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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 2002 Large-scale Survey

2003 Technical Report

Prepared by: **Federal Research Centre for Forestry and Forest Products (BFH)**

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PREFACE

A deterioration of forest condition in Europe observed more than twenty years ago raised fears that air pollution could cause catastrophical forest dieback. More than two decades of forest damage research and 17 years of monitoring forest condition at the European-wide scale have contributed to the enlightenment of the actual role of air pollution and the complex causes and effects involved. Ascertaining the true extent, the development and the causes of forest damage requires continued long-term systematic and intensive monitoring. 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. 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.

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.

Originally having set out to assess effects of air pollution on forests, the programme has provided important information for the implementation of clean air policies under CLRTAP of UNECE and will continue to do so in the future. However, its well established infrastructure, its multidisciplinary monitoring approach and its comprehensive data base permit significant contributions to other processes of international environmental politics.

It pursues the objectives of Resolutions S1, H1 and L2 and provides information on three indicators out of 27 indicators for sustainable forest management of MCPFE. In addition, the soil data of the programme are expected to contribute to the assessment of carbon sinks as a contribution of the European Union to the Kyoto Protocol under the Framework Convention on Climatic Change (FCCC). Besides this, the programme receives increasing attention by research institutions and political bodies outside Europe. An example is its recently launched cooperation with the Acid Deposition Monitoring Network in East Asia (EANET).

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 2002. It is the twelfth 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

Large-scale surveys of forest condition in Europe started with the first crown condition assessment 17 years ago 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 2002 crown condition was assessed on 323 712 sample trees on 17 779 sample plots of different national grids in 34 of the participating 39 countries. Results on the European scale were derived from a subsample of 131 741 trees on 5 929 plots being part of the 16 x 16 km transnational grid covering 32 countries.

The transnational survey of 2002 revealed a mean defoliation of 19.8%. Of the main species, *Quercus robur* and *Q. petraea* had by far the highest mean defoliation (24.1%), followed by *Fagus sylvatica* (19.8%), *Picea abies* (19.1%) and *Pinus sylvestris* (18.6%). The long-term development of defoliation was calculated for subsamples of those trees having been observed continuously between 1989 and 2002. The largest increase in defoliation was found for *Pinus pinaster* (from 7.1% to 15.8%) and for *Quercus ilex* and *Quercus rotundifolia* (from 11.8% to 21.4%), which was explained mainly by summer heat and drought. *Pinus sylvestris* showed an increase in defoliation from 17.1% in 1989 to 20.6% in 1994. After a subsequent recuperation attributed to reduced air pollution stress in central and eastern Europe, crown condition of *Pinus sylvestris* recently deteriorated again due to fungi attack and storm events particularly in northern Europe. Defoliation of *Picea abies* and *Fagus sylvatica* varied over time without any clear trend, mainly reflecting weather extremes and insect attacks.

Defoliation was rarely attributed to depositions of air pollutants by the countries, because the relationship between both stands out against the effects of other factors only in cases of severe local air pollution. Therefore, the statistical relationships between crown condition of *Picea abies* and *Quercus robur* and *Quercus petraea* on one hand and biotic agents, soil condition, deposition and meteorology on the other hand were analysed on the European scale. The temporal variation of defoliation of *Picea abies* is positively correlated with sulphur deposition which is the second strongest predictor variable behind insects. It is negatively correlated with precipitation from April to June of the actual year and from April to September of the previous year. The spatial variation of medium-term mean defoliation was largely explained by insect attack and ammonium deposition. For *Quercus robur* and *Quercus petraea* insects and fungi were significant predictors of the spatial variation of medium-term mean defoliation.

Chemical analyses of tree needles and leaves give valuable insights into tree nutrition which in turn reflects environmental changes. Since 1987 the elemental foliar composition on 36 Finnish and 71 Austrian Level I plots has been determined annually. Needle sulphur concentrations in Finland and Austria were low during the past 15 years. Decreasing needle sulphur concentrations reflected the reduction of sulphur emissions. The nitrogen concentrations have remained low in both countries. However, trends in some areas raise concern. In all, nutrition of the monitored forests was characterised by balanced nutrient ratios in both countries. In general, the variation in foliar nutrient concentrations is greater between stands than between successive survey years. This suggests that spatial developments should be studied on a denser network than temporal developments.

1 INTRODUCTION

The present report describes the results of the large-scale transnational survey of the year 2002. The transnational survey aims to assess the spatial and temporal variation of forest condition in relation to natural and anthropogenic factors, particularly air pollution. For this purpose, crown condition has been assessed annually for 17 years on approximately 6 000 sample plots. Moreover, soil condition was surveyed on about 5 300 and foliage chemistry was assessed on about 1 400 of these plots.

The report is outlined as follows:

In Chapter 2 an overview of the methods of the large-scale transnational surveys on crown condition, soil condition and foliage chemistry is given. For crown condition assessment there are subchapters on the methods of data quality control, on data evaluation including statistical methods and on the interpretability of results.

Chapter 3 provides the results of the crown condition assessment of the year 2002. Emphasis is laid upon the current status and the development of crown condition with respect to species, regions and identified damage types.

Chapter 4 presents the results of geostatistical and multivariate evaluations of the spatial and temporal variation of crown condition in relation to biotic damage, weather condition and depositions of air pollutants. For this purpose, the age trend in defoliation as well as systematic differences due to methodological inconsistencies between countries is eliminated.

In Chapter 5 the results of an evaluation of the Finnish and Austrian foliar data sets are provided. The spatial and temporal variation and the development of forest nutrition are analysed for both countries. In addition to forest nutrition in Finland and Austria, the approach of the foliar survey itself is discussed.

Chapter 6 consists of national reports by the participating countries, focussing on crown condition in 2002 as well as on its development and its causes.

A discussion and interpretations of the results are given in Chapter 7.

Maps, graphs and tables concerning the transnational and the national results are presented 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 2002

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.

In the transnational survey of the year 2002 5 929 plots were assessed in 30 countries. The number of plots in each participating country is presented in Table 2.2.1-1 for the last 13 years. In addition, 13 plots were assessed 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). They are, however, 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.

The spatial distribution of the plots assessed in 2002 is shown in Figure 2.2.1-1. 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 1990 to 2002 according to the actual database.

