure 3.2.1-2: Development of mean defoliation of CSTs$_{88}$ of the 6 most frequent species. Mean defoliation could be calculated only from 1989 onwards, because in 1988 defoliation was assessed in the traditional defoliation classes instead of 5% steps. Number of trees: *Pinus sylvestris*: 2532; *Picea abies*: 3012; *Quercus robur* and *Q. petraea*: 1215; *Fagus sylvatica*: 2593; *Pinus pinaster*: 1374; *Quercus ilex* and *Q. rotundifolia*: 2254.

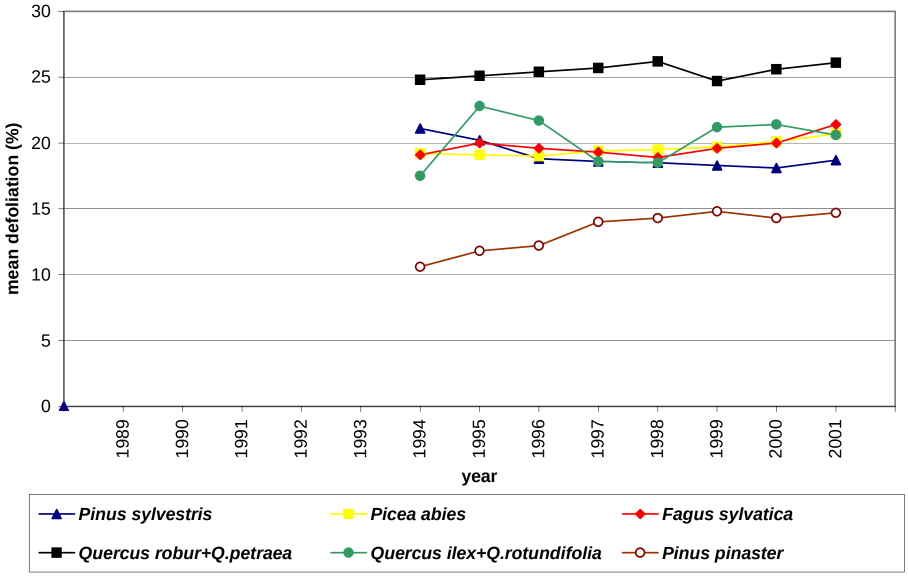


Figure 3.2.1-3: Development of mean defoliation of CSTs$_{94}$ of the 6 most frequent species. Number of trees: *Pinus sylvestris*: 17098; *Picea abies*: 12278; *Quercus robur* and *Q. petraea*: 3640; *Fagus sylvatica*:5883; *Pinus pinaster*:1918; *Quercus ilex* and Q. *rotundifolia*: 2876.

3.2.2 *Pinus sylvestris*

Pinus sylvestris represents the largest share of the CSTs$_{94}$ and is the only species present in all of the climatic regions. The Sub-Atlantic region contains the highest percentage (44.1%) of its CSTs$_{94}$, followed by the Boreal and Boreal (temperate) regions (17.7% each).

From the start of the surveys on, the share of undamaged CSTs$_{88}$ (0-10% defoliation) decreased from 54.3% to a minimum of 31.2% in 1994 (Figure 3.2.2-1a). In the same period the share of damaged trees (>25% defoliation) increased slightly to its peak of 26.2%. The year 1994 was followed by a remarkable recuperation, with the shares of damaged trees of both the CSTs$_{88}$ and the CSTs$_{94}$ decreasing to their minima in 1999 and 2001, respectively.

The development of defoliation varied greatly among the 10 different regions. The defoliation over all regions differed greatly even from that in the Sub-Atlantic region with its high share of CSTs (Figure 3.2.2-1b). In the Sub-Atlantic region the share of damaged trees was mostly higher than that of the undamaged trees. Here, however, the recuperation since 1994 was particularly pronounced, this being due to the statistically significant decrease in defoliation in Poland (Figure 3.2.2-2). A smaller cluster of plots of decreasing defoliation is obvious in Estonia.

A statistically significant improvement of crown condition was observed on 15.9% of the plots and a statistically significant deterioration on 7.0% of the plots.

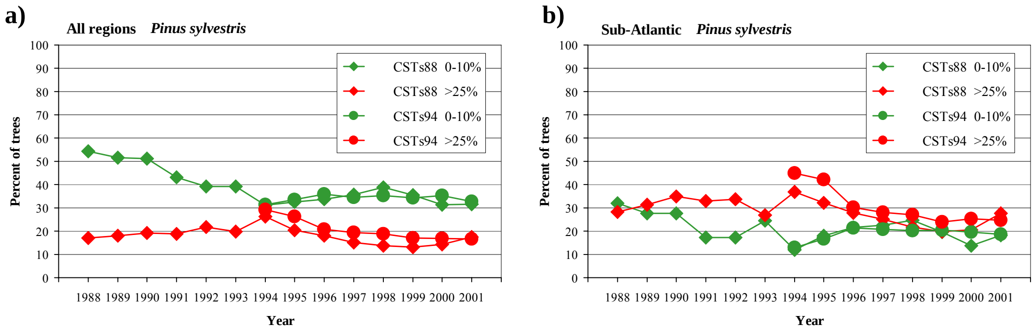


Figure 3.2.2-1: a) Sample sizes in all regions: CSTs$_{88}$ = 2532; CSTs$_{94}$ = 17098.
b) Sample sizes in the Sub-Atlantic region: CSTs$_{88}$ = 1090; CSTs$_{94}$ = 7537.

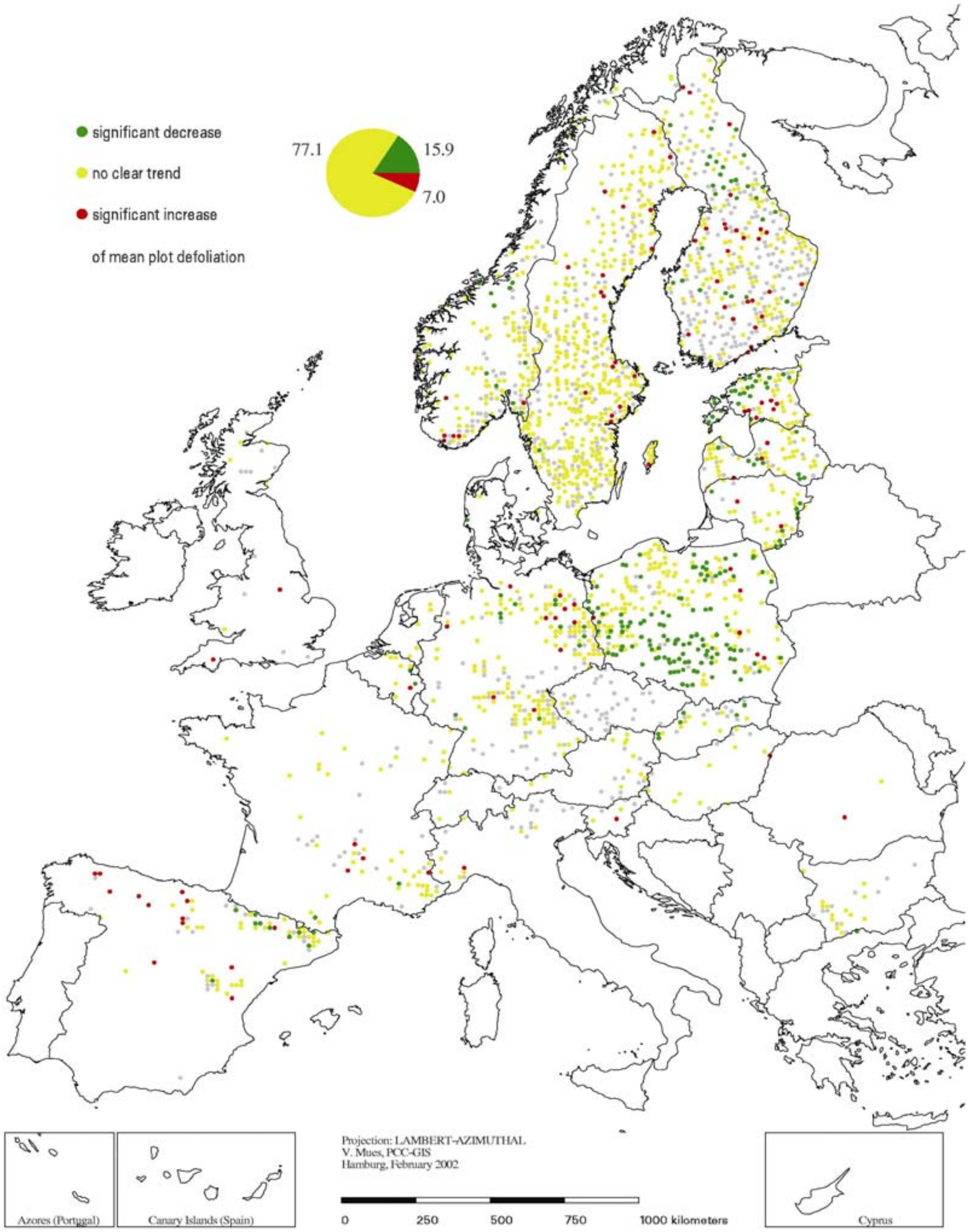


Figure 3.2.2-2: Trend of mean plot defoliation (slope of linear regression) of *Pinus sylvestris* over the years 1994 to 2001 (1997 to 2001 for France and Italy due to changes in the assessment methodology and for Sweden due to changes in the sampling; grey plots contain *Pinus sylvestris* trees for which no trends in defoliation could be calculated).

3.2.3 *Picea abies*

Picea abies was the most abundant species in the CSTs$_{88}$, with particularly large shares in the Sub-Atlantic and Atlantic (south) regions. It was not present in the Atlantic (South) and in the two Mediterranean regions. Despite a remarkable increase in the sample size due to the participation of several new countries after 1988, *Picea abies* is only the second most frequent species after *Pinus sylvestris* in the CSTs$_{94}$.

The development of defoliation over all regions shows no distinct trend (Figure 3.2.3-1a). Only minor fluctuations occurred in the samples of both the CSTs$_{88}$ and CSTs$_{94}$. The decrease in undamaged and the slight increase in damaged trees from 2000 to 2001 reflect the clear deterioration observed in the Mountainous (south) region and in particular in the Boreal and Boreal (temperate) regions (Figure 3.2.3-1b and Figure 3.2.3-2). In the Boreal region the share of undamaged trees dropped from 50.2% in 1999 to 42.1% in 2001. The share of damaged trees showed a sharp increase from 20.5% in 2000 to 23.1% in 2001. In the Boreal and Boreal (temperate) regions the deteriorating plots are situated in southern Finland, a part of southern Sweden, Estonia and Lithuania. The deteriorating plots in the Mountainous (south) region are concentrated in Austria, Slovenia and Romania.

Within the CSTs$_{94}$ crown condition deteriorated on 15.2% of the plots. On 6.4% of the plots an improvement was observed.

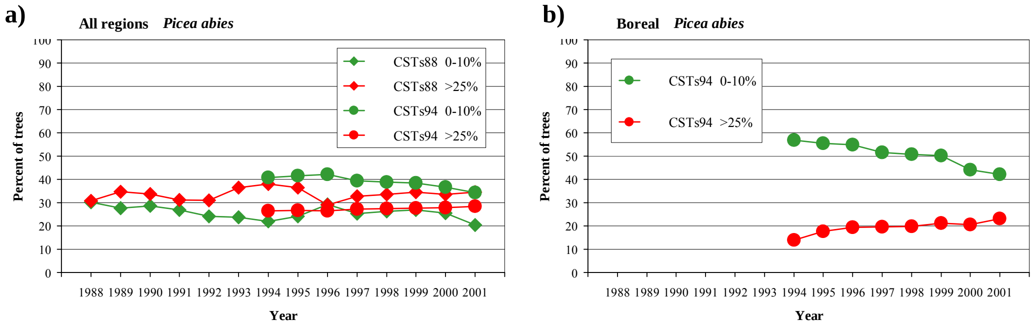


Figure 3.2.3-1: a) Sample sizes in all regions: CSTs$_{88}$ = 3012; CSTs$_{94}$ = 12278.
b) Sample size in the Boreal region: CSTs94 = 2081.

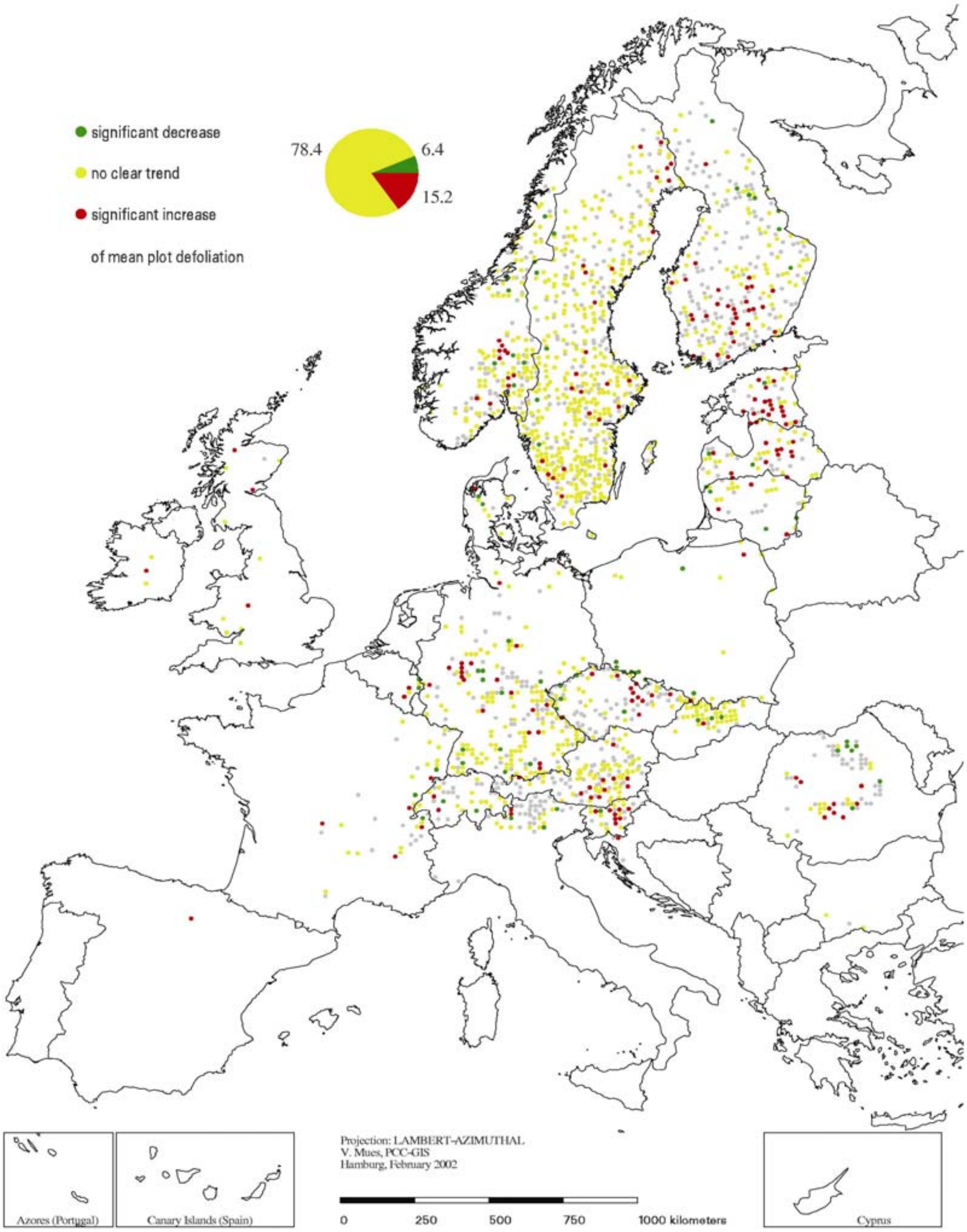


Figure 3.2.3-2: Trend of mean plot defoliation (slope of linear regression) of *Picea abies* over the years 1994 to 2001 (1997 to 2001 for France and Italy due to changes in the assessment methodology and for Sweden due to changes in the sampling; grey plots contain *Picea abies* trees for which no trends in defoliation could be calculated).

3.2.4 *Fagus sylvatica*

Fagus sylvatica was the most frequent broad-leaved tree species on the evaluated Level I plots (Table 3.2.1-1 and 3.2.1-2). It mainly occurs in the Sub-Atlantic and Atlantic (south) regions where more than 50% of the CSTs for *Fagus sylvatica* are located. The species lacks in the Boreal region and in the Mountainous (north) region.

Crown condition of *Fagus sylvatica* shows a marked deterioration over all regions compared to 2000 (Figure 3.2.4-1a). The percentage of damaged trees increased from 23.5% to 26.7% (CSTs$_{94}$). This is the largest share since the beginning of this evaluated time series. Also, mean defoliation of *Fagus sylvatica* in all regions was at the highest level since the beginning of the monitoring (Figures 3.2.1-2 and 3.2.1-3).

About one third of the sample is located in the Atlantic (south) region. The trends in crown condition in that region are characterised by a deterioration between 1991 and 1997 and by comparatively strong fluctuations from 1998 on (Figure 3.2.4-1b). Also, the sub-sample in the Atlantic (south) reflects the sharp increase in the share of damaged trees between 2000 and 2001.

Significance tests for the plotwise medium term development reveal no statistically significant trend for the major share (73.6%) of the *Fagus sylvatica* plots between 1994 and 2001. The percentage of deteriorating plots (16.3%) is however larger than the percentage of improving plots (10.1%) (Figure 3.2.4-2). Deteriorating plots are located in north western Germany and Wallonia, in Slovenia, Croatia and Romania. In Romania there are also clusters of improving plots.

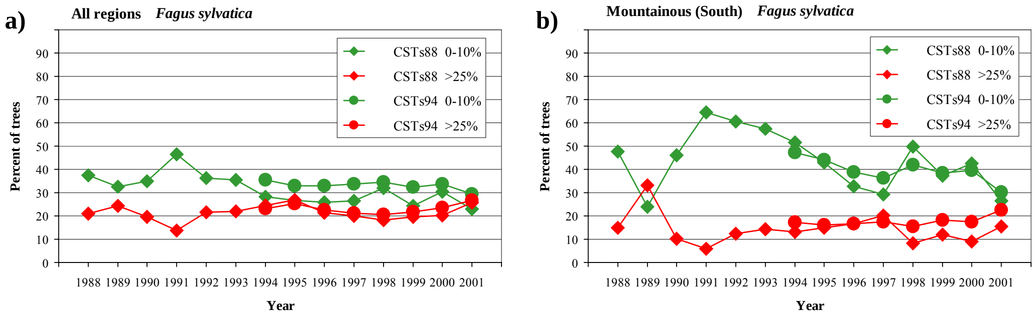


Figure 3.2.4-1: a) Sample sizes in all regions: CSTs$_{88}$ =2593; CSTs$_{94}$ = 5883.
b) Sample sizes in the Atlantic (south) region: CSTs$_{88}$ = 765; CSTs$_{94}$ = 1918.

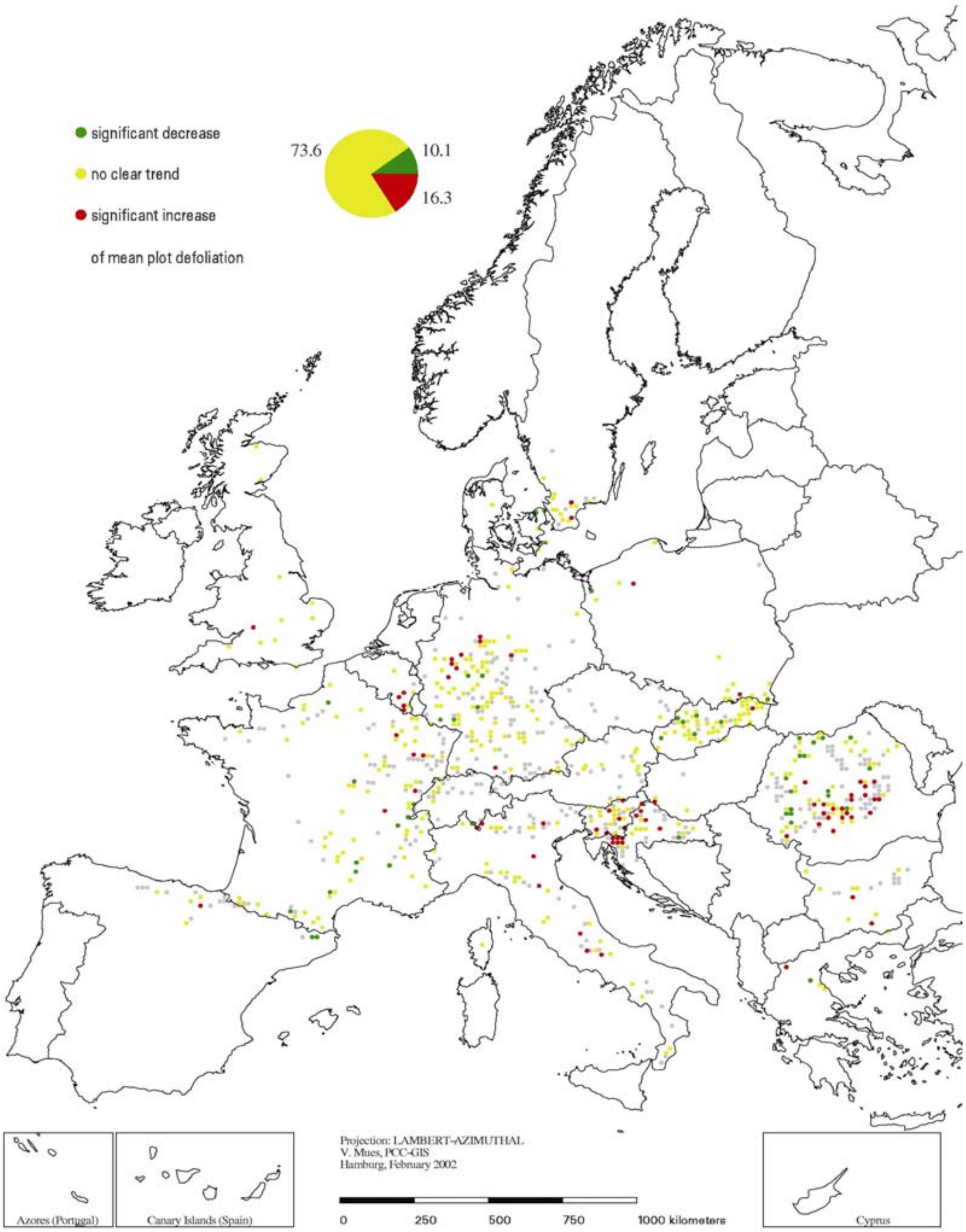


Figure 3.2.4-2: Trend of mean plot defoliation (slope of linear regression) of *Fagus sylvatica* over the years 1994 to 2001 (1997 to 2001 for France and Italy due to changes in the assessment methodology and for Sweden due to changes in the sampling; grey plots contain *Fagus sylvatica* trees for which no trends in defoliation could be calculated).

3.2.5 *Quercus robur* and *Q. petraea*

Most of the *Quercus robur* and *Q. petraea* trees are located in the Sub-Atlantic region. The species group is the second most frequent species of the CSTs_{94}.

The share of damaged trees was high from 1993 to 1998. It decreased in 1999 (and also in 2000 for the CSTs_{88}) but increased again since then (Figure 3.2.5-1a). Also the evaluation of mean defoliation shows a deterioration in the last two years (Figures 3.2.1-2 and 3.2.1-3). The trees in the Sub-Atlantic region reflect the same trend but the level of damage was higher in the mid nineties (Figure 3.2.6-1b).

Even though that mean defoliation and the shares of damaged trees indicate a slight deterioration since 1994, the development from 1994 to 2001 was not statistically significant for 76.6% of the plots (Figure 3.2.6-2). The share of improving plots (11.4%) was nearly equal to the share of plots with deteriorating crown condition (12.0%). The only regions with clustered improving or deteriorating plots are north western Germany and north western France where several deteriorating plots are located and central Germany with a number of improving plots located rather closely together.

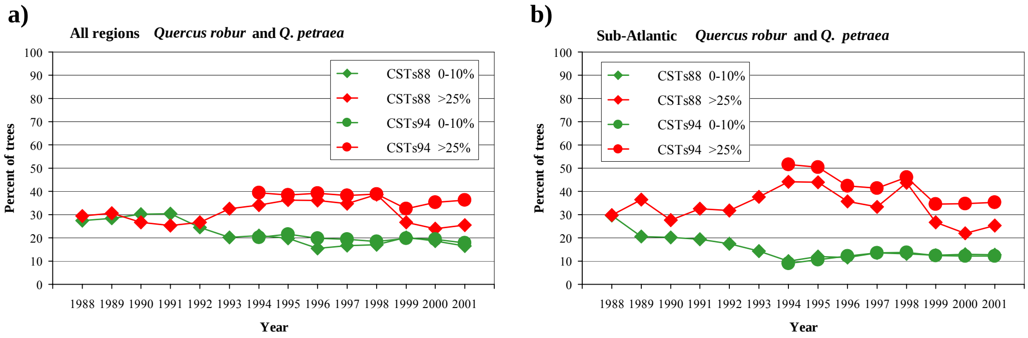


Figure 3.2.5-1: a) Sample sizes in all regions: $\text{CSTs}_{88} = 1215$; $\text{CSTs}_{94} = 3640$.
b) Sample sizes in the Sub-Atlantic region: $\text{CSTs}_{88} = 679$; $\text{CSTs}_{94} = 1344$.

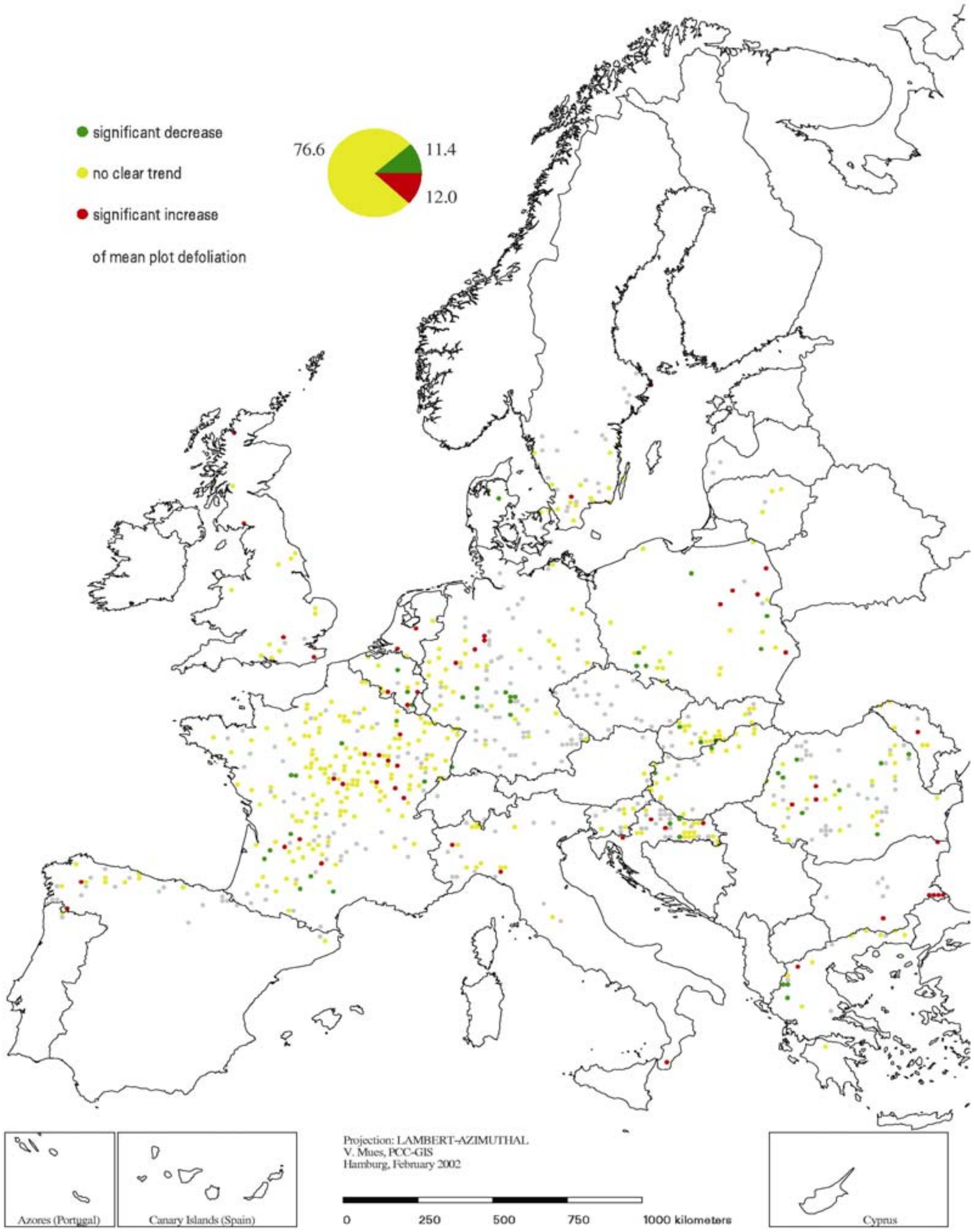


Figure 3.2.5-2: Trend of mean plot defoliation (slope of linear regression) of *Quercus robur* and *Q. petraea* over the years 1994 to 2001 (1997 to 2001 for France and Italy due to changes in the assessment methodology and for Sweden due to changes in the sampling; grey plots contain *Quercus robur* or *Q. petraea* trees for which no trends in defoliation could be calculated).

3.2.6 *Quercus ilex* and *Q. rotundifolia*

The main distribution area of *Quercus ilex* and *Q. rotundifolia* is the Mediterranean (lower) region (Tables 3.2.1-1 and 3.2.1-2). The second most trees (CSTs$_{88}$ and CSTs$_{94}$) are located in the Mediterranean (higher) region.

In the first years of the survey a strong deterioration was depicted by the survey results (Figures 3.2.6-1a and 3.2.6-1b). Only in the Mediterranean (higher) region from 1988 to 1989 crown condition improved. After an improvement in the years from 1995 to 1998 a deterioration was registered in 1999. Whereas for the year 2000 no significant change in crown condition was found, there could be detected a slight improvement for 2001 for all regions. The slight decrease of the share of undamaged trees in the Mediterranean (higher) region is contradicting to this process.

Figure 3.2.6-2 maps the slope of the linear trend for the plots with *Quercus ilex* and *Q. rotundifolia*. Most impressing is the high share of plots without any statistically significant trend in the period from 1994 to 2001 (80.4%). This is convincing the results from the Figures 3.6.2-1a and 3.6.2-1b of relatively low changes in this period. Most of the plots with statistically significant deterioration (12.9%) are located near to the border between Portugal and Spain or in an area in southern Spain. The plots with improving crown condition (6.7%) are located mostly in the east of Spain.

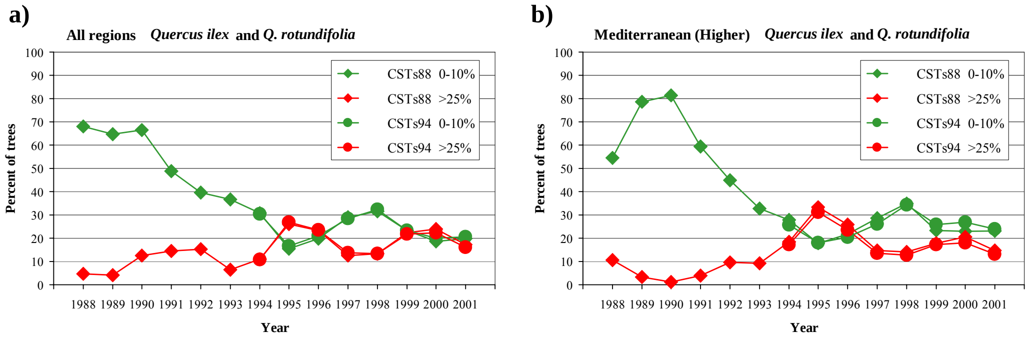


Figure 3.2.6-1: a) Sample sizes in all regions: CSTs$_{88}$ = 2254; CSTs$_{94}$ = 2876.
b) Sample sizes in the Mediterranean (higher) region: CSTs$_{88}$ = 467; CSTs$_{94}$ = 620.

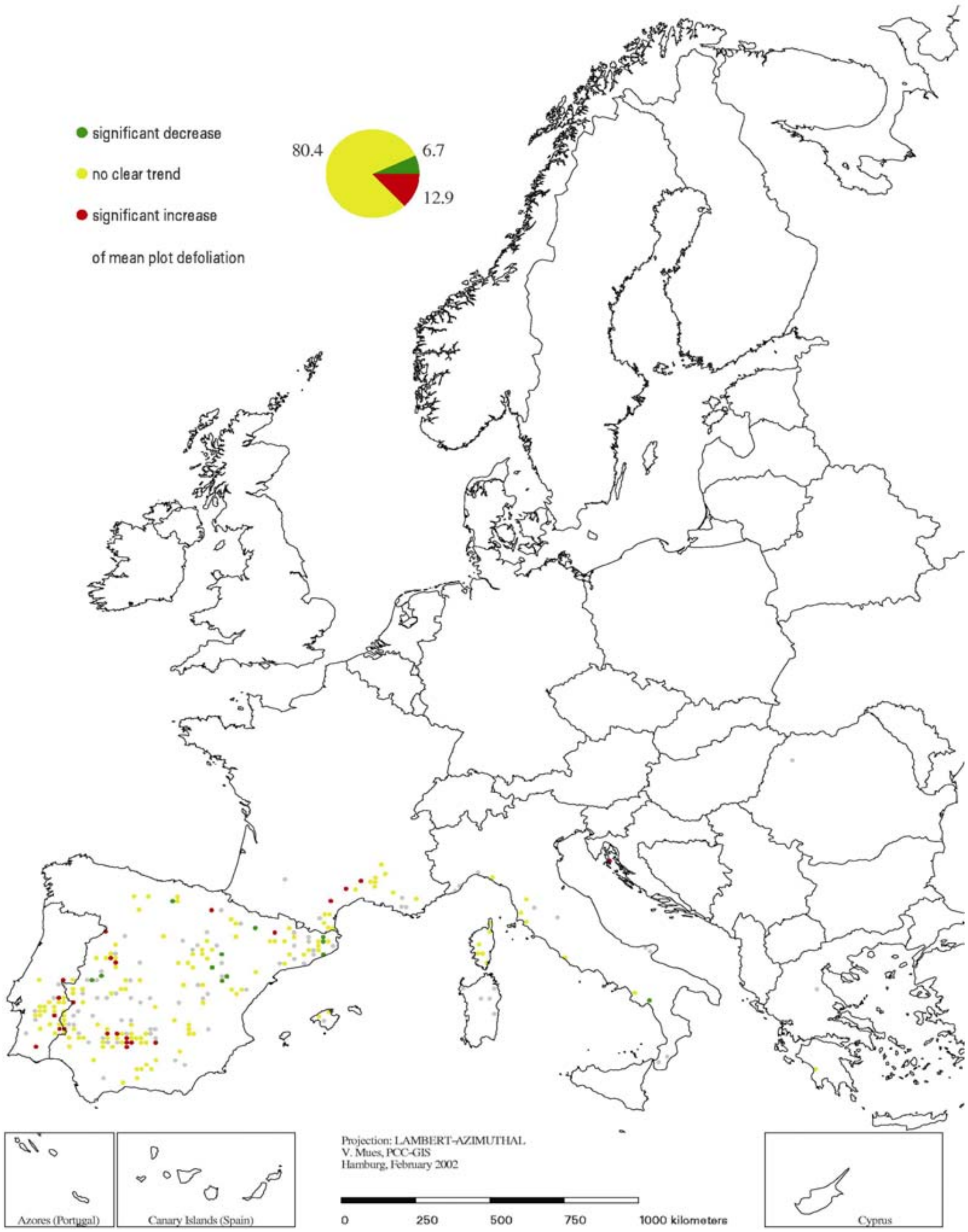


Figure 3.2.6-2: Trend of mean plot defoliation (slope of linear regression) of *Quercus ilex* and Q. *rotundifolia* over the years 1994 to 2001 (1997 to 2001 for France and Italy due to changes in the assessment methodology; grey plots contain *Quercus ilex* or *Q. rotundifolia* trees for which no trends in defoliation could be calculated).

3.2.7 *Pinus pinaster*

The main distribution area of *Pinus pinaster* is in the Mediterranean (lower) region with most plots located in Portugal (Tables 3.2.1-1 and 3.2.1-2 and Figure 3.2.7-2). A second centre of distribution is in the south west of France in the Atlantic (South) region, where slightly more plots are located than in the Mediterranean (higher) region.

For the sum of all regions a clear deterioration was found over the entire survey period (Figure 3.2.7-1a). However, the share of undamaged trees has constantly remained larger than the share of damaged trees. For 1990 a very strong deterioration and for 1992 a strong improvement of crown condition was found. This development had its centre in the Atlantic (South) region (Figure 3.2.7-1b). This result is confirmed by the map of the slopes of linear time trend (Figure 3.2.7-2), which is depicting a recuperation for a number of plots in the south west of France on average. This is reflected by the decrease of the share of damaged trees in the Atlantic (South) region (Figure 3.2.7-1b).

Whereas the most plots show no statistically significant trend (64.6%), the share of plots with statistically significant deterioration (24.1%) is more than twice as high as the share of plots with a statistically significant improvement of crown condition (11.3%).

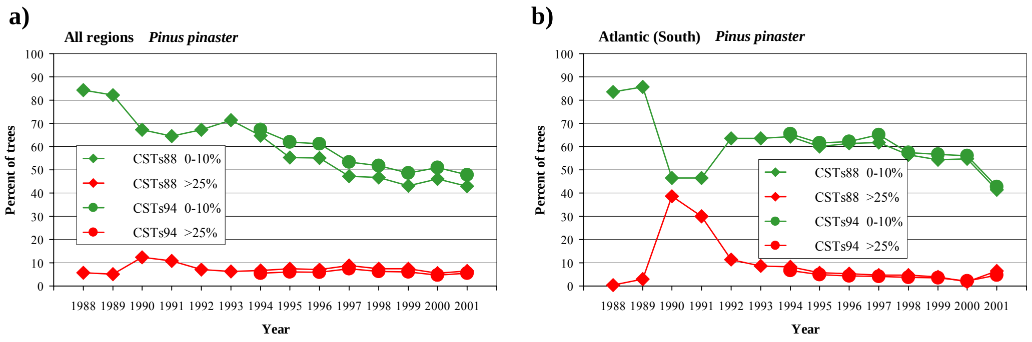


Figure 3.2.7-1: a) Sample sizes in all regions: $CSTs_{88}$ = 1374; $CSTs_{94}$ = 1918.
b) Sample sizes in the Atlantic (South) region: $CSTs_{88}$ = 230; $CSTs_{94}$ = 341.

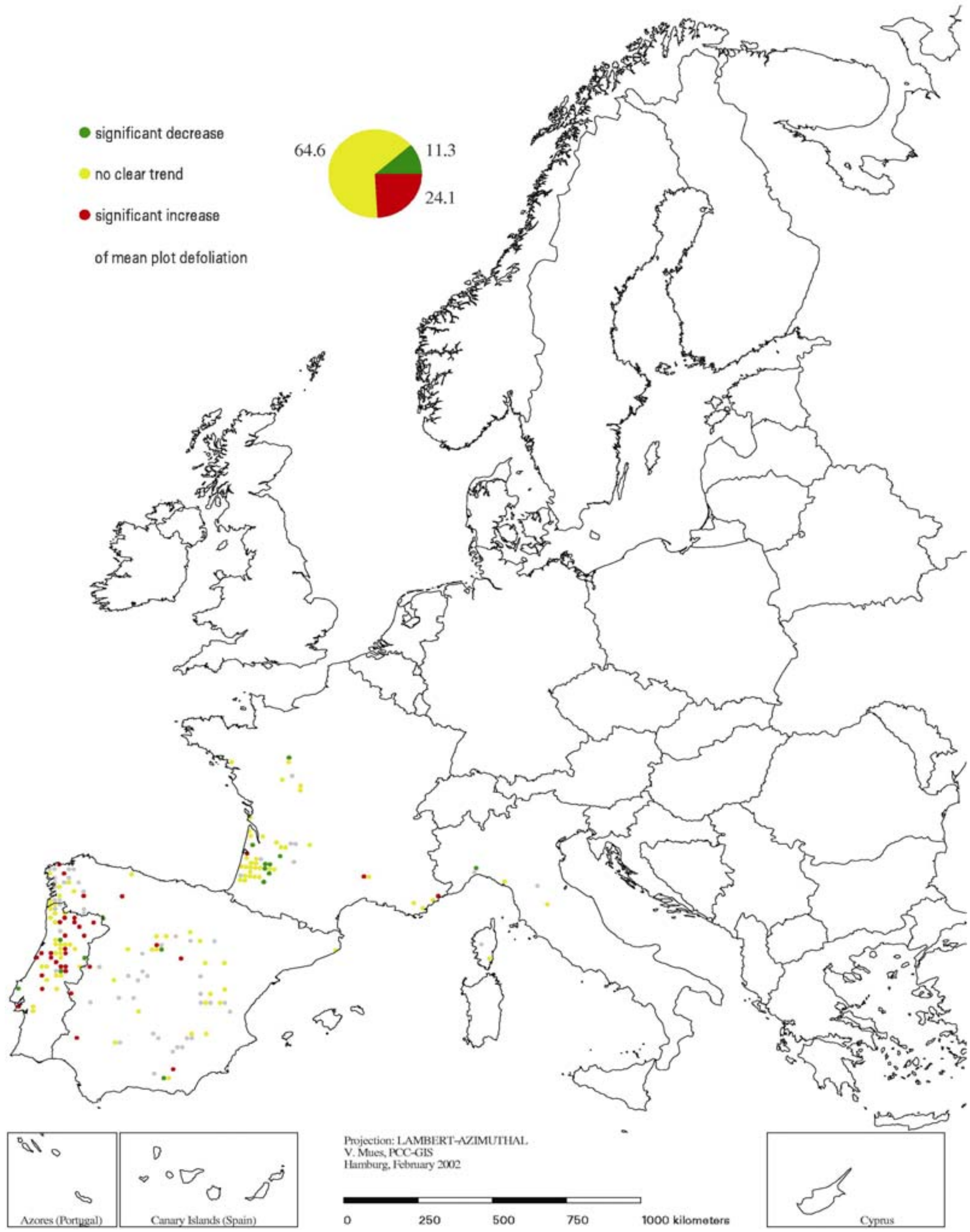


Figure 3.2.7-2: Trend of mean plot defoliation (slope of linear regression) of *Pinus pinaster* over the years 1994 to 2001 (1997 to 2001 for France and Italy due to changes in the assessment methodology; grey plots contain *Pinus pinaster* trees for which no trends in defoliation could be calculated).

4 Results of Integrative Studies

The results of the integrative studies are regression models on one hand and maps of certain plot-wise parameters of these regressions on the other hand (2.5.3). The results of the calculated linear regressions show a low but statistically significant relationship between crown condition in terms of defoliation and deposition of sulphur for Scots pine. Higher defoliation values coincide with elevated sulphur deposition. One of the strongest trends of improvement in the evaluation period (1994 to 1999) was detected for southern Poland, where a strong reduction of sulphur deposition on high level was observed in this period.

In addition to sulphur deposition nitrogen inputs – oxidised as well as reduced – showed a strong but statistically not significant correlation with defoliation. There were negative correlations as well as positive ones detected for both components. Therefore, the results concerning nitrogen deposition are more difficult to interpret.

Additionally, drought stress was described by precipitation sums which showed negative correlation with defoliation in most cases. However, these relationships were statistically not significant.

Interaction terms of soil properties and precipitation led to plausible results. It could be shown that the influence of precipitation on defoliation depends on the water availability. Sites with excessive water availability even showed a positive correlation of defoliation with precipitation, whereas for sites with sufficient or especially with insufficient water availability negative correlation was found.

To get a measure of higher comparability of the level of defoliation among the countries, a country-wise correction of the age trend was calculated (UNECE, CEC, 2001) during the evaluations of the spatial variation of defoliation. This was not necessary for the evaluations concerning the temporal variation of defoliation.

4.1 Pinus sylvestris

For the evaluation of the temporal and spatial variation of defoliation for *Pinus sylvestris*, 1313 plots were available with complete data for the period from 1994 to 1999. For evaluations including water availability and pH in the topsoil, the number was reduced to 620 plots.

The results for *Pinus sylvestris* show low but statistically significant correlation of sulphur deposition with defoliation for the analysis of temporal variation as well as for spatial variation. Therefore, descriptive statistics of the values at those plot which were basis for the analyses are listed in Table 4.1-1. Calculations were done with values in g/m^2 (= 10kg/ha) which is the original unit of the EMEP data. All interpretations of the results are done in kg/ha.

Table 4.1–1: Sulphur deposition and respective referenced values at plots which were used for calculations concerning temporal and spatial variation of defoliation of *Pinus sylvestris*

		deposition S [kg/ha]				difference from plot mean [kg/ha]			
Year	N	mean	std	min	max	mean	std	min	max
1994	1313	11.8	8.70	1.4	36.8	2.8	2.78	0.2	13.2
1995	1313	10.5	7.52	1.3	31.1	1.5	1.55	0.1	7.5
1996	1313	9.4	6.45	1.3	25.7	0.5	0.40	-0.7	2.0
1997	1313	8.3	5.56	1.2	23.0	-0.7	0.72	-3.5	0.2
1998	1313	7.3	4.62	1.1	19.6	-1.7	1.70	-8.0	0.1
1999	1313	6.6	4.08	1.1	17.6	-2.4	2.25	-10.7	-0.1
all	7878	9.0	6.61	1.1	36.8	0.0	2.52	-10.7	13.2

4.1.1 Temporal variation of defoliation

The temporal variation of *Pinus sylvestris* was calculated as linear trend according to model 5 in Table 4.1.1-1. The regression coefficients β_{5i} of YEAR, which are presented in Figure 4.1.1-1, are analogue to equation (2) reduced to the component YEAR, which leads to equation (4):

$$\text{ref}(D)_{ij} = \beta_{5i}\,\text{ref}(\text{YEAR})_{ij} + \varepsilon_{ij} \qquad (4)$$

The same information, interpolated with the geostatistical kriging, is presented in Figure 4.1.1-2. The interpolated presentation allows a quicker overview.

There is a clear improvement of crown condition in Slovakia, Lithuania, and Poland, especially in the south of Poland and west of Slovakia. Additionally the heterogeneous development in Norway, Sweden, Finland, Latvia, and Germany reveals a differentiation within the countries. In Spain a strong gradient from improvement in the east to a deterioration in the centre of Spain can be observed. For Bulgaria a clear deterioration during the evaluation period was found. For most plots in Bulgaria the assumption of a linear trend over time does not hold true due to extraordinarily high defoliation values at the end of the observation period. These could be explained by unfavourable weather conditions (STOICHKOVA, pers. comm.).

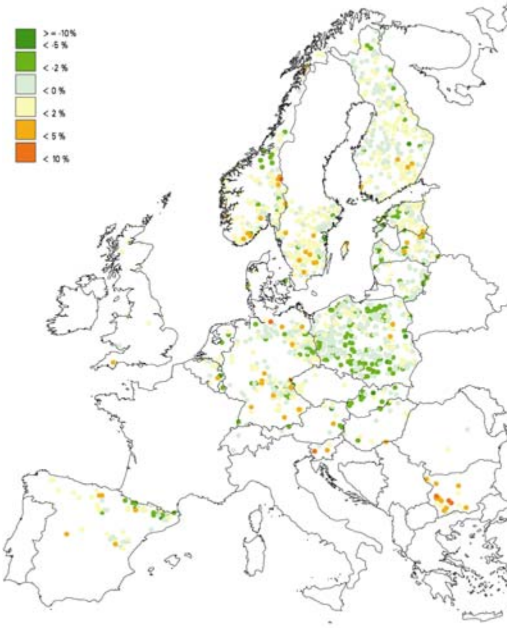


Figure 4.1.1-1: Linear temporal trend of defoliation for *Pinus sylvestris* (plot-wise presentation)

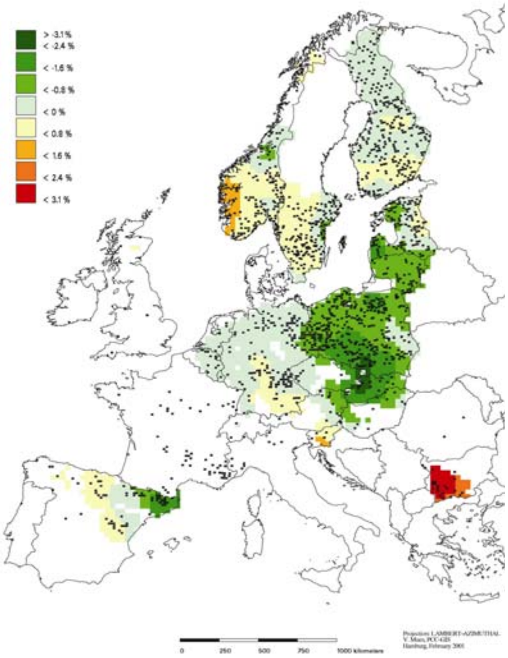


Figure 4.1.1-2: Linear temporal trend of defoliation for *Pinus sylvestris* (kriging interpolation; nugget: 2.05 sill: 0.88 range: 700km)

Table 4.1.1–1: Linear regression models for temporal variation of defoliation of *Pinus sylvestris*; all predictors were referenced (2.5.3); statistically significant predictors shaded.

No.	R^2	precipitation [mm] Jan.-Jun.	insect	fungi	deposition [g/m^2] S	NHy	NOx	YEAR [1)]
1	44.5	-0.003	+ 2.1	-0.5	+10.2	+15.7	-82.9	o
2	44.5	-0.003	+2.1		+10.2	+15.6	-83.3	o
3	43.8				+11.0			o
4	5.8				+4.6			
5	43.3							o

[1)] The regression coefficients for YEAR are calculated plot-wise, can be positive or negative, and can therefore not be tested for plausibility for all plots in one.

The detected temporal variation was analysed by multiple linear regressions (Table 4.1.1-1). The regression coefficients can be interpreted as exemplarily done here for model 1:

- 100mm precipitation above the mean plot precipitation is related with a mean decrease in defoliation of 0.3%.
- Each percent point of insect infestation above the medium-term mean insect infestation corresponds with a 2.1% defoliation above the medium-term mean defoliation.
- A fungi infestation above the plot mean index value by 1 percent point is related with a mean decrease of 0.5% defoliation on average.

- A more of 10kg/ha sulphur deposition is related with a defoliation which is on average 10.2% above the medium-term mean defoliation.

The listed R^2 values are calculated by models of the type of equation (2). Statistical significance was tested by a modification of split-plot analysis, which uses a model of the type of equation (2b) (2.5.3, DIGGLE et al., 1994, HENDRIKS et al., 2000).

The sum of precipitation from January to June showed stronger correlation (TYPE III Sum of Squares) than the other tested drought stress indices (precipitation sum from April to September, annual sum of precipitation). Results show that the higher the precipitation from January to June is, the lower is the defoliation in the respective year.

Kommentar: weglassen, der Leser den diese detatils interessieren weiß auch, dass i.d.R. mehrere parameter getested werden und nur der, mit den besten Results gezeigt wird.

The negative correlation of the fungi index with defoliation (the less fungi, the more defoliation) is implausible and was therefore rejected from the regression model (Table 4.1.1-1). The reduced model number 2 reaches just the same R^2 value of 44.5% explained variance. The index for the impact of insects is still included and shows plausible positive regression coefficients or correlation, respectively.

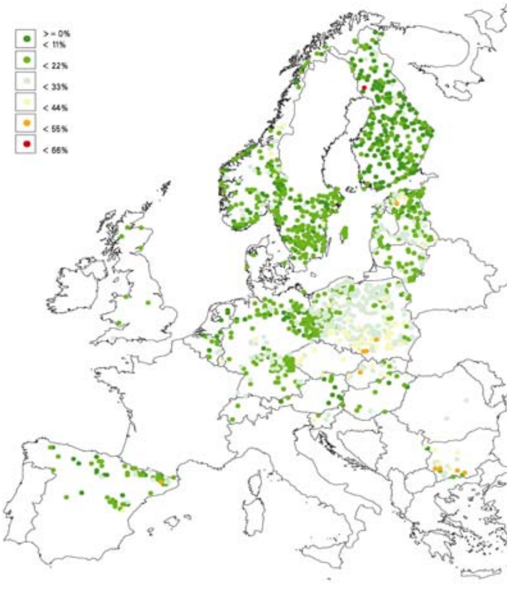
The deposition of sulphur is the only predictor in the models, which is statistically significant. The regression coefficients for sulphur are positive in all models. This positive correlation suggesting higher defoliation with higher sulphur deposition is plausible. Not as clear is the correlation of defoliation with nitrogen deposition. Reduced nitrogen (Ammonium) is related to deterioration, whereas the oxidised nitrogen seems to improve the crown condition.

The largest share of the variance is explained by the adapted linear trend, which is calculated by the integration of the predictor YEAR (referenced year of observation, compare 2.5.3). Model number 5 (Table 4.1.1-1), which is the basis for Figure 4.1.1-1 and Figure 4.1.1-2, reaches a R^2 value of 43.3%. The integration of sulphur deposition can improve the R^2 value by only 0.5 percent points, but a model with only sulphur deposition reaches 5%. The fact, that sulphur deposition is a statistically significant predictor, whereas YEAR is not, although reaching higher R^2 values, can be explained by the varying regression coefficients of YEAR among the plots. The regression coefficient for sulphur deposition is only *one* value, which can explain a low but statistically significant part of defoliation's temporal variation.

A test of homogeneity of slopes showed that the regression coefficient for precipitation sum (January to June) varies for plots in different water availability classes. For plots with sufficient water availability and especially for those with insufficient water availability a negative correlation was found meaning higher precipitation coincides with lower defoliation. For plots with excessive water availability higher sums of precipitation coincided with higher defoliation values.

4.1.2 Spatial variation of defoliation

The maps of medium-term mean defoliation (Figure 4.1.2-1 and Figure 4.1.2-2) show some regions of high levels of defoliation. Especially the high values in Poland make clear that the improvement of crown condition (4.1.1) takes place on a high level of damage. Other regions and 'hot spots' are not as clear as they only become visible on the maps of preliminary adjusted defoliation (PAD; Figure 4.1.2-3 and Figure 4.1.2-4). These values reflect medium-term mean defoliation corrected for country-wise age effects (compare UNECE, CEC, 2001). Regions of relatively high defoliation levels are located in Estonia, Finland, Spain, Norway, Germany and Bulgaria.



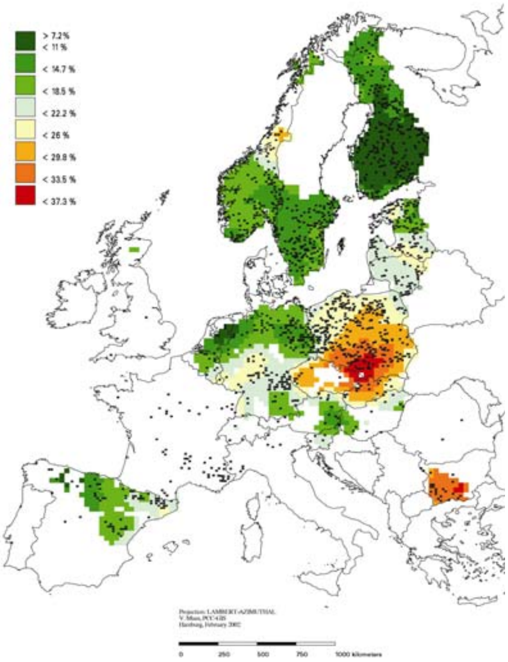
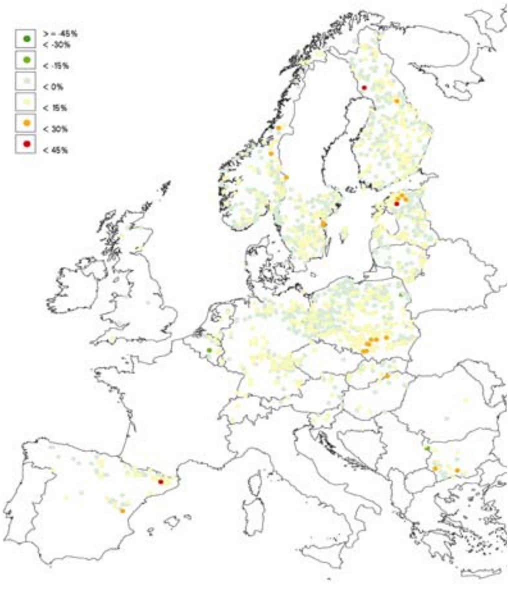


Figure 4.1.2-1: Spatial variation of medium term mean defoliation for *Pinus sylvestris* (plot-wise presentation)

Figure 4.1.2-2: Spatial variation of medium-term mean defoliation for *Pinus sylvestris* (kriging interpolation; nugget: 31.45 sill: 53.7 range: 1020km)



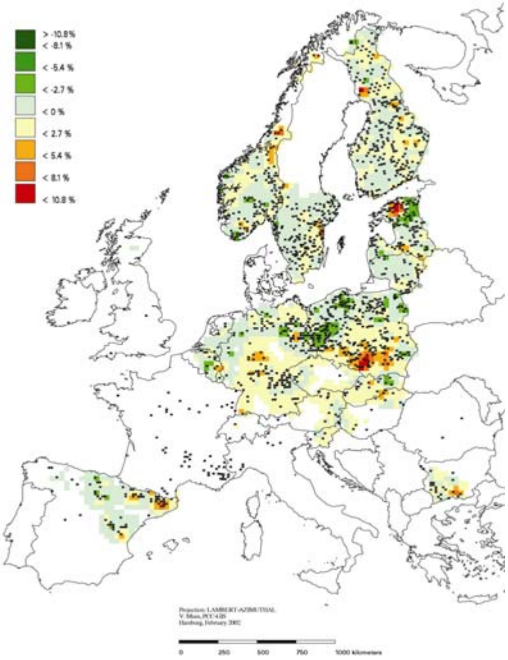


Figure 4.1.2-3: PAD for *Pinus sylvestris* (spatial variation of defoliation corrected for

Figure 4.1.2-4: PAD for *Pinus sylvestris* (kriging interpolation; nugget: 18.7 sill: 10.2

country-wise age effects; plot-wise presentation) range: 70km)

Multiple linear regression models Table 4.1.2-1 can explain a large part of the spatial variation by various predictors. A model only based on country and country-wise age-effects reaches a R^2 value of 60.4%. A model with only country included as predictor reaches 49.5% and a model only including the country-wise age effect explains 27.6% of the observed variance. The inclusion of other variables only causes a comparatively small increase of the R^2. Nevertheless they show plausible results. The index for insect infestation and the deposition of sulphur contribute statistically significantly to the explanation of the spatial variation *Pinus sylvestris* defoliation (model 2, Table 4.1.2-1). The influence of nitrogen deposition shows ambiguous conditions. Whereas the deposition of reduced nitrogen coincides with high defoliation, the deposition of oxidised is negatively correlated with defoliation.

Table 4.1.2–1: Linear regression models for spatial distribution of medium-term mean defoliation of *Pinus sylvestris*; statistically significant predictors shaded.

No.	R^2	precipitation [mm]	insect	fungi	deposition [g/m^2]			country	$age_{country}$
	[%]	Jan.-Jun.			S	NHy	NOx		[year]
1	60.9	-0.007	+4.1		+2.1	+0.9	-1.2	o	o
2	60.8		+3.7		+1.9			o	o
3	60.4							o	o

prec jan-jun	difference of mean precipitation from January to June in the years 1994 to 1999 from the long term mean precipitation in the same months in the years 1961 to 1990
insect, fungi, deposition	plot-wise means of the values for the years from 1994 to 1999
country	class variable
$age_{country}$	age of stand in years, calculated country-wise

4.2 *Fagus sylvatica*

For the evaluation of the temporal and spatial variation of defoliation for *Fagus sylvatica* 399 plots were available with complete data for the period from 1994 to 1999. For evaluations including water availability this number was reduced to 333 and for pH in the topsoil there were only 341 plots available. The integration of both parameters reduces the number of plots to 277. The maps shown in this section, however, are based on the database of 399 plots.

4.2.1 Temporal variation of defoliation

The temporal trend of *Fagus sylvatica* mapped in Figure 4.2.1-1 plot-wise and in Figure 4.2.1-2 after a kriging interpolation, shows high spatial variability in Europe. This is reflected by the relatively low range of 100 km of the adapted theoretical semivariogramm (not depicted). The maps represent the plot-wise calculated regression coefficients for YEAR of model 2 in Table 4.2.1-1.

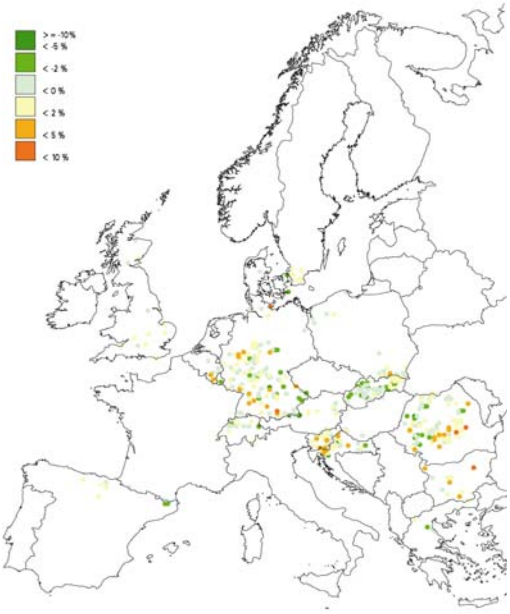


Figure 4.2.1-1: Linear temporal trend of defoliation for *Fagus sylvatica* (plot-wise presentation)

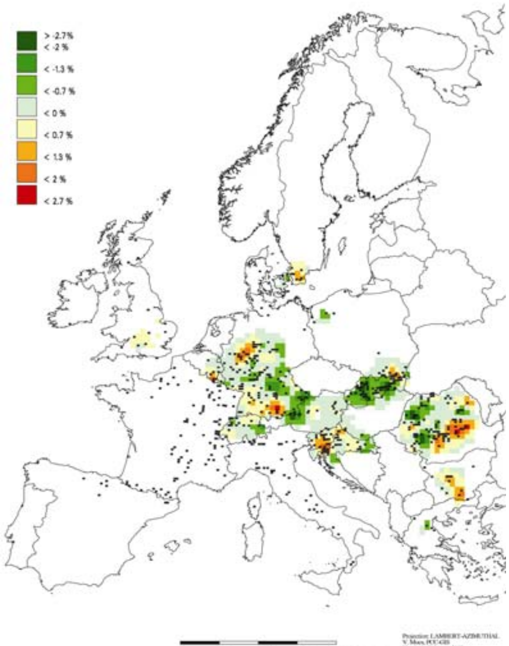


Figure 4.2.1-2: Linear temporal trend of defoliation for *Fagus sylvatica* (kriging interpolation; nugget: 2.06 sill: 1.78 range: 100 km)

Figure 4.2.1-3 and Figure 4.2.1-4 show the regression coefficients for YEAR of model 1 in Table 4.2.1-1. The inclusion of the additional predictors leads to other plot-wise regression coefficients for YEAR.

The most comprehensive model number 1 (Table 4.2.1-1) explained 39.3% of the temporal variation of defoliation on *Fagus sylvatica*. This is quite high in view of the low number of predictors. The fact that 37.4% of the variation can be explained by a linear trend itself should not be over emphasised. In contrast to the other predictors, the linear temporal trend is only a descriptive component that can not directly contribute to the explanation of cause-effect relationships. A part of its explanation power (in the statistical sense) and even 2% more can be explained by the other predictors. Nevertheless the linear trend over time is a predictor variable of high explanation power and emphasises that further factors influence defoliation, which could not yet be described by the other predictor variables.

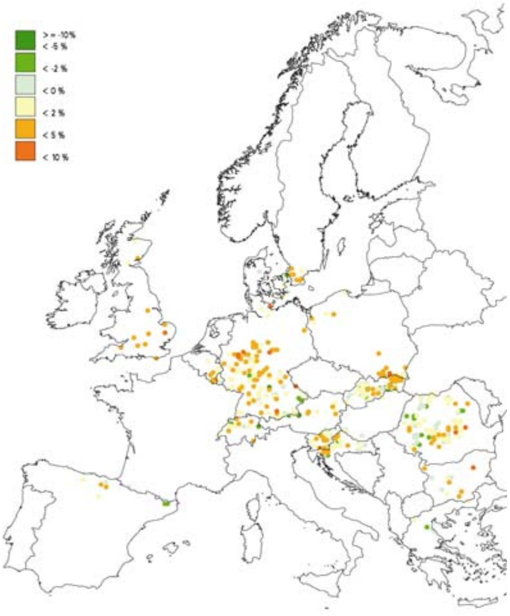


Figure 4.2.1-3: Unexplained linear temporal trend of defoliation for *Fagus sylvatica* according to model 1 of Table 4.2.1-1; plot-wise presentation

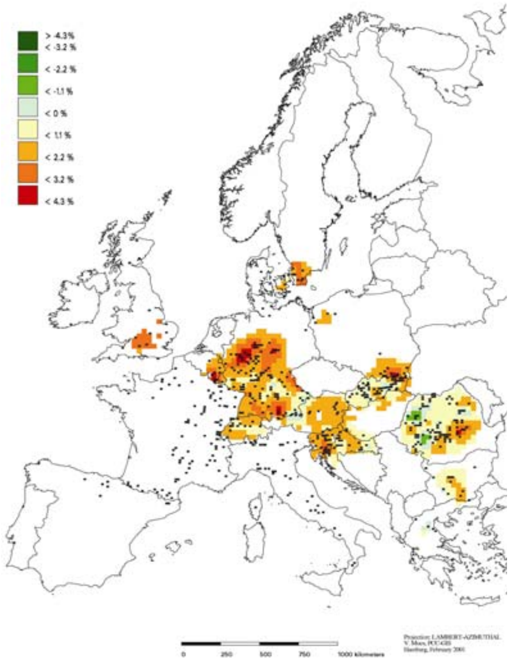


Figure 4.2.1-4: Unexplained linear temporal trend of defoliation for *Fagus sylvatica* (kriging interpolation; nugget: 1.5 sill: 2.3 range: 120 km)

For *Fagus sylvatica* the precipitation sum from April to September was used instead of January to June, which was used in case of *Pinus sylvestris*. The sum of precipitation of the first half of the year led to implausible positive correlations in the models of *Fagus sylvatica* and was therefore rejected. The sum of precipitation in summer (April to September) showed stronger correlation with defoliation than the annual sum of precipitation and was therefore selected as the only index for drought stress.

Table 4.2.1–1: Linear regression models for temporal variation of defoliation of *Fagus sylvatica*; all predictors were included referenced (2.5.3); no predictor statistically significant.

No.	R^2	precipitation [mm] Apr.-Sep.	insect	fungi	deposition [g/m^2]			YEAR 1)
					S	NHy	NOx	
1	39.3	-0.002	+3.2	+0.3	+15.9	-33.1	+1.6	o
2	37.4							o

1) The regression coefficients for YEAR are calculated plot-wise, vary concerning their sign, and can therefore not be tested for plausibility for all plots in one test

The regression coefficients of all other predictors (see model 1 in Table 4.2.1-1) show plausible signs. The indices for the impact of insects and fungi showed a positive correlation with defoliation (the higher the index value, the higher the defoliation). The deposition of sulphur coincides with higher defoliation, which might be explained by its acidification effect. The deposition of reduced nitrogen shows a negative sign, suggesting that lower defoliation coincides with higher deposition values.

4.2.2 Spatial variation of defoliation

Four maps show the spatial variation of *Fagus sylvatica* (medium-term mean defoliation in Figure 4.2.2-1 and Figure 4.2.2-2, preliminarily adjusted defoliation, PAD, in Figure 4.2.2-3 and Figure 4.2.2-4). The PAD maps in particular show a picture of high variability.

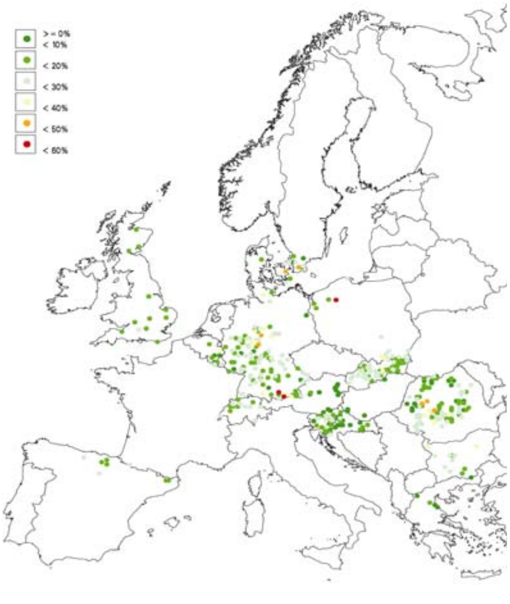


Figure 4.2.2-1: Spatial variation of medium term mean defoliation for *Fagus sylvatica* (plot-wise presentation)

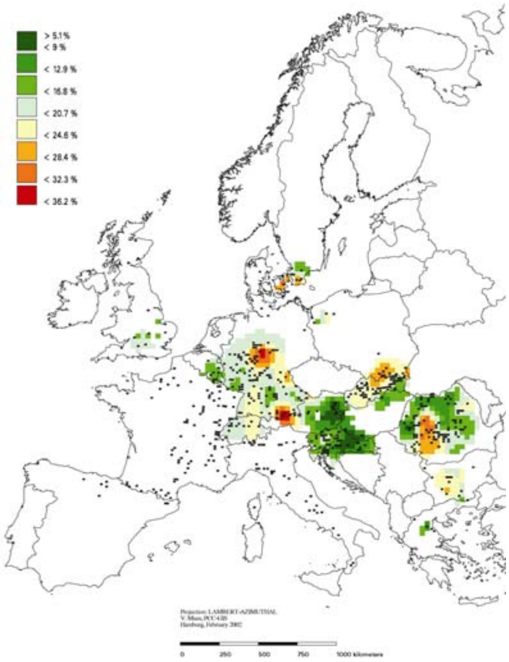


Figure 4.2.2-2: Spatial variation of medium-term mean defoliation for *Fagus sylvatica* (kriging interpolation; nugget: 34 sill: 51.5 range: 160km)

Both pictures of the level of defoliation on the plots, the absolute one (Figure 4.2.2-1 and Figure 4.2.2-2) as well as the PAD, which is the difference of medium-term mean defoliation on the plots to the model value for country-wise age effects (Figure 4.2.2-3 and Figure 4.2.2-4), show high variation of defoliation in Europe for *Fagus sylvatica*. Whereas the absolute values of medium-term mean defoliation show a border effect between Austria and Slovak Republic, there is a smooth transition in PAD maps.

The highest variability of defoliation is found within Germany and Romania. In the north and south of Germany as well as in the centre of Romania and in the south of Sweden the level of defoliation is very high.

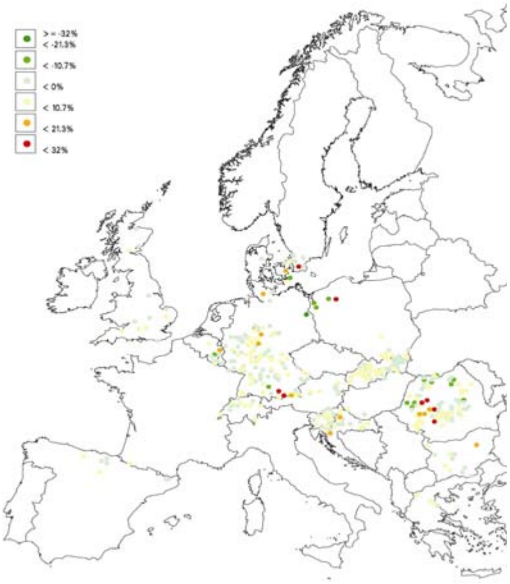


Figure 4.2.2-3: PAD for *Fagus sylvatica* (spatial variation of defoliation corrected for country-wise age effects; plot-wise presentation)

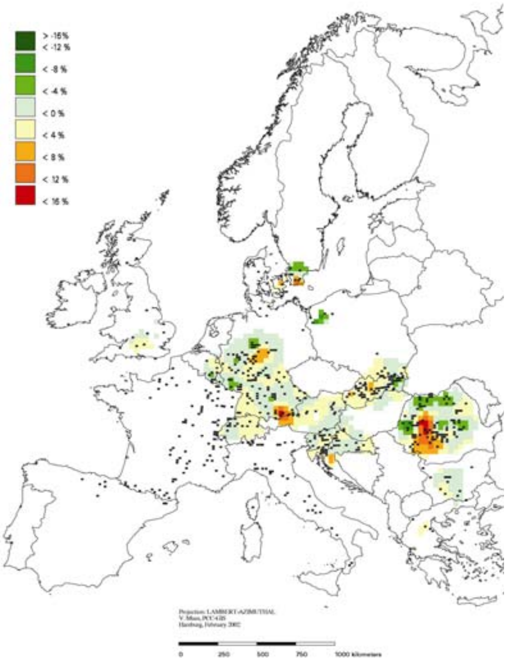


Figure 4.2.2-4: PAD for *Fagus sylvatica* (kriging interpolation; nugget: 22.75 sill: 30.75 range: 110km)

The linear regression models explaining the spatial variation of medium-term mean defoliation (Table 4.2.2-1) reach R^2 values of over 40%. The explanation by country-wise age effects alone can explain 38.1% of the spatial variation. More interesting in sense of cause-effect relationships is the statistically significant contribution of the precipitation index and the index for fungi infestation, both showing plausible signs. Whereas the regression coefficient for the precipitation index is negative (the more precipitation, the less defoliation), the fungi index is correlated positively with defoliation.

In addition to the two statistically significant predictors additional plausible ones were found. Again nitrogen compounds show ambiguous relations. In contrast to the spatial distribution of defoliation on *Pinus sylvestris*, in model 1 (Table 4.2.2-1) reduced nitrogen shows a negative correlation with defoliation and oxidised nitrogen a positive one.