Country	Number of sample plots												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Austria	72	79	77	76	76	76	130	130	130	130	130	130	133
Belgium	29	29	29	29	29	29	29	29	29	30	29	29	29
Denmark	25	25	25	25	25	24	23	22	23	23	21	21	20
Finland		359	413	405	382	455	455	460	459	457	453	454	457
France	514	513	505	506	534	543	540	540	537	544	516	519	518
Germany	408	411	414	412	417	417	420	421	421	433	444	446	447
Greece	101	101	98	96	96	95	95	94	93	93	93	92	91
Ireland	22	22	22	22	21	21	21	21	21	20	20	20	20
Italy	204	206	202	212	209	207	207	181	177	239	255	265	258
Luxembourg	4	4	4	4	4	4	4	4	4	4	4	-	4
The Netherlands	14	14	14	13	13	13	12	11	11	11	11	11	11
Portugal	152	151	149	143	147	141	142	144	143	143	143	144	145
Spain	447	436	462	460	444	454	447	449	452	598	607	607	607
Sweden	38	45	67	59	340	726	766	758	764	764	769	770	769
United Kingdom	74	74	72	69	66	63	79	82	88	85	89	86	86
EU	2104	2469	2553	2531	2803	3268	3370	3346	3352	3574	3584	3594	3595
Belarus								416	416	408	408	408	407
Bulgaria					109	120	120	120	135	115	108	109	99
Croatia				84	88	82	83	86	89	84	83	81	80
Cyprus												15	15
Czech Republic	93	362	156	178	205	199	196	196	116	139	139	139	140
Estonia				86	90	90	91	91	91	91	90	89	92
Hungary	67	66	65	65	62	63	60	58	59	62	63	63	62
Latvia	80	101	100	101	94	94	99	96	97	98	94	97	97
Lithuania			73	74	73	73	67	67	67	67	67	66	66
Moldova				12	12	11	10	10	10	10	10	10	-
Norway			387	390	384	386	387	386	386	381	382	408	414
Poland	474	476	476	476	441	432	431	431	431	431	431	431	433
Romania			215	167	199	241	224	237	235	238	235	232	231
Russian Fed.					7	134							
Slovak Republic	111	111	111	111	111	111	110	110	109	110	111	110	110
Slovenia				34	34	42	42	42	41	41	41	41	39
Switzerland	45	45	45	45	45	47	49	49	49	49	49	49	49
Total Europe	2974	3630	4181	4354	4757	5393	5339	5741	5683	5898	5895	5942	5929

Table 2.2.1-2: Distribution of the 2002 sample plots over the climatic regions.

Climatic region	Number of plots	Percentage of plots
Boreal	998	16.8
Boreal (Temperate)	943	15.9
Atlantic (North)	342	5.8
Atlantic (South)	288	4.9
Sub-atlantic	1120	18.8
Continental	242	4.1
Mountainous (North)	271	4.6
Mountainous (South)	714	12.0
Mediterranean (Higher)	396	6.7
Mediterranean (Lower)	615	10.4
All regions	5929	100.0

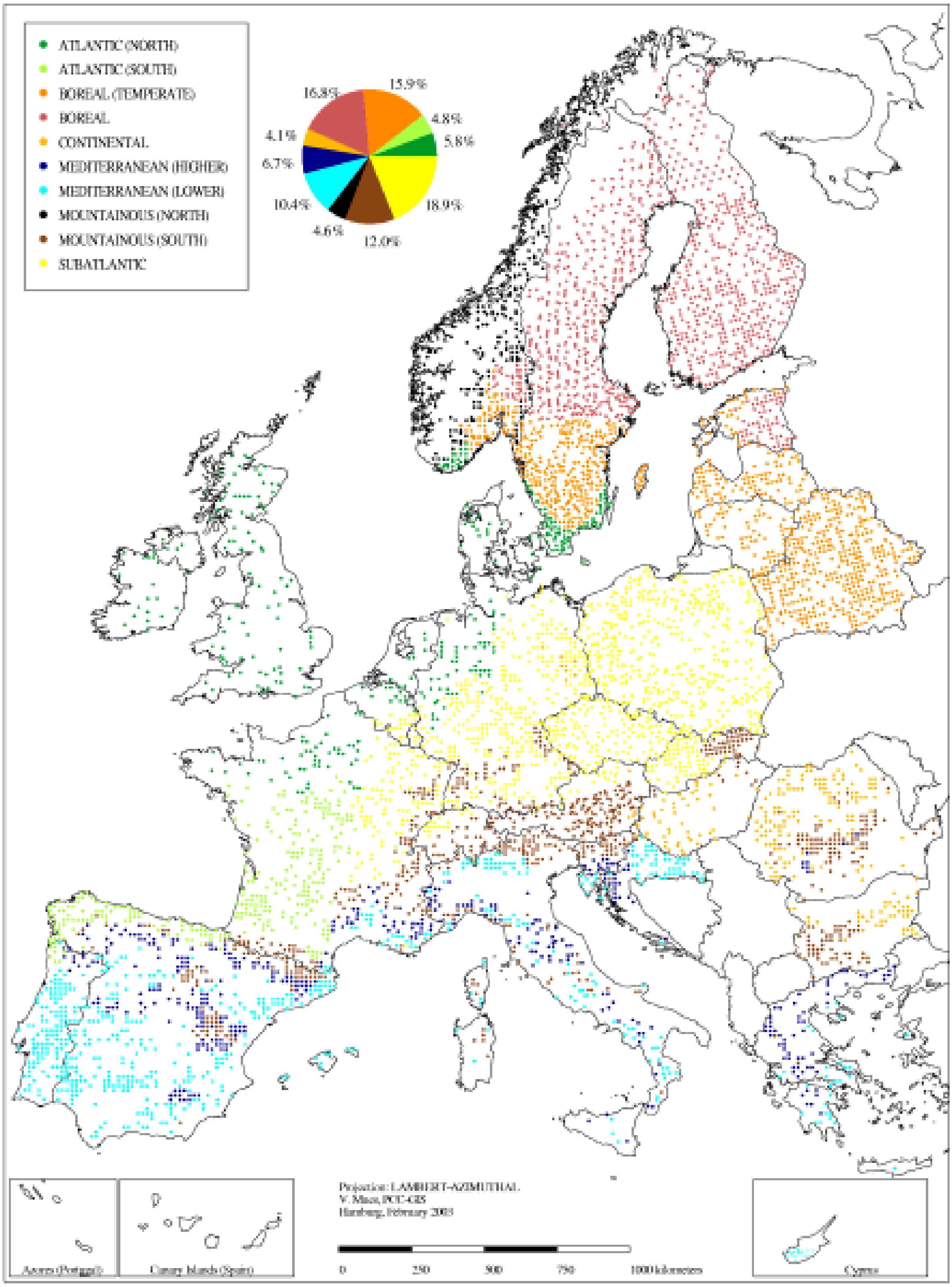

Figure 2.2.1-1: Plots according to climatic regions (2002).