Table 4.2.2–1: Linear regression models for spatial distribution of medium-term mean defoliation of *Fagus sylvatica*; statistically significant predictors shaded.

No.	R^2 [%]	precipitation [mm] Jan.-Jun.	insect	fungi	deposition [g/m^2] S	NHy	NOx	country	age$_{country}$ [year]
1	41.1	-0.027	+4.0	+13.6	+0.2	-7.3	+9.0	o	o
2	40.2	-0.022		+15.1				o	o
3	38.1							o	o

prec jan-jun	difference of mean precipitation from January to June in the years 1994 to 1999 from the long term mean precipitation in the same months in the years 1961 to 1990
insect, fungi, deposition	plot-wise means of the values for the years from 1994 to 1999
country	class variable
age$_{country}$	age of stand in years, calculated country-wise

5 NATIONAL SURVEY REPORTS in 2001

In 2001, 33 countries contributed summaries of their national Level I crown condition survey results. These reports are presented in the following.

Numerical data presenting the crown condition in the participating countries were made available by 34 countries. These tabulated results are presented in Annex II. In Annex II-1 basic information on the forest area and survey design of the participatory countries is given. The distribution of the trees over the defoliation classes for all species is given in Annex II-2. Annexes II-3 and II-4 contain the data for conifers and for broad-leaved trees, respectively. The annual changes of crown condition are presented for all species in Annex II-5, for the conifers in Annex II-6, and for broad-leaved trees in Annex II-7. Graphical presentations of the results are given in Annex II-8. It has to be noted, however, that it is not possible to directly compare the national survey results of individual countries. The sample sizes and survey designs may differ substantially and therefore conflict with comparisons. Gaps in the Annexes, both tabulated and plotted, may indicate that data for certain years are missing. Gaps also may occur if large differences in the samples were given e.g. due to changes in the grid, or the participation of a new country.

5.1 Northern Europe

5.1.1 Estonia

Forest condition in Estonia has been systematically assessed since 1988. 2136 trees were assessed in 2001 on 89 permanent Level I plots.

In former years the most defoliated tree species in Estonia was *Pinus sylvestris*. However, an improvement of crown condition was observed from 1991 to 2000. The percentage of healthy trees was 40.9 in 1988 but only 22.3 in 1991, 37.2 in 1995 and 43.1 in 2001. 7.2% of the assessed *Pinus sylvestris* trees were in the defoliation classes 2–4 in 2001. In 2001 the share of healthy *Picea abies* was 2.4 percent points lower than in 2000 and 17 percent points lower than in 1995. The percentage of healthy *Picea abie*s on Level I plots was 62.6 in 1988, 58.3 in 1991, 74.6 in 1995 and 57.3 in 2001. The percentage of dead *Picea abies* (2.3 in 2001) was the highest since the beginning of the assessments. In total, the state of the deciduous species was markedly better than that of the conifers, but the share of damaged deciduous species was clearly higher than in 1999.

As in previous years, the most severe defoliation of *Picea abies* and of *Pinus sylvestris* occurred in the western and north western part of Estonia.

Diseases, especially the shoot blight caused by *Ascocalyx abietina* and needle cast caused by *Lophodermium seditiosum* played an important role as damage causes for *Pinus sylvestris*. Warm and dry summers in 1999 and 2001 might be a reason for drought stress and the colonisation of *Picea abies* by bark beetles. Heavy wind damages which occurred in December 1999 and July and November 2001, could be another reason of increased defoliation of *Picea abies*. Some sample points with high levels of defoliation of *Picea abies* were close to local sources of air pollution in the north east of Estonia.

5.1.2 Finland

The 2001 forest condition survey was conducted on 454 sample points arranged in 24 x 32 and 16 x 16 km grids. No changes were observed in the average defoliation level of any tree species between the years 2000 and 2001. In 2001 the average defoliation was 9% in *Pinus sylvestris,* 19% in *Picea abies,* and 12% in broad-leaves. Tree mortality was at the same level as in the previous years (0.2%).

On *Pinus sylvestris* and broad-leaves the proportion of discoloured trees (extent of discoloured needle/leaf mass more than 10%) remained at the same level (under 1%) as in 2000, and that of *Picea abies* decreased from 8% to 6%. The most frequent discolouration symptoms were needle tip yellowing and needle yellowing.

The most extensive cause of forest damage in 2001 were the heavy storms in November. They caused a volume of over 7 million m^3 wood being lost as wind throw in southern Finland. Due to the very warm and rainy autumn in 2000, fungal diseases were more common in 2001 than in 2000. In some regions in southern and western Finland, the outbreak of *Gremmeniella abietina* on *Pinus sylvestris* was the worst for more than a decade. Rust fungi, especially *Chrysomyxa ledi* on *Picea abies*, were common throughout almost the whole country. There were no extensive insects outbreaks in 2001. No correlation was found between the defoliation pattern of conifers or broad-leaves and the modelled sulphur or nitrogen deposition (1993) at the national level.

5.1.3 Latvia

The forest condition survey 2001 in Latvia was conducted on 365 permanent monitoring plots.

Mean defoliation of *Pinus sylvestris* in the year 2001 was 21.0%, slightly lower than in 2000 (21.8%). The improvement has been observed since 1993 when the defoliation level reached 33.2%. In 2001 the proportion of moderately and severely damaged trees has, as compared to 2000, decreased from 18.5% to 14.0%. *Picea abies* has shown a slight improvement in crown condition after some years of deterioration. In 2001 mean defoliation was 20.8%, in 2000 it was 21.5%. The proportion of undamaged and slightly damaged trees has increased by 3.8 percent points. After a deterioration period since 1996 defoliation of *Betula pendula* has decreased by 2 percent points compared to the year 2000.

Conifers were mostly damaged by game (29% of the damaged trees), direct action of man (24%), fungi (21%) and abiotic factors (20%). Broad-leaves suffered mainly from insect damages (63.5% of the damaged trees).

5.1.4 Lithuania

The forest condition survey 2001 was conducted on a network of 286 permanent sample plots in a combined 16 x 16 and 8 x 8 km grid. In total 6 664 sample trees representing 12 tree species were assessed.

With respect to all species, 14.6% of the sample trees showed no symptoms of defoliation (defoliation class 0). 11.7% of the trees were assessed as damaged (defoliation classes 2-4). The mortality rate for the trees was 0.7%. In 2001, the average defoliation of all species was 19.9% (20.8% in 2000). For *Fraxinus excelsior* a severe deterioration has been observed since 1996. The highest proportion of damaged trees of this species (51.2%) was recorded in 2001. In 2001 discolouration (classes 1-4) was observed on 0.2% of the conifers and 0.6% of the broad-leaves.

Only 6.7% of all trees assessed had symptoms of identified damage type in 2001. This was the lowest percentage since 1991. The slight improvement in crown condition of the main tree species is considered as a response to the stepwise decrease of air pollution during the last decade and to the more favourable climatic conditions (higher precipitation during the vegetation period in 2001).

5.1.5 Norway

32.0% of all sample trees on Level I plots showed no defoliation. The mortality rate for trees was 0.5%. Average crown density was 80.6% (81.2% in 2000), 82.4% (82.8% in 2000) and 77.3% (76.4% in 2000) for *Picea abies*, *Pinus sylvestris* and *Betula pendula*, respectively. There were 36.4% (41.3% in 1999) fully leafed conifer trees and 17.3% (14.7% in 1999) fully leafed *Betula pendula* trees. Of the spruce trees, 23.9% (21.7% in 2000) were discoloured. Of the *Pinus sylvestris* trees, 11.1% (4.1% in 2000) were discoloured. Only minor changes in discolouration were detected for *Betula pendula* since last year.

The main identified damage symptom in 2001 was related to attacks of fungi (*Gremmeniella abietina*) on *Pinus sylvestris* in southern Norway.

In general, the observed crown condition results from an interaction between adverse climate, pests, pathogens and general stress. The results of this year's assessment confirm the forest vitality recorded over the last few years.

See also: www.NISK.no/forskning/skogpatologi/ops

5.1.6 Russia

The 2001 survey was carried out on 130 plots on the regional level (Leningrad region and part of Pskov region, 5800 mln hectares of investigated area), using grid sizes 16 x 16 km and 32 x 32 km. 2966 sample trees were assessed, mostly *Pinus sylvestris* as the most sensitive indicator of air pollution.

Considering all investigated trees, the results of 2001 confirm the continuous trend of deterioration of health condition in north-western Russian forests. There were no major changes in crown condition compared to 1997-2000.

41.7% of all investigated trees showed no symptoms of defoliation, 48.5% were slightly, 8.6% moderately, and 0.3% severely defoliated, 0.9% were dead.

For the share of trees in defoliation classes 2, 3, and 4 an increase by 3.8 percent points was observed, compared to 1990. The deterioration on Scots pine was mostly caused by insects (*Tomicus piniperda, Tomicus nigra*) and human impact (crushed trees and plots were excluded from calculations).

The concentration of the main air pollutants has considerably decreased since the beginning of the survey in 1990. The industry emission amount was reduced more than twice during 1992-2000 in the survey area. Areas of clean zones with low deposition of sulphur dioxide, dust and other pollutants increased. Numerous sample plots came out from aerial contamination zones of industry emitants. However, influence of diffuse sources (traffic, domestic heating, far transport, fire), deposition, and recreation press are still high.

In all, 2001 was the fifth of period of years slowly revealing a stabilised trend in defoliation.

5.1.7 Sweden

In 2001 defoliation of *Pinus sylvestris* and *Picea abies* deteriorated in the southern part of the country. An increased defoliation of *Picea abies* in northern Sweden has been recorded in 2001 and marks the end of the improvement noticed since the mid 90ies. Only small changes in discolouration have been recorded. Discolouration is particularly low for *Pinus sylvestris*.

An outbreak of *Gremmeniella abietina*, the largest for decades, strongly influenced the damage situation in 2001. The mostly affected areas are located in mid Sweden and the central part of southern Sweden. Almost 400 000 ha of the pine forest were slightly affected, i.e. more than 10% of the trees show symptoms on more than 25% of the tree crown. Severe damage was observed on about 80 000 ha of the pine forest. Other known biotic damages occurred to an extent comparable to previous years.

The forest damage level as well as the year-to-year variation is interpreted as an effect of natural stress factors. Air pollution inflicts and interacts with these factors.

5.2 Central Europe

5.2.1 Austria

Following a deterioration of crown condition in the last year, the 2001 crown condition survey again showed an increase in defoliation with respect to all investigated species. The proportion of not defoliated trees decreased by 5.5 percent points, the proportion of severely damaged trees increased by 0.8 percent points. A remarkable deterioration occurred for *Pinus sylvestris* and *Fagus sylvatica.* The percentages of not defoliated trees decreased by 19.1 and 18.0 percent points respectively. The most common coniferous species *Picea abies, Abies alba* and *Larix decidua* showed a minor deterioration. Out of the main tree species only the crown condition of *Quercus* spp. improved. The proportion of not defoliated trees increased by 15.1 percent points while the proportion of severely damaged trees decreased by 10.1 percent points. The improvement of crown condition of this species is partly due to the fact that 10% of the sample trees have been removed since last year's survey.

Identified damage types were recorded for about 47% of the sample trees. The main reason for this year’s deterioration of crown condition is considered to be the climatic influence. The temperatures for spring and summer 2001 exceeded the long term average. The amount of precipitation in some parts of Austria was far below the long term mean and damages caused by drought were observed in summer. Another reason for the comparatively high defoliation might be the intense flowering of the main tree species observed in 2001 as scientific studies show a correlation between flowering and defoliation.

5.2.2 Croatia

The forest condition survey 2001 was carried out on 81 sample points on the 16 x 16 km grid net.

Despite a relatively high degree of damage, forest condition in Croatia has remained stable in the course of the last few years. Monitoring results for the year 2001 have not shown major differences in the percentage of trees within classes 2-4 (all species), compared to 2000. Due to the low share of conifers, their high damage is hardly reflected in the result for all species

Abies alba is the most damaged species. The lowest value, 36.6% of moderately to severely damaged trees was recorded in 1988, whereas in 1993 the share was 70.8%. In the year 2000 it reached 77.1%, and this year it is exceptionally high with 84.5%. The lowest damage for *Quercus robur* was recorded in 1988 (8.1%), the maximum in 1994 (42.5%), while it has been fairly constant in the past few years at around 25-30%. This year it decreased to 16.7%. For *Fagus sylvatica*, the share of trees in classes 2-4 remained low in the past ten years, but in comparison with the year 2000 (5.7%) it more than doubled in 2001.

The main ecological factor influencing tree defoliation was late frost, especially in the lowland parts of Croatia where oak was severely damaged. A positive effect of the frost was however, that the attack of defoliators was less prominent.

5.2.3 Czech Republic

A moderate increase in defoliation was observed for the majority of the forest tree species when compared with the last year’s results. This worsening was reflected in a shift of trees from defoliation class 1 into class 2. The most significant shift was found for the higher age classes of *Larix decidua* and for the total of all age classes of *Fagus sylvatica*.

In 2001 temperature and precipitation conditions were markedly more favourable than in the previous year. However, forest stands (both coniferous and deciduous ones) were heavy mechanically damaged by hailstorm and destructive wind – partly even with the character of a tornado - during the summer season of 2001. The principal share of damage can be assigned to these downbursts. Especially *Picea abies* and *Fagus sylvatica* stands in the central Moravia and the south Bohemia were damaged. *Armillaria ostoyae*, activated by the favourable climatic conditions in the previous year, was most extended in the forest areas of north Moravia where it caused damage in the *Picea abies* stands. *Hypoderma desmazieri* caused by the fungus *Meloderma desmazieriessii* is still causing calamities in the national park “Labské Sandstone”.

In 2001 the decrease of air pollution was more distinct when compared with the previous years. Nitrogen (NOx) has remained approximately at the same level since 1995. In 2000 the exposure index for ozone AOT40 in forests exceeded the critical value 10 ppmh on the greater part (99.8%) of the Czech Republic territory. When compared to the year 1999 the exposure index increased particularly in southern Moravia. It is suspected that these high ozone levels in the year 2000 have increased defoliation of the forest stands in this area in 2001.

5.2.4 Germany

Since 1984 forest condition has annually been surveyed in Germany on a systematic grid net.

After a peak in 1992 mean defoliation of all species had in 1995 again reached the level of the mid-eighties. Since then there has been a stabilisation. The percentages of all species in defoliation classes 2-4 were 22% in 1999, 23% in 2000 and again 22% in 2001. For *Picea abies* and *Pinus sylvestris* the shares of trees in classes 2-4 were 26% and 14% in 2001. The figures have hardly changed since 1995 and remain clearly below the levels calculated at the beginning of the survey in 1984. The situation is different as regards the main broad-leaved species. In the 18-years of monitoring the share of *Fagus sylvatica* showing severe damage increased to 29% in 1998 and further on to 40% in 2000. In 2001 there was a recuperation to 32 %. Between 1984 and 1997 the share of severely damaged *Quercus petraea* and *Quercus robur* increased more or less continuously to 47 % but decreased since then to 33% in 2001. It seems that the negative development of crown condition for these species has now come to an end and that a reverse trend has started.

Numerous factors determine the condition of forests. Climatic factors, insect damage as well as other natural factors have an impact on forest ecosystems and influence tree vitality. Within this context anthropogenic air pollution plays a key role in cause-effect relationships. Air pollution, with its euthrophicating, potentially toxic, acid-forming and alkaline characteristics has a major impact on the nutrient cycle and vitality of forests and their sustainable development.

5.2.5 Poland

The 2001 forest condition survey was carried out on 1 180 permanent observation plots in a national network, including 431 plots of the transnational Level I grid. Each plot consists of 20 marked dominant trees.

Forest condition was almost at the same level as in the previous year. 9.9% of all sample trees were without any defoliation. This is a slight decrease by 0.5 percent points compared to 2000. The proportion of damaged trees (defoliation classes 2-4) decreased by 1.5 percent points to an actual level of 30.6% of all trees. The share decreased by 1.7 percent points for conifers and by 0.6 percent points for broad-leaves. In 2001, discolouration (classes 1-4) was observed at 0.9% of the conifers and at 1.0% of the broad-leaves.

In 2001 a worsening was observed for *Abies alba*, for which the share of damaged trees increased by 11.4 percent points. *Abies alba* remained the species with the highest defoliation (67.3% trees in classes 2-4). In 2001, a share of 42.1% of all *Quercus* spp. was in damage classes 2-4. This species indicated a slight improvement with the share of trees defoliated more than 25% decreasing by 4.7 percent points. Nevertheless, as in the previous survey, the highest defoliation amongst broad-leaved trees was observed for *Quercus* spp.

5.2.6 Slovak Republic

The 2001 national crown condition survey was carried out on 110 Level I plots on the 16 x 16 km grid net. The survey revealed comparatively high defoliation values mainly due to the overall bad crown condition of the conifers. Time series analyses show stable crown condition for broad-leaves and a statistically significant improvement for coniferous species and for the sample of all species.

The assessments covered 4 241 dominant or co-dominant trees. 31.7% of the trees were damaged (defoliation classes 2-4). The respective figures were 38.7% for conifers and 26.9% for broad-leaves. Compared to 2000, the share of damaged trees increased by 8.2 percent points. From 1987 until 2001, the lowest damage was observed for *Fagus sylvatica* and *Carpinus betulus*. The most severe damage was observed for *Abies alba*, *Picea abies* and *Robinia pseudoacacia*.

Compared to 2000, a pronounced increase in average defoliation was observed for *Larix decidua, Carpinus betulus,* and *Fagus sylvatica*. Main reason for the deterioration of the latter two species was the strong fructification.

14.4% of all sample trees had some kind of identifiable damage symptoms. The most frequent damage was caused by logging activities (5.3%) and fungi (3.7%) as a consequence of tree stem damages, followed by insects (2.6%) and abiotic agents (1.5%).

5.2.7 Slovenia

In the 2001 national forest condition survey a total of 984 trees on 41 sample plots was assessed. The sampling and assessment methods were the same as in previous forest condition surveys.

The mean defoliation of all tree species has been estimated with 23.2% while the proportion of damaged trees (>25% defoliation) has attained 28.9%. Both results indicate a statistically increasing defoliation (in 2000 mean defoliation was 22.0%, the proportion of damaged trees was 24.8%).

Since 1985 opposite trends for conifers and broad-leaves can be observed. While the share of damaged conifers decreased (in 1985 it was 42.6%; in 2001 it was 28.8%) the share of damaged broad-leaves increased from 1.3% in 1985 to 22.7% in 2001.

The mean defoliation of *Picea abies* remained at the same level as in 2000, while the share of damaged trees (defoliated more than 25%) slightly decreased by 1.0 percent point. The crown condition of *Fagus sylvatica* has deteriorated. The mean defoliation has increased by 1.5 percent points and so has the share of damaged trees which is 4.2 percent points higher than last year. The deterioration of *Fagus sylvatica* can be largely attributed to heavy hail storms in spring 2001 and to heavy mast production, especially in southern parts of Slovenia.

5.2.8 Switzerland

In 2001 the Swiss national forest health inventory was carried out on the 16 x 16 km grid using the same sampling and assessment methods as in 2000. Following the large increase in defoliation in 2000 (both for the mean defoliation and for the proportion of trees with >25% defoliation), defoliation decreased again in 2001. In 2001 18.2% of the trees had more than 25% unexplained defoliation (i.e. subtracting the known causes such as insect damage, or frost damage), and 26.2% of the trees had more than 25% total defoliation. These results are similar to the ones found in the years 1999 and 1998. Reasons may be the more favourable climatic condition in 2001 and the recovery of trees following the storm in December 1999. From 1985 to 1995 the proportion of trees with more than 25% unexplained defoliation had doubled in Switzerland. Since then a stabilising situation with large annual fluctuations has been observed, which is partially due to the reduced sample size. Due to the small sample size, no evaluations for individual species or regions can be made.

Tree mortality remained at 0.4% annually, which is just about average. Following the storm in December 1999, removal of trees were above average in 2000, and below average in 2001. However, as a consequence of the storm, a large-scale out-break of *Ips typographus* on *Picea abies* has been reported since mid-summer 2001. Although this has not yet influenced the 2001 survey, an increase in spruce mortality and salvage cutting over the next years is expected.

5.3 Southern Europe

5.3.1 Cyprus

The year 2001 was the first year in which the forest damage survey was conducted at Level I plots in Cyprus. The establishment and survey of the plots was carried out by the Forestry Department of Cyprus (Forest Research Section) of the Ministry of Agriculture, Natural Resources and Environment. A total number of fifteen plots was established in 2001 and the survey was carried out in September 2001. Three coniferous species (*Pinus brutia, Pinus nigra* and *Cedrus brevifolia*), being the dominant forest tree species in Cyprus Forests, were included. *Pinus brutia* was represented by 300 trees while *Pinus nigra* and *Cedrus brevifolia* were represented by 36 and 24 trees respectively.

The conducted survey showed that in the year 2001, 25.8% of the total sample trees were not defoliated while 65.3% were slightly defoliated and 8.9% were moderately defoliated. When all species taken together, 98.6% of the sample trees were not discoloured while 0.8% of them showed slight discolouration and 0.6% moderate discolouration.

In *Pinus brutia*, 19.3% of the sample trees showed no defoliation while 70% and 10.7% of them were slightly and moderately defoliated, respectively. In *Pinus nigra*, 75% of the sample trees showed no defoliation while the remaining 25% of them were slightly defoliated. In *Cedrus brevifolia*, 33.3% of the sample trees showed no defoliation and 66.7% of them were slightly defoliated. No discolouration was observed.

From the total number of sample trees inspected, 58.9% showed signs of insect attack and 6.1% showed signs of lichens and rats. Specifically, 35% were attacked by *Leucaspis* spp., 9.7% by *Thaumetopoea wilkinsoni* and 1.4% by both insects. Additionally, 12.8% were attacked by unspecified insect defoliators, 5.3% by lichens and 0.8% by rats (*Rattus rattus*). In addition to the above biotic factors causing defoliation, the adverse climatic conditions (low precipitation and high temperatures) prevailing in Cyprus during the last years seem to contribute to the observed defoliation. No damages were attributed to any of the known pollutants.

Comparisons and more information will be available the coming years, when subsequent surveys at Level I plots will be conducted and the installation of Level II plots will be completed.

5.3.2 Greece

78.3% of all assessed trees were not or slightly, 17.1% were moderately and 3.0% and 1.6% were severely defoliated and dead respectively. In the conifers, 43.1% showed no defoliation, 39.7% were slightly, 13.0% were moderately and 1.9% and 2.3% were severely defoliated and dead, respectively.

A comparison of the 2001 survey results with those of the previous year shows a deterioration in the condition of both coniferous and broad-leaved species.

From the total number of trees inspected, about 25.3% showed signs of insect attack and 12.6%, 1.8%, and 16.9%, showed signs of adverse effects by abiotic, human and “other agents”, respectively. No damages were attributed to any of the known pollutants.

The year 2001 was relatively dry and warm.

5.3.3 Italy

The 2001 crown condition assessment was carried out on 7 351 sample trees on 265 Level I plots of the 16 x16 km transnational grid. Considering the total sample of trees, 38.4% were moderately defoliated to dead (defoliation classes 2-4). The respective shares for conifers and broad-leaves were 19.1% and 46.3%, reflecting a substantial higher defoliation degree in broad-leaves. Compared to the previous year, crown condition of conifers remained stable (-0.1 percent points), broad-leaves deteriorated slightly by 5.8 percent points.

With regard to age classes and tree species, 30.0% of the *Pinus sylvestris* trees younger than 60 years were in defoliation classes 2-4, whereas in this age class *Picea abies* showed a good health status with only 5.1% in defoliation classes 2-4. 14.9% of *Pinus nigra* and 12.5% of *Larix decidua* younger than 60 years were in defoliation classes 2-4. For conifers older than 60 years, condition was worst for *Larix decidua* with 34.4% in defoliation classes 2-4. For broad-leaves in the age class <60 years, 66.5% of the assessed *Quercus pubescens* and 57.0% *Castanea sativa* were in defoliation classes 2-4, whereas *Fagus sylvatica* and *Quercus cerris* showed lower defoliation with only 37.2% and 39.9% of trees in defoliation classes 2-4. In the age class ≥60 years, 91.2% of *Quercus cerris*, 75% of *Quercus petraea*, 61% of *Castanea sativa* and 51% of *Fagus sylvatica* were in defoliation classes 2-4.

Analysing the presence of biotic and abiotic factors as possible causes for defoliation and discolouration, 62.1% of all sample trees revealed one or more damage types. The respective values were 27.8% for conifers and 76.2% for broad-leaves. Insects, fungi and climatic stress were the most frequently observed damaging factors.

5.3.4 Portugal

In 2001, on 144 forest plots a number of 4 320 trees was assessed, of which 72% had an age less than 60 years.

A trend of improving crown condition has been noted for several years and still holds on. For all species, the share of damaged trees reached its maximum with 30.8% in 1990, decreased rapidly to 5.7% in 1994 and was 9.1% in 1995. From 1995 until 2000 a slight variation has been observed, reaching 10.1% in 2001. The largest share of damaged broad-leaves (36.6%) was found in 1991, whilst the share of damaged conifers was at its largest (25.7%) in 1990.

The share of trees in defoliation class 1 increased slightly from 43.3% in 2000 to 43.6% in 2001. This increase is based on the broad-leaves, of which 42.6% were in defoliation class 1 in 2000 and 43.6% in 2001. In 2001, the conifers showed a decrease in the percentage of trees in class 1 (43.7%) compared to 2000 (44.7%).

Quercus suber shows the severest decline since 1988. The share of damaged trees reached a peak in 1991 (52.7%). Also for *Quercus ilex* the respective percentage reached its maximum in 1991 (42.6%). The share of damaged trees was generally far lower for *Pinus pinaster* with a maximum of 26.3% in 1990, and for *Eucalyptus globulus* with 7.3% in 1991. The high defoliation of several tree species in the years 1990 and 1991 is most probably due to fungi and insect attacks as well as to forest fires, triggered by a sequence of dry years (1989 – 1991). The obvious recuperation after that time was interrupted in 1995 mainly due to a new drought period in connection with forest fires. The improvement of crown condition observed in 1996 is interpreted as an effect of more favourable weather conditions. The slight worsening observed from 1997 to 2001, affecting mainly the broad-leaves, can be interpreted as an effect of not so favourable weather conditions.

5.3.5 Spain

In 2001, 87.0% of the assessed trees were classified into defoliation classes 0 and 1. 10.7% of the trees were in classes 2 and 3. These results show a slight improvement compared to 2000. The percentage of dead trees has also decreased remarkably although a more in-depth analysis is necessary to confirm this first impression.

Quercus ilex shows a remarkable improvement, continuing the recovery process initiated in year 2000, although it doesn't reach the level of healthy trees of other species. For *Pinus halepensis* a more accentuated worsening has been observed. Both *Quercus pyrenaica* and *Pinus sylvestris*, typical species of medium slope and high mountain areas show a worsening after the recovery of last year. The erratic behaviour of *Pinus halepensis* during the last years is remarkable.

The observed variations show some regional characteristics. A general improvement has been detected for the *Quercus* forests in Andalucía. The improvement is mainly ascribed to the adequate water supply in the vegetation period. In contrast, the forests on the Baleares seem to continue to suffer from the lack of rainfalls during the last years and from insect calamities. Most relevant were *Tomicus* spp. in pine forests and *Cerambix cerdo* causing the *Quercus ilex* decline. For Madrid, data show a punctual damage due to the drought, which has affected mainly river side trees. In Galicia, the worsening is due to the presence of defoliating insects and fungi, which has doubled the shares of damaged trees, the main cause mentioned is the presence of blight affecting mostly *Pinus* spp. and *Eucalyptus* spp. The development of crown condition in Navarra is totally erratic and with the current data it is impossible to detect causes, which have negatively affected the general state of forests there.

Country wide insects, fungi and parasitic phanerogams made up for 38% of the assessed damages, followed by abiotic damages, mainly water shortage with 28%. The importance of atmospheric pollution for the development of forest health can not be quantified directly, due to the fact that it is disguised by other processes which are more apparent. However it predisposes forest stands for additional directly acting damage factors.

5.3.6 Yugoslavia

The national crown condition survey was carried out on 114 Level I plots of the 16 x 16 km transnational grid. The assessments include 379 conifers and 2 295 broad-leaved trees.

For the total tree sample, 65.2% of the trees belonged to class 0 (not defoliated), 20.8% to class 1 (slightly defoliated), 14.0% to classes 2-3 (moderately to severely defoliated) and 0.4% to class 4 (dead trees). In comparison to last year, the percentage of damaged conifers has increased except for *Abies*. The increase is negligible for the subsample of all broad-leaved trees. An increased percentage of damaged trees has been noted for *Carpinus betulus*, *Populus* spp. *Fraxinus* spp., *Quercus freinetto* and *Fagus sylvatica*.

The die-back trend is continuing, especially after extremely dry months and high temperatures during the summers of the previous years.

In 2001 for the first time chemical analysis of leaves and needles were carried out at four plots.

5.4 Western Europe

5.4.1 Belgium

Wallonia

The mean defoliation since 1993 seemed stable for *Quercus* spp., with a small increase this year. For *Picea abies* it decreased however. For *Fagus sylvatica* it has increased continuously since 1996; the small decrease in 2001 is due to a high number of replaced trees. Common sample trees show an increase in mean defoliation from 15.6 in 1999 to 18.3 in 2001. *Quercus robur* and *Fagus sylvatica* show the worst condition. A slight increase was observed for discolouration, both for conifers and broad-leaves.

Identifiable damage types were observed on only 10.1% of the trees in 2001; nevertheless, insects, sometimes fungi and abiotic agents could explain the annual changes of defoliation, as they are linked to higher defoliation rates.

The special problem which occurred for *Fagus sylvatica* in the Ardennes in 2000 has increased in 2001: a special inventory in May-June showed very high damage by *Scolytidae* (mainly *Trypodendron signatum* and *T. domesticum*) and fungi (mainly *Fomes fomentarius*); damaged trees recorded in 2001 constitute for about 10% of the standing *Fagus sylvatica* wood volumes, when taking into account any level of damage. Special measures have been taken, aiming to take damage trees out of the forests and to control the insect population levels (use of trap-trees with pheromons and pyrethroids). The condition of *Quercus* spp. and *Fagus sylvatica* stands is a major concern in Wallonia, without single identifiable causes for *Quercus* spp. Nevertheless, poor soils, especially for Mg, Ca and sometimes P, partly explain the problem, while nitrogen deposition is a cause of aggravation.

Water availability was good in 2000, with very high rainfall (highest since 1833) in spring and in September.

Flanders

The annual crown condition assessment was conducted on 72 plots in a 4 x 4 km grid. In 2001 the share of trees in defoliation classes 2-4 was 22.1%. Discolouration was observed on 5.4% of the trees. Only 16.7% showed no symptoms of defoliation. The mortality rate was 0.5%. With 21.4% of the trees damaged, the condition of conifers was slightly better compared to broad-leaves (22.5% damaged). Both defoliation and discolouration decreased compared to previous year. The share of damaged trees decreased by 2.6 percent points.

The proportion of trees with moderate to severe leaf loss remained at the same level for broad-leaves (-0.9 percent points) and decreased by 6.1 percent points for conifers. Crown condition improved for *Fagus sylvatica* and *Quercus robur* but deteriorated for *Quercus rubra* and *Populus* spp. *Fagus sylvatica* is the species with the lowest defoliation. For *Fagus sylvatica* and *Quercus robur* 12% and 24% were classified in defoliation classes 2-

4, respectively. The share of damaged *Quercus rubra* increased to 26%. *Populus* spp remains the species with the worst crown condition. The percentage of trees with moderate to severe damage amounted to 49%. Crown condition of coniferous species improved. The share of damaged trees decreased to 18% for *Pinus sylvestris* and 34% for *Pinus nigra subsp. laricio*.

Several *Quercus* spp. plots were damaged by winter moth (*Erannis defoliaria* and *Operophtera brumata*). Insect attacks occurred in May but damage was still visible by the time of the crown assessments. In some plots severe leaf loss was observed for five consecutive years. Damage by the red-black pine bug (*Haematoloma dorsatum*) in *Pinus* stands was less important than in 2000. The improved crown condition of *Fagus sylvatica* was partly attributable to the smaller mast production compared to previous year. Contrary to the southern part of Belgium, *Fagus sylvatica* die-back did not occur on a large scale.

5.4.2 Denmark

In 2001 the mean defoliation and the share of damaged trees was the lowest since 1990 for *Quercus* spp. and *Fagus sylvatica*. The defoliation of *Picea abies* was at the same level as in 2000.

The results of the crown condition survey in 2001 showed that 66% of all coniferous trees and 48% of all deciduous trees were undamaged. 27% of all coniferous and 43% of all deciduous trees showed warning signs of damage, and 7% of all coniferous trees and 9% of all deciduous trees were damaged.

There was no major change in the health condition of *Picea abies* from 2000 to 2001. However, the mean defoliation improved from 12% to 11% and the share of damaged trees decreased from 10% to 6%.

The mean defoliation for *Fagus sylvatica* decreased from 16% in 2000 to 13% in 2001. This is the lowest defoliation ever recorded since the survey started. The share of damaged trees decreased remarkably from 14% to 7%.

The condition of *Quercus* spp. in Denmark is influenced by attacks of *Operophtera brumata*, *Tortrix viridana* and *Microsphaera alphitoides*. The levels of defoliation have been high compared to the other tree species during all years since the crown condition survey started. The mean defoliation was particularly high in 1996 and 1997 (34% in both years). In 1998 and 1999 the defoliation decreased to 28% and 29%. In 2000 and 2001 the mean defoliation decreased to 22% and 19% and the share of damaged trees decreased to 19% and 14%.

5.4.3 France

In the 2001 survey, 10 373 trees were assessed on 519 plots. Since the severe storms in 1999 assessments at 30 Level I plots are interrupted until the trees will again have the minimum height for assessment.

In general, a slight increase in defoliation could be stated for most species in 2001 contrarily to a slight decrease observed in the three previous years. Broad-leaves still show a distinctly higher defoliation than conifers. Discolouration varies within the different species, remains however on a low degree effecting only about 10% of the assessed trees. The percentage of dead trees has slightly increased but is still on a very low level with 0.2% dead trees. 2.3% of the total sample trees were replaced in 2001; for more than half of the trees the reason is unknown; only 14 conifers were replaced for reason of *Scolytidae* attacks, whereas one estimates about 1 million m^3 of dead wood due to damage by *Scolytidae* in total France. The percentage of dead trees assessed in 2001 does not actually reflect the full extent of mortality as the bark beetles usually cause very localised damage. Altogether, bark beetle damage was estimated to about 1 million cubic meter (mostly in northeastern France and in the Aquitaine).

Since five years damage due to abiotic and biotic factors have been assessed, since 2000 also indicating the damage level. The increase in defoliation observed in 2001 may be due to some of the following damage factors: *Micropsphaera alphitoides* on *Quercus petraea*, *Coreobus bisfasciatus* on *Quercus pubescens*, *Rhynchaenus fagi* on *Fagus sylvatica*, and *Crumenulopsis sororia* on *Pinus halepensis*.

Regarding climate, overall few climatic anomalies were recorded in 2001, with the exception of a heat wave in the Mediterranean area. The possible influence of excessive rain (which triggered flooding) is difficult to assess. An increase of defoliation between 2000 and 2001 was found in the areas damaged by the 1999 storms, but it is not clear whether it is a coincidence or an after-effect of the storms (damage to roots).

5.4.4 Ireland

The annual assessment of crown condition was conducted on the Level I plots in Ireland between July 18thand September 5th 2001. Overall mean defoliation and discolouration was 15.8% and 4.9% respectively. This represents a deterioration in crown condition of Irish forests between the 2000 and 2001 survey of 1.4 percent points for defoliation but an improvement of 0.2 percent points for discolouration. Defoliation levels recorded in 2001 were greater than the 12-year average of 15.4% but discolouration in 2001 was well below the 12 year average of 4.9% points. In terms of species, defoliation decreased in the order of *Picea abies* (26.3%) > *Pinus contorta* (15.1%) > *Picea stichensis* (13.1%), while the trend in discolouration was in the order of *Pinus contorta* (7.4%) > *Picea stichensis* (4.2%) > *Picea abies* (1.5%). These results do not vary significantly from those recorded in the 2000 survey.

The trends in crown density among species are similar to last years survey. In 2001, *Picea abies* had the highest defoliation levels as was observed in 2000 and 1999 also. This was the result of a combination of defoliation levels decreasing in *Pinus contorta* and increasing somewhat in both spruce species. *Pinus contorta* had the highest discolouration levels of the three species in 2001, which was also the observation in last years survey.

The number of trees with absolutely no damage (i.e. 0% defoliation and 0% discolouration) increased in 2001 by 3% points to 17% of trees in the survey. An additional 33% of trees had such low levels of defoliation and discolouration that the causes of damage were indiscernible. However, this represents a considerable reduction, some 11% points, in the number of trees recorded in this category in 2000. Of the remaining trees where causes of damage could be identified, approximately 17% of trees had greater than 25% defoliation and less than 5% of trees had greater than 25% discolouration. Exposure continued to be the greatest single cause of damage to the sample trees in 2001. The instances of observed aphid damage were similar to 2000 with less than 3% of trees affected in 2001. (Over 14% of trees were affected by aphids in the 1998 survey.) Other damage types (shoot die-back, top-dying, nutritional problems, and sawfly damage) accounted for damage in a very small percentage of the trees. Damage due to grazing was apparent in 2001 for the first time in this survey; recorded on the young spruce trees at Ballinglen. No instances of damage directly attributable to atmospheric deposition were recorded in the 2001 survey.