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 6 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	tree wise 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	133	133	128	133	133	133	128
Belgium	29	29	29	29	29	29	28
Denmark	20	20	20	20	20	20	20
Finland	457	457	457	457	457	457	457
France	518	518	518	518	518	518	518
Germany	447	447	447	447	447	447	411
Greece	91	91	89	91	91	91	91
Ireland	20	20	20	20	20	20	20
Italy	258	258	258	258	258	258	0
Luxembourg	4	4	4	4	4	4	4
The Netherlands	11	11	11	11	11	11	11
Portugal	145	145	145	145	145	145	136
Spain	607	607	607	607	607	607	431
Sweden	769	769	758	769	769	769	569
United Kingdom	86	86	86	86	86	86	86
EU	3595	3595	3577	3595	3595	3595	2910
Percent of EU plot sample		100.0	99.5	100.0	100.0	100.0	81.0
Belarus	407	406	0	0	407	407	0
Bulgaria	99	99	99	99	99	99	99
Croatia	80	80	80	80	80	80	66
Cyprus	15	15	15	15	15	15	0
Czech Republic	140	140	59	140	140	140	59
Estonia	92	92	89	92	92	92	89
Hungary	62	62	41	62	62	62	62
Latvia	97	97	97	97	97	97	97
Lithuania	66	66	1	66	66	66	66
Rep. of Moldova	-	-	-	-	-	-	-
Norway	414	0	369	414	414	414	368
Poland	433	433	433	433	433	433	38
Romania	231	231	231	231	231	231	221
Slovak Republic	110	0	110	110	110	110	110
Slovenia	39	39	39	39	39	39	39
Switzerland	49	46	46	49	49	49	46
Total Europe	5929	5401	5286	5522	5929	5929	4270
Percent of total plot sample		91.1	89.2	93.1	100.0	100.0	72.0

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	1995	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	38
Romania	1993	1995	242
Slovak Republic	1993	1993	111
Slovenia	1994	1995	34
Switzerland	1993	1993	48
Total Europe	1985	1998	5205

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 O	organic layer saturated with water 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 mandatory 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. Information on soil parent material and some physical properties (texture, coarse fragments and bulk density) was - on a voluntary basis - scarcely provided. However, the reference methods (UNECE, 1998) were not used in all cases. Therefore different methodological deviations 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
Poland			38
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 2002

The total numbers of trees assessed from 1990 to 2002 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.

Of the 2002 tree sample 110 species were reported. The species remained unreported for 364 broadleaved and 41 coniferous trees. 64.0% of the plots were dominated by conifers, 35.7% by broadleaves 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 20.0%, *Fagus sylvatica* with 9.0%, 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 1990 to 2002 according to the current database.

Country	Number of sample trees												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Austria	2132	2244	2167	2121	2107	2101	3670	3604	3577	3535	3506	3451	3503
Belgium	684	686	673	685	684	678	684	683	692	696	686	682	684
Denmark	600	600	600	600	600	576	552	528	552	552	504	504	480
Finland		3899	4545	4427	4261	8754	8732	8788	8758	8662	8576	8579	8593
France	10280	10255	10093	10118	10672	10851	10800	10800	10740	10883	10317	10373	10355
Germany	10511	10662	10767	10729	10866	10907	10980	10990	13178	13466	13722	13478	13534
Greece	2392	2392	2320	2272	2272	2248	2248	2224	2204	2192	2192	2168	2144
Ireland	458	458	460	462	441	441	441	441	441	417	420	420	424
Italy	5701	5741	5643	5884	5791	5703	5836	4873	4939	6710	7128	7350	7165
Luxembourg	96	96	95	95	93	96	96	96	96	96	96		96
The	279	280	280	260	260	257	237	220	220	225	218	231	232
Portugal	4563	4585	4508	4308	4414	4230	4260	4319	4290	4290	4290	4320	4350
Spain	10728	10462	11088	11040	10656	10896	10728	10776	10848	14352	14568	14568	14568
Sweden	146	265	300	311	3989	10310	10925	10910	11044	11135	11361	11283	11278
United	1776	1770	1728	1656	1584	1512	1896	1968	2112	2039	2136	2064	2064
EU	50346	54395	55267	54968	58690	69560	72085	71220	73691	79250	79720	79471	79470
Belarus								9974	9896	9745	9763	9761	9723
Bulgaria					4370	4812	4789	4788	5389	4379	4197	4209	3753
Croatia				2016	2150	1970	1974	2030	2066	2015	1991	1941	1910
Cyprus												360	360
Czech Rep	2325	8971	3882	4423	5087	4933	4853	4844	2899	3475	3475	3475	3500
Estonia				2064	2159	2160	2184	2184	2184	2184	2160	2136	2169
Hungary	1351	1371	1348	1361	1322	1342	1298	1257	1383	1470	1488	1469	1446
Latvia	1920	2424	2396	2420	2257	2262	2368	2297	2326	2348	2256	2325	2340
Lithuania			1768	1843	1760	1776	1643	1634	1616	1613	1609	1597	1583
Moldova				288	288	263	236	253	234	259	234	234	-
Norway			4001	4016	3942	3905	3948	4028	4069	4052	4051	4304	4444
Poland	9476	9520	9520	9520	8820	8640	8620	8620	8620	8620	8620	8620	8660
Romania			5155	4004	4776	5688	5375	5687	5637	5712	5640	5568	5544
Russian Fed.					183	3180							
Slovak Rep	5333	5296	5251	5144	5115	5091	5018	5033	5094	5063	5157	5054	5076
Slovenia				816	816	1008	1008	1008	984	984	984	984	936
Switzerland	479	487	488	500	509	824	854	880	868	857	855	834	827
Total Europe	71230	82464	89076	93383	102244	117414	116253	125737	126956	132026	132200	132342	131741

2.4 International Cross-calibration Courses

The test phase for the revision of the International Cross-calibration Courses (ICC) was finished 2002. Three of these courses are normally offered per year, one in southern, one in central and one in northern Europe, assembling national team leaders in the forests. The courses in 2002 were planned to be held in late summer after the main survey period. All courses were planned to follow the new concept for ICCs (FERRETTI et al., 2002) which lays down the main ideas for the new course design in detail. The aims of the ICCs are to

(i) document the relative position of individual National Reference Teams (NRTs) within the international context,
(ii) monitor the consistency of NRTs' position through time,
(iii) improve the traceability of the data by establishing a direct connection with the data collected at national level. This will help also explaining anomalous year-by-year fluctuations, and
(iv) explore the relationships between the performance of the various NRTs and the major site and stand characteristics.

The course in Pirna in Saxony/Germany (August 26-29) had to be cancelled due to the heavy flooding in this area. The two remaining courses were held in Oslo/Norway (September 1-4) on *Pinus sylvestris* and *Picea abies* and in Spain (September 10-13) on *Quercus ilex* and *Pinus pinaster*. The reduction to two tree species per course allowed for a higher number of assessments under varying stand and site conditions. The respective increase especially of the number of plots is important to gain data which allow conclusions if several stand or site conditions influence the comparability of the applied methodologies. The results of the defoliation assessments in 2002 are presented by MUES (2003) generally following the methodology presented by SEIDLING (2002) for the evaluation of ICC data. The main outcomes of the 2002 ICCs were:

- In contrast to national courses of this kind no single value can be understood or defined to be the true one. Therefore measures of agreement and correlation were used to evaluate the data.
- A high similarity of the assessment behaviour concerning the ranking of the trees on each plot was found for all teams. For some species even participant groups of very similar assessment behaviour – expressed by correlation coefficients between the team assessments – and level of assessment values – expressed by percentages of absolute agreement – could be found.
- Besides some outliers the assessments of participants from one country were of very high similarity concerning behaviour and level of the assessment values.
- For Scots pine in Norway and less pronounced for Maritime pine in Spain consistent relations between the teams could be found indicating constant levels of the assessments. In case of Scots pine this was at least partly due to the high comparability of the site conditions of the plots and was observed even at varying tree ages.
- It was found that the higher comparability of plots which are located closely together is an advantage of the new concept. On the other hand general conclusions for the entire distribution area of a tree species may only be valid if a wide range of site and stand conditions is covered by the analyses. This demand is met at least partly if the entirety of all ICCs is considered.
- Recent thinning in some of the assessed stands underlined the need of a good documentation by the host countries, which was very well done again in 2002, as well as by the participants. Respective adaptations of the forms will be developed as a result of the ICCs in 2002.
- It was found to be very important to document the share of the crown which was assessed by each participant. Many of the differences found during the ICCs 2002 were based on differences in the definition of the assessable crown.
- Future evaluations will be discussed during meetings of the Expert Panel on Crown Condition Assessment and/or during the ICCs where the national experts meet annually and can point at questions of interest.