5.4.5 The Netherlands

Since 1999 crown condition has been assessed only on the 11 plots of the systematic gridnet and on 14 plots of the intensive monitoring plots. The data from the systematic gridnet show that for conifer species the crown condition is stable, while broad-leaved species, in particular *Quercus* spp. show an increase in defoliation.

5.4.6 United Kingdom

As in 2000, rainfall was well distributed throughout the growing season and growth was generally good in all five species included in the survey, namely *Picea abies*, *Pinus sylvestris*, *Picea sitchensis*, *Quercus robur* and *Fagus sylvatica*. Considering all species together, crown condition was similar to that recorded last year, continuing a period of little change since 1998.

A marked improvement in the condition of *Fagus sylvatica* was largely attributable to much reduced mast formation compared to last year, although recovery was not complete, probably reflecting an increase in the incidence of damage by *Rhynchaenus fagi* in 2001. The condition of *Quercus robur* was largely unchanged since last year and continued to display marked regional differences. Whilst severe reductions in the crown density of *Quercus robur* were generally associated with defoliation by winter moths such as *Operophthera brumata* and *Erranis defoliaria*, the dieback of unknown cause known as “oak decline” was recorded in a few cases.

Among the conifers, *Picea sitchensis* displayed little change in condition with the incidence of damage by *Elatobium abietinum* being generally low. Increases in the incidence of male flowering, damage by *Tomicus piniperda* and defoliation by the fungus *Lophodermium seditiosum*, contributed to a slight deterioration in *Pinus sylvestris*. An improvement in the condition of *Picea abies* largely reflected a reduction in the incidence of shoot dieback caused by *Cucurbitaria piceae* combined with an increase in the production of secondary shoots by a majority of the surveyed trees.

5.5 South-eastern Europe

5.5.1 Bulgaria

In 2001 the forest condition survey was carried out on 120 plots in a grid net of 16 x 16 km, 8 x 8 km and 4 x 4 km. A total of 4 323 sample trees was assessed, 2 415 of them conifers and 1908 broad-leaves.

For all assessed tree species the share of slightly to severely damaged trees (defoliation classes 1-4) decreased significantly compared to the 2000 results. Trees without visible defoliation increased from 20.3% in 2000 to 31.6% in 2001. In general, the condition of the conifers improved in the current year. For trees younger than 60 years the shares in class 0 increased significantly by 15.8 percent points for *Pinus sylvestris* and by 14 percent points for *Abies alba*. However, a deterioration of crown condition of *Picea abies* was observed - the share of not defoliated trees decreased by 40 percent points. The crown condition of all conifers older than 60 years improved. The share of trees without visible damage (defoliation class 0) increased significantly by 20.6 percent points for *Pinus sylvestris*, by 16.1 percent points for *Pinus nigra* and by 35.3 percent points for *Abies alba* compared to the 2000 results. The condition of the broad-leaves was better compared to the 2000 results. *Fagus sylvatica* was in a better condition than *Quercus* spp. Compared to the 2000 results, a positive trend was however observed for *Quercus* spp. Moderately to severely damaged trees decreased in both age groups. The only exception was the increase of dead oak trees older than 60 years by 7.6 percent points.

As in previous years forest condition was influenced by a number of natural and anthropogenic stress factors, the importance of which depends on the region, tree species, and site characteristics. In particular, attacks by *Cecidomyia fagi*, *Rhinchaenus fagi*, *Cynips kollari*, *Leucaspis* spp., *Chermes abietis, Botrytis cinnerea, Dryomia circinuans, Melampsorella caryophylla, Lophodermium pinastri, Gremmenilla abietina* were observed. In spite of the large areas affected by forest fires in 2001 no damage was observed on the monitoring plots during the assessment period.

5.5.2 Hungary

Defoliation has increased slightly in 2001, whereas the number of sample trees with discolouration was lower than in previous year. This indicates the stabilisation of the crown condition compared to the moderate deterioration observed in 2000.

Robinia pseudoacacia, Quercus robur and *Quercus petraea* had the highest defoliation; 28.1%, 26.3% and 24.1% of the trees were damaged (defoliation class 2-4) respectively, while *Carpinus betulus, Pinus nigra* and *Quercus cerris* were the tree species with the best crown condition (13.9%, 14.6% and 15.4% damaged respectively). Despite the high defoliation of *Quercus* spp., symptoms of oak decline were only scarcely observed on the sample plots in the recent years. *Fagus sylvatica* had the lowest defoliation since the beginning of the survey, but in 2001 – due to the extremely high fructification throughout the country – the proportion of “damaged” trees was nearly 20%, more than twice than in previous years. As this phenomenon – intensive fructification decreases the leaf mass – is widely known, high defoliation should not be considered a threat, rather a good omen of the successful natural regeneration in old stands.

Floods and high level of inland water as well as wind and snow caused less damage in the forests than in the previous year. Spatial distribution of the precipitation was unusual, leaving the western part of the country well below the average rainfall in the growing season. Drought damage in young stands was frequently observed. Uneven distribution of precipitation can be in relation to the reduction of defoliated *Robinia pseudoacacia*. This tree species is more frequent in eastern Hungary, where the rainfall stimulated new shoots to grow even in August. *Pinus nigra* has also improved, but this can hardly be assigned to water supply, rather to the decrease of fungal diseases.

Mild winter expected to be favourable for insects, however leaf damages due to insect attacks were even less important than in the last years. Only leaf miners (*Parectopa robiniella* and *Phillonoricter robiniella*) on *Robinia pseudoacacia* caused – like in 2000 – widespread damages in the whole country.

5.5.3 Romania

In 2001, the monitoring results revealed a slightly improved forest condition as compared to the previous year.

From the total number of tree species assessed (110 190), 13.3% were in defoliation classes 2-4 (9.6% conifers, 14.7% broad-leaves). The lowest values of defoliation percentage in classes 2-4 was recorded for *Picea abies* (8.1%), followed by *Fagus sylvatica* (11.3%) and *Abies alba* (13.7%).

The highest percentages of damaged trees were registered for *Quercus pubescens* + *Q. pedunculiflora* (32.7%), *Quercus frainetto* (27.7%), indigenous *Populus* species (23.4%), *Robinia pseudoaccacia* (22.5%) and *Quercus robur* (21.2%).

Generally, compared to 2000, all these species revealed a decreasing percentage of trees in classes 2-4. This slightly improved crown condition from 14.3% in 2000 to 13.3% of trees in classes 2-4 in 2001 is explained by the increase in precipitation in springtime. As in general the last two years are characterised by a strong drought, the reaction of trees was immediate, in the same vegetation season. For some species like *Populus* spp. and xerophytic *Quercus* species this reaction did not occur.

In the southern part of the country, crown condition revealed a high level of defoliation.

5.6 Eastern Europe

5.6.1 Republic of Moldova

The forest condition survey was carried out on the national 2 x 2 km grid. From the total number of assessed tress 63.1% were in classes 0-1 and 36.9% were in classes 2-4. 69.7% of the assessed conifers were in defoliation classes 0-1 and 30.3% in classes 2-4. For broad-leaved trees from 14 127 assessed trees 63.0% were in classes 0-1 and 46.5% in classes 2-4.

Of the main tree species, *Robinia pseudoacacia* was the most defoliated one (51.4% damaged) followed by *Populus* spp. (47.5%), *Quercus robur* (43%), *Fraxinus excelsior*

(38.2%), *Ulmus* spp. (37.1%) and *Quercus petraea* (28.9%). For *Quercus robur*, *Quercus pubescens* and *Fraxinus excelsior* trees in the higher age class were more defoliated, for other species the younger trees were more defoliated.

A strong influence of biotic and abiotic stressors upon the health state of trees was recognized. 48.9% of the assessed trees in damage classes 2-4 were damaged by defoliating insects. Storm events in autumn 2000 affected forests in the regions of Orhei, Soroca, Soldanesti. Many trees were broken and uprooted. *Quercus* coppices were affected by *Microspaera alphitoides.*

5.6.2 Ukraine

In 2001 1 685 sample trees were assessed on 71 forest monitoring plots in 5 administrative regions of Ukraine which represent about 20% of total area of country. The monitoring plots are located in eastern and southern parts of Ukraine, where natural conditions are unfavourable for forest growth and the air pollution level is the highest.

Mean defoliation of conifers was 18.8% and of broad-leaved trees was 28.2%. In general, a clear improvement of tree condition was observed for the total sample compared to the previous year. In 2001, the percentage of healthy trees was more then two times higher in comparison with 2000 (6.1% against 2.6%). At the same time, the share of moderately to severely defoliated trees decreased from 60.7% to 38.9%. For the sample of common sample trees (CSTs, 1 630 trees) positive changes were observed too. Mean defoliation of all species in 2001 (26.7%) was less than in 2000 (34.7%). This difference is statistically significant. Obvious improvement of tree condition was registered for the CSTs of almost all tree species. Statistically significant improvements were observed for *Quercus robur, Quercus petraea, Fagus sylvatica, Pinus sylvestris* and *Pinus Pallasiana.* Improvements were not significant for *Fraxinus excelsior*.

The main reason for crown condition improvement were the relatively favourable weather conditions.

5.7 Northern America

5.7.1 Canada

The Canadian Forest Service does not currently carry out a national forest health survey program. Emphasis is on regional issue-based surveys. Canada, along with the provinces is in the initial stages of a new plot-based National Forest Inventory. Pilot studies are currently under way to finalise plot designs, logistics and measurement and compilation of appropriate attributes to monitor. These attributes will include ones related to forest health and biodiversity.

Currently, two regional ecological gradient initiatives related to anthropogenic and natural stresses on forest health are being carried out by CFS in collaboration with partners.

Forest Indicators of Global Change

The CFS Forest Indicators of Global Change Project (FIGCP) was initiated in 1998 to develop and field-test new indicators to meet the global change challenge. FIGCP has three goals: develop new, early warning indicators of forest condition; relate patterns of global change to forest health, function and productivity; and, establish an array of permanent research-monitoring plots on which to conduct more detailed studies, particularly of nutrient/carbon cycling in eastern Canada.

The project comprises 26 eastern Canadian forested, permanent sample plots arranged across four zones of acidic deposition (sulfur/nitrogen) critical load exceedance and four of ozone critical level exceedance. The 1800 km transect features a 2 - 7 degree Celsius variation of mean annual temperature, and a 700- 1500 mm variation of mean annual precipitation. The most westerly plot is located at Turkey Lakes in north-central Ontario with the most easterly plot situated near the Bay of Fundy, New Brunswick. *Acer saccharum* is contiguous as a dominant species across the gradient; *Pinus strobus* dominates as coniferous species in Ontario. *Picea rubens* predominates in Quebec and New Brunswick. These species have been the most prominent north-eastern species suffering decline since the 1960s.

Indicators assessed

Tree condition: Protocols for tree condition developed for the old Acid Rain National Early Warning System (ARNEWS) network of plots are used to measure various tree health attributes. Each tree per FIGCP plot is rated in early August for crown condition, length of bare top, percentage needle retention (conifers), level of storm damage, percent of current defoliation, abiotic foliage symptoms, seed production, and pest conditions. Tree condition rating is accomplished yearly by visual assessment of tree vigour using a calibrated and inter-operator checked system of condition classes. Using a stand visualization system, tree condition status for each plot is converted to a GIS image, which allows for a visual time series

Leaf surface condition: Analyses of conifer needle cuticular wax samples for *Pinus strobus* and *Picea rubens* are being compiled. Preliminary results appear to show that trees from plots with the highest acid loadings and ozone levels also have the lowest wax amounts. However, at this initial stage, no cause-effect linkage is inferred.

Leaf litter fall: A second year of litter collection has been completed on 10 *Acer* plots in Ontario. Chemical analysis for macro-elements is under way.

Leaf litter decomposition: Terylene-mesh litter bags containing known quantities of dried, standard *Acer saccharum* or *Pinus strobus* leaf litter were installed in groups of 15 of each species on each of three sub-plots at 17 FIGCP plots in 1999. Five litter bags of each species from each sub-plot were collected during October 2000, returned to the laboratory, re-dried and weighed. They are being analysed for C, N, P, K, Ca, Mg, S, Fe, Zn, Cu, Na, and Al. A second sampling was made during October 2001 and a third sampling will be made in October 2002. Percent mass loss will be regressed against the main gradient variables: mean annual temperature, mean seasonal temperature, growing season length, sulfate and nitrate exceedances, etc.

Ion leaching: Resin discs are being assessed as a viable tool for use throughout the gradient.

Nitrogen mineralization: analysis is under way

Soil microbial respiration: microbial C is currently being assayed.

Ozone monitors: Ground-level passive ozone monitors (CanOxy Plates) are collected during three periods (May to August) of O_3 measurement on all FIGCP plots

FIGCP data are integrated with the CFS Forest health and Biodiversity database. This database links historical forest data with volumes of individual researcher data into a central, organized national repository accessible by CFS scientists addressing global change, forest health and biodiversity issues.

Climate Change Impacts on the Productivity and Health of Aspen (CCIPHA)

Populus tremuloides is the most widely distributed tree species in North America, and the most abundant deciduous tree species in the Canadian boreal forest. Thus it is both ecologically and commercially important. Since the 1980s, dieback and reduced growth of the species has been noted, especially along the southern edge of the boreal forest and the aspen parkland. Studies to date suggest that dieback in these areas is caused by a combination of climatic factors and defoliation by insects.

CCIPHA has four objectives:

- provide early detection of climate change impacts
- understand how climatic variation, insects and other factors have affected health and growth of aspen forests of western Canada
- through carbon-based models, predict future changes in biomass, productivity and health of aspen forests of western Canada
- provide a framework linking collaborative research, regional monitoring of biomass, productivity, ecosystem function and carbon sequestration of aspen forests of western Canada.

CCIPHA is a research and monitoring initiative of CFS in collaboration with Environment Canada and other partners. It consists of a system of long-term research plots along a regional climate gradient extending from the cold, moist boreal forest to the warmer and drier aspen parkland. Twelve study areas have been established throughout this gradient. In each study area, three undisturbed, mature *Populus* stands have been selected and two plots have been established in each stand. There are a minimum of 25 trees per plot. Crown dieback, tree vigour, pest incidence and damage levels, and leaf area index are assessed annually. Tree ring analysis, measurements of tree height and diameter, and classification of dominance are made every five years. White growth rings are being noted as a record of past defoliation and compared with historic insect survey records. Daily temperature and precipitation data are obtained from Environment Canada climate stations close to each study area.

6 DISCUSSION

The results of the transnational survey of the year 2001 confirm the deterioration of crown condition of the main tree species observed over the previous years. In 2001 defoliation of the six most abundant species decreased only in *Quercus ilex* and *Q. rotundifolia*, whereas it increased in all of the other five species (*Pinus sylvestris*, *Picea abies*, *Fagus sylvatica*, *Quercus robur* and *Q. petraea* and *Pinus pinaster*) at the European-wide scale. Of the latter five species, the share of not defoliated trees (defoliation up to 10%) was the lowest since 1994 or 1995. The spatial variation of defoliation was high and its main causes differed largely between species and regions. The main causes quoted by the participating countries are insects, fungi and weather extremes (heat, drought, frost and recently especially storm). Air pollution was mentioned as a predisposing or contributing factor, with only severe local air pollution having a triggering effect. Referring to these main causes, section 6.1 explains the development of crown condition for individual species and regions.

Statistical analyses confirm the impact of the factors quoted by individual countries also on the large scale. In agreement with previous results of the transnational survey, stand age and country were found to explain a large part of the spatial variation of defoliation. Accounting for these two dominant predictor variables was an important precondition for the explanation of the spatial variation of defoliation by further factors. Such statistical analyses can be further improved as soon as additional independent information on the systematic differences between the national crown condition data becomes available from International Cross-calibration Courses. Section 6.2 discusses the correlations between defoliation and predictor variables identified by means of statistical models which distinguish strictly between temporal and spatial variation.

6.1 Development of crown condition

Pinus sylvestris showed a clear increase in defoliation from the first year of the transnational survey until 1994. After that year a pronounced improvement of crown condition was observed especially in eastern Germany, Poland and parts of the Baltic States. This recuperation is attributed to reduced air pollution particularly by Poland and Lithuania. In recent years, however, defoliation has been increasing again. In 2001 *Gremmeniella abietina* defoliated *Pinus sylvestris* in southern Finland and in central Sweden.

From the beginning the transnational crown condition assessment has been showing high defoliation of *Picea abies*. This reflects partly the poor crown condition of this species in the main damage areas of central and eastern Europe, where it was noticed well before the first survey (Ardö et al., 1997) and attributed by forest damage research largely to atmospheric depositions (e.g. Schulze, 1989, Gobold and Hüttermann, 1994, Freer-Smith, 1998). In 2001 *Picea abies* experienced a pronounced increase in defoliation in the Boreal and Boreal (temperate) regions due to weather extremes and subsequent biotic damage. Severe storm events caused forest damage in southern Finland and in Estonia. An unusually warm autumn in 2001 fostered fungal diseases in southern Finland. In Estonia drought and heat in the summers of 1999 and 2000 led to bark beetle attack, and local air pollution had been responsible for defoliation at a few sites.

After years of deterioration *Quercus robur* and *Q. petraea* became the most damaged species in Europe from the mid 1990s on. This decline was attributed to a complex of several stressors including largely insects (Fischer, 1999) and weather extremes (Landmann et al., 1993, Mather et al., 1995). A pronounced recuperation occurred in 1998 especially in the Sub-atlantic region.

In 2001 *Fagus sylvatica* showed the steepest increase in defoliation among the main species in Europe, reflecting a recent deterioration in the Mountainous (south) region. This development was particularly obvious in Croatia, Romania and Slovenia. In Slovenia the decline was explained by hail storms.

Quercus ilex and *Q. rotundifolia* and *Pinus pinaster* experienced the severest deterioration of crown condition since the beginning of the transnational survey which Spain and Portugal attribute mainly to summer heat and drought. Mean defoliation of *Quercus ilex* and *Q. rotundifolia* increased from 11.8% in 1989 to 21.0% in 2001, i.e. to a level higher than that of *Pinus sylvestris* and comparable to that of *Fagus sylvatica*. Defoliation of *Pinus pinaster* experienced a similarly steep increase in defoliation, but at a far lower level, rendering this species the least defoliated one among the six main species over the total period of observation.

6.2 Integrative evaluations

The integrative evaluations aimed to analyse the spatial variation of defoliation as well as the temporal variation. A statistical method to correct the defoliation data for country wise age effects was presented in the last year's integrative evaluation (PAD, UNECE, CEC, 2001). The new evaluation method of integrative evaluations in this year's report is the introduction of referenced values (2.5.3). These allow to analyse temporal variation separately from spatial variation. Nevertheless, results of these analyses can be presented distributed over space by mapping plot wise calculated coefficients of multiple linear regression models (4.1.1 and 4.2.1).

The slope of linear regressions over time or differences between observations of two distinct years or other indices were used in former studies of the temporal variation of defoliation (e.g. KLAP et al., 1997, GHOSH et al., 1997). There the dependent variables were calculated based on the assessed defoliation data in a first step. In a second step these derived variables (DIGGLE et al., 1994) were analysed by regression or geostatistical methods. Because the indices are always a model of the assessed values, some share of valuable temporal variation is always lost during step 1. This disadvantage could be avoided by using referenced values − of the response variable defoliation as well as for the predictor variables − for the evaluations. Transformed values are used instead of the assessed values. Thus, for every assessed value a transformed one is used for calculation instead of calculating a single index value for a plot with 6 repeated measures. A similar transformation of meteorological predictor variables was done by KLAP et al. (1997) but they used both types of variables, the referenced as well as the medium-term mean values, in one model of defoliation which combines the analyses of spatial and temporal variation.

Only such predictor variables which are varying over time itself were used to analyse the temporal variation of defoliation. Again, transformed (referenced, 2.5.3) values were used in the analyses of temporal variation and the medium-term mean values were used in the analysis of spatial variation for predicting the medium-term mean defoliation. Time constant predictor variables, thus, were only used in combination with time varying variables during the analysis of temporal variation (e.g. interaction term of sum of precipitation * water availability).

The underlying assumption of the usage of time varying predictor variables of the same year as defoliation data is that the impact of factors described by the predictor variables on defoliation can be observed in the same year. For many cause-effect relationships a time lag between observed impact and observation of response can be expected (e.g. acidification processes). This could be the reason e.g. for the negative correlation which was found between defoliation and fungi index for temporal variation of *Pinus sylvestris* (s. below). The positive correlation between sulphur deposition and defoliation of this tree species, perhaps, could only be found because of the constant decrease of both variables in Poland during the evaluation period and the early nineties. On the other hand direct impact of acid deposition on leaves (commonly known as classical smoke damage) or direct nitrogen uptake in the crown could be an argument for the examination of values of the same year. Nevertheless, the possibility of time lags between impact and response should be regarded in further analyses of temporal variation of defoliation.

Additionally, a further improvement of the quality of the predictor variables is needed but cannot easily be achieved. Most of the used predictors are interpolated and/or modelled values (deposition, precipitation) or indices (fungi, insects). Further improvements of models for deposition and meteorological data are expected but could be inconsistent with older models. For an analysis of temporal variation consistent time series of predictor variables are a precondition. Improvements in the assessment of insects and fungi infestations on forests within the programme are discussed.

The mapped regression coefficients in chapters 4.1.1 and 4.2.1 are those of the predictor variable YEAR, which is the referenced year of observation. It can be interpreted as the mean change in defoliation during the evaluation period (1994 to 1999) from one year to the following on the respective plot. High positive values are indicating a deterioration, high negative values an improvement of crown condition. In bivariate models explaining the temporal variation of defoliation with the only predictor variable YEAR the plot wise regression coefficients of YEAR are a description of the mean development in the evaluation period. In multiple models the regression coefficients of YEAR describe that mean development, which could not be explained by any other predictor variable contained in the model. Thus, the analysis of those mapped regression coefficients (Figures 4.2.1-3 and 4.2.1-4) shows where unexplained changes in defoliation were surveyed and in comparison with those of bivariate models (e.g. Figures 4.2.1-1 and 4.2.1-2) they show, where temporal variation could be explained statistically by the multiple linear regression model.

The chosen methodology does not recognise the temporal autocorrelation. Anyway, it seems to be plausible that observations in year x are at least to a small part dependent on the observations in the years before. A pilot study based on data for Norway spruce from the years 1994 to 2000 did not reveal any temporal autocorrelation for nearly all of the analysed plots. Because of the high variability of the analysed variable longer time series may be needed for a useful study concerning temporal autocorrelation. Because of the lack of longer time series especially for the temporal predictor variables, perhaps, those studies must be conducted based on the Level I data base only.

The evaluation of the spatial variation of defoliation emphasised the importance of a correction of the defoliation values for country specific age trend. Whereas the uncorrected medium-term mean defoliation shows strong border effects among some countries, the PAD values depict regions of relatively high/low defoliation without comparably strong inconsistencies at national borders. Because of the possible loss of 'real' differences in mean defoliation between neighbouring countries it is, nevertheless, a basic necessity to validate or even substitute the found statistical relationships by empirical values from International Cross-calibration courses.

Both variables, the uncorrected medium-term mean defoliation as well as the preliminarily adjusted defoliation (PAD), show a high spatial variation of the mean level of defoliation in Europe for the evaluated tree species *Pinus sylvestris* and *Fagus sylvatica*. Thus, mean values of defoliation calculated for large regions of Europe or even total Europe must be interpreted with care.

6.2.1 *Pinus sylvestris*

The most interesting result for the temporal variation of defoliation is the improvement of crown condition in Poland, especially in the south of Poland (4.1.1). A strong reduction of sulphur deposition during the evaluation period in this region was found to be statistically linked to this positive development. Whereas some authors described similar results (MATHER et al., 1995, DOBBERTIN et al., 1997, SEIDLING, 2001) there are other studies which did not find a similar relation between defoliation and sulphur deposition (INNES and BOSWELL, 1988, SOLBERG and TØRSETH, 1997, NEULAND et al., 1990, for an overview s. Seidling, 2000). Especially the study conducted by SEIDLING (2001) in a region of high sulphur deposition, the "black triangle" in the border region between Poland, the Czech Republic and Germany, indicates that effects of pollutants can only be found in statistical models if a high level of impact is given and can be described by the data. Variation of defoliation as well as sulphur deposition on a high level was assessed in Poland during the evaluation period. Additionally, the sulphur deposition can be expected to have decreased in this region continuously from the beginnings of the nineties on because of strong changes in the industrial activities after 1990. Thus, even delayed responses on a decrease of sulphur deposition could be observed by the data and lead to the positive correlation found. Nevertheless, every other factor, which is correlated with sulphur deposition but still cannot be described by a respective variable could be the reason for the observed improvement of crown condition.

Especially the mapping of the regression coefficients for YEAR of models with and without regard of sulphur deposition (not depicted) support the positive correlation and consistent decrease of sulphur deposition and defoliation in Poland. Nevertheless, the level of defoliation is still very high in this region (4.1.2). These findings agree completely with those in the respective National Reports and with the findings of national experts (WAWRZONIAK, personal communication).

For Bulgaria a clear deterioration during the evaluation period was found. This can be explained by extreme environmental conditions in the last years of the evaluation period

(STOICHKOVA, pers. comm.). The occurrence of extreme situations was found too by high values of the plot wise calculated rooted mean of squared error of the linear time trend in this region (not depicted).

The deposition of nitrogen could not be explained by a single cause-effect relationship. Whereas the reduced nitrogen (Ammonium) coincides with deterioration, the oxidised nitrogen is correlated with an improvement of crown condition in the evaluation period (Table 4.1.1-1). For both results of the regression analysis a plausible explanation can be found with acidification and eutrophication processes respectively. An extended evaluation of the found relationships with regard to site quality could lead to valuable results.

The unexpected negative correlation between defoliation and the fungi index should be analysed further. An in depth study of those plots with extremely high values of the fungi index could lead to a better understanding. Especially the delayed observation of fungi infestation could be a possible explanation.

The negative correlation of defoliation with the sum of precipitation during the first six months of the year as an index for drought stress was expected and seems to be plausible. The test of homogeneity (GLM, SAS, 1990) by the integration of the interaction term between precipitation and water availability (Level I parameter, 2.3.1) led to more specific results: A negative correlation of defoliation with precipitation was found on stands, which were assessed to be of insufficient water availability and less pronounced on those of sufficient water availability (the more precipitation, the less defoliation). For stands of excessive water availability the correlation was positive. The increase of defoliation on stands of the latter type may be caused by lower respiration of the roots or lower transpiration rates during spring because of unfavourable weather conditions, which are related to high rates of precipitation.

6.2.2 Fagus sylvatica

The most comprehensive model (model number 1 in Table 4.2.1-1) explained 39.3 % of the temporal variation of defoliation on *Fagus sylvatica*. This is a considerable amount considering the small number of predictors. It should be possible to explain even a bigger amount by refining the predictors and take into account effects of temporal autocorrelation. The definition of more powerful indices for drought stress seems to be a promising way.

The sum of precipitation of the first half of the year led to implausible positive signs in the models of *Fagus sylvatica* and was therefore rejected. Instead, the sum of precipitation in summer was integrated in the models. The plausibility of the contribution of precipitation variables was always checked by interpreting them as indices of drought stress. On the other hand, the positive correlation of the sum of precipitation of the first half of the year with defoliation could be plausible if the sum of precipitation is interpreted as an index for unfavourable weather conditions in the period, when leaves are flushing.

Even more complex is the interpretation of nitrogen components in deposition. In contrast to the results for *Pinus sylvestris* the deposition of reduced (oxidised) nitrogen showed a negative (positive) correlation with defoliation. Nevertheless, it is possible that the physiology of *Fagus sylvatica* is different from that of *Pinus sylvestris* concerning the reaction on nitrogen deposition components. Possible interactions with site parameters (e.g. base saturation, pH) should be object of further in depth studies.

The regression coefficients for YEAR of model 1 in Table 4.2.1-1 can be interpreted as the unexplained remainder of the linear temporal trend of defoliation. Possible reasons for such a trend can be the lack of additional predictors, which could explain this unexplained error, or a temporal inconsistency concerning the assessment method applied in the respective region. In any case, Figure 4.2.1-3 and Figure 4.2.1-4 show that the models cannot explain the total temporal variation for *Fagus sylvatica*. For example, the deterioration in north western Germany and Wallonia could possibly be explained by the occurrence of a complex disease of *Fagus sylvatica*, starting with an infestation by *Cryptococcus fagisuga* (Lind.) in this region (EISENBARTH et al., 2001). This example shows that the indices for insect and fungi infestation today are crude and should be improved further.

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Annexes

Annex I-1
Climatic regions

The **Boreal** region comprises Finland, the central and northern parts of Sweden, Estonia except the coastal regions and some plots in northern and central Norway. The climate is mainly cold with a short vegetation period. In the northernmost parts the climate changes to arctic conditions. The Boreal region is dominated by *Picea abies* and *Pinus sylvestris*. In 2001, 16.7% of the plots of the European survey were located in the Boreal region.

The **Boreal (temperate)** region covers most parts of southern Sweden and Norway, the whole of the Baltic countries Latvia and Lithuania, the coastal regions of Estonia and the largest part of Belarus. This region contains a higher proportion of deciduous tree species, compared to the colder Boreal region. 15.9% of the assessed trees were in the Boreal (temperate) region.

The **Atlantic (north)** region comprises the United Kingdom, Ireland, Denmark, the Netherlands, the southern coasts of Sweden and Norway, north-west Germany, northern Belgium and France. The climate is characterised by mild winters, a relatively uniform distribution of precipitation over the year and long transitional seasons. The forests consist of *Picea abies, Pinus sylvestris, Picea sitchensis, Quercus robur* and *Fagus sylvatica*. 5.7% of the plots were situated in this region.

The **Atlantic (south)** region comprises central and south-western France, the atlantic coast of Spain and the northern parts of Portugal. The climate is warm, with high precipitation in winter, but very little frost and snow. There is a higher proportion of oak species, dependent on warmer summers, than in the Atlantic (north) region. Also frequent are *Castanea sativa, Pinus pinaster, Pinus radiata* and *Pinis sylvestris.* 4.9% of the plots were located in this region.

The plots of the **Subatlantic** region are located in Poland, the Czech Republic, the western parts of Slovakia, the southwesternmost tip of Belarus, northern Austria and Switzerland, eastern and southern Germany, southern Belgium, central-eastern France, and the whole of Luxembourg. The climate is typically temperate and characterised by large temperature differences between summer and winter, with a gradient from the western parts to the eastern parts. If the whole region is considered, the forests are very heterogeneous, dominated by *Picea abies, Pinus sylvestris* and *Fagus sylvatica*. In this region 18.7% of all plots were located.

The **Continental** region consists of the Republic of Moldova, large parts of Romania, eastern and northern Bulgaria and nearly all Hungary. The climate is typically continental with warm and dry summers, and low temperatures in winter. The forests are characterised by oak species, *Fagus sylvatica, Robinia pseudoacacia, Carpinus betulus, Picea abies* and *Abies alba.* Only 4.3% of the sample plots were located in this region.

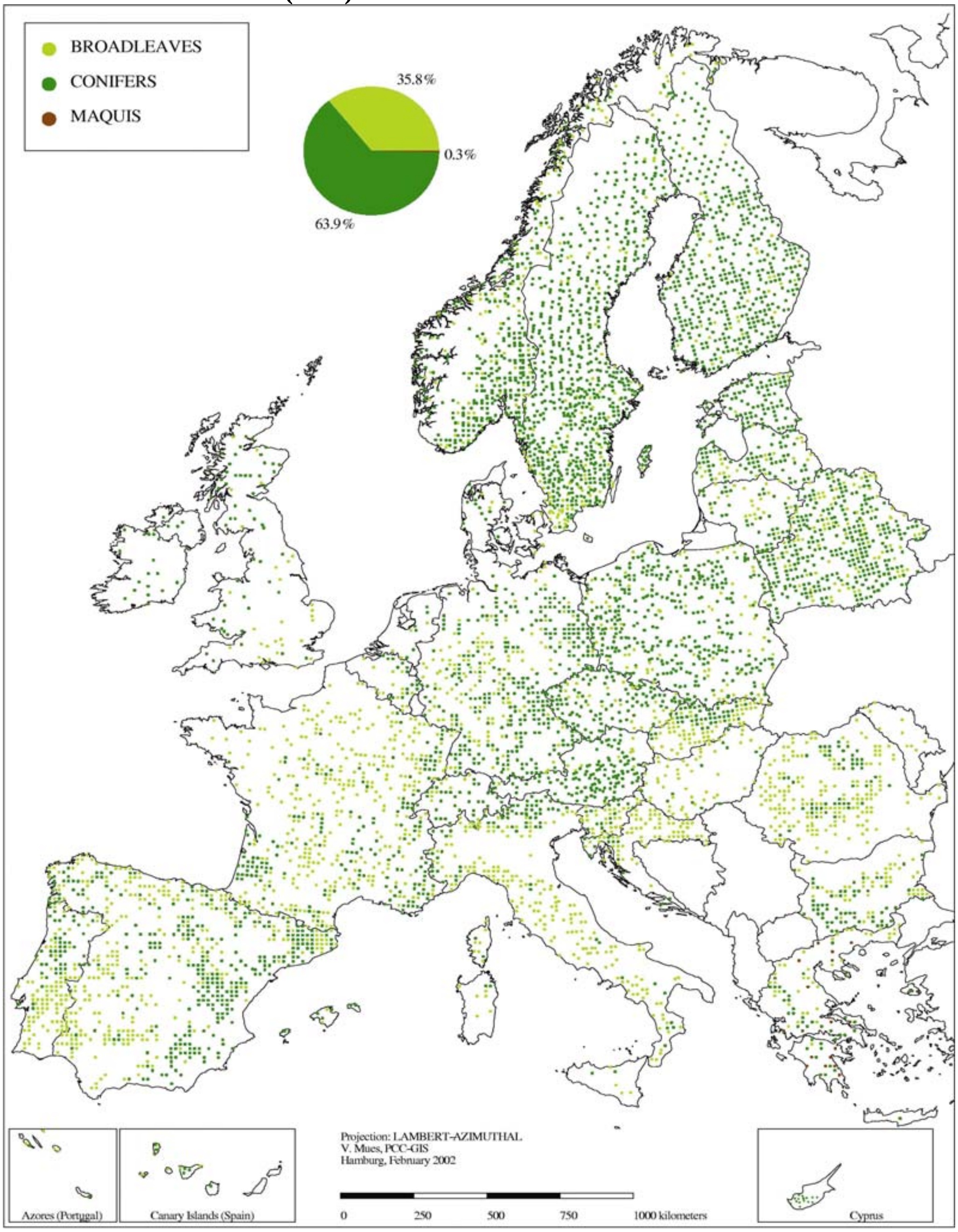
The **Mountainous (south)** regions comprise plots on several mountain ridges. These regions all share steep climatic gradients and consequently complex geobotanical structures, depending on altitude and exposition. They comprise the Alpine system (Pyrenees, Alps, Tatras, Carpathians and the Balkan), the Appenin, the Vosges, and in Germany the Black Forest and the Bavarian/Bohemian Forests. The dominant species are *Picea abies, Fagus sylvatica, Larix decidua, Pinus nigra, Pinus sylvestris* and *Abies alba*. These regions comprised 12.2% of all sample plots.

The **Mountainous (north)** region was introduced to account for the peculiarities of the mountainous climate in northernmost Europe in comparison to that in the other parts of Europe. This region is located only in Norway. It is characterised by large seasonal variations in climate, but with a generally shorter vegetation period. The plots in lower altitudes on the Atlantic coast are influenced by the Gulf stream and have a more temperate climate. The most frequently occurred species are *Betula pubescens, Picea abies* and *Pinus sylvestris.* 4.5% of the sample plots were located in the Mountainous (north) region.