These results and other consequences for the organization and conduction of future courses were discussed on the 1st workshop and the 4th meeting of the Expert Panel on Crown Condition Assessment in Helsingør, Denmark, February 3-6, 2003. It was decided to integrate an annex based on the concept for the "New Design of International Cross-Calibration Courses of ICP Forests and the EU Scheme" (FERRETTI et al., 2002) during the forthcoming revision of the Manual (UNECE, 1998).

Following the concept of periodically assessed test ranges the forthcoming ICCs will for the first time provide assessment values for stands and trees which were assessed already 4 years ago. This will allow the documentation of temporal consistency of the applied methodology. It will be possible to get first results on this important aim of the new concept of ICCs.

Photo techniques were used during all courses in the ICC test phase 2001/2002 and are an integral part of the concept for the future ICCs. An important step into this direction was the description of the methods which are necessary for taking and assessing useful photographs from tree crowns. The Expert Panel on Crown Condition Assessment agreed on the integration of a photo manual which describes the methodology of photo QA as an annex to the revised crown condition assessment manual. The aims and objectives of the use of photographs 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 suitability of the photos will be tested during the next two years with the additional aim to test whether it is possible to get scores for digital photos from a wide range of assessors via internet. Appropriate studies in this direction will be prepared as well as evaluations of time series of photo assessments which aim at the documentation of temporal consistency of the applied methodologies.

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 robur and Quercus petraea* are evaluated together and referred to as "*Quercus robur and Q. petraea*". Similarly, *Quercus ilex* and *Quercus rotundifolia* are evaluated together and noted as "*Quercus ilex* and *Q. rotundifolia*".

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≥3). This limit is a compromise which on one hand should avoid the presentation of results which are based on the observation of only one or two trees and on the other hand guarantees that not too much information on plot level is lost due to a too sharp limit, or higher minimum number of trees, respecitvely.

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, 2002) used statistical and geostatistical methods to analyse the spatial and temporal variation of crown condition. The target variable for the analyses of the spatial variation is the medium-term mean defoliation 1994 to 2000. The temporal variation is defined as the annual deviation from this plot-wise calculated medium-term mean defoliation, the so-called 'referenced' defoliation. This transformation is called *referenced* to underline that this transformation is calculated plot specific and therefore is different from a typical standardization or normalization.

Whereas the last year's integrative evaluations aimed on the spatial and temporal variation of *Pinus sylvestris* and *Fagus sylvatica* this year's evaluations are based on the data available for *Picea abies* (1046 plot) and for *Quercus robur* and *Q. petraea* (291 plots). The spatial variation of defoliation can be explained at least partly be a country-wise age-effect. It is expressed by linear regression that locations ("plots") with older trees – on average – take higher defoliation values than those with younger ones (UNECE, CEC, 2001, 2002, SEIDLING, 2000, KLAP et al., 2000). 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. The expansion of the database by the integration of precipitation data of the Global Precipitation Climatology Centre (GPCC[1]) 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.

In addition the *temporal* variation of defoliation of *Picea abies* and *Quercus robur* and *Q. petraea* is in the focus of this year's 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?

Within the last year's report it could be shown that at least a part of the temporal – and spatial – variation of defoliation is correlated with the variation of 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 (SOx-S) and nitrogen (NOx-N as well as NHx-N) in g/m^2. Additionally the monthly sum of precipitation in mm could be quantified for the Level I plots using respective 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.

To present a more recent description of the spatial and temporal variation of defoliation for the six main tree species *Pinus sylvestris*, *Picea abies*, *Fagus sylvatica*, *Quercus robur* and *Q. petraea*, *Quercus ilex and Q. rotundifolia*, and *Pinus pinaster* the PAD and the slopes of a plot-wise regression of defoliation over the year of observation were calculated, interpolated with the geostatistical kriging (s. below) and mapped for the period 1997-2002 without any further statistical analyses (4.3).

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[1] GPCC (2000): Global Precipitation Centre homepage: HTTP://www.dwd.de/research/gpcc

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:

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

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 ($\mathrm{MMD_i} = \overline{\mathrm{X}}_{\mathrm{i}}$ of defoliation) was already used in the last year's integrative evaluation (UNECE, CEC, 2001) for quantifying the spatial variation of defoliation. The $\mathrm{MMD_i}$ 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).

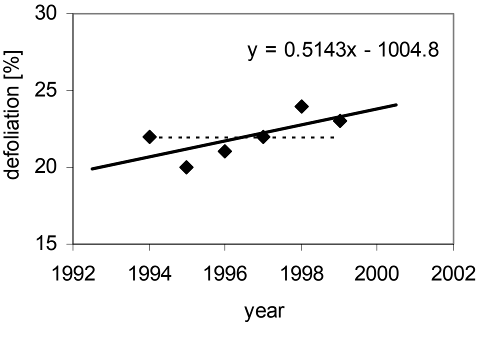


Figure 2.5.3-1: Linear trend of defoliation vs. year (untransformed)

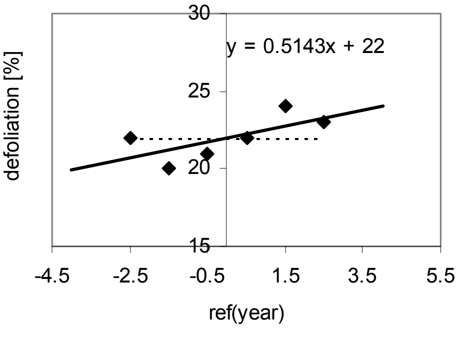


Figure 2.5.3-2: Linear trend of defoliation vs. referenced year, ref(year)

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:

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

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
ß_{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:

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

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

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

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

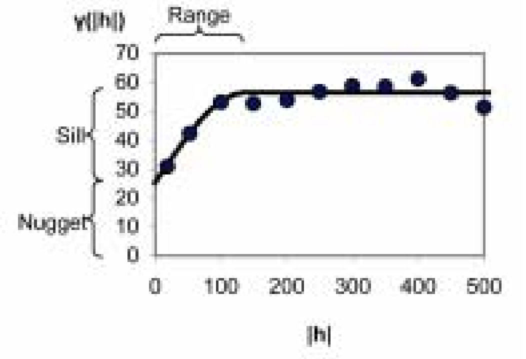
In equation 2b the plot-wise medium-term mean defoliation MMD_i as time-constant spatial variation is used to "explain" a part of the variation of defoliation. The part, which is explained by the plot-wise variable medium-term mean defoliation, was used in a modification of split-plot analyses to test 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 the applied general linear models (GLM, SAS, 1990). 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 index1), insect index1), 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 regionalized 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.



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

$N(h)$ – 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:

---

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

- 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 "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 2002

3.1 Crown condition in 2002

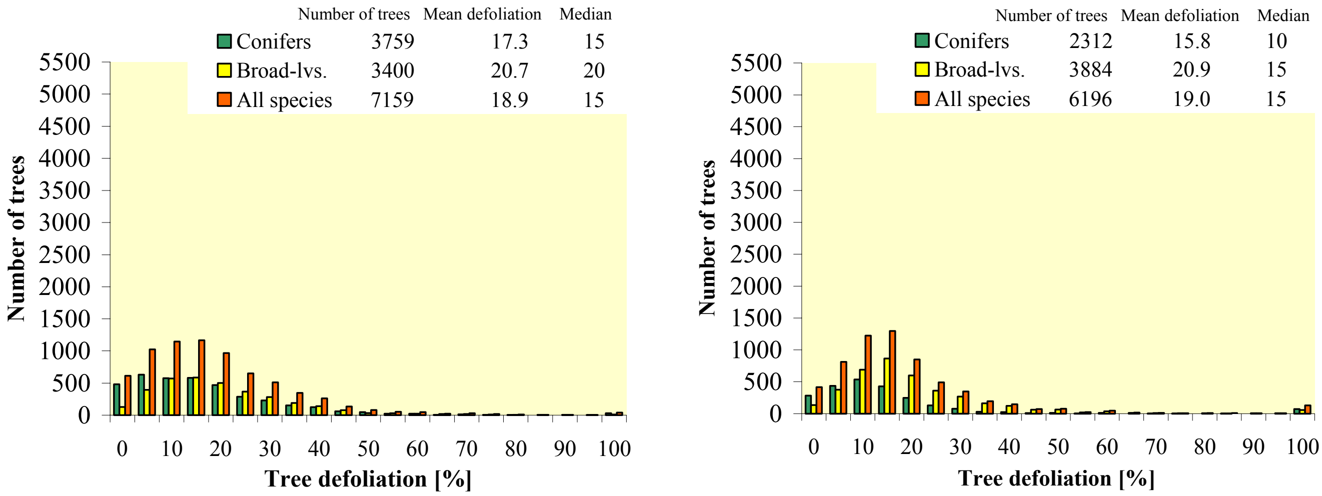
3.1.1 Defoliation and discolouration by region and species

In the transnational survey of the year 2002, defoliation of 131 741 sample trees was assessed on 5 929 sample plots. 21.3% of these trees had a defoliation of more than 25%, i.e. were classified as “damaged” (Table 3.1.1-1). The share of damaged broadleaves exceeded with 23.3% the share of damaged conifers with 20.0%. The share of damaged trees in the EU-Member States (18.9%) was lower than in total Europe, as a result of areas with higher defoliation being mainly located in the non-EU countries, namely in parts of central and Eastern Europe. This holds true in particular for the coniferous trees in the EU-Member States the share of which (16.3%) was clearly lower than that of the broadleaves (23.9%). The percentages of damaged trees are mapped for each plot in Annex I-4.

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	29.7	46.4	76.1	21.4	1.8	0.7	23.9	21.1	20	32301
	Conifers	45.1	38.6	83.7	14.2	1.3	0.8	16.3	17.1	15	47169
	All species	38.8	41.7	80.5	17.2	1.5	0.8	19.5	18.7	15	79470
Total Europe	*Fagus sylv.*	33.6	44.6	78.2	19.9	1.3	0.6	21.8	19.8	15	11911
	Quercus robur + Q. petraea	19.0	48.6	57.6	30.0	1.9	0.5	32.4	24.1	20	8256
	Broad-leaves	30.5	46.2	76.7	20.8	1.7	0.8	23.3	20.8	20	53251
	Picea abies	40.6	34.7	75.3	22.3	1.8	0.6	24.7	19.1	15	26353
	Pinus sylv.	34.2	49.6	83.8	14.5	1.0	0.7	16.2	18.6	15	35194
	Conifers	36.5	43.5	80.0	17.8	1.4	0.8	20.0	19.0	15	78490
	All species	34.1	44.6	78.7	19.0	1.5	0.8	21.3	19.8	15	131741

The classical defoliation classes are of uneven width. Therefore, frequency distributions in 5%-defoliation steps were calculated. The frequency distributions for the broadleaved 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* given for each species in Table 3.1.1.-1. Plots qualified for inclusion into a map whenever the number of trees of the given species on them was at least three.

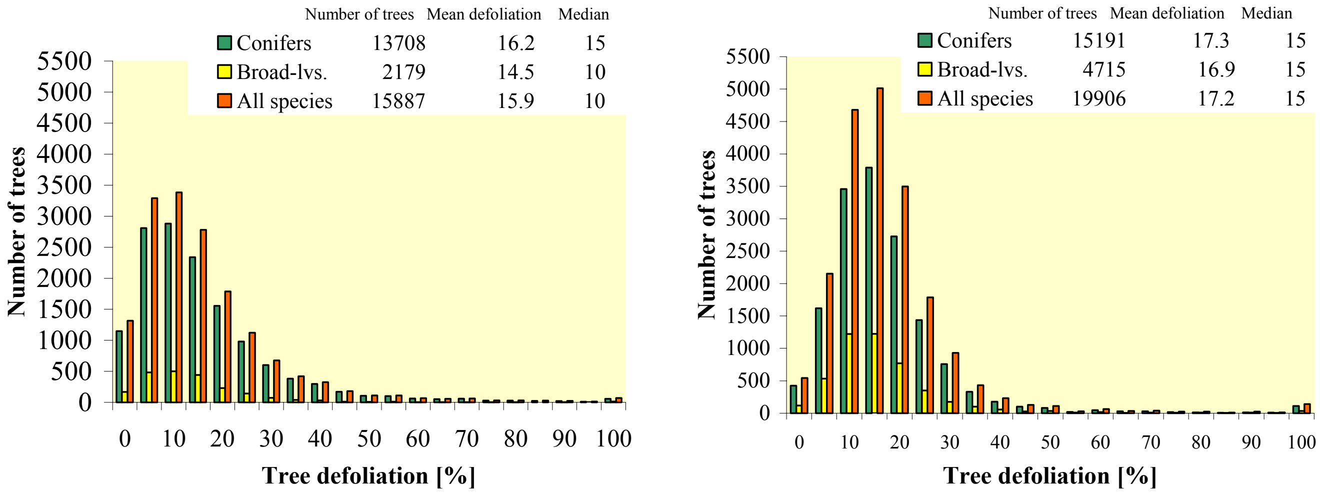


Atlantic (North)

	Number of trees	Mean defoliation	Median
🟩 Conifers	3759	17.3	15
🟨 Broad-lvs.	3400	20.7	20
🟧 All species	7159	18.9	15

Atlantic (South)

	Number of trees	Mean defoliation	Median
🟩 Conifers	2312	15.8	10
🟨 Broad-lvs.	3884	20.9	15
🟧 All species	6196	19.0	15