The Mediterranean region as a whole is divided in the **Mediterranean (higher)** and **Mediterranean (lower)** regions. The higher areas (6.8% of the plots) are situated between 400 m and ca. 1000 m altitude in Portugal, Spain, southern France, Italy, Slovenia, Croatia, Romania and Greece with humid climate. The Mediterranean (lower) regions (10.3% of the plots) cover Cyprus and lower parts of the countries mentioned above. The climate is characterised by hot and dry summers and frequent drought periods in summer. Both Mediterranean regions are dominated by *Pinus halepensis, Pinus nigra, Pinus pinaster, Quercus ilex, Quercus cerris* and *Quercus pubescens.*

Annex I-2

Braodleaves and conifers (2001)



Projection: LAMBERT-AZIMUTHAL
V. Mues, PCC-GIS
Hamburg, February 2002

Annex I-3
Species assessed (2001)

	Observed trees		**Observed plots**	
Species	**Number**	**%**	**Number**	**%**
Pinus sylvestris	35321	26.69	1823	17.79
Picea abies	26322	19.89	1474	14.39
Fagus sylvatica	11780	8.90	660	6.44
Quercus robur	4925	3.72	441	4.30
Quercus ilex	3881	2.93	227	2.22
Pinus pinaster	3807	2.88	191	1.86
Betula pubescens	3685	2.78	624	6.09
Betula pendula	3672	2.77	642	6.27
Quercus petraea	3589	2.71	357	3.48
Pinus nigra	3164	2.39	165	1.61
Pinus halepensis	2639	1.99	135	1.32
Quercus pubescens	2023	1.53	166	1.62
Abies alba	2021	1.53	204	1.99
Carpinus betulus	1759	1.33	233	2.27
Eucalyptus spp.	1684	1.27	76	0.74
Quercus cerris	1681	1.27	134	1.31
Quercus suber	1656	1.25	99	0.97
Castanea sativa	1410	1.07	158	1.54
Larix decidua	1239	0.94	185	1.81
Populus tremula	1139	0.86	258	2.52
Fraxinus excelsior	1016	0.77	190	1.85
Quercus pyrenaica	969	0.73	55	0.54
Picea sitchensis	963	0.73	48	0.47
Alnus glutinosa	939	0.71	132	1.29
Robinia pseudoacacia	887	0.67	71	0.69
Quercus frainetto	843	0.64	45	0.44
Quercus rotundifolia	661	0.50	38	0.37
Pseudotsuga menziesii	570	0.43	49	0.48
Acer pseudoplatanus	513	0.39	156	1.52
Pinus pinea	470	0.36	38	0.37
Populus hybrides	461	0.35	23	0.22
Quercus faginea	399	0.30	50	0.49
Pinus brutia	377	0.28	19	0.19
Other broadleaves	367	0.28	79	0.77
Ostrya carpinifolia	361	0.27	58	0.57
Pinus radiata	330	0.25	18	0.18
Tilia cordata	319	0.24	71	0.69
Juniperus thurifera	300	0.23	23	0.22

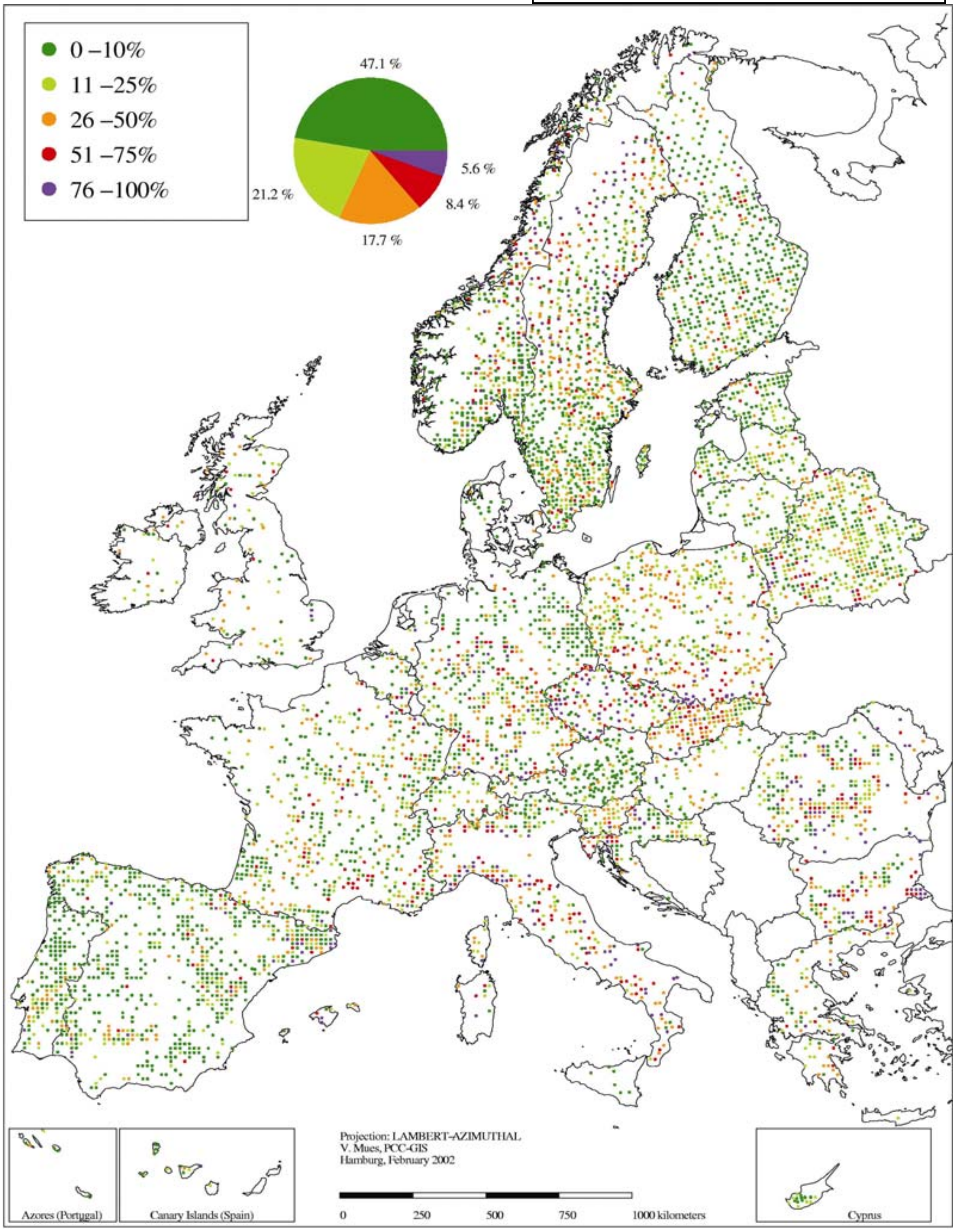
	Observed trees		**Observed plots**	
Species	**Number**	**%**	**Number**	**%**
Abies cephalonica	269	0.20	13	0.13
Alnus incana	247	0.19	44	0.43
Quercus coccifera	224	0.17	17	0.17
Prunus avium	220	0.17	103	1.01
Abies borisii-regis	179	0.14	10	0.10
Pinus contorta	177	0.13	13	0.13
Olea europaea	176	0.13	20	0.20
Acer campestre	168	0.13	66	0.64
Quercus rubra	165	0.12	22	0.21
Pinus uncinata	146	0.11	13	0.13
Fraxinus ornus	122	0.09	39	0.38
Fagus moesiaca	121	0.09	6	0.06
Fraxinus angustifolia	120	0.09	14	0.14
Populus nigra	120	0.09	12	0.12
Acer platanoides	119	0.09	39	0.38
Pinus cembra	96	0.07	10	0.10
Tilia platyphyllos	95	0.07	16	0.16
Platanus orientalis	89	0.07	6	0.06
Alnus cordata	86	0.06	5	0.05
Sorbus aucuparia	82	0.06	30	0.29
Larix kaempferi	68	0.05	8	0.08
Pinus strobus	63	0.05	8	0.08
Arbutus unedo	54	0.04	10	0.10
Populus canescens	52	0.04	5	0.05
Juniperus oxycedrus	50	0.04	18	0.18
Salix caprea	49	0.04	32	0.31
Ulmus glabra	49	0.04	24	0.23
Sorbus aria	48	0.04	28	0.27
Juniperus phoenicea	46	0.03	10	0.10
Populus alba	44	0.03	10	0.10
Acer monspessulanum	43	0.03	12	0.12
Juniperus communis	43	0.03	7	0.07
Other conifers	41	0.03	9	0.09
Phillyrea latifolia	40	0.03	9	0.09
Quercus trojana	37	0.03	4	0.04
Cupressus sempervirens	37	0.03	6	0.06
Cedrus atlantica	32	0.02	4	0.04
Salix alba	28	0.02	4	0.04
	Observed trees		**Observed plots**	
Species	**Number**	**%**	**Number**	**%**
Acer opalus	26	0.02	14	0.14
Sorbus torminalis	26	0.02	21	0.20
Salix spp.	24	0.02	10	0.10
Cedrus brevifolia	24	0.02	1	0.01

Arbutus andrachne	22	0.02	2	0.02
Buxus sempervirens	21	0.02	3	0.03
Quercus macrolepsis	21	0.02	1	0.01
Ulmus minor	20	0.02	9	0.09
Quercus fruticosa	19	0.01	1	0.01
Fagus orientalis	15	0.01	1	0.01
Corylus avellana	12	0.01	8	0.08
Pyrus communis	12	0.01	8	0.08
Pinus leucodermis	11	0.01	1	0.01
Pistacia terebinthus	10	0.01	1	0.01
Tsuga spp.	9	0.01	1	0.01
Juglans regia	8	0.01	4	0.04
Sorbus domestica	8	0.01	8	0.08
Ulmus laevis	8	0.01	4	0.04
Cercis siliquastrum	8	0.01	1	0.01
Cupressus lusitanica	8	0.01	1	0.01
Alnus viridis	7	0.01	1	0.01
Ilex aquifolium	7	0.01	4	0.04
Carpinus orientalis	5	0.00	1	0.01
Juglans nigra	4	0.00	4	0.04
Cedrus deodara	4	0.00	1	0.01
Ceratonia siliqua	3	0.00	2	0.02
Abies grandis	3	0.00	1	0.01
Pinus mugo	3	0.00	1	0.01
Thuya spp.	3	0.00	1	0.01
Malus domestica	2	0.00	1	0.01
Prunus padus	2	0.00	2	0.02
Prunus serotina	2	0.00	1	0.01
Pistacia lentiscus	2	0.00	1	0.01
Salix cinerea	1	0.00	1	0.01
Salix eleagnos	1	0.00	1	0.01
Crataegus monogyna	1	0.00	1	0.01
Taxus baccata	1	0.00	1	0.01
All species	132350	100.00	10246	100.00

Annex I-4

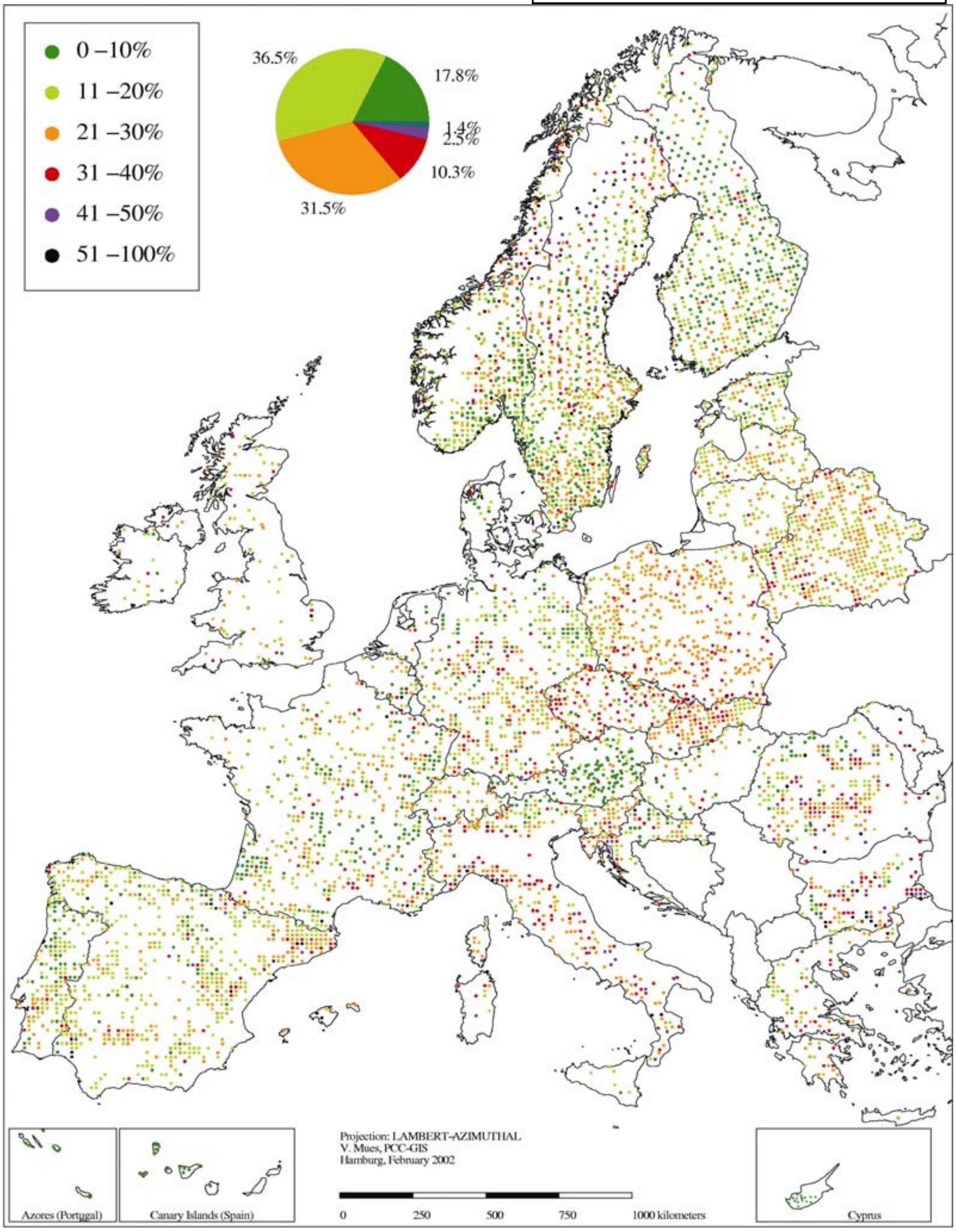
Percentage of trees damaged (2001)

Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction however does not affect the reliability of the trends over time.



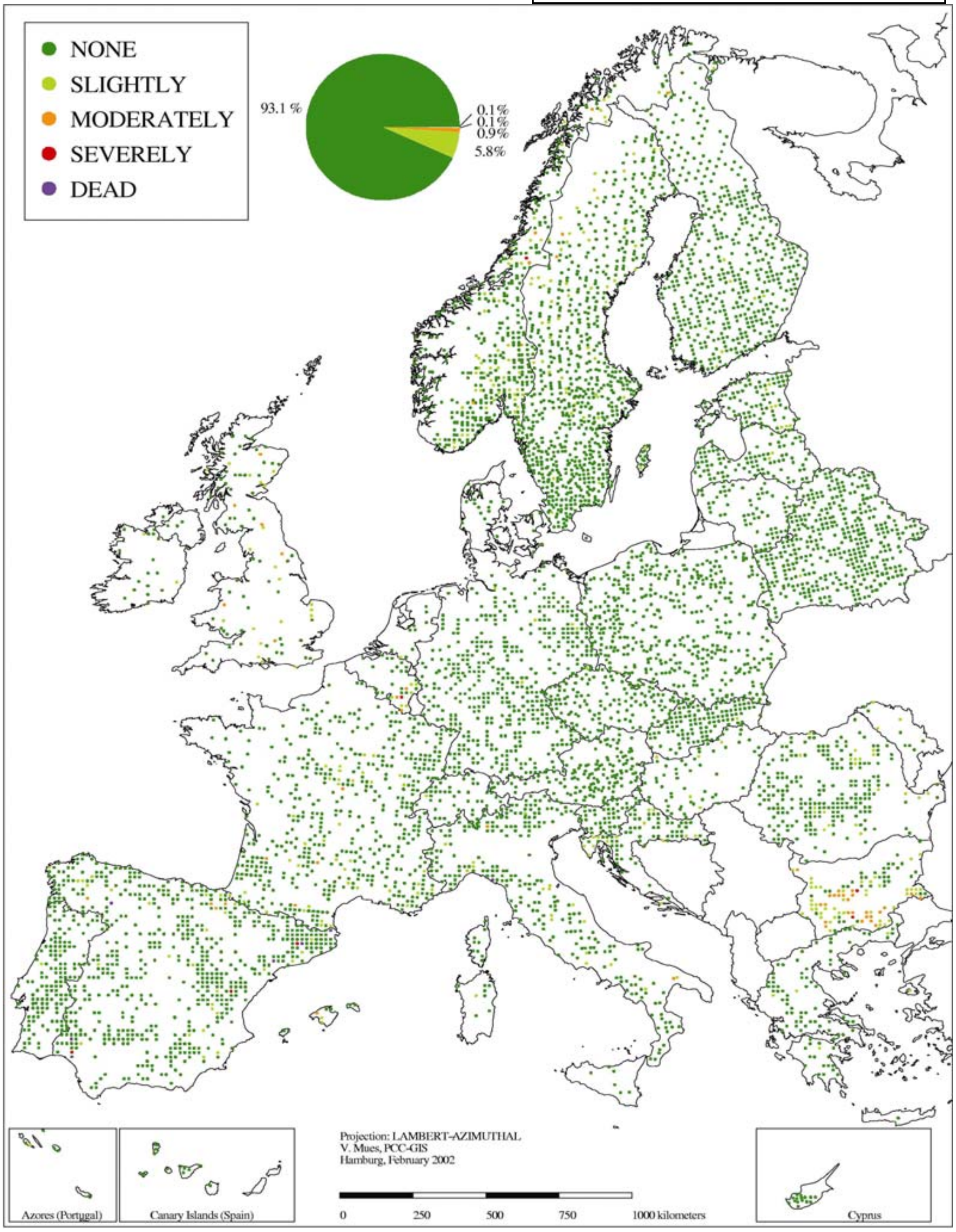
Annex I-5
Mean plot defoliation of all species (2001)

Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction however does not affect the reliability of the trends over time.



Annex I-6
Plot discolouration (2001)

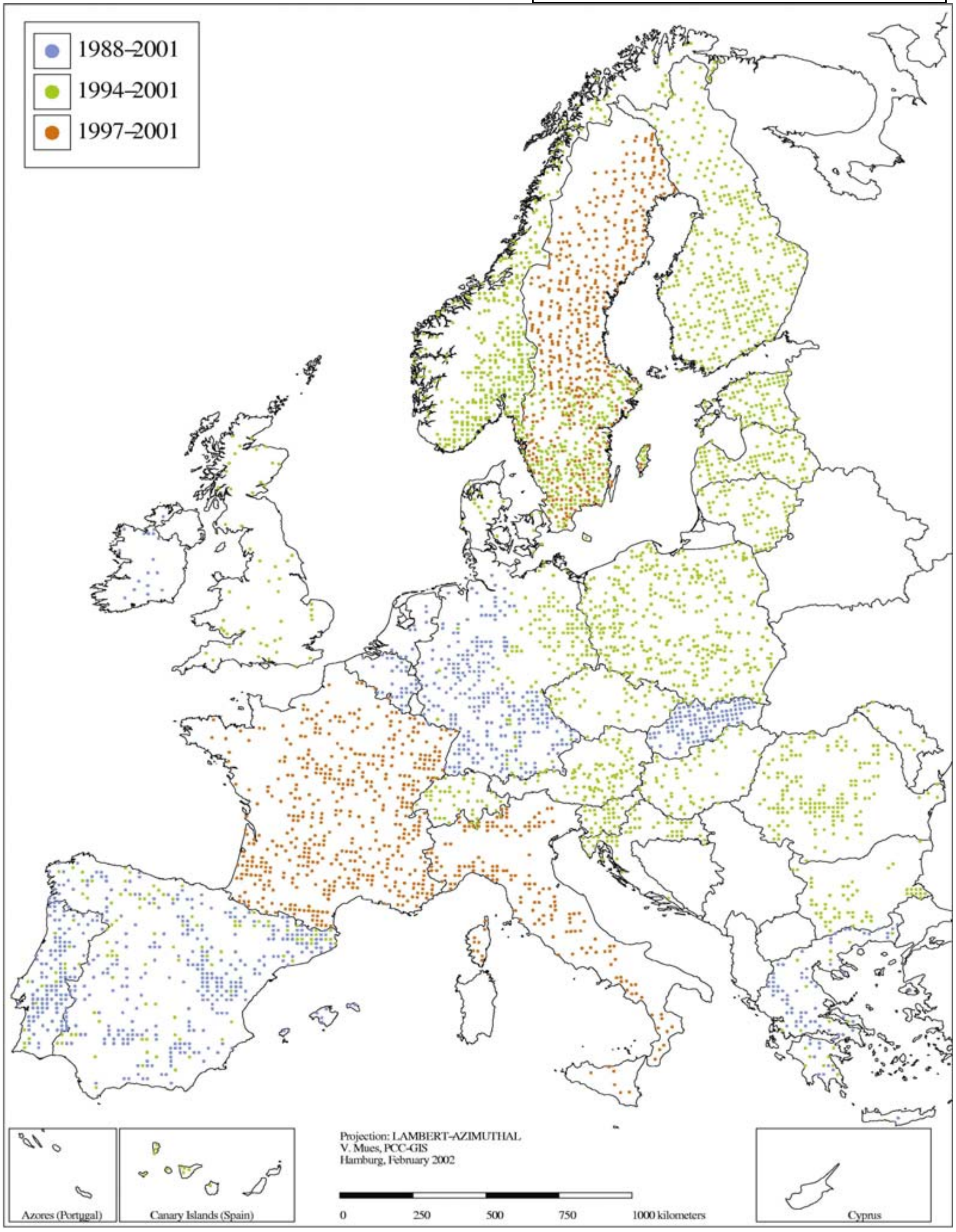
Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction however does not affect the reliability of the trends over time.



Annex I-7

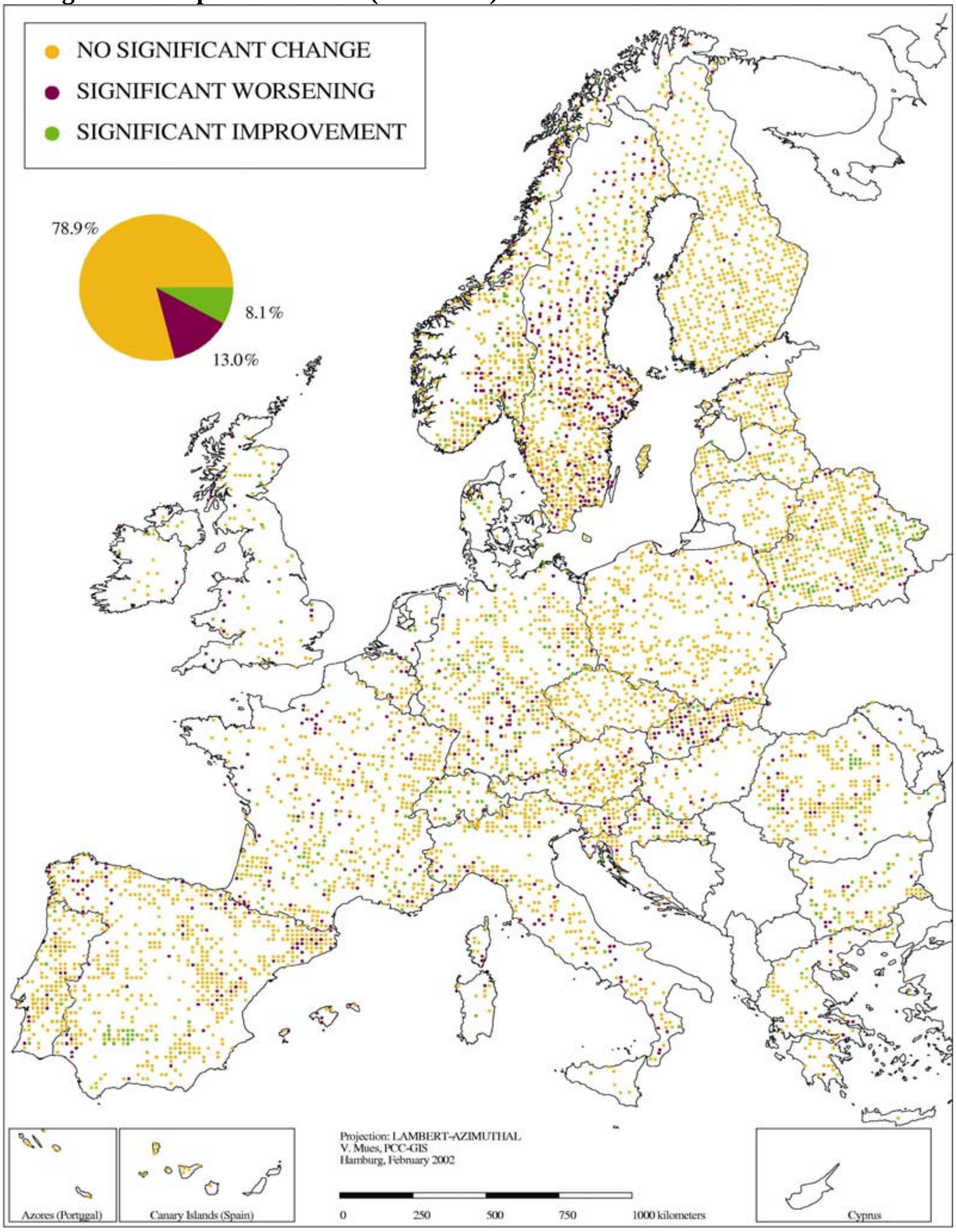
Distribution of plots of the CSTs$_{88}$, CSTs$_{94}$, and CSTs$_{97}$

Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction however does not affect the reliability of the trends over time.



Annex I-8

Changes in mean plot defoliation (2000-2001)



Annex I-9

Development of defoliation of most common species (1988-2001)

Picea abies

ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1988	55.1	25.9	19
1989	47.6	34.7	17.7
1990	46.3	31.3	22.4
1991	44.9	32.7	22.4
1992	37.4	49.0	13.6
1993	39.4	35.4	25.2
1994	38.7	36.1	25.2
1995	41.5	35.4	23.1
1996	44.2	29.9	25.9
1997	41.5	28.6	29.9
1998	44.2	29.3	26.5
1999	47.6	19.7	32.7
2000	38.7	25.2	36.1
2001	40.8	25.9	33.3

SUB-ATLANTIC	0-10%	>10-25%	>25%
1988	30.0	38.0	32.0
1989	28.8	37.7	33.5
1990	28.0	38.6	33.4
1991	27.8	41.4	30.8
1992	29.2	44.1	26.7
1993	26.4	39.5	34.1
1994	23.7	40.1	36.2
1995	24.7	37.3	38.0
1996	30.0	42.6	27.4
1997	25.1	41.9	33.0
1998	26.6	40.1	33.3
1999	25.5	38.3	36.2
2000	24.2	39.9	35.9
2001	21.5	42.6	35.9

MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%
1988	26.6	43.4	30.0
1989	22.1	38.2	39.7
1990	27.2	36.3	36.5
1991	21.8	45.2	33.0
1992	11.5	46.0	42.5
1993	15.3	41.5	43.2
1994	15.4	40.7	43.9
1995	20.1	44.4	35.5
1996	25.1	41.6	33.3
1997	23.0	44.1	32.9
1998	22.8	41.7	35.5
1999	26.4	42.4	31.2
2000	26.1	45.7	28.2
2001	14.5	53.8	31.7

ALL REGIONS	0-10%	>10-25%	>25%
1988	30.2	39.1	30.7
1989	27.7	37.6	34.7
1990	28.6	37.6	33.8
1991	26.8	42.1	31.1
1992	24.2	44.9	30.9
1993	23.7	39.8	36.5
1994	21.9	40.1	38.0
1995	24.1	39.4	36.5
1996	29.2	41.7	29.1
1997	25.3	41.9	32.8
1998	26.3	40.1	33.6
1999	26.9	38.6	34.5
2000	25.5	41.0	33.5
2001	20.3	45.2	34.5

Pinus sylvestris

ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1988	68.9	26.0	5.1
1989	58.8	33.6	7.6
1990	53.3	39.8	6.9
1991	54.4	38.9	6.7
1992	60.2	31.1	8.7
1993	53.2	39.6	7.2
1994	48.8	42.7	8.5
1995	46.6	46.5	6.9
1996	40.9	50.4	8.7
1997	47.7	47.2	5.1
1998	56.4	38.0	5.6
1999	46.4	44.7	8.9
2000	46.7	41.2	12.1
2001	42.3	46.5	11.2

SUB-ATLANTIC	0-10%	>10-25%	>25%
1988	31.9	39.9	28.2
1989	27.6	41.0	31.4
1990	27.6	37.5	34.9
1991	17.3	49.8	32.9
1992	17.3	49.0	33.7
1993	24.5	48.6	26.9
1994	11.9	51.2	36.9
1995	18.1	49.7	32.2
1996	21.6	50.6	27.8
1997	22.5	52.4	25.1
1998	24.7	53.5	21.8
1999	19.6	60.6	19.8
2000	13.7	65.7	20.6
2001	18.3	54.0	27.7

MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%
1988	55.2	26.0	18.8
1989	58.1	27.1	14.8
1990	64.0	22.7	13.3
1991	47.7	36.7	15.6
1992	37.7	41.5	20.8
1993	33.8	45.2	21.0
1994	25.0	44.4	30.6
1995	27.3	58.1	14.6
1996	34.8	50.8	14.4
1997	33.8	55.6	10.6
1998	38.3	50.2	11.5
1999	42.3	47.1	10.6
2000	33.1	53.8	13.1
2001	31.7	55.0	13.3

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1988	86.5	11.1	2.4
1989	90.8	8.1	1.1
1990	90.0	8.1	1.9
1991	85.9	12.2	1.9
1992	71.8	18.2	10.0
1993	62.6	20.9	16.5
1994	62.9	22.5	14.6
1995	55.6	29.5	14.9
1996	51.8	37.9	10.3
1997	51.2	41.5	7.3
1998	52.3	40.9	6.8
1999	53.4	42.0	4.6
2000	55.3	41.7	3.0
2001	51.2	45.0	3.8

ALL REGIONS	0-10%	>10-25%	>25%
1988	54.3	28.7	17.0
1989	51.6	30.4	18.0
1990	51.2	29.5	19.3
1991	43.1	38.0	18.9
1992	39.3	38.9	21.8
1993	39.3	40.8	19.9
1994	31.2	42.6	26.2
1995	32.5	47.2	20.3
1996	33.8	48.1	18.1
1997	35.7	49.2	15.1
1998	38.9	47.3	13.8
1999	35.5	51.3	13.2
2000	31.3	54.4	14.3
2001	31.6	51.0	17.4

Fagus sylvatica

ATLANTIC (NORTH)	0-10%	>10-25%	>25%	SUB-ATLANTIC	0-10%	>10-25%	>25%	MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%
1988	44.4	46.2	9.4	1988	31.0	43.6	25.4	1988	47.7	37.3	15.0
1989	37.2	47.1	15.7	1989	34.1	42.6	23.3	1989	23.9	42.9	33.2
1990	20.6	40.4	39.0	1990	28.0	49.4	22.6	1990	46.1	43.7	10.2
1991	38.1	44.4	17.5	1991	36.0	46.1	17.9	1991	64.6	29.5	5.9
1992	22.9	47.1	30.0	1992	21.8	51.5	26.7	1992	60.5	27.2	12.3
1993	22.0	50.6	27.4	1993	23.2	49.9	26.9	1993	57.4	28.2	14.4
1994	28.7	49.3	22.0	1994	12.6	54.8	32.6	1994	51.6	35.3	13.1
1995	17.0	53.0	30.0	1995	16.2	50.0	33.8	1995	42.9	42.1	15.0
1996	17.9	52.5	29.6	1996	18.7	57.0	24.3	1996	32.8	50.5	16.7
1997	25.1	48.9	26.0	1997	22.1	57.9	20.0	1997	29.3	50.6	20.1
1998	28.7	48.0	23.3	1998	20.2	55.8	24.0	1998	49.8	42.0	8.2
1999	12.1	61.9	26.0	1999	15.4	60.3	24.3	1999	37.3	50.8	11.9
2000	10.3	35.9	53.8	2000	23.7	54.2	22.1	2000	42.6	48.4	9.0
2001	19.3	39.5	41.2	2001	17.6	51.9	30.5	2001	26.5	58.1	15.4

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1988	35.0	45.0	20.0	1988	37.5	41.6	20.9
1989	43.8	56.2	0.0	1989	32.6	43.1	24.3
1990	76.2	20.0	3.8	1990	35.0	45.4	19.6
1991	71.2	26.3	2.5	1991	46.4	39.8	13.8
1992	75.0	25.0	0.0	1992	36.2	42.3	21.5
1993	67.4	31.3	1.3	1993	35.4	42.6	22.0
1994	60.0	35.0	5.0	1994	28.2	47.3	24.5
1995	44.9	36.3	18.8	1995	26.6	46.6	26.8
1996	69.9	28.8	1.3	1996	25.8	52.8	21.4
1997	56.2	28.8	15.0	1997	26.5	53.5	20.0
1998	62.4	33.8	3.8	1998	32.0	49.8	18.2
1999	60.0	35.0	5.0	1999	24.3	56.0	19.7
2000	61.2	33.8	5.0	2000	30.3	49.6	20.1
2001	61.2	36.3	2.5	2001	22.9	51.5	25.6

Quercus ilex and *Q. rotundifolia*

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%	MEDITERR. (LOWER)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1988	54.6	34.9	10.5	1988	71.7	25.2	3.1	1988	68.0	27.2	4.8
1989	78.6	18.0	3.4	1989	60.3	35.3	4.4	1989	64.7	31.2	4.1
1990	81.3	17.6	1.1	1990	63.0	22.2	14.8	1990	66.5	20.9	12.6
1991	59.5	36.6	3.9	1991	45.8	36.3	17.9	1991	48.8	36.6	14.6
1992	45.0	45.4	9.6	1992	38.3	45.6	16.1	1992	39.7	45.0	15.3
1993	32.8	58.0	9.2	1993	37.7	56.6	5.7	1993	36.6	56.9	6.5
1994	27.8	53.8	18.4	1994	32.4	58.7	8.9	1994	30.7	58.4	10.9
1995	17.8	48.8	33.4	1995	15.2	59.9	24.9	1995	15.5	58.4	26.1
1996	21.8	52.3	25.9	1996	19.3	57.4	23.3	1996	19.8	56.8	23.4
1997	28.7	56.5	14.8	1997	28.8	59.0	12.2	1997	29.1	58.4	12.5
1998	34.9	51.0	14.1	1998	30.3	56.4	13.3	1998	31.6	55.1	13.3
1999	23.3	58.9	17.8	1999	22.6	53.3	24.1	1999	23.3	54.4	22.3
2000	22.9	56.5	20.6	2000	16.9	57.6	25.5	2000	18.6	57.5	23.9
2001	23.1	62.1	14.8	2001	19.2	63.1	17.7	2001	19.8	63.0	17.2

Pinus pinaster

ATLANTIC (SOUTH)	0-10%	>10-25%	>25%	MEDITERR. (HIGHER)	0-10%	>10-25%	>25%	MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1988	83.5	16.1	0.4	1988	94.4	5.6	0.0	1988	81.6	10.0	8.4
1989	85.7	11.3	3.0	1989	87.8	10.7	1.5	1989	79.2	14.2	6.6
1990	46.5	14.8	38.7	1990	78.6	15.8	5.6	1990	68.6	23.6	7.8
1991	46.5	23.5	30.0	1991	81.6	15.3	3.1	1991	64.1	27.7	8.2
1992	63.5	25.2	11.3	1992	85.2	13.8	1.0	1992	63.4	29.0	7.6
1993	63.5	27.8	8.7	1993	80.1	18.9	1.0	1993	70.9	22.1	7.0
1994	64.3	27.4	8.3	1994	70.4	26.5	3.1	1994	63.6	29.3	7.1
1995	60.0	34.3	5.7	1995	63.7	33.7	2.6	1995	51.4	39.5	9.1
1996	61.3	33.5	5.2	1996	67.3	29.6	3.1	1996	49.6	41.9	8.5
1997	61.7	33.5	4.8	1997	71.0	27.0	2.0	1997	36.8	51.7	11.5
1998	56.5	38.7	4.8	1998	70.4	27.6	2.0	1998	37.4	52.9	9.7
1999	54.4	41.7	3.9	1999	63.2	32.7	4.1	1999	34.4	56.3	9.3
2000	54.8	43.5	1.7	2000	62.7	33.7	3.6	2000	39.1	53.7	7.2
2001	41.3	52.2	6.5	2001	59.2	38.8	2.0	2001	38.8	53.8	7.4

Pinus pinaster

ALL REGIONS	0-10%	>10-25%	>25%
1988	84.3	10.1	5.6
1989	82.2	12.7	5.1
1990	67.3	20.3	12.4
1991	64.6	24.6	10.8
1992	67.3	25.6	7.1
1993	71.3	22.4	6.3
1994	64.7	28.7	6.6
1995	55.3	37.3	7.4
1996	55.1	37.8	7.1
1997	47.2	44.0	8.8
1998	46.6	45.9	7.5
1999	43.2	49.4	7.4
2000	46.1	48.4	5.5
2001	43.0	50.6	6.4

Quercus suber

MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1988	92.1	7.1	0.8
1989	64.5	28.5	7.0
1990	36.9	20.4	42.7
1991	25.0	31.4	43.6
1992	26.5	38.1	35.4
1993	48.3	43.6	8.1
1994	40.4	49.0	10.6
1995	20.7	56.5	22.8
1996	33.1	52.3	14.6
1997	35.6	52.3	12.1
1998	25.9	60.8	13.3
1999	22.5	57.5	20.0
2000	21.4	60.8	17.8
2001	21.1	61.4	17.5