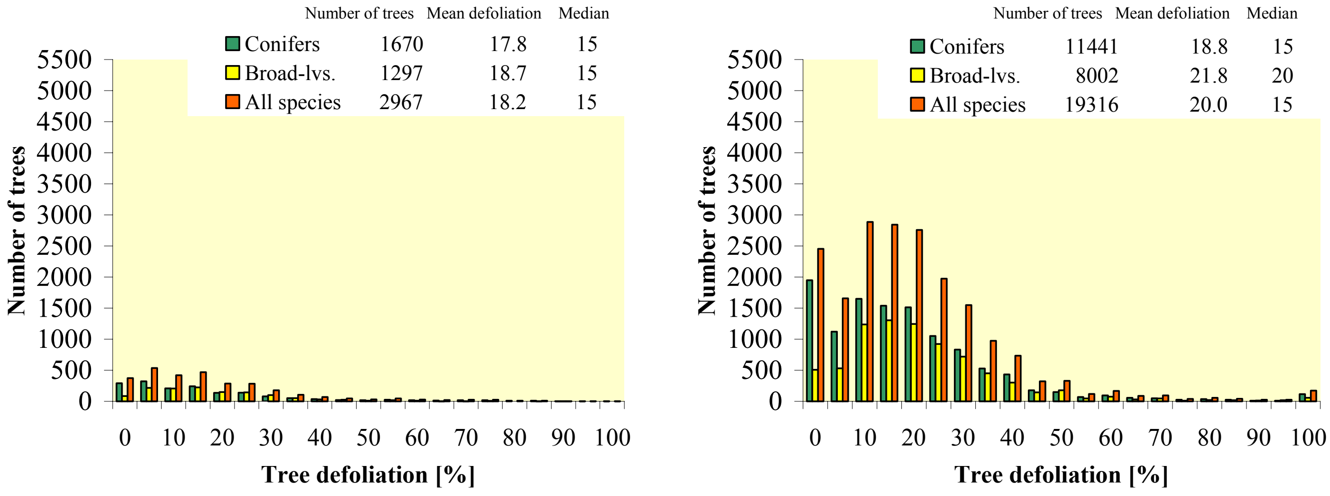


Boreal

	Number of trees	Mean defoliation	Median
🟩 Conifers	13708	16.2	15
🟨 Broad-lvs.	2179	14.5	10
🟧 All species	15887	15.9	10

Boreal (Temperate)

	Number of trees	Mean defoliation	Median
🟩 Conifers	15191	17.3	15
🟨 Broad-lvs.	4715	16.9	15
🟧 All species	19906	17.2	15



Mountainous (North)

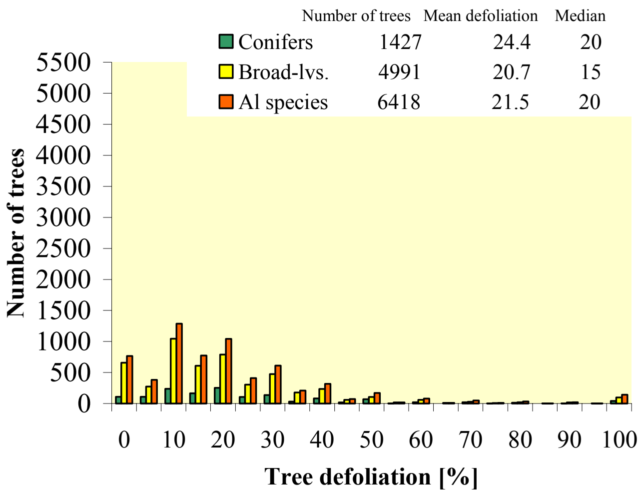
	Number of trees	Mean defoliation	Median
🟩 Conifers	1670	17.8	15
🟨 Broad-lvs.	1297	18.7	15
🟧 All species	2967	18.2	15

Mountainous (South)

	Number of trees	Mean defoliation	Median
🟩 Conifers	11441	18.8	15
🟨 Broad-lvs.	8002	21.8	20
🟧 All species	19316	20.0	15

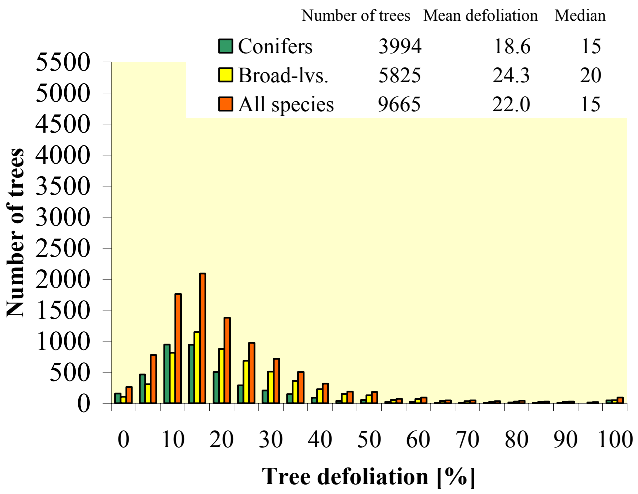
Figure 3.1.1-1a: Frequency distribution of trees in 5%-defoliation steps.

Continental



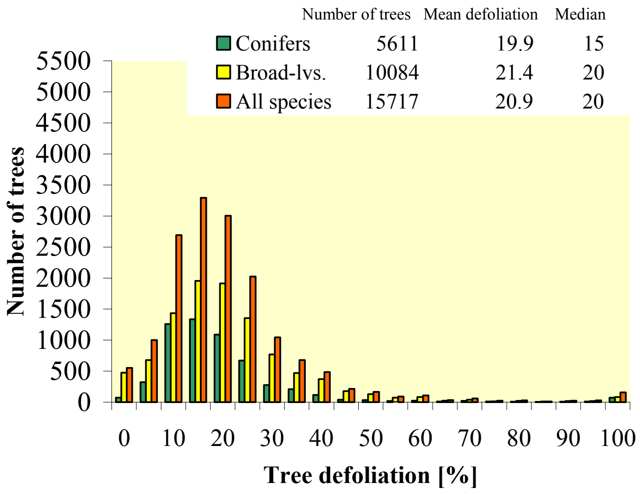
	Number of trees	Mean defoliation	Median
🟩 Conifers	1427	24.4	20
🟨 Broad-lvs.	4991	20.7	15
🟧 Al species	6418	21.5	20

Mediterranean (Higher)



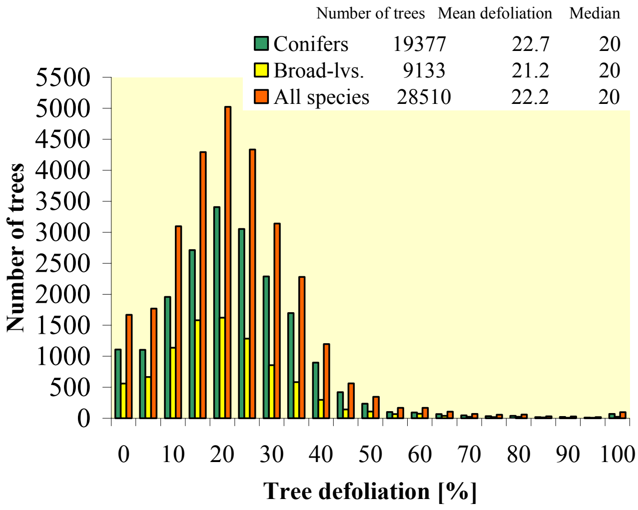
	Number of trees	Mean defoliation	Median
🟩 Conifers	3994	18.6	15
🟨 Broad-lvs.	5825	24.3	20
🟧 All species	9665	22.0	15