ALL REGIONS	0-10%	>10-25%	>25%
1988	92.3	6.9	0.8
1989	62.9	27.8	9.3
1990	36.3	20.1	43.6
1991	25.0	31.0	44.0
1992	26.3	37.6	36.1
1993	49.7	42.4	7.9
1994	42.1	47.6	10.3
1995	22.7	55.2	22.1
1996	34.1	51.7	14.2
1997	37.3	50.9	11.8
1998	27.2	59.8	13.0
1999	23.7	56.9	19.4
2000	22.7	60.0	17.3
2001	21.4	61.4	17.2

Quercus robur and *Q. petraea*

ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1988	28.4	46.5	25.1
1989	44.8	47.5	7.7
1990	73.2	25.7	1.1
1991	53.0	41.5	5.5
1992	32.8	55.2	12.0
1993	30.6	49.7	19.7
1994	45.4	42.6	12.0
1995	50.8	38.8	10.4
1996	25.1	45.4	29.5
1997	25.7	53.0	21.3
1998	27.9	50.2	21.9
1999	33.3	38.3	28.4
2000	35.0	44.2	20.8
2001	26.2	53.0	20.8

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1988	12.8	59.5	27.7
1989	31.4	53.2	15.4
1990	19.1	57.0	23.9
1991	28.2	48.4	23.4
1992	33.0	39.9	27.1
1993	14.4	51.6	34.0
1994	27.1	42.6	30.3
1995	12.8	45.2	42.0
1996	14.9	43.1	42.0
1997	16.5	42.5	41.0
1998	14.9	46.3	38.8
1999	26.6	52.1	21.3
2000	23.4	51.1	25.5
2001	19.7	54.2	26.1

SUB-ATLANTIC	0-10%	>10-25%	>25%
1988	29.6	40.5	29.9
1989	20.6	42.9	36.5
1990	20.2	52.1	27.7
1991	19.4	48.1	32.5
1992	17.4	50.9	31.7
1993	14.3	48.1	37.6
1994	10.0	45.8	44.2
1995	11.9	44.2	43.9
1996	11.6	52.8	35.6
1997	13.5	53.2	33.3
1998	13.1	43.2	43.7
1999	12.5	60.8	26.7
2000	13.0	65.1	21.9
2001	12.8	61.9	25.3

ALL REGIONS	0-10%	>10-25%	>25%
1988	27.5	43.0	29.5
1989	28.5	40.9	30.6
1990	30.2	43.2	26.6
1991	30.4	44.3	25.3
1992	24.5	48.8	26.7
1993	20.1	47.3	32.6
1994	20.9	45.0	34.1
1995	19.8	44.0	36.2
1996	15.5	48.5	36.0
1997	16.7	48.6	34.7
1998	17.1	44.3	38.6
1999	20.1	53.2	26.7
2000	18.7	57.4	23.9
2001	16.5	58.1	25.4

Abies alba

MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1988	26.6	25.6	47.8	1988	24.4	26.1	49.5
1989	16.6	28.1	55.3	1989	16.4	26.5	57.1
1990	22.1	30.7	47.2	1990	20.2	28.2	51.6
1991	25.6	33.7	40.7	1991	23.0	30.7	46.3
1992	15.6	43.2	41.2	1992	15.3	35.9	48.8
1993	12.6	31.2	56.2	1993	13.2	28.9	57.9
1994	15.6	42.2	42.2	1994	13.9	36.9	49.2
1995	14.6	41.2	44.2	1995	13.9	36.9	49.2
1996	12.1	34.2	53.7	1996	12.9	32.1	55.0
1997	11.6	42.2	46.2	1997	14.3	37.6	48.1
1998	14.6	37.7	47.7	1998	18.5	32.1	49.4
1999	11.6	43.7	44.7	1999	12.5	40.4	47.1
2000	13.6	45.2	41.2	2000	15.0	39.7	45.3
2001	11.6	43.2	45.2	2001	12.5	38.7	48.8

Picea sitchensis

ATLANTIC (NORTH)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1988	81.4	17.3	1.3	1988	81.4	17.3	1.3
1989	51.3	30.7	18.0	1989	51.3	30.7	18.0
1990	78.7	20.0	1.3	1990	78.7	20.0	1.3
1991	66.7	25.3	8.0	1991	66.7	25.3	8.0
1992	64.0	28.0	8.0	1992	64.0	28.0	8.0
1993	47.3	30.7	22.0	1993	47.3	30.7	22.0
1994	42.0	45.3	12.7	1994	42.0	45.3	12.7
1995	52.6	32.7	14.7	1995	52.6	32.7	14.7
1996	62.6	26.7	10.7	1996	62.6	26.7	10.7
1997	67.3	24.7	8.0	1997	67.3	24.7	8.0
1998	56.6	28.7	14.7	1998	56.6	28.7	14.7
1999	74.0	14.7	11.3	1999	74.0	14.7	11.3
2000	68.6	18.7	12.7	2000	68.6	18.7	12.7
2001	70.0	17.3	12.7	2001	70.0	17.3	12.7

All species

ATLANTIC (NORTH)	0-10%	>10-25%	>25%	ATLANTIC (SOUTH)	0-10%	>10-25%	>25%	SUB-ATLANTIC	0-10%	>10-25%	>25%
1988	60.1	30.7	9.2	1988	84.0	11.9	4.1	1988	32.6	39.4	28.0
1989	50.9	38.6	10.5	1989	86.8	10.0	3.2	1989	29.0	39.7	31.3
1990	55.0	32.6	12.4	1990	67.8	14.1	18.1	1990	26.6	41.4	32.0
1991	50.8	37.5	11.7	1991	63.5	19.4	17.1	1991	27.8	44.1	28.1
1992	46.1	39.8	14.1	1992	70.4	21.0	8.6	1992	23.2	45.9	30.9
1993	41.8	40.9	17.3	1993	63.3	27.0	9.7	1993	23.2	44.0	32.8
1994	41.6	43.1	15.3	1994	63.8	29.2	7.0	1994	16.0	45.6	38.4
1995	40.6	42.4	17.0	1995	60.9	32.4	6.7	1995	18.7	43.8	37.5
1996	38.2	43.5	18.3	1996	57.2	37.4	5.4	1996	21.8	49.8	28.4
1997	42.9	41.8	15.3	1997	59.9	35.3	4.8	1997	22.9	50.1	27.0
1998	47.0	38.2	14.8	1998	55.0	39.2	5.8	1998	22.7	47.1	30.2
1999	42.9	39.8	17.3	1999	55.9	39.0	5.1	1999	20.0	52.0	28.0
2000	41.0	36.0	23.0	2000	50.4	43.4	6.2	2000	21.2	51.5	27.3
2001	40.2	38.6	21.2	2001	43.5	46.8	9.7	2001	18.9	48.7	32.4

MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%	MEDITERR. (HIGHER)	0-10%	>10-25%	>25%	MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1988	45.3	34.5	20.2	1988	60.5	29.4	10.1	1988	77.0	18.6	4.4
1989	40.3	30.8	28.9	1989	67.2	25.7	7.1	1989	71.5	24.2	4.3
1990	46.5	31.9	21.6	1990	66.0	25.8	8.2	1990	62.4	21.9	15.7
1991	47.0	35.1	17.9	1991	60.7	29.0	10.3	1991	53.7	28.9	17.4
1992	35.9	39.0	25.1	1992	52.1	34.4	13.5	1992	45.6	37.2	17.2
1993	34.0	38.7	27.3	1993	46.3	39.8	13.9	1993	50.2	41.5	8.3
1994	30.5	42.2	27.3	1994	43.3	40.4	16.3	1994	44.3	44.0	11.7
1995	28.3	48.1	23.6	1995	35.3	41.2	23.5	1995	28.3	50.8	20.9
1996	29.2	46.4	24.4	1996	37.7	42.2	20.1	1996	32.2	50.9	16.9
1997	29.1	46.5	24.4	1997	41.1	42.5	16.4	1997	33.5	55.5	11.0
1998	35.7	42.5	21.8	1998	44.7	41.4	13.9	1998	33.7	54.4	11.9
1999	33.7	46.2	20.1	1999	41.7	45.7	12.6	1999	28.8	54.9	16.3
2000	32.0	49.4	18.6	2000	39.5	47.3	13.2	2000	27.2	55.9	16.9
2001	22.3	55.7	22.0	2001	35.5	49.3	15.2	2001	27.0	57.7	15.3

All species

ALL REGIONS	0-10%	>10-25%	>25%
1988	55.5	29.5	15.0
1989	52.6	30.5	16.9
1990	49.7	30.3	20.0
1991	46.3	34.6	19.1
1992	39.5	39.2	21.3
1993	39.0	41.0	20.0
1994	34.2	43.0	22.8
1995	28.6	45.6	25.8
1996	30.8	47.5	21.7
1997	32.4	48.9	18.7
1998	34.2	46.7	19.1
1999	31.0	49.6	19.4
2000	30.0	50.4	19.6
2001	26.7	51.8	21.5

Annex I-10

Development of defoliation of most common species (1994-2001)

Picea abies

BOREAL	0-10%	>10-25%	>25%	BOREAL (TEMPERATE)	0-10%	>10-25%	>25%	ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1994	56.9	29.1	14.0	1994	43.2	39.6	17.2	1994	57.0	26.7	16.3
1995	55.5	26.9	17.6	1995	49.4	36.0	14.6	1995	53.6	30.8	15.6
1996	55.0	25.5	19.5	1996	40.0	42.6	17.4	1996	55.8	28.3	15.9
1997	51.6	28.7	19.7	1997	39.6	43.3	17.1	1997	58.8	26.2	15.0
1998	50.7	29.4	19.9	1998	38.4	45.0	16.6	1998	52.0	34.2	13.8
1999	50.2	28.7	21.1	1999	33.5	45.7	20.8	1999	53.7	32.0	14.3
2000	44.1	35.4	20.5	2000	36.3	44.8	18.9	2000	55.5	28.9	15.6
2001	42.1	34.8	23.1	2001	33.2	47.1	19.7	2001	57.1	27.1	15.8

SUB-ATLANTIC	0-10%	>10-25%	>25%	CONTINENTAL	0-10%	>10-25%	>25%	MOUNTAINOUS (NORTH)	0-10%	>10-25%	>25%
1994	22.0	37.3	40.7	1994	43.2	28.2	28.6	1994	48.4	20.5	31.1
1995	23.4	34.7	41.9	1995	43.5	29.0	27.5	1995	45.9	21.8	32.3
1996	26.7	34.0	39.3	1996	44.0	27.8	28.2	1996	45.0	17.8	37.2
1997	21.9	36.1	42.0	1997	40.8	31.0	28.2	1997	44.6	20.9	34.5
1998	22.3	36.6	41.1	1998	42.7	29.8	27.5	1998	44.6	20.1	35.3
1999	22.3	35.7	42.0	1999	44.3	34.9	20.8	1999	47.3	22.8	29.9
2000	20.7	36.6	42.7	2000	41.9	36.9	21.2	2000	44.8	27.4	27.8
2001	18.2	39.3	42.5	2001	41.6	39.2	19.2	2001	48.2	21.5	30.3

MOUNTAINOUS (SOUTH)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1994	47.7	29.7	22.6	1994	40.8	32.8	26.4
1995	48.2	31.5	20.3	1995	41.5	31.9	26.6
1996	51.5	28.9	19.6	1996	42.2	31.3	26.5
1997	48.9	31.0	20.1	1997	39.5	33.2	27.3
1998	48.8	29.6	21.6	1998	38.8	33.8	27.4
1999	49.9	30.8	19.3	1999	38.5	33.9	27.6
2000	47.1	31.7	21.2	2000	36.7	35.5	27.8
2001	43.0	35.4	21.6	2001	34.4	37.1	28.5

Pinus sylvestris

BOREAL	0-10%	>10-25%	>25%	BOREAL (TEMPERATE)	0-10%	>10-25%	>25%	ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1994	68.1	27.1	4.8	1994	22.2	49.1	28.7	1994	49.8	40.9	9.3
1995	71.8	23.5	4.7	1995	25.9	53.7	20.4	1995	47.1	44.1	8.8
1996	72.5	23.2	4.3	1996	27.7	55.1	17.2	1996	42.5	48.7	8.8
1997	69.9	26.2	3.9	1997	24.6	59.8	15.6	1997	50.8	42.1	7.1
1998	69.9	26.3	3.8	1998	31.0	56.3	12.7	1998	51.2	40.9	7.9
1999	69.7	26.4	3.9	1999	22.3	66.2	11.5	1999	45.9	43.3	10.8
2000	71.0	25.9	3.1	2000	29.8	60.0	10.2	2000	46.4	42.7	10.9
2001	67.3	28.3	4.4	2001	22.1	66.8	11.1	2001	36.6	50.1	13.3

SUB-ATLANTIC	0-10%	>10-25%	>25%	CONTINENTAL	0-10%	>10-25%	>25%	MOUNTAINOUS (NORTH)	0-10%	>10-25%	>25%
1994	13.0	42.1	44.9	1994	54.6	27.8	17.6	1994	52.4	34.4	13.2
1995	16.6	41.2	42.2	1995	62.6	10.7	26.7	1995	53.8	33.9	12.3
1996	21.3	48.5	30.2	1996	55.1	14.4	30.5	1996	52.6	34.8	12.6
1997	20.7	51.2	28.1	1997	53.0	16.0	31.0	1997	47.8	36.8	15.4
1998	20.1	52.9	27.0	1998	57.2	15.0	27.8	1998	44.2	39.6	16.2
1999	20.4	55.7	23.9	1999	56.1	23.0	20.9	1999	47.9	38.1	14.0
2000	19.6	55.2	25.2	2000	56.1	21.4	22.5	2000	52.3	37.1	10.6
2001	18.6	56.7	24.7	2001	55.6	32.6	11.8	2001	51.6	37.6	10.8

MOUNTAINOUS (SOUTH)	0-10%	>10-25%	>25%	MEDITERR. (HIGHER)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1994	33.9	40.6	25.5	1994	53.6	33.3	13.1	1994	31.3	39.5	29.2
1995	26.6	49.2	24.2	1995	47.7	39.6	12.7	1995	33.5	40.2	26.3
1996	29.8	39.8	30.4	1996	47.9	43.5	8.6	1996	35.8	43.4	20.8
1997	27.2	42.0	30.8	1997	47.4	45.9	6.7	1997	34.6	45.9	19.5
1998	27.2	35.2	37.6	1998	45.1	49.0	5.9	1998	35.3	45.8	18.9
1999	35.2	32.2	32.6	1999	48.0	46.9	5.1	1999	34.3	48.7	17.0
2000	26.2	44.5	29.3	2000	53.6	42.7	3.7	2000	35.2	48.0	16.8
2001	33.5	42.5	24.0	2001	51.6	43.3	5.1	2001	32.7	50.7	16.6

Fagus sylvatica

ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1994	35.9	45.3	18.8
1995	24.4	45.3	30.3
1996	27.8	43.8	28.4
1997	35.7	42.6	21.7
1998	30.9	47.1	22.0
1999	25.3	50.9	23.8
2000	19.0	45.3	35.7
2001	30.9	44.0	25.1

SUB-ATLANTIC	0-10%	>10-25%	>25%
1994	15.1	51.8	33.1
1995	16.8	47.0	36.2
1996	20.1	52.3	27.6
1997	22.6	52.8	24.6
1998	21.0	52.0	27.0
1999	18.1	55.0	26.9
2000	22.7	49.9	27.4
2001	19.0	48.7	32.3

CONTINENTAL	0-10%	>10-25%	>25%
1994	44.3	32.9	22.8
1995	39.1	37.6	23.3
1996	32.9	39.7	27.4
1997	40.4	35.2	24.4
1998	38.8	39.1	22.1
1999	42.9	33.5	23.6
2000	44.7	28.5	26.8
2001	40.5	29.6	29.9

MOUNTAINOUS (SOUTH)	0-10%	>10-25%	>25%
1994	47.2	35.6	17.2
1995	44.1	39.9	16.0
1996	38.8	44.5	16.7
1997	36.2	46.4	17.4
1998	42.0	42.6	15.4
1999	38.4	43.4	18.2
2000	39.7	42.8	17.5
2001	30.1	47.3	22.6

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1994	60.3	30.3	9.4
1995	53.5	32.1	14.4
1996	70.4	22.4	7.2
1997	56.3	24.9	18.8
1998	57.4	34.3	8.3
1999	56.7	33.6	9.7
2000	57.8	32.1	10.1
2001	49.5	35.7	14.8

MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1994	79.9	11.8	8.3
1995	75.7	20.1	4.2
1996	86.1	9.7	4.2
1997	81.2	13.9	4.9
1998	80.5	15.3	4.2
1999	86.8	10.4	2.8
2000	83.3	11.8	4.9
2001	65.9	16.0	18.1

ALL REGIONS	0-10%	>10-25%	>25%
1994	35.5	41.4	23.1
1995	32.9	41.8	25.3
1996	32.9	44.6	22.5
1997	33.8	45.1	21.1
1998	34.5	45.0	20.5
1999	32.3	45.9	21.8
2000	33.8	42.7	23.5
2001	29.4	43.9	26.7

Quercus ilex* and *Q. rotundifolia

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1994	25.6	57.1	17.3
1995	18.1	50.8	31.1
1996	20.3	56.2	23.5
1997	26.0	60.5	13.5
1998	34.4	52.9	12.7
1999	25.8	56.9	17.3
2000	26.8	55.1	18.1
2001	24.0	62.8	13.2

MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1994	32.6	58.3	9.1
1995	16.6	57.1	26.3
1996	21.0	54.8	24.2
1997	28.7	57.1	14.2
1998	31.3	54.9	13.8
1999	21.9	54.5	23.6
2000	17.7	58.3	24.0
2001	19.8	63.5	16.7

ALL REGIONS	0-10%	>10-25%	>25%
1994	30.4	58.8	10.8
1995	16.7	56.4	26.9
1996	20.9	55.5	23.6
1997	28.4	57.8	13.8
1998	32.3	54.3	13.4
1999	23.3	54.9	21.8
2000	20.0	57.7	22.3
2001	20.5	63.5	16.0

Pinus pinaster

ATLANTIC (SOUTH)	0-10%	>10-25%	>25%
1994	65.4	27.9	6.7
1995	61.6	33.4	5.0
1996	62.2	33.4	4.4
1997	65.1	30.8	4.1
1998	57.5	38.7	3.8
1999	56.6	39.9	3.5
2000	56.0	41.9	2.1
2001	42.8	52.5	4.7

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1994	77.8	20.3	1.9
1995	74.5	23.9	1.6
1996	76.8	21.3	1.9
1997	79.0	19.7	1.3
1998	77.7	21.0	1.3
1999	72.9	24.5	2.6
2000	72.9	24.5	2.6
2001	69.3	29.4	1.3

MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1994	65.0	28.9	6.1
1995	58.5	34.0	7.5
1996	56.2	36.5	7.3
1997	42.5	47.5	10.0
1998	42.6	49.1	8.3
1999	39.4	52.7	7.9
2000	43.1	50.7	6.2
2001	43.0	50.4	6.6

ALL REGIONS	0-10%	>10-25%	>25%
1994	67.2	27.4	5.4
1995	62.0	32.0	6.0
1996	61.1	33.0	5.9
1997	53.3	39.3	7.4
1998	51.7	42.1	6.2
1999	48.7	45.3	6.0
2000	50.9	44.4	4.7
2001	47.8	46.8	5.4

Quercus suber

MEDITERR. (LOWER)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1994	40.5	46.9	12.6	1994	42.1	45.6	12.3
1995	19.8	55.1	25.1	1995	21.9	53.7	24.4
1996	33.3	52.7	14.0	1996	34.4	52.0	13.6
1997	34.2	53.5	12.3	1997	35.8	52.2	12.0
1998	27.3	58.3	14.4	1998	28.7	57.3	14.0
1999	24.0	56.7	19.3	1999	25.3	55.9	18.8
2000	22.4	59.8	17.8	2000	23.8	58.9	17.3
2001	21.7	58.3	20.0	2001	22.2	58.2	19.6

Quercus robur and *Q. petraea*

ATLANTIC (NORTH)	0-10%	>10-25%	>25%	ATLANTIC (SOUTH)	0-10%	>10-25%	>25%	SUB-ATLANTIC	0-10%	>10-25%	>25%
1994	38.1	40.0	21.9	1994	59.0	31.5	9.5	1994	9.1	39.4	51.5
1995	36.9	45.0	18.1	1995	46.5	46.5	7.1	1995	10.6	39.0	50.4
1996	28.6	40.6	30.8	1996	41.7	53.5	4.8	1996	12.1	45.5	42.4
1997	25.3	45.8	28.9	1997	41.1	54.7	4.2	1997	13.5	45.1	41.4
1998	23.1	47.4	29.5	1998	41.1	52.4	6.5	1998	13.7	40.3	46.0
1999	23.0	48.4	28.6	1999	46.4	48.2	5.4	1999	12.4	53.1	34.5
2000	28.9	50.3	20.8	2000	39.3	53.0	7.7	2000	12.2	53.1	34.7
2001	19.5	49.1	31.4	2001	27.4	62.5	10.1	2001	12.2	52.5	35.3
MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%	CONTINEN-TAL	0-10%	>10-25%	>25%	MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1994	10.6	50.3	39.1	1994	17.6	39.2	43.2	1994	24.9	41.5	33.6
1995	16.3	43.6	40.1	1995	24.9	33.3	41.8	1995	14.8	45.0	40.2
1996	9.9	33.3	56.8	1996	23.6	31.1	45.3	1996	15.3	44.1	40.6
1997	13.8	26.0	60.2	1997	21.5	40.3	38.2	1997	16.2	40.2	43.6
1998	13.1	36.9	50.0	1998	21.4	41.5	37.1	1998	16.2	43.6	40.2
1999	16.3	35.9	47.8	1999	26.5	37.6	35.9	1999	26.6	49.4	24.0
2000	15.4	36.5	48.1	2000	20.6	22.7	56.7	2000	22.7	50.2	27.1
2001	15.4	38.8	45.8	2001	23.6	24.1	52.3	2001	20.1	50.2	29.7
MEDITERR. (LOWER)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%				
1994	19.6	39.3	41.1	1994	20.1	40.4	39.5				
1995	25.7	33.2	41.1	1995	21.6	39.9	38.5				
1996	29.3	37.8	32.9	1996	19.8	41.0	39.2				
1997	24.6	36.4	39.0	1997	19.5	42.3	38.2				
1998	16.8	42.1	41.1	1998	18.4	42.8	38.8				
1999	19.3	48.2	32.5	1999	19.9	47.5	32.6				
2000	16.1	48.2	35.7	2000	19.5	45.3	35.2				
2001	20.0	48.2	31.8	2001	17.9	45.8	36.3				

Abies alba

SUB-ATLANTIC	0-10%	>10-25%	>25%	MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1994	7.4	22.4	70.2	1994	30.4	35.7	33.9	1994	22.0	28.6	49.4
1995	8.0	27.4	64.6	1995	26.1	38.2	35.7	1995	19.4	34.2	46.4
1996	8.7	31.4	59.9	1996	24.8	31.7	43.5	1996	17.4	32.1	50.5
1997	11.0	31.4	57.6	1997	22.5	36.4	41.1	1997	16.8	33.0	50.2
1998	12.0	28.4	59.6	1998	20.5	35.5	44.0	1998	16.2	31.4	52.4
1999	9.0	32.4	58.6	1999	17.2	41.7	41.1	1999	14.1	35.3	50.6
2000	9.0	29.4	61.6	2000	18.1	38.6	43.3	2000	13.3	33.3	53.4
2001	10.0	27.4	62.6	2001	20.5	41.6	37.9	2001	15.6	34.3	50.1

Picea sitchensis

ATLANTIC (NORTH)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1994	41.0	44.7	14.3	1994	41.0	44.7	14.3
1995	46.6	39.1	14.3	1995	46.6	39.1	14.3
1996	48.1	40.4	11.5	1996	48.1	40.4	11.5
1997	47.2	35.1	17.7	1997	47.2	35.1	17.7
1998	39.4	41.0	19.6	1998	39.4	41.0	19.6
1999	50.6	31.7	17.7	1999	50.6	31.7	17.7
2000	45.4	32.6	22.0	2000	45.4	32.6	22.0
2001	45.6	34.8	19.6	2001	45.6	34.8	19.6

All species

BOREAL	0-10%	>10-25%	>25%
1994	63.0	27.9	9.1
1995	64.8	24.9	10.3
1996	64.9	24.5	10.6
1997	62.3	27.1	10.6
1998	61.7	27.8	10.5
1999	61.5	27.3	11.2
2000	59.0	30.6	10.4
2001	56.4	31.5	12.1

BOREAL (TEMPERATE)	0-10%	>10-25%	>25%
1994	32.8	45.0	22.2
1995	38.0	44.9	17.1
1996	35.5	48.5	16.0
1997	32.6	52.7	14.7
1998	35.2	51.4	13.4
1999	28.3	57.6	14.1
2000	31.7	54.4	13.9
2001	26.4	59.2	14.4

ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1994	45.0	39.1	15.9
1995	41.8	40.3	17.9
1996	40.3	40.5	19.2
1997	44.4	38.3	17.3
1998	41.5	41.1	17.4
1999	40.0	41.9	18.1
2000	39.9	39.8	20.3
2001	38.7	41.0	20.3

ATLANTIC (SOUTH)	0-10%	>10-25%	>25%
1994	65.5	28.6	5.9
1995	61.4	32.9	5.7
1996	58.4	37.1	4.5
1997	61.2	33.7	5.1
1998	54.5	40.0	5.5
1999	54.7	40.1	5.2
2000	50.4	43.5	6.1
2001	41.6	50.0	8.4

SUB-ATLANTIC	0-10%	>10-25%	>25%
1994	15.6	41.3	43.1
1995	18.1	40.0	41.9
1996	21.9	44.8	33.3
1997	21.3	46.8	31.9
1998	20.8	46.7	32.5
1999	20.4	49.6	30.0
2000	20.4	48.7	30.9
2001	18.6	49.5	31.9

CONTINEN-TAL	0-10%	>10-25%	>25%
1994	33.5	35.7	30.8
1995	35.0	33.1	31.9
1996	33.4	33.8	32.8
1997	34.5	36.1	29.4
1998	33.6	36.8	29.6
1999	38.2	34.6	27.2
2000	38.0	25.3	36.7
2001	37.3	29.2	33.5

MOUNTAIN-OUS (NORTH)	0-10%	>10-25%	>25%
1994	46.2	30.2	23.6
1995	45.5	29.1	25.4
1996	44.9	28.9	26.2
1997	42.2	35.1	22.7
1998	40.9	34.8	24.3
1999	42.4	35.5	22.1
2000	45.0	37.0	18.0
2001	46.2	34.8	19.0

MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%
1994	40.0	36.0	24.0
1995	37.6	39.4	23.0
1996	37.9	37.2	24.9
1997	37.2	37.7	25.1
1998	38.8	35.1	26.1
1999	39.2	36.0	24.8
2000	36.2	38.4	25.4
2001	32.6	41.5	25.9

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1994	42.0	41.0	17.0
1995	35.3	41.7	23.0
1996	38.7	41.8	19.5
1997	40.7	41.6	17.7
1998	43.7	41.2	15.1
1999	40.9	43.9	15.2
2000	39.5	45.4	15.1
2001	34.3	48.2	17.5

MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1994	44.8	41.7	13.5
1995	31.8	46.5	21.7
1996	35.5	46.9	17.6
1997	35.7	51.3	13.0
1998	36.2	50.0	13.8
1999	31.3	52.0	16.7
2000	29.7	53.6	16.7
2001	28.3	55.2	16.5

ALL REGIONS	0-10%	>10-25%	>25%
1994	36.2	38.6	25.2
1995	34.7	39.1	26.2
1996	36.1	40.6	23.3
1997	35.7	42.7	21.6
1998	35.9	42.3	21.8
1999	34.5	44.2	21.3
2000	33.8	44.1	22.1
2001	31.2	46.1	22.7

	CSTs$_{89}$			**CSTs$_{94}$**		
Year	**No. of trees** N	**Mean defoliation** ξ	**Standard error** $s_\xi = s\sqrt{N}$	**No. of trees** N	**Mean defoliation** ξ	**Standard error** $s_\xi = s\sqrt{N}$
Pinus sylvestris						
1989	2532	17.2	0.32			
1990	2532	17.6	0.33			
1991	2532	17.9	0.27			
1992	2532	19.7	0.31			
1993	2532	18.0	0.25			
1994	2532	20.6	0.27	17098	21.1	0.11
1995	2532	19.0	0.25	17098	20.2	0.10
1996	2532	18.2	0.24	17098	18.8	0.10
1997	2532	17.5	0.24	17098	18.6	0.10
1998	2532	17.0	0.23	17098	18.5	0.10
1999	2532	17.2	0.22	17098	18.3	0.10
2000	2532	18.1	0.23	17098	18.1	0.10
2001	2532	18.8	0.26	17098	18.7	0.10
Picea abies						
1989	3012	23.2	0.31			
1990	3012	22.8	0.31			
1991	3012	21.7	0.26			
1992	3012	22.0	0.24			
1993	3012	23.5	0.27			
1994	3012	25.1	0.29	12278	19.2	0.15
1995	3012	24.4	0.30	12278	19.1	0.15
1996	3012	21.6	0.27	12278	19.0	0.15
1997	3012	23.1	0.28	12278	19.4	0.14
1998	3012	23.2	0.29	12278	19.5	0.14
1999	3012	23.6	0.30	12278	19.7	0.14
2000	3012	23.7	0.29	12278	20.1	0.14
2001	3012	24.3	0.28	12278	20.7	0.15

Quercus robur and *Q. petraea*						
1989	1215	22.7	0.47			
1990	1215	20.9	0.43			
1991	1215	20.5	0.40			
1992	1215	21.6	0.38			
1993	1215	23.2	0.39			
1994	1215	23.4	0.39	3640	24.8	0.24
1995	1215	24.4	0.43	3640	25.1	0.26
1996	1215	24.5	0.40	3640	25.4	0.26
1997	1215	24.8	0.43	3640	25.7	0.27
1998	1215	25.3	0.43	3640	26.2	0.28
1999	1215	22.4	0.39	3640	24.7	0.27
2000	1215	22.3	0.39	3640	25.6	0.29
2001	1215	22.9	0.40	3640	26.1	0.30
Fagus sylvatica						
1989	2593	19.8	0.27			
1990	2593	18.0	0.24			
1991	2593	15.4	0.23			
1992	2593	19.0	0.27			
1993	2593	18.6	0.25			
1994	2593	20.7	0.25	5883	19.1	0.17
1995	2593	21.2	0.25	5883	20.0	0.18
1996	2593	20.1	0.22	5883	19.6	0.18
1997	2593	19.6	0.22	5883	19.3	0.18
1998	2593	18.4	0.23	5883	18.9	0.18
1999	2593	19.7	0.22	5883	19.6	0.18
2000	2593	19.5	0.25	5883	20.0	0.20
2001	2593	21.4	0.25	5883	21.4	0.20
Pinus pinaster						
1989	1374	7.1	0.26			
1990	1374	12.5	0.34			
1991	1374	12.7	0.32			
1992	1374	11.6	0.27			
1993	1374	10.0	0.28			
1994	1374	11.9	0.29	1918	10.6	0.24
1995	1374	13.3	0.30	1918	11.8	0.24
1996	1374	13.7	0.31	1918	12.2	0.25
1997	1374	15.4	0.30	1918	14.0	0.25
1998	1374	15.5	0.27	1918	14.3	0.23
1999	1374	15.9	0.26	1918	14.8	0.22
2000	1374	15.3	0.26	1918	14.3	0.22
2001	1374	15.7	0.30	1918	14.7	0.24

CSTs$_{89}$				**CSTs$_{94}$**		
Year	**No. of trees** N	**Mean defoliation** ξ	**Standard error** $s_{\xi} = s\sqrt{N}$	**No. of trees** N	**Mean defoliation** ξ	**Standard error** $s_{\xi} = s\sqrt{N}$
Quercus ilex and *Q. rotundifolia*						
1989	2254	11.8	0.16			
1990	2254	14.0	0.28			
1991	2254	16.1	0.25			
1992	2254	16.6	0.21			
1993	2254	15.5	0.17			
1994	2254	17.5	0.22	2876	17.5	0.19
1995	2254	22.6	0.25	2876	22.8	0.23
1996	2254	21.4	0.25	2876	21.7	0.23
1997	2254	18.1	0.22	2876	18.6	0.21
1998	2254	18.4	0.24	2876	18.5	0.22
1999	2254	21.1	0.26	2876	21.2	0.24
2000	2254	21.9	0.26	2876	21.4	0.22
2001	2254	21.0	0.26	2876	20.6	0.22

Annex II

National Surveys

Annex II-1

Forests and surveys in European countries (2001)

Participating countries	Total area (1000 ha)	Forest area (1000 ha)	Coniferous forest (1000 ha)	Broadleav. forest (1000 ha)	Area surveyed (1000 ha)	Grid size (km x km)	No. of sample plots	No. of sample trees
Albania	2875	1028	173	599	1028	10 x 10	216	6480
Austria	8385	3878	2683	798	3481	8.7 x 8.7	260	7002
Belarus	20760	6001	4122	1879	6001	16 x 16	407	9652
Belgium	3035	691	281	324	593	$4^2 / 8^2$	142	3374
Bulgaria	11100	3314	1172	2142	3314	$4^2/8^2/16^2$	120	4323
Croatia	5654	2061	321	1740	1175	16 x 16	81	1941
Cyprus	925	298	172		138	16x16	15	360
Czech Republic	7886	2630	2057	573	2630	$8^2/16^2$	139	6808
Denmark	4309	445	271	146	417	$7^2/16^2$	52	1248
Estonia	4510	2249	1177	1072	2249	16 x 16	89	2136
Finland	30460	20032	18089	1663	15006	16^2 / 24x32	454	8579
France	54926	14591	9228	4058	13100	16 x 16	519	10373
Germany	35562	10264	6869	3395	10264	$16^2 / 4^2$	446	13478
Greece [a]	12890	2512	954	1080	2512	16 x 16	76	1792
Hungary	9300	1787	253	1534	1787	4 x 4	1141	26808
Ireland	6889	436	399	37	399	16 x 16	21	420
Italy	30128	8675	1735	6940	7699	16 x 16	265	7351
Latvia	6459	2888	1610	1193	2888	8 x 8	365	8695
Liechtenstein	16	8	6	2	no survey in 2001			
Lithuania	6520	1858	1144	714	1858	8x8/16x16	286	6664
Luxembourg	259	89	30	54	no survey in 2001			
Rep. of Moldova	3376	318	6	312	318	2 x 2	580	14058
The Netherlands	3482	334	158	52	210	16 x 16	11	231
Norway	32376	12000	6800	5200	12000	$9^2/18^2$	1647	7891
Poland	31268	8756	6868	1970	6786	16 x 16	1180	23600
Portugal	8893	3234	1081	2153	3234	16 x 16	144	4320
Romania	23750	6244	1929	4315	6244	4 x 4	4221	110190
Russian Fed. [b]	10540	7610	5800		5800	varying	130	2966
Slovak Republic	4901	1961	815	1069	1961	16 x 16	110	4241
Slovenia	2027	1099	410	688	1099	16 x 16	41	984
Spain	50471	11792	5637	6155	11792	16 x 16	620	14880
Sweden	41000	23400	19600	900	20600	varying	4139	16442
Switzerland	4129	1186	818	368	1186	16 x 16	49	1073
Turkey	77945	20199	9426	10773	no survey in 2001			
Ukraine	60350	9316	3969	5347	1285	16 x 16	71	1685
United Kingdom	24100	2156	1520	636	2156	random	341	8184
Yugoslavia	102173	2858				16 x 16	114	2674
TOTAL	743629	198198	111783	69881	151294	varying	18492	340903

a) Excluding maquis. b) Leningrad and Pskov regions.

Annex II-2

Defoliation of all species by classes and class aggregates (2001)

Participating countries	Area surveyed (1000 ha)	No. of sample trees	0 none	1 slight	2 moderate	3+4 severe and dead	2+3+4
Albania	1028	6480	51.5	38.3	9.2	1.0	10.2
Austria	3481	7002	57.7	32.6	8.5	1.2	9.7
Belarus	6001	9652	18.0	61.3	19.4	1.3	20.7
Belgium	593	3374	42.1	40.0	16.0	1.9	17.9
Bulgaria	3314	4323	31.6	34.6	25.5	8.3	33.8
Croatia	1175	1941	36.1	38.9	22.0	3.0	25.0
Cyprus	138	360	25.8	65.3	8.9	0.0	8.9
Czech Republic	2630	6808	11.3	36.6	51.3	0.8	52.1
Denmark	417	1248	58.6	34.0	5.4	2.0	7.4
Estonia	2249	2136	49.0	42.5	7.0	1.5	8.5
Finland	15006	8579	56.8	32.3	10.0	0.9	10.9
France	13100	10373	44.2	35.5	18.7	1.6	20.3
Germany	10264	13478	35.7	42.4	20.8	1.1	21.9
Greece [a)]	2512	1792	38.8	39.5	17.1	4.6	21.7
Hungary	1787	26808	37.0	41.8	16.3	4.9	21.2
Ireland	399	420	55.2	27.4	13.1	4.3	17.4
Italy	7699	7351	20.3	41.3	34.2	4.2	38.4
Latvia	2888	8695	18.2	66.2	13.9	1.7	15.6
Liechtenstein			no survey in 2001				
Lithuania	1858	6664	14.6	73.7	9.9	1.8	11.7
Luxembourg			no survey in 2001				
Rep. of Moldova	318	14058	32.4	30.7	27.5	9.4	36.9
The Netherlands	210	231	56.3	23.8	19.5	0.4	19.9
Norway	12000	7891	32.0	40.8	23.6	3.6	27.2
Poland	6868	23600	9.9	59.5	28.8	1.8	30.6
Portugal	3234	4320	46.3	43.6	9.4	0.7	10.1
Romania	6244	110190	62.5	24.2	12.0	1.3	13.3
Russian Fed. [b)]	5800	2966	41.7	48.5	8.6	1.2	9.8
Slovak Republic	1961	4241	15.5	52.8	30.0	1.7	31.7
Slovenia	1099	984	31.4	39.7	24.3	4.6	28.9
Spain	11792	14880	28.9	58.1	9.7	3.3	13.0
Sweden	20600	16442	52.1	30.4	14.8	2.7	17.5
Switzerland	1186	1073	33.7	48.1	11.0	7.2	18.2
Turkey			no survey in 2001				
Ukraine	1285	1685	6.1	54.3	37.6	2.0	39.6
United Kingdom	2156	8184	32.4	46.5	19.8	1.3	21.1
Yugoslavia	2858	2674	65.2	20.8	8.9	5.1	14.0

a) Excluding maquis. b) Leningrad and Pskov regions.

Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

Annex II-3

Defoliation of conifers by classes and class aggregates (2001)

Participating countries	Coniferous forest (1000 ha)	No. of sample trees	0 none	1 slight	2 moderate	3+4 severe and dead	2+3+4
Albania	173	2870	42.9	44.7	11.3	1.1	12.4
Austria	2683	6120	58.4	32.0	8.4	1.2	9.6
Belarus	4122	7075	14.1	62.5	22.1	1.3	23.4
Belgium	281	1255	43.2	39.3	16.1	1.4	17.5
Bulgaria	1172	2415	27.9	33.0	30.5	8.6	39.1
Croatia	321	266	7.1	27.8	57.2	7.9	65.1
Cyprus	172	360	25.8	65.3	8.9	0.0	8.9
Czech Republic	2057	5670	9.3	32.6	57.3	0.8	58.1
Denmark	271	717	66.4	26.9	3.8	2.9	6.7
Estonia	1177	2041	47.3	43.9	7.2	1.6	8.8
Finland	18089	7301	56.4	32.2	10.4	1.0	11.4
France	9228	3606	58.2	27.8	12.8	1.2	14.0
Germany	6869	9337	36.2	43.8	19.4	0.6	20.0
Greece [a)]	954	944	43.1	39.7	13.0	4.2	17.2
Hungary	239	3948	41.0	39.5	15.2	4.3	19.5
Ireland	399	420	55.2	27.4	13.1	4.3	17.4
Italy	1735	2141	43.0	37.9	17.6	1.5	19.1
Latvia	1610	6368	16.1	68.1	14.1	1.7	15.8
Liechtenstein	6		no survey in 2001				
Lithuania	1073	4668	15.7	74.5	8.5	1.3	9.8
Luxembourg			no survey in 2001				
Rep. of Moldova	6		only broadleaves assessed				
The Netherlands	158	150	68.6	10.7	20.7	0.0	20.7
Norway	6800	6030	36.4	38.5	21.4	3.7	25.1
Poland	5334	18020	9.1	60.6	28.3	2.0	30.3
Portugal	1081	1404	52.0	43.7	3.9	0.4	4.3
Romania	1929	27995	69.6	20.8	8.6	1.0	9.6
Russian Fed. [b)]	5800	2966	41.7	48.5	8.6	1.2	9.8
Slovak Republic	815	1714	11.8	49.5	36.7	2.0	38.7
Slovenia	410	391	27.6	40.2	26.9	5.3	32.2
Spain	5637	7522	33.8	54.6	8.6	3.0	11.6
Sweden	13090	14626	50.7	30.9	15.7	2.7	18.4
Switzerland	818	749	32.0	48.9	12.7	6.4	19.1
Turkey			no survey in 2001				
Ukraine	3969	633	7.7	75.5	16.2	0.6	16.8
United Kingdom	1520	4824	32.0	47.4	19.4	1.2	20.6
Yugoslavia		379	54.1	24.6	12.6	8.7	21.3

a) Excluding maquis. b) Leningrad and Pskov regions.

Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

Annex II-4

Defoliation of broadleaves by classes and class aggregates (2001)

Participating countries	Broadleav. forest (1000 ha)	No. of sample trees	0 none	1 slight	2 moderate	3+4 severe and dead	2+3+4
Albania	599	3610	58.3	33.2	7.5	1.0	8.5
Austria	798	882	53.0	36.6	9.0	1.4	10.4
Belarus	1879	2577	28.7	58.0	12.0	1.3	13.3
Belgium	324	2119	41.3	40.4	16.0	2.3	18.3
Bulgaria	2142	1908	36.9	37.1	19.1	6.9	26.0
Croatia	1740	1675	40.7	40.6	16.4	2.3	18.7
Cyprus			only conifers assessed				
Czech Republic	573	1138	21.3	57.0	21.0	0.7	21.7
Denmark	146	531	48.0	43.5	7.7	0.8	8.5
Estonia	1072	95	85.3	12.6	2.1	0.0	2.1
Finland	1663	1278	58.5	32.7	8.0	0.8	8.8
France	4058	6767	36.7	39.7	21.8	1.8	23.6
Germany	3395	4141	34.9	39.7	23.6	1.8	25.4
Greece [a)]	1080	848	34.1	39.3	21.6	5.0	26.6
Hungary	1450	22860	36.2	42.3	16.5	5.0	21.5
Ireland	37		only conifers assessed				
Italy	6940	5210	11.0	42.7	40.9	5.4	46.3
Latvia	1193	2327	24.0	61.2	13.2	1.6	14.8
Liechtenstein	2		no survey in 2001				
Lithuania	701	1996	12.0	71.7	13.1	3.2	16.3
Luxembourg	54		no survey in 2001				
Rep. of Moldova		14058	32.4	30.7	27.5	9.4	36.9
The Netherlands	52	81	33.3	48.2	17.3	1.2	18.5
Norway [b)]	5200	1861	17.7	48.6	30.7	3.0	33.7
Poland	1105	5580	12.7	55.9	30.1	1.3	31.4
Portugal	2153	2916	43.6	43.6	12.0	0.8	12.8
Romania	4315	82195	60.0	25.3	13.2	1.5	14.7
Russian Fed.			only conifers assessed				
Slovak Republic	1069	2527	18.0	55.1	25.5	1.4	26.9
Slovenia	688	593	33.9	39.4	22.6	4.1	26.7
Spain	6155	7358	23.9	61.7	10.9	3.5	14.4
Sweden [b)]	900	1816	54.7	31.2	11.0	3.1	14.1
Switzerland	368	324	37.1	46.6	7.5	8.8	16.3
Turkey	10773		no survey in 2001				
Ukraine	5347	1052	5.1	41.6	50.6	2.7	53.3
United Kingdom	636	3360	32.9	45.2	20.4	1.5	21.9
Yugoslavia		2295	76.2	17.1	5.2	1.5	6.7

a) Excluding maquis. b) Special study on birch.

Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

Annex II-5

Defoliation of all species (1990-2001)

Participating countries	All species												change
	Defoliation classes 2-4												% points
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2000/ 2001
Albania									9.8	9.9	10.1	10.2	0.1
Austria	9.1	7.5	6.9	8.2	7.8	6.6	7.9	7.1	6.7	6.8	8.9	9.7	0.8
Belarus	54.0		29.2	29.3	37.4	38.3	39.7	36.3	30.5	26.0	24.0	20.7	-3.3
Belgium	16.2	17.9	16.9	14.8	16.9	24.5	21.2	17.4	17.0	17.7	19.0	17.9	-1.1
Bulgaria	29.1	21.8	23.1	23.2	28.9	38.0	39.2	49.6	60.2	44.2	46.3	33.8	-12.5
Croatia			15.6	19.2	28.8	39.8	30.1	33.1	25.6	23.1	23.4	25.0	1.6
Cyprus												8.9	
Czech Rep. a)		45.3	56.1	51.8	57.7	58.5	71.9	68.6	48.8	50.4	51.7	52.1	0.4
Denmark	21.2	29.9	25.9	33.4	36.5	36.6	28.0	20.7	22.0	13.2	11.0	7.4	-3.6
Estonia	only conifers assessed								8.7	8.7	7.4	8.5	1.1
Finland	17.3	16.0	14.5	15.2	13.0	13.3	13.2	12.2	11.8	11.4	11.6	11.0	-0.6
France b)	7.3	7.1	8.0	8.3	8.4	12.5	17.8	25.2	23.3	19.7	18.3	20.3	2.0
Germany c)	15.9	25.2	26.4	24.2	24.4	22.1	20.3	19.8	21.0	21.7	23.0	21.9	-1.1
Greece d)	17.5	16.9	18.1	21.2	23.2	25.1	23.9	23.7	21.7	16.6	18.2	21.7	3.5
Hungary	21.7	19.6	21.5	21.0	21.7	20.0	19.2	19.4	19.0	18.2	20.8	21.2	0.4
Ireland	5.4	15.0	15.7	29.6	19.7	26.3	13.0	13.6	16.1	13.0	14.6	17.4	2.8
Italy e)	16.3	16.4	18.2	17.6	19.5	18.9	29.9	35.8	35.9	35.3	34.4	38.4	4.0
Latvia	36.0		37.0	35.0	30.0	20.0	21.2	19.2	16.6	18.9	20.7	15.6	-5.1
Liechtenstein			16.0										
Lithuania	20.4	23.9	17.5	27.4	25.4	24.9	12.6	14.5	15.7	11.6	13.9	11.7	-2.2
Luxembourg		20.8	20.4	23.8	34.8	38.3	37.5	29.9	25.3		23.4		
Rep. of Moldova				50.8		40.4	41.2				29.1	36.9	7.8
The Netherlands	17.8	17.2	33.4	25.0	19.4	32.0	34.1	34.6	31.0		21.8	19.9	-1.9
Norway	17.2	19.7	26.2	24.9	27.5	28.8	29.4	30.7	30.6	28.6	24.3	27.2	2.9
Poland	38.4	45.0	48.8	50.0	54.9	52.6	39.7	36.6	34.6	30.6	32.0	30.6	-1.4
Portugal	30.7	29.6	22.5	7.3	5.7	9.1	7.3	8.3	10.2	11.1	10.3	10.1	-0.2
Romania		9.7	16.7	20.5	21.2	21.2	16.9	15.6	12.3	12.7	14.3	13.3	-1.0
Russian Fed. f)					10.7	12.5						9.8	
Slovak Rep.	41.5	28.5	36.0	37.6	41.8	42.6	34.0	31.0	32.5	27.8	23.5	31.7	8.2
Slovenia	18.2	15.9		19.0	16.0	24.7	19.0	25.7	27.6	29.1	24.8	28.9	4.1
Spain	4.7	7.4	12.3	13.0	19.4	23.5	19.4	13.7	13.6	12.9	13.8	13.0	-0.8
Sweden	only conifers assessed					14.2	17.4	14.9	14.2	13.2	13.7	17.5	3.8
Switzerland	15.5	16.1	12.8	15.4	18.2	24.6	20.8	16.9	19.1	19.0	29.4	18.2	-11.2
Turkey													
Ukraine	2.9	6.4	16.3	21.5	32.4	29.6	46.0	31.4	51.5	56.2	60.7	39.6	-21.1
United Kingd. g)	39.0	56.7	58.3	16.9	13.9	13.6	14.3	19.0	21.1	21.4	21.6	21.1	-0.5
Yugoslavia		9.8					3.6	7.7	8.4	11.2	8.4	14.0	5.6

a) Only trees older than 60 years assessed until 1997. b) Due to methodological changes, only the time series 1990-94 and 1997-2001 are consistent, but not comparable to each other. c) For 1990, only data for former Federal Republic of Germany. d) Excluding maquis. e) Due to methodological changes, only the time series 1989-96 and 1997-2001 are consistent, but not comparable to each other. f) Only Kaliningrad and Leningrad Regions. g) The difference between 1992 and subsequent years is mainly due to a change of assessment method in line with that used in other States.

Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

Annex II-6

Defoliation of conifers (1990-2001)

Participating countries	Conifers												change % points
	Defoliation classes 2-4												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2000/ 2001
Albania									12.0	12.1	12.3	12.4	0.1
Austria	8.3	7.0	6.6	8.2	7.9	6.6	7.3	6.3	6.3	6.4	9.1	9.6	0.5
Belarus	57.0		33.7	33.8	44.0	43.9	43.1	41.2	33.9	28.9	26.1	23.4	-2.7
Belgium	23.6	23.4	23.0	18.3	21.2	21.0	25.8	19.2	13.5	15.5	19.5	17.5	-2.0
Bulgaria	37.4	26.5	25.5	26.9	25.0	41.4	46.5	53.5	69.8	48.9	46.4	39.1	-7.3
Croatia			26.2	33.9	39.3	57.5	57.0	68.7	45.8	53.2	53.3	65.1	11.8
Cyprus												8.9	
Czech Rep a)	46.9	46.3	57.9	51.5	59.0	60.7	74.9	71.9	54.6	57.4	58.3	58.1	-0.2
Denmark	18.8	31.4	28.6	37.0	38.7	34.8	23.2	15.9	17.0	9.9	8.8	6.7	-2.1
Estonia	20.0	28.0	29.5	21.2	16.0	14.2	14.6	11.4	9.0	9.1	7.5	8.8	1.3
Finland	18.0	17.2	15.2	15.6	13.1	13.7	13.7	12.8	12.2	11.9	12.0	11.4	-0.6
France b)	6.6	6.7	7.1	8.2	8.2	9.2	13.5	16.2	16.8	14.1	12.0	14.0	2.0
Germany c)	15.0	24.8	23.8	21.4	21.6	18.3	16.7	15.4	19.0	19.2	19.6	20.0	0.4
Greece d)	10.0	7.2	12.3	13.9	13.2	13.6	14.4	13.8	12.9	13.5	16.5	17.2	0.7
Hungary	23.3	17.8	20.1	20.1	21.2	18.7	17.8	17.4	18.7	17.6	21.5	19.5	-2.0
Ireland	5.4	15.0	15.7	29.6	19.7	26.3	13.0	13.6	16.1	13.0	14.6	17.4	2.8
Italy e)	19.2	13.8	17.2	15.1	15.0	19.4	25.1	28.1	25.5	23.1	19.2	19.1	-0.1
Latvia	43.0		45.0	41.0	34.0	23.0	24.8	21.9	18.9	20.6	20.1	15.8	-4.3
Liechtenstein			18.0										
Lithuania	22.9	27.8	17.5	29.2	26.3	26.6	12.9	13.9	13.6	11.5	12.0	9.8	-2.2
Luxembourg		7.9	6.3	9.0	12.8	12.9	12.7	8.0	10.5		7.0		
Rep. of Moldova				45.2		33.3	48.4						
The Netherlands	21.4	21.4	34.7	30.6	27.7	45.4	43.5	45.3	43.2		23.5	20.7	-2.8
Norway	17.1	19.0	23.4	20.9	22.4	24.0	25.1	28.5	27.5	24.3	21.8	25.1	3.3
Poland	40.7	46.9	50.3	50.8	55.6	54.5	40.5	36.8	34.6	30.6	32.1	30.3	-1.8
Portugal	25.7	19.8	11.3	7.1	5.4	6.6	5.6	7.8	6.6	6.0	4.3	4.3	0.0
Romania		6.9	10.9	16.6	15.5	15.2	10.4	10.3	9.0	9.1	9.8	9.6	-0.2
Russian Fed. f)	6.0	4.2	5.4	4.5	9.4	10.1	9.4					9.8	
Slovak Rep.	55.5	38.5	44.0	49.9	50.3	52.0	41.0	42.2	40.3	40.2	37.9	38.7	0.8
Slovenia	34.6	31.3		27.0	19.0	33.6	26.0	32.5	36.7	38.0	34.5	32.2	-2.3
Spain	4.5	7.3	13.5	14.7	19.1	18.1	18.1	11.5	12.9	9.8	12.0	11.6	-0.4
Sweden	16.1	12.3	16.9	10.6	16.2	14.5	16.9	15.9	15.0	13.6	13.5	18.4	4.9
Switzerland	17.9	18.0	14.1	17.4	19.6	23.2	21.4	19.9	19.7	18.3	33.0	19.1	-13.9
Turkey													
Ukraine	3.0	6.4	13.8	21.7	34.8	25.7	45.8	32.7	64.9	50.0	47.3	16.8	-30.5
United Kingd. g)	45.0	51.5	52.7	16.8	15.0	13.0	13.9	17.0	19.8	20.1	20.2	20.6	0.4
Yugoslavia		15.9					4.4	7.9	6.0	9.2	10.0	21.3	11.3

a) Only trees older than 60 years assessed until 1997. b) Due to methodological changes, only the time series 1990-94 and 1997-2001 are consistent, but not comparable to each other. c) For 1990, only data for former Federal Republic of Germany. d) Excluding maquis. e) Due to methodological changes, only the time series 1989-96 and 1997-2001 are consistent, but not comparable to each other. f) Only Kaliningrad and Leningrad Regions; 1995 and 1996: Only Leningrad Region. g) The difference between 1992 and subsequent years is mainly due to a change of assessment method in line with that used in other States.

Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

Annex II-7

Defoliation of broadleaves (1990-2001)

Participating countries	Broadleaves												change % points
	Defoliation classes 2-4												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2000/2001
Albania									8.0	8.1	8.4	8.4	0.0
Austria	14.9	11.1	9.3	7.7	7.4	6.5	11.6	12.2	9.6	9.4	7.6	10.4	2.8
Belarus	45.0		14.8	16.6	18.6	22.9	29.2	23.0	19.3	17.0	16.9	13.3	-3.6
Belgium	10.0	13.5	11.8	11.7	12.8	26.6	18.5	16.1	19.2	19.1	18.8	18.3	-0.5
Bulgaria	17.3	15.3	18.0	16.6	34.4	32.7	33.0	43.9	48.4	35.9	45.8	26.0	-19.8
Croatia			13.6	15.6	26.4	35.2	26.0	27.8	21.9	16.8	18.3	18.7	0.4
Cyprus													
Czech Rep. [a]		37.6	29.2	54.4	48.0	30.6	34.0	26.5	13.5	17.1	21.4	21.7	0.3
Denmark	25.4	27.3	21.2	27.0	32.4	39.7	36.1	28.4	30.1	18.8	13.9	8.5	-5.4
Estonia	only conif. ass.		0.0	1.1	2.0	1.1	5.3	7.4	1.0	1.1	9.5	2.1	-7.4
Finland	11.6	7.7	10.1	12.8	12.0	11.0	10.3	8.4	9.4	8.6	9.9	8.8	-1.1
France [b]	7.7	7.4	8.5	8.4	8.4	14.3	20.1	29.9	26.9	22.9	21.6	23.6	2.0
Germany [c]	23.8	26.5	32.0	29.9	30.1	29.9	30.8	28.6	25.2	26.9	29.9	25.4	-4.5
Greece [d]	26.5	28.5	25.0	29.8	35.0	38.2	34.6	34.9	31.7	20.2	20.2	26.6	6.4
Hungary	21.5	19.9	21.8	21.2	21.8	20.2	19.5	19.7	19.0	18.2	20.8	21.5	0.7
Ireland	only conifers assessed												
Italy [e]	15.4	17.1	18.5	18.3	20.7	18.5	31.2	38.0	38.9	39.3	40.5	46.3	5.8
Latvia	27.0		19.0	17.8	15.0	10.0	11.4	11.3	13.6	14.2	22.2	14.8	-7.4
Liechtenstein			8.0										
Lithuania	15.8	14.9	17.6	23.8	23.3	20.8	12.2	15.9	19.7	11.8	17.7	16.3	-1.4
Luxembourg		33.9	30.5	31.0	46.8	51.4	49.8	41.8	33.3		33.5		
Rep. of Moldova				50.9	21.9	40.5	41.1	30.0		41.4	29.2	36.9	7.7
The Netherlands	11.5	9.4	31.1	13.1	5.1	10.8	19.2	17.8	14.0		18.8	18.5	-0.3
Norway	18.2	25.1	38.9	42.1	47.6	47.4	45.0	38.9	42.2	44.8	34.0	33.7	-0.3
Poland	25.6	34.8	40.4	45.6	51.5	46.7	37.4	35.8	34.8	31.1	32.0	31.4	-0.6
Portugal	34.1	36.6	29.1	7.5	5.8	10.4	8.3	8.6	12.0	13.7	13.2	12.8	-0.4
Romania		10.4	18.4	21.4	22.9	18.0	18.7	16.9	13.3	14.0	15.8	14.7	-1.1
Russian Fed. [f]	10.2				39.4	34.4							
Slovak Rep.	31.3	21.1	30.0	29.1	35.6	35.8	28.0	23.3	27.0	19.3	13.9	26.9	13.0
Slovenia	4.4	5.8		11.0	13.0	19.3	15.0	21.4	21.7	23.2	18.4	26.7	8.3
Spain	4.8	7.4	11.2	11.4	19.6	28.7	20.7	15.8	14.4	16.1	15.7	14.4	-1.3
Sweden	only conifers assessed					7.9	20.7	6.1	7.4	8.7	7.5	14.1	6.6
Switzerland	12.3	13.3	11.1	12.7	16.2	27.0	19.8	12.5	18.1	20.4	22.1	16.3	-5.8
Turkey													
Ukraine	2.7	6.4	20.2	21.6	29.9	33.0	46.2	30.7	43.2	59.7	69.6	53.3	-16.3
United Kingd. [g]	28.8	65.6	67.8	17.1	12.4	14.5	15.0	22.0	22.9	23.2	23.8	21.9	-1.9
Yugoslavia		8.2					3.5	7.4	10.1	13.0	6.7	6.7	0.0

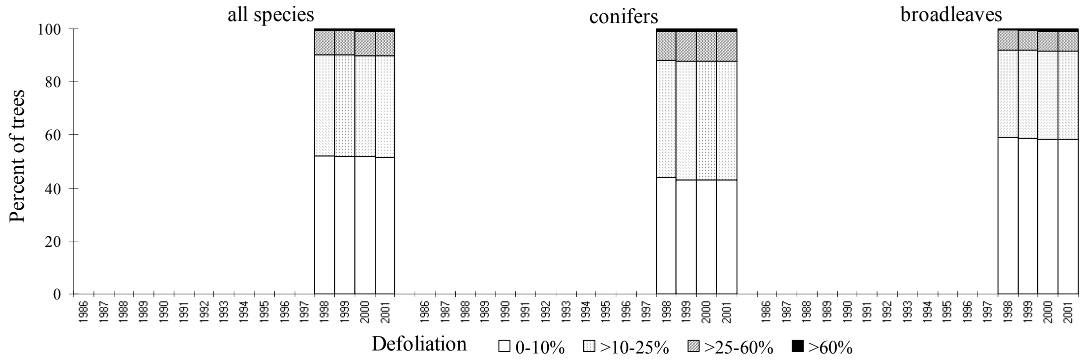
a) Only trees older than 60 years assessed until 1997. b) Due to methodological changes, only the time series 1990-94 and 1997-2001 are consistent, but not comparable to each other. c) For 1990, only data for former Federal Republic of Germany. d) Excluding maquis. e) Due to methodological changes, only the time series 1989-96 and 1997-2001 are consistent, but not comparable to each other. f) Only Kaliningrad and Leningrad Regions.

g) The difference between 1992 and subsequent years is mainly due to a change of assessment method in line with that used in other States.

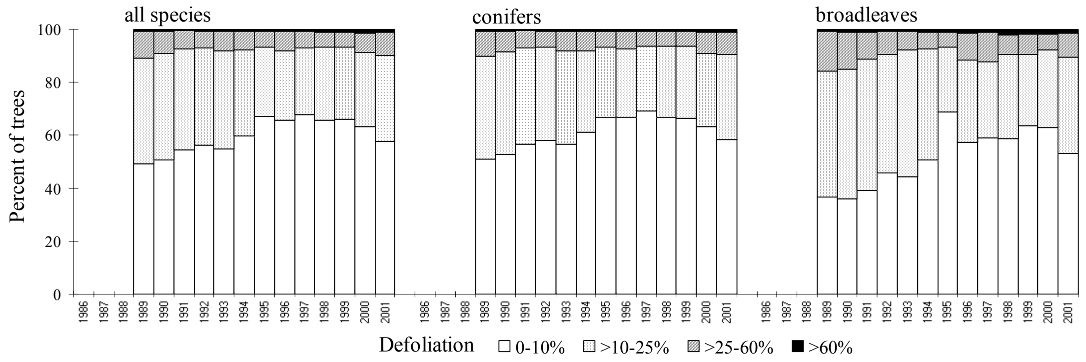
Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

Annex II-8
Changes in defoliation (1986-2001)

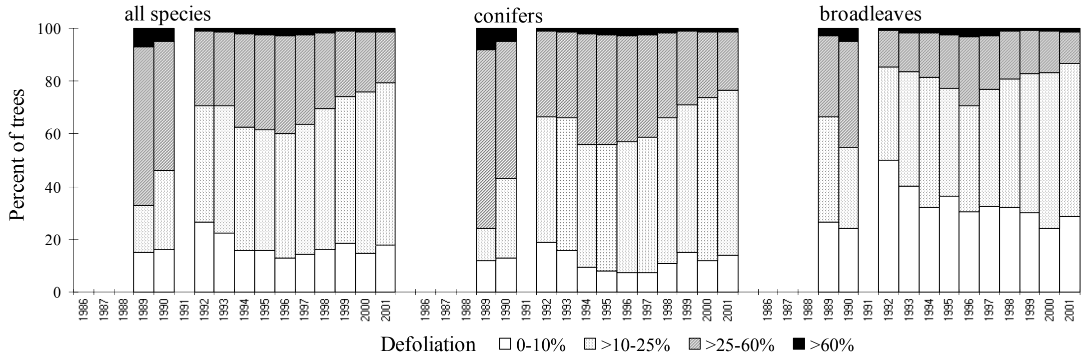
Albania



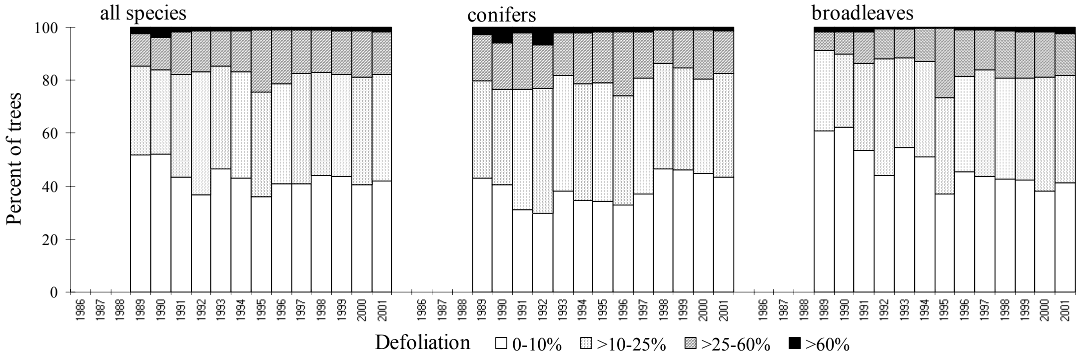
Austria



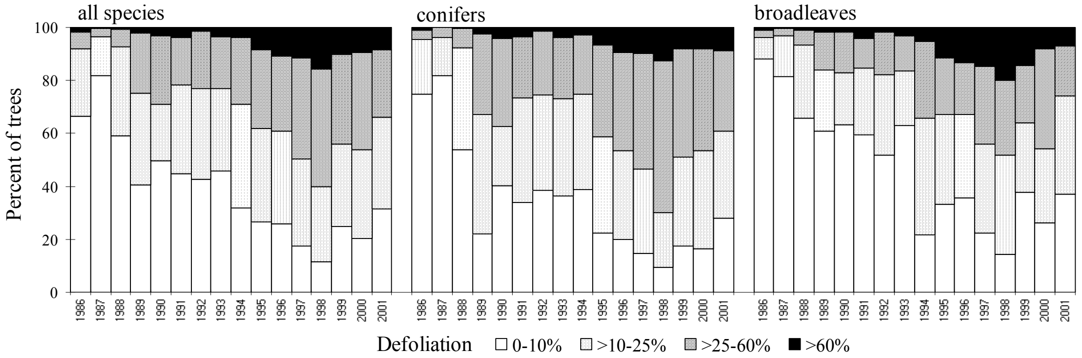
Belarus



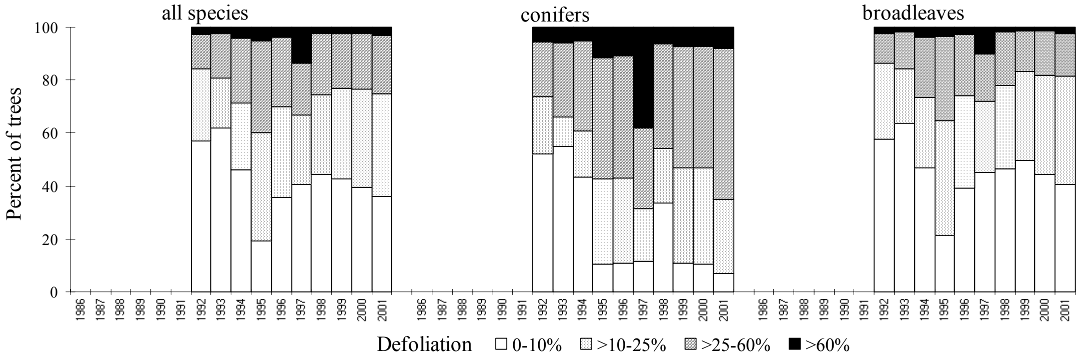
Belgium



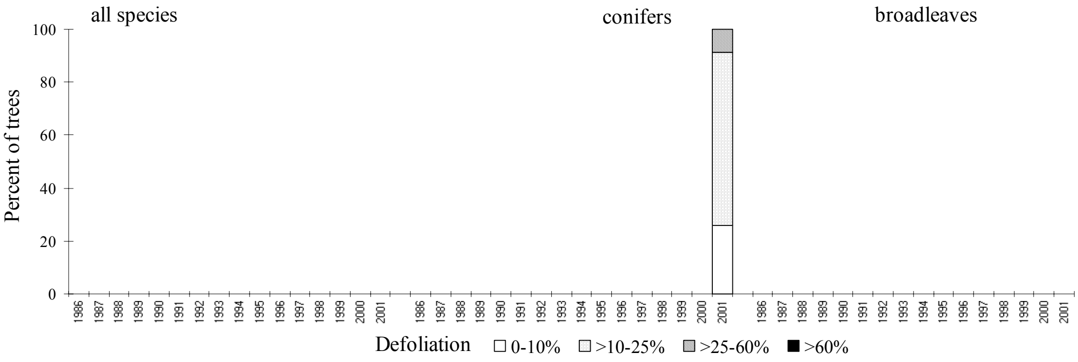
Bulgaria



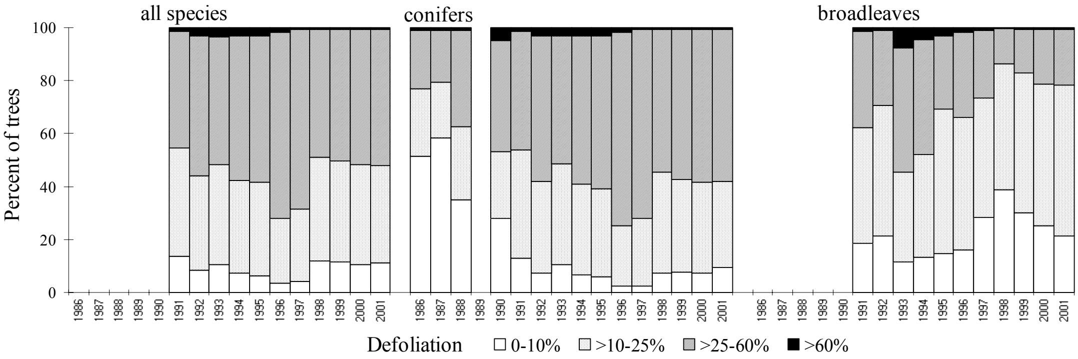
Croatia



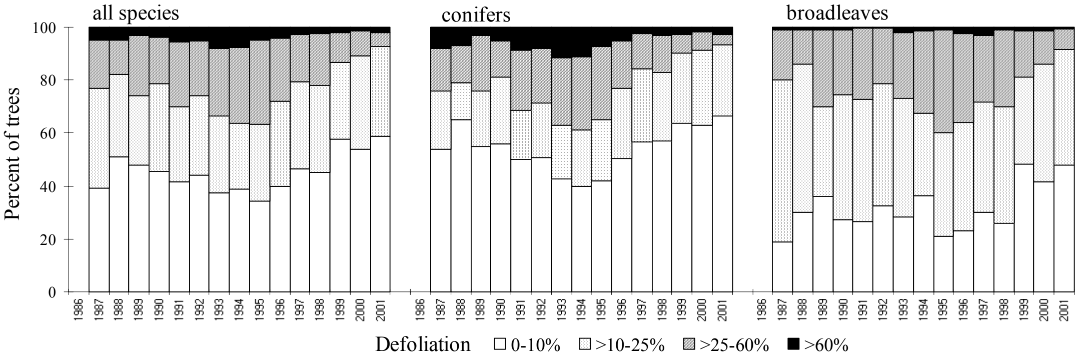
Cyprus



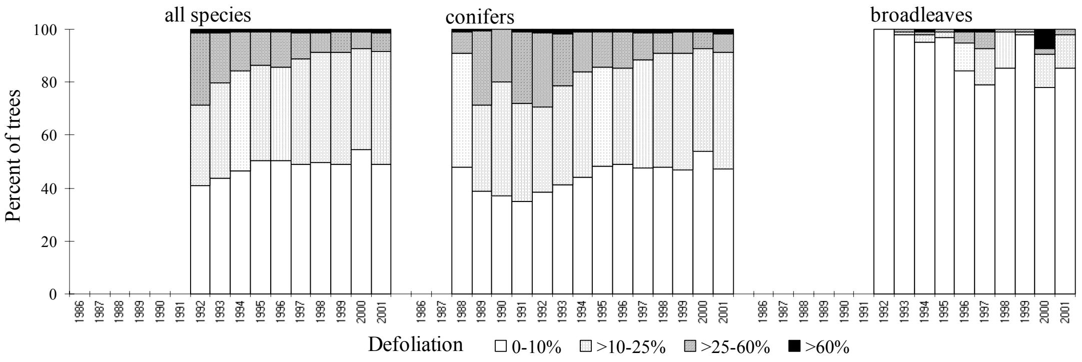
Czech Republic



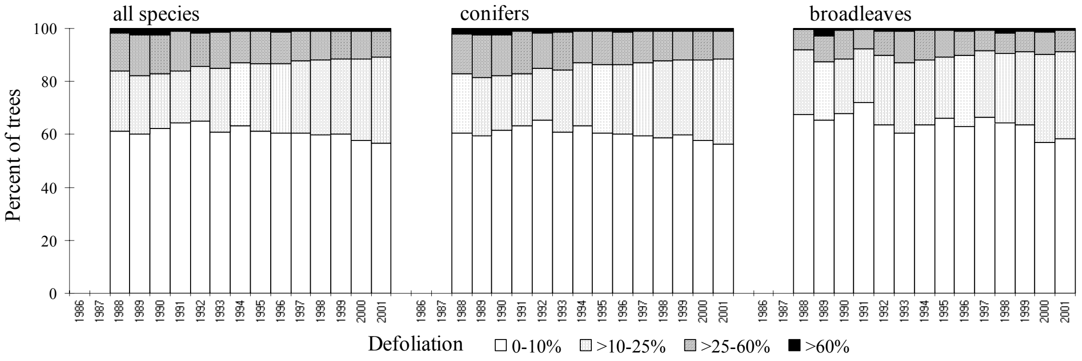
Denmark



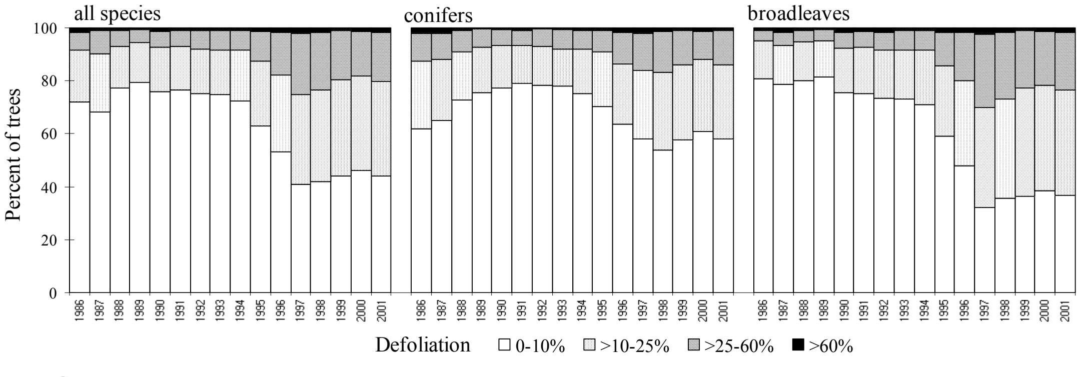
Estonia



Finland

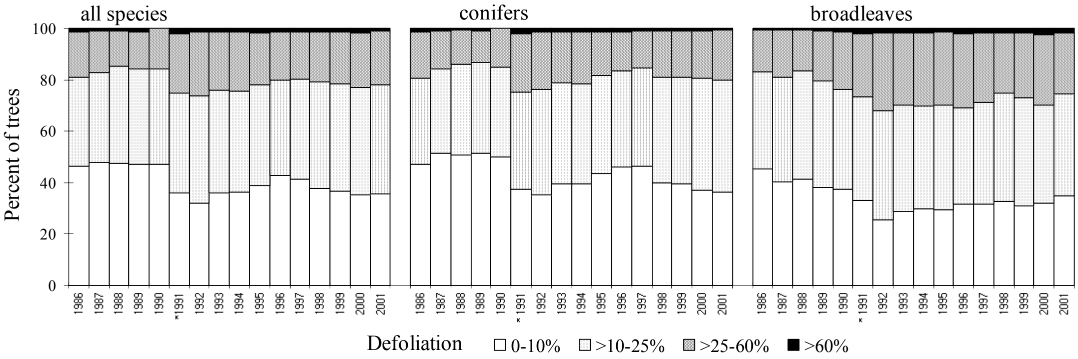


France *



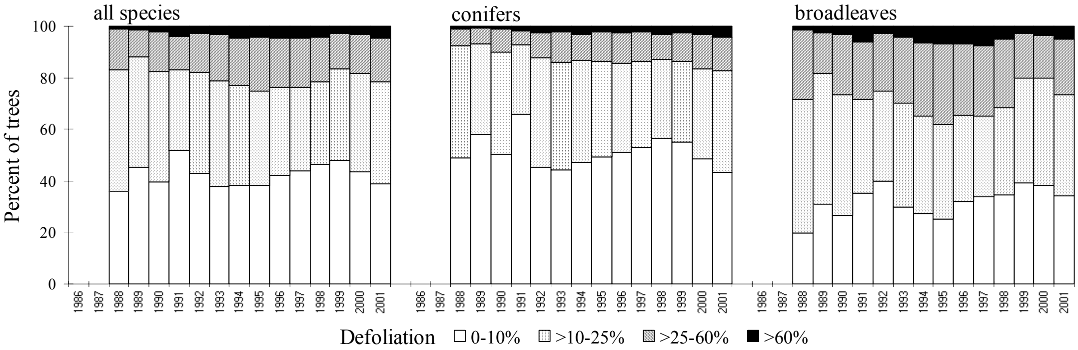
* due to methodological changes, only the time series 1988-94 and 1997-99 are consistent, but not comparable to each other.