Mediterranean (Lower)



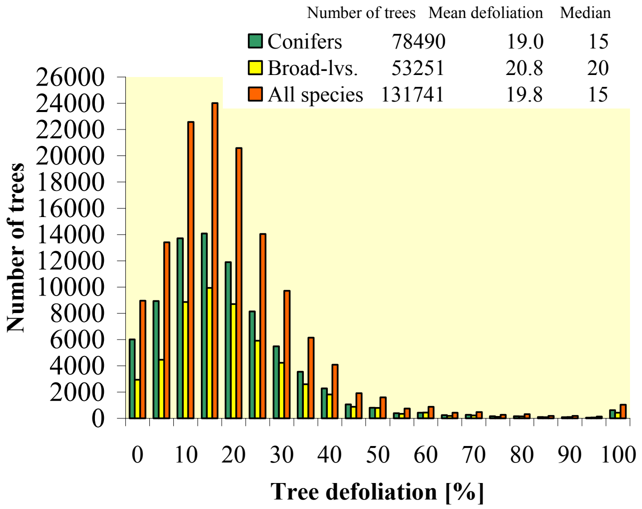
	Number of trees	Mean defoliation	Median
🟩 Conifers	5611	19.9	15
🟨 Broad-lvs.	10084	21.4	20
🟧 All species	15717	20.9	20

Sub-Atlantic



	Number of trees	Mean defoliation	Median
🟩 Conifers	19377	22.7	20
🟨 Broad-lvs.	9133	21.2	20
🟧 All species	28510	22.2	20

All regions



	Number of trees	Mean defoliation	Median
🟩 Conifers	78490	19.0	15
🟨 Broad-lvs.	53251	20.8	20
🟧 All species	131741	19.8	15

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

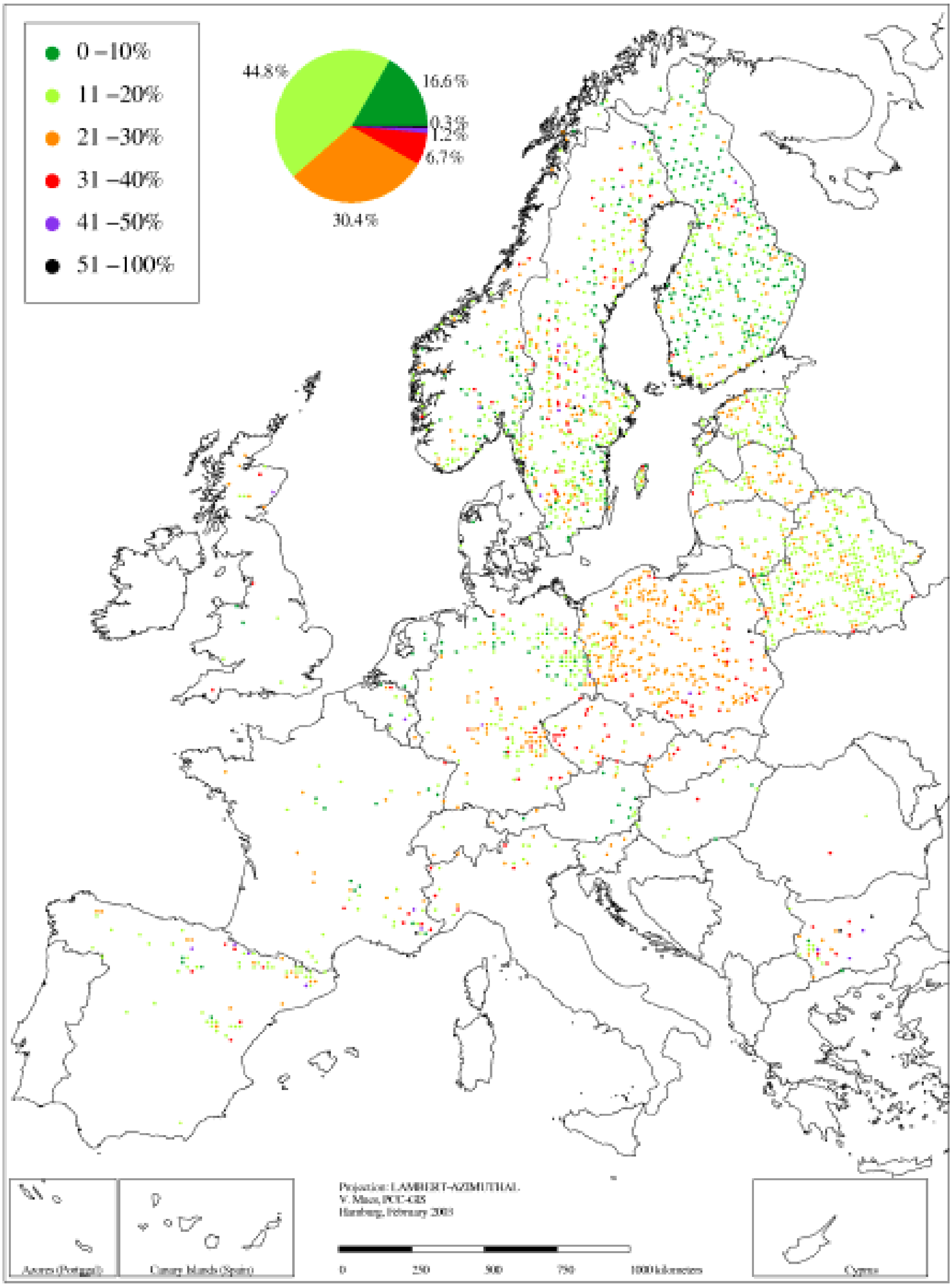


Figure 3.1.1-2: Mean plot defoliation of *Pinus sylvestris*.