Germany

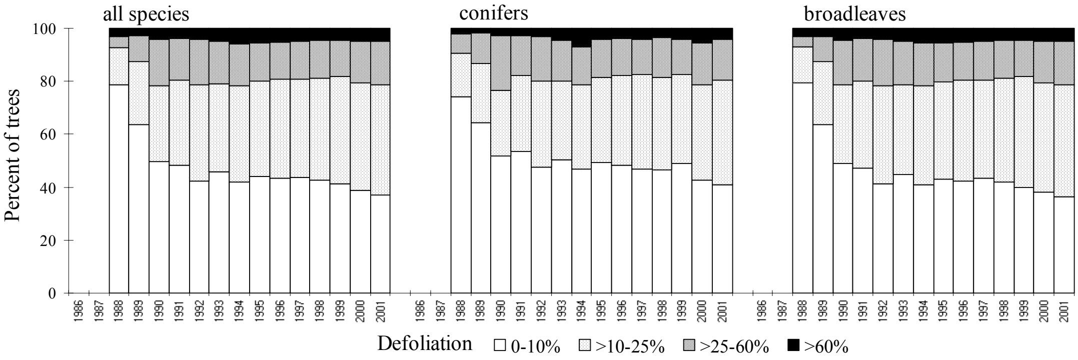


* since 1991 with former GDR

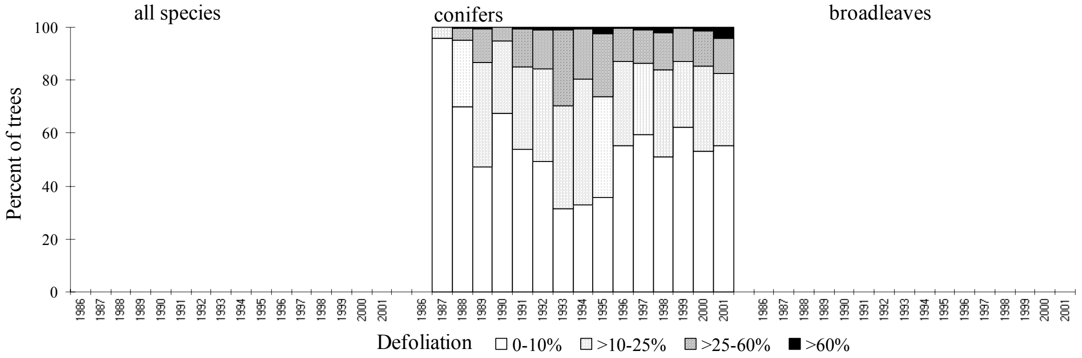
Greece



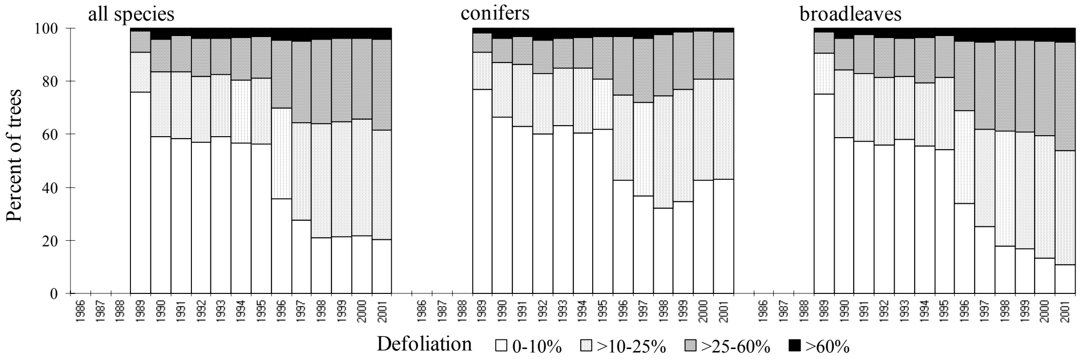
Hungary



Ireland

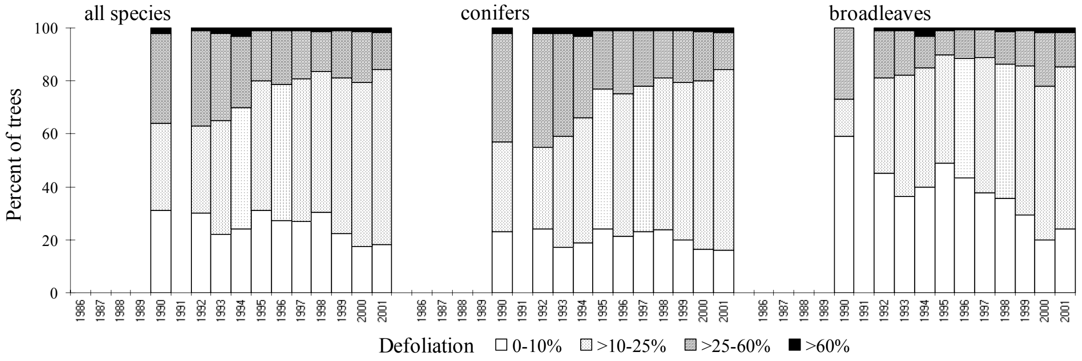


Italy *

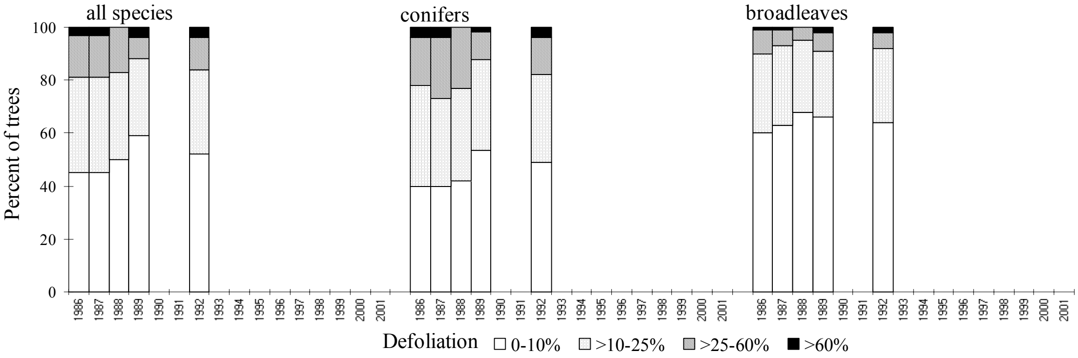


* Due to methodological changes, only the time series 1989-96 and 1997-2001 are consistent, but not comparable to each other.

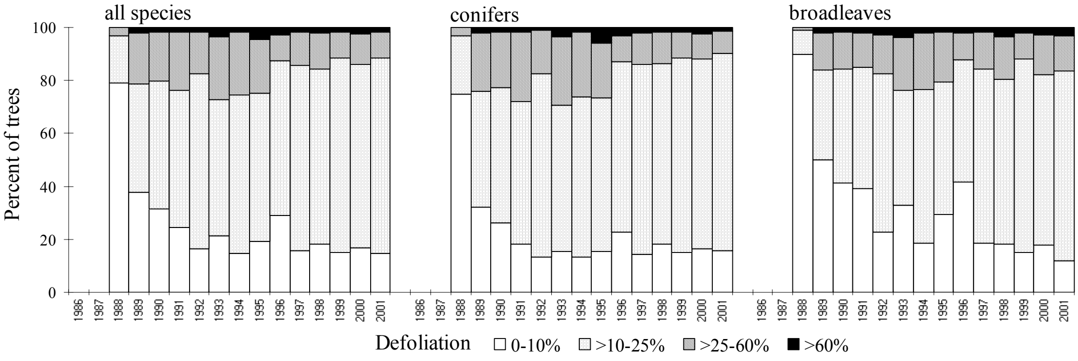
Latvia



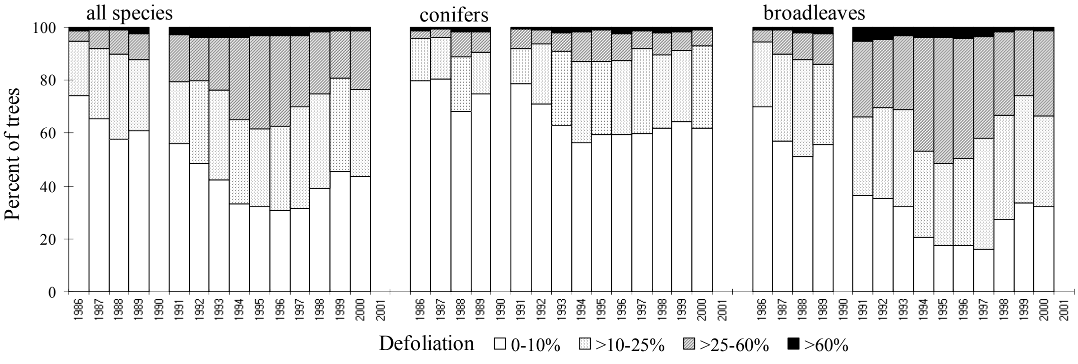
Liechtenstein



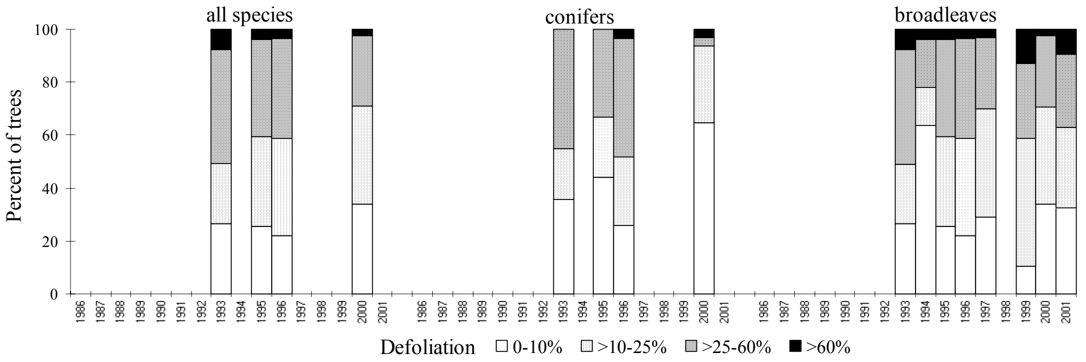
Lithuania



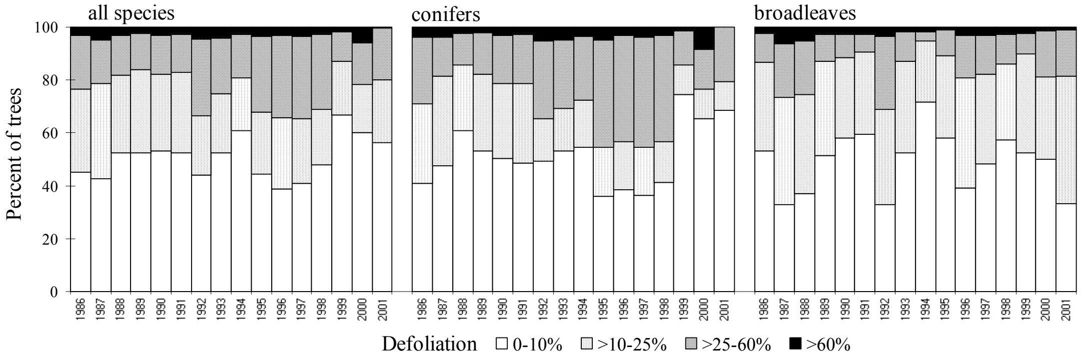
Luxembourg



Republic of Moldova

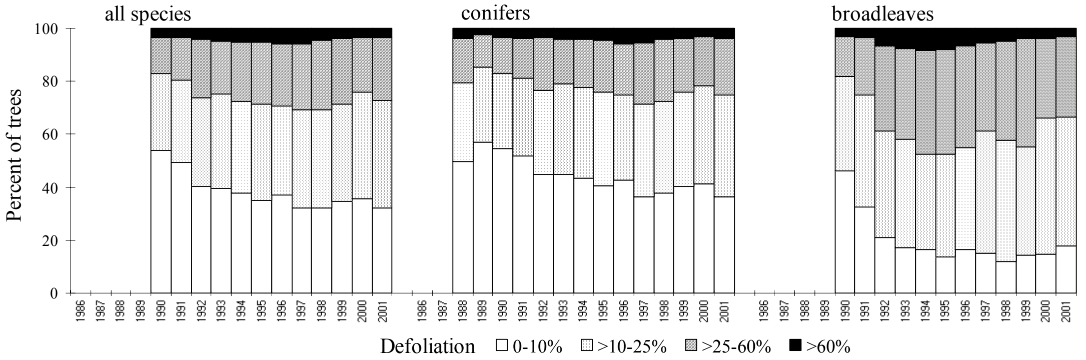


The Netherlands*

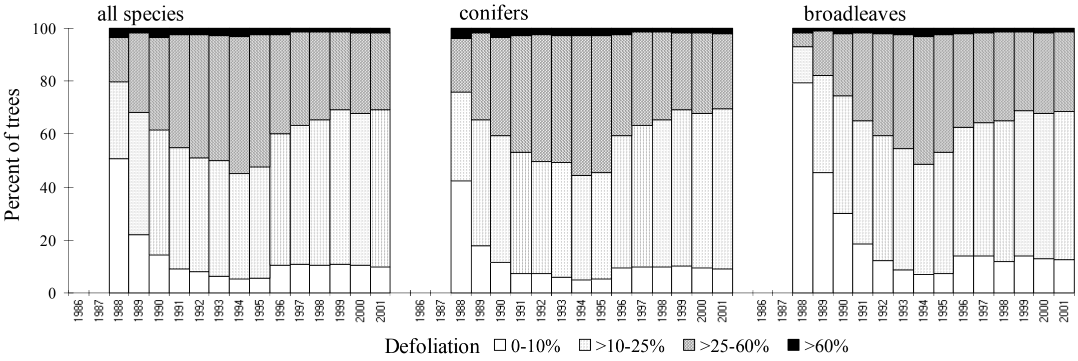


* 1989-1994: 1500 plots, 1995-1998: 200 plots, since 1999: 11 plots

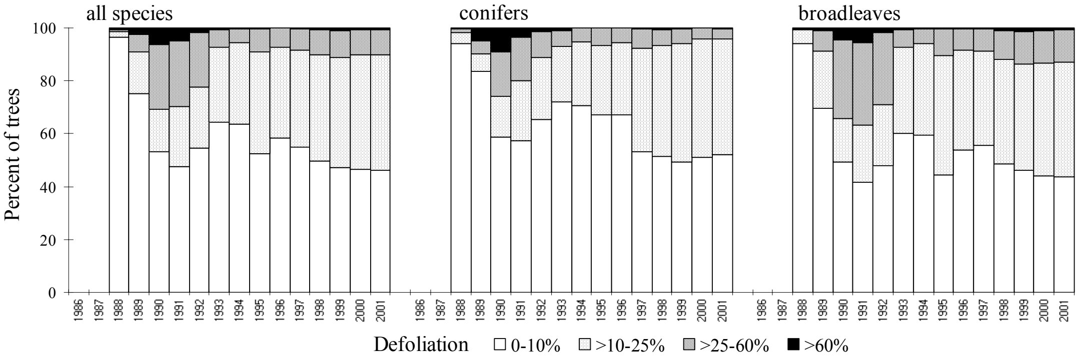
Norway



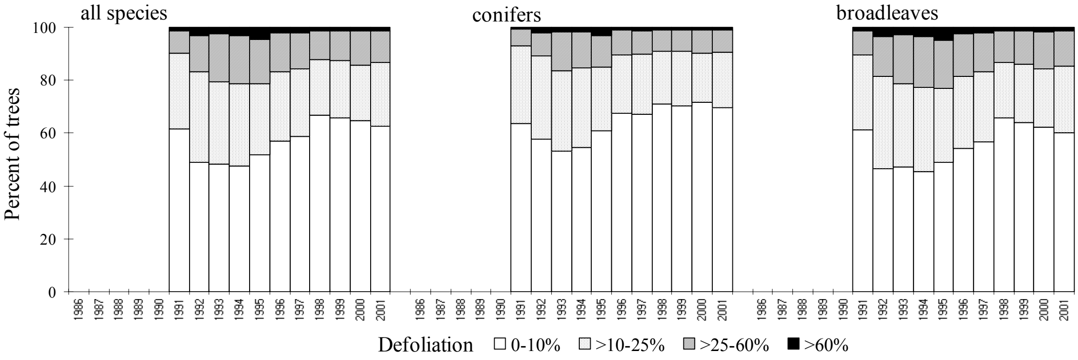
Poland



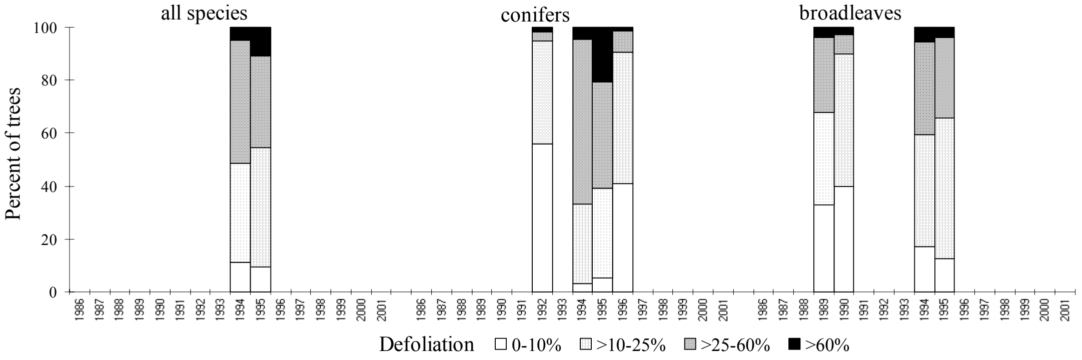
Portugal



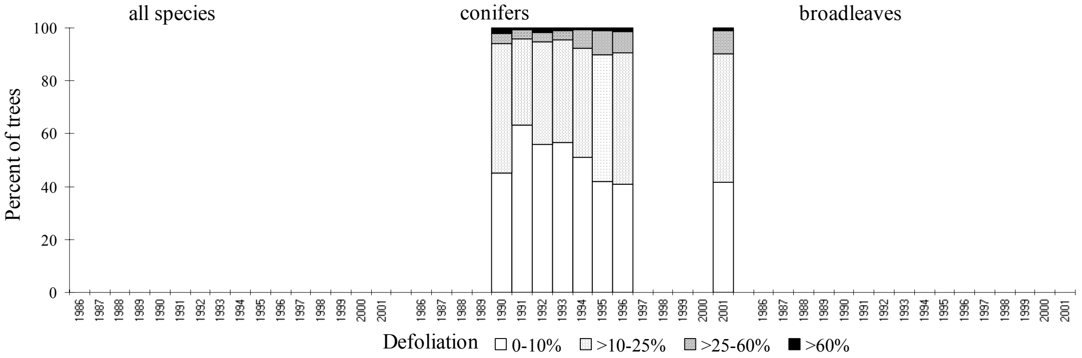
Romania



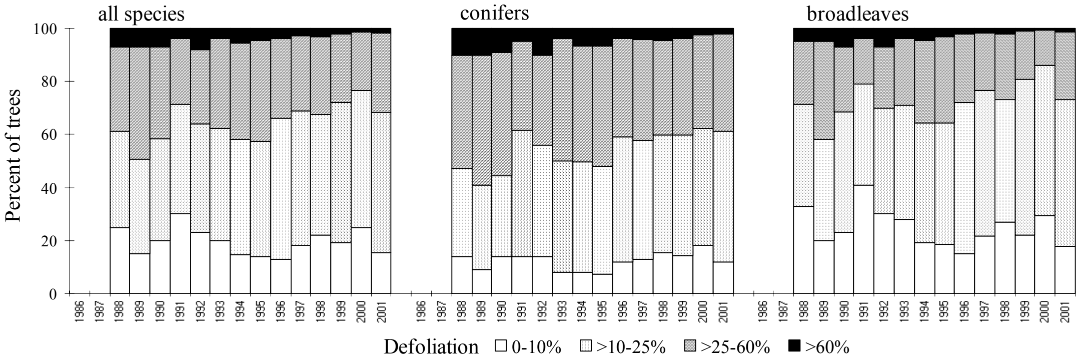
Russian Fed. (Kaliningrad Region)



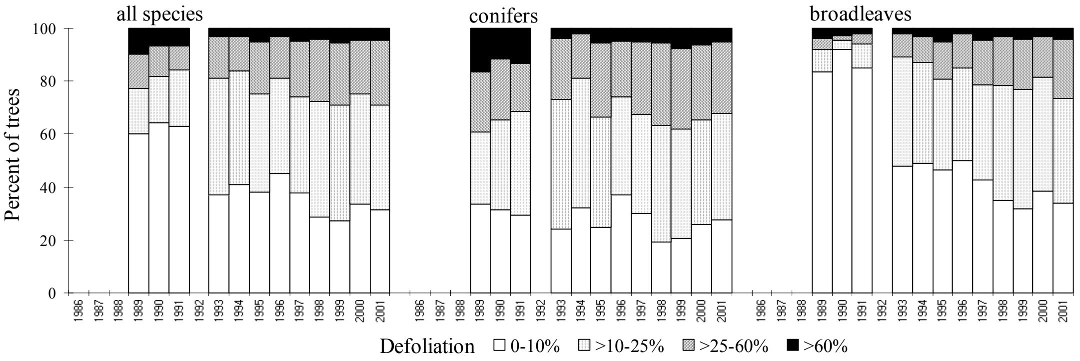
Russian Fed. (Leningrad Region)



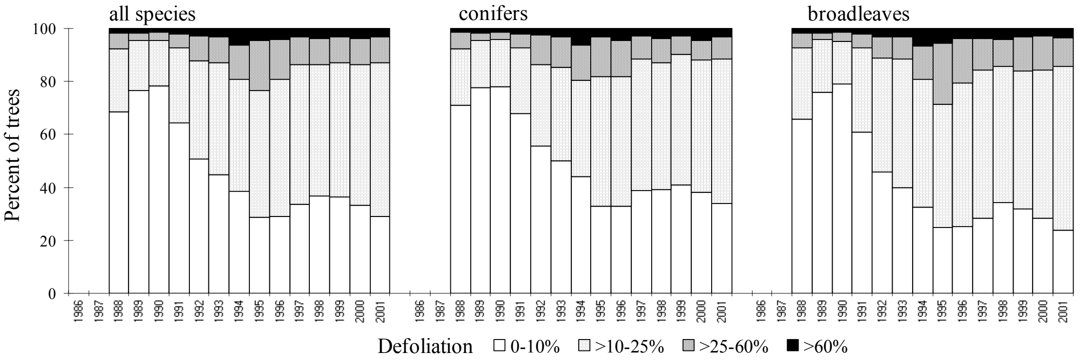
Slovak Republic



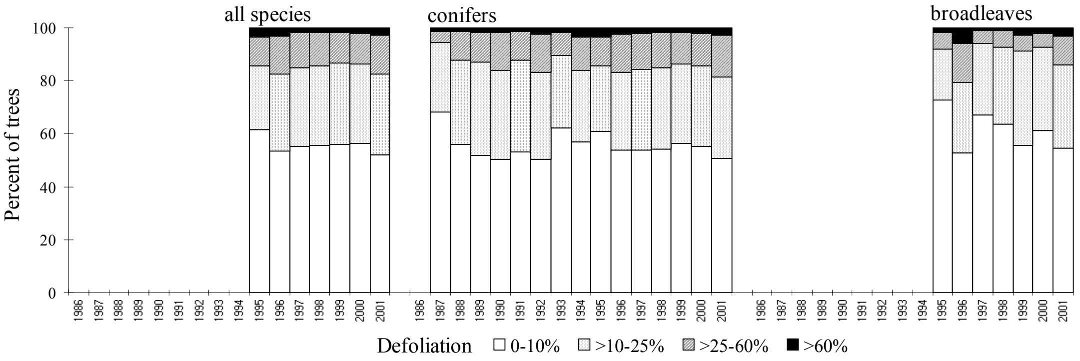
Slovenia



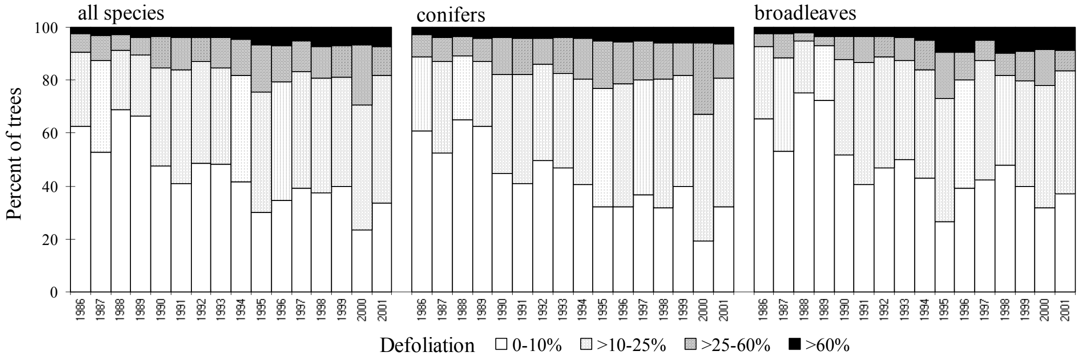
Spain



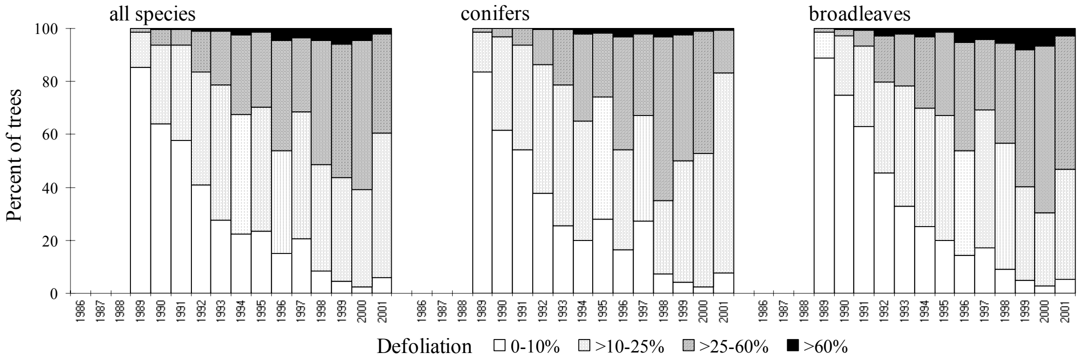
Sweden



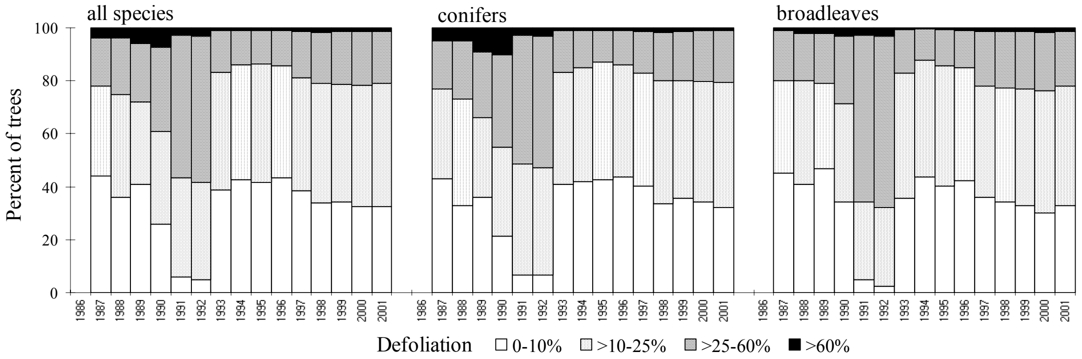
Switzerland



Ukraine

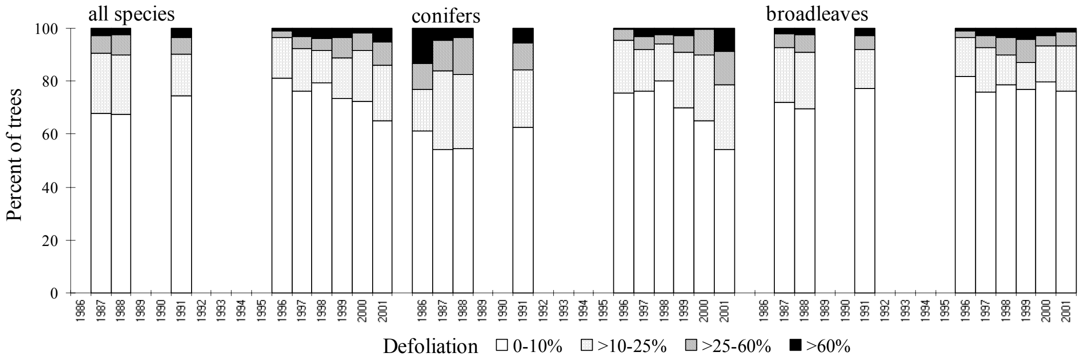


United Kingdom



after 1992 change of assessment method in line with that used in other countries

Yugoslavia


all species
conifers
broadleaves
Percent of trees
100
80
60
40
20
0
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Defoliation
□ 0-10%
▨ >10-25%
▩ >25-60%
■ >60%

Annex III

Main species referred to in the text

Botanical name	**Danish**	**Dutch**	**English**	**Finnish**	**French**	**German**
Fagus sylvatica	Bøg	Beuk	Common beech	Pyökki	Hêtre	Rotbuche
Quercus petraea	Vintereg	Wintereik	Sessile oak	Talvitammi	Chêne rouvre	Traubeneiche
Quercus robur	Stilkeg	Zomereik	European oak	Metsätammi	Chêne pédonculé	Stieleiche
Quercus ilex	Steneg	Steeneik	Holm oak	Rautatammi	Chêne vert	Steineiche
Quercus suber	Korkeg	Kurkeik	Cork oak	Korkkitammi	Chêne liège	Korkeiche
Pinus sylvestris	Skovfyr	Grove den	Scots pine	Metsämänty	Pin sylvestre	Gemeine Kiefer
Pinus nigra	Østrigsk fyr	Oostenrijkse Corsicaanse zwarte den	Corsican/ Austrian black pine	Euroopanmustamänty	Pin noir	Schwarzkiefer
Pinus pinaster	Strandfyr	Zeeden	Maritime pine	Rannikkomänty	Pin maritime	Seestrandkiefer
Pinus halepensis	Aleppofyr	Aleppoden	Aleppo pine	Aleponmänty	Pin d'Alep	Aleppokiefer
Picea abies	Rødgran	Fijnspar	Norway spruce	Metsäkuusi	Epicéa commun	Rotfichte
Picea sitchensis	Sitkagran	Sitkaspar	Sitka spruce	Sitkankuusi	Epicéa de Sitka	Sitkafichte
Abies alba	Ædelgran	Zilverden	Silver fir	Saksanpihta	Sapin pectiné	Weißtanne
Larix decidua	Lærk	Europese lariks	European larch	Euroopanlehtikuusi	Mélèze d'Europe	Europäische Lärche

Botanical name	**Greek**	**Italian**	**Portuguese**	**Russian**	**Spanish**	**Swedish**
Fagus sylvatica	Οξυά δασική	Faggio	Faia	бук лесной	Haya	Bok
Quercus petraea	Δρυς απόδισκος	Rovere	Carvalho branco Americano	дуб скальный	Roble albar	Bergek
Quercus robur	Δρυς ποδισκοφόρος	Farnia	Carvalho roble	дуб черещатый	Roble común	Ek
Quercus ilex	Αριά	Leccio	Azinheira	дуб каменный	Encina	Stenek
Quercus suber	Φελλοδρύς	Sughera	Sobreiro	дуб пробковый	Alcornoque	Korkek
Pinus sylvestris	Δασική πεύκη	Pino silvestre	Pinheiro silvestre	сосна обыкновенная	Pino silvestre	Tall
Pinus nigra	Μαύρη πεύκη	Pino nero	Pinheiro Austríaco	сосна чёрная	Pino laricio	Svarttall
Pinus pinaster	Θαλασσία πεύκη	Pino marittimo	Pinheiro bravo	сосна приморская	Pino negral	Terpentintall
Pinus halepensis	Χαλέπιος πεύκη	Pino d'Aleppo	Pinheiro de alepo	сосна алеппская	Pino carrasco	Aleppotall
Picea abies	Ερυθρελάτη υψηλή	Abete rosso	Picea	ель европейская	Abeto rojo	Gran
Picea sitchensis	Ερυθρελάτη	Picea di Sitka	Picea de Sitka	ель ситхинская	Picea de Sitka	Sitkagran
Abies alba	Λευκή ελάτη	Abete bianco	Abeto branco	пихта белая	Abeto común	Sivergran
Larix decidua	Λάριξ ευρωπαϊκή	Larice	Larício Europeu	литвенница европейская	Alerce	Europeisklärk

Annex IV
Statistical formulae

Testing statistical significance of the differences in mean plot defoliation between two years of assessment.

Differences between mean plot defoliation were statistically examined for Common Sample Trees (CSTs) using the following test statistic:

$$t = \frac{\left| \bar{x}_{2001} - \bar{x}_{2000} \right| \sqrt{N}}{s_d}$$

where $\bar{x}_{2001} - \bar{x}_{2000}$ is the difference in mean plot defoliation between the assessments in 2000 and 2001,

s_d - the standard deviation of this difference,

N - number of common sample trees on plots being tested.

The standard deviation s_d is calculated from pairwise assigned differences in tree defoliation for both years of assessment

$$d_i = x_{2001(i)} - x_{2000(i)}, \qquad i = 1,2,3,...,N$$

with N - number of trees per plot.

It can be shown that the standard deviation of $d_i \, (i = 1,2,3,...,N)$ is

$$s_d = \sqrt{s_{2000}^2 + s_{2001}^2 - 2r_{2000,2001} s_{2000} s_{2001}}$$

with standard deviations s_{2000}, s_{2001} and $r_{2000,2001}$ derived from the pairs of defoliation scores for the years 2000 and 2001.

The latter equation reveals that a high correlation between the two damage assessments as quantified by the correlation coefficient $r_{2000,2001}$ contributes to the diminution of the standard deviation s_d thus increasing the test statistic t, which makes the differences in mean defoliation more likely to prove statistically significant.

The minimal difference for qualifying a plot as having changed its mean defoliation was 5%. This applies to the map in Annex I-8. This additional criterion to the formal statistical test was chosen since 5% is the highest accuracy in the assessment of defoliation in the field.

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