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

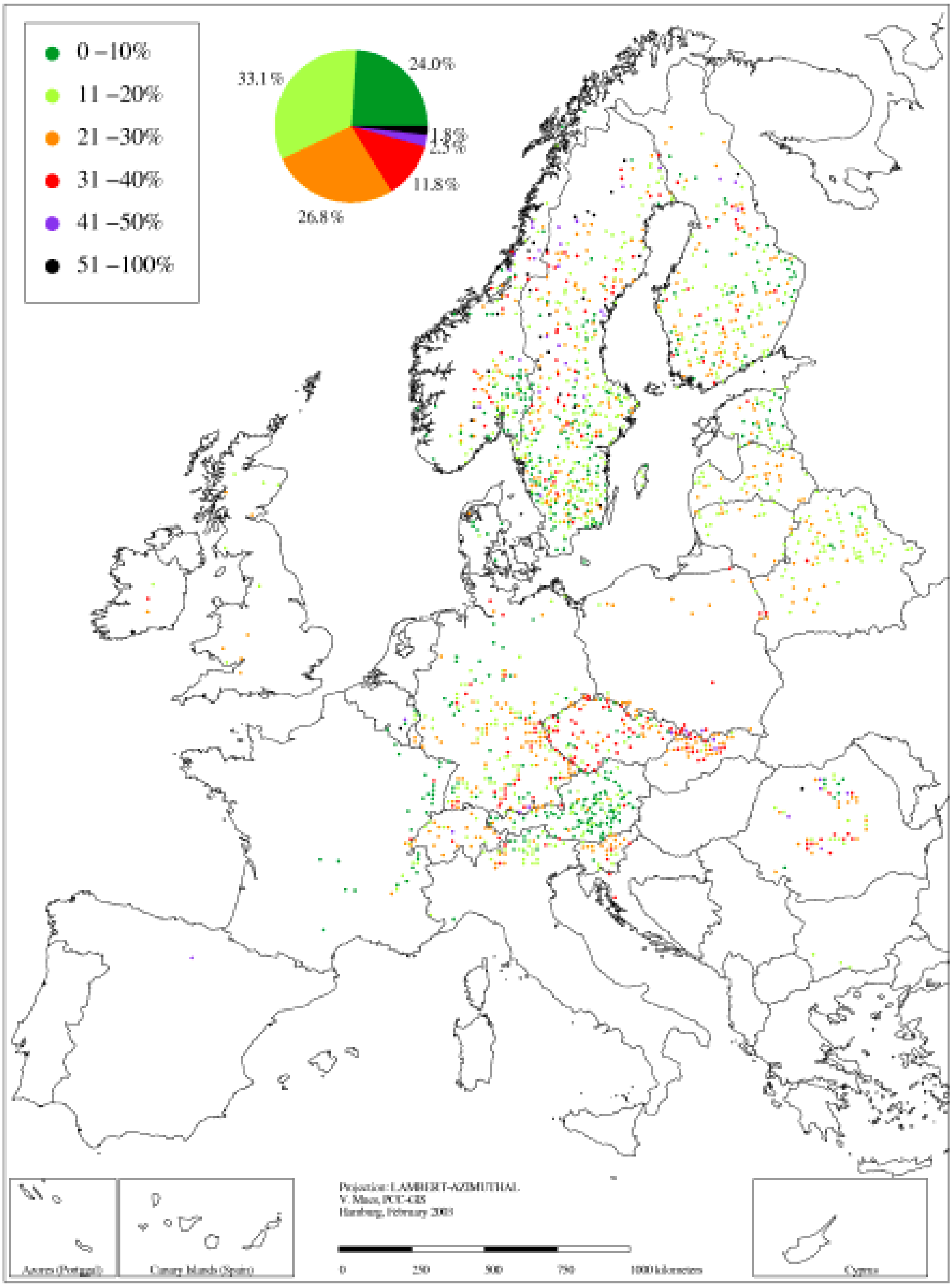


Figure 3.1.1-3: Mean plot defoliation of *Picea abies*.

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

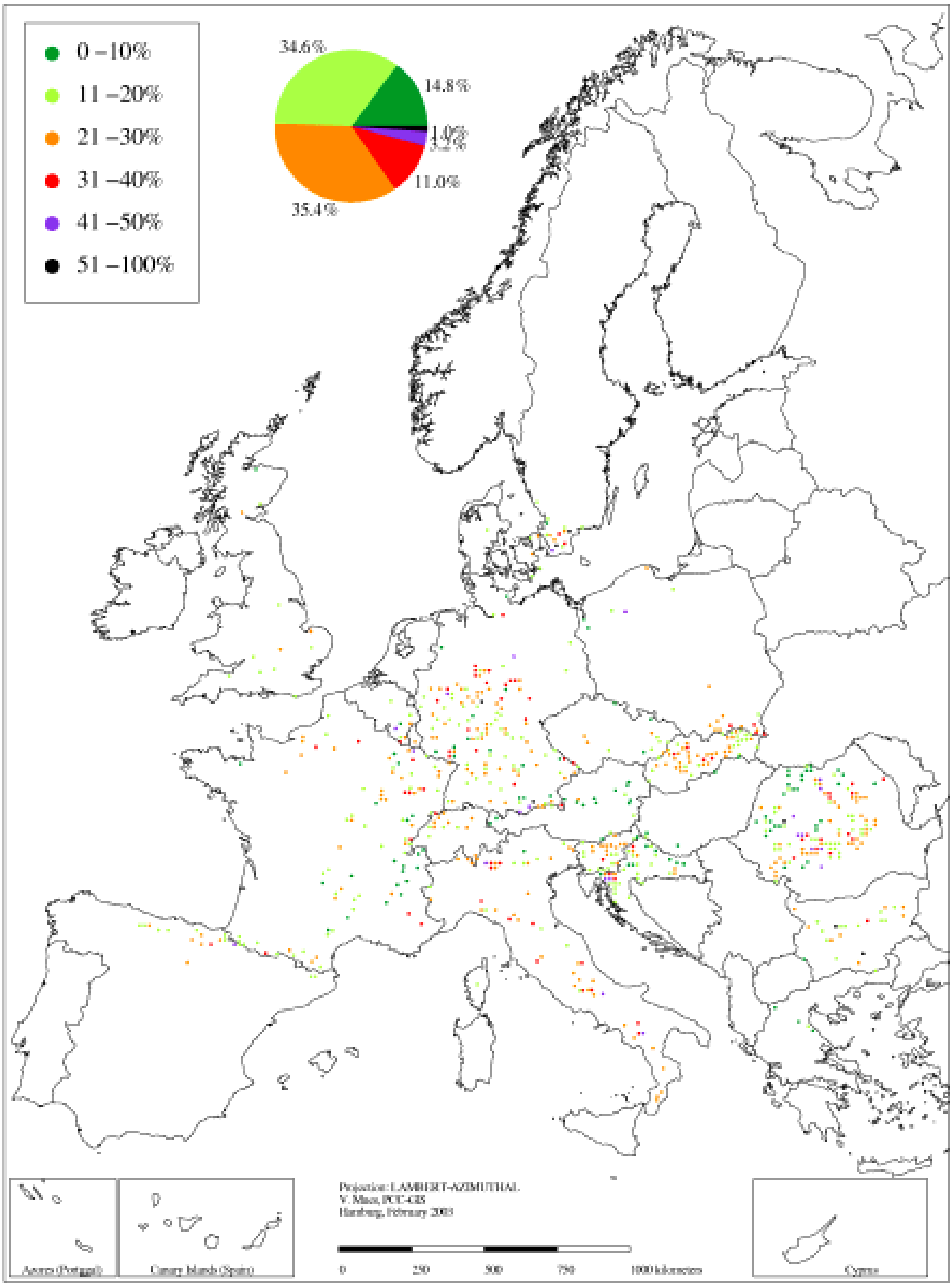


Figure 3.1.1-4: Mean plot defoliation of *Fagus sylvatica*.

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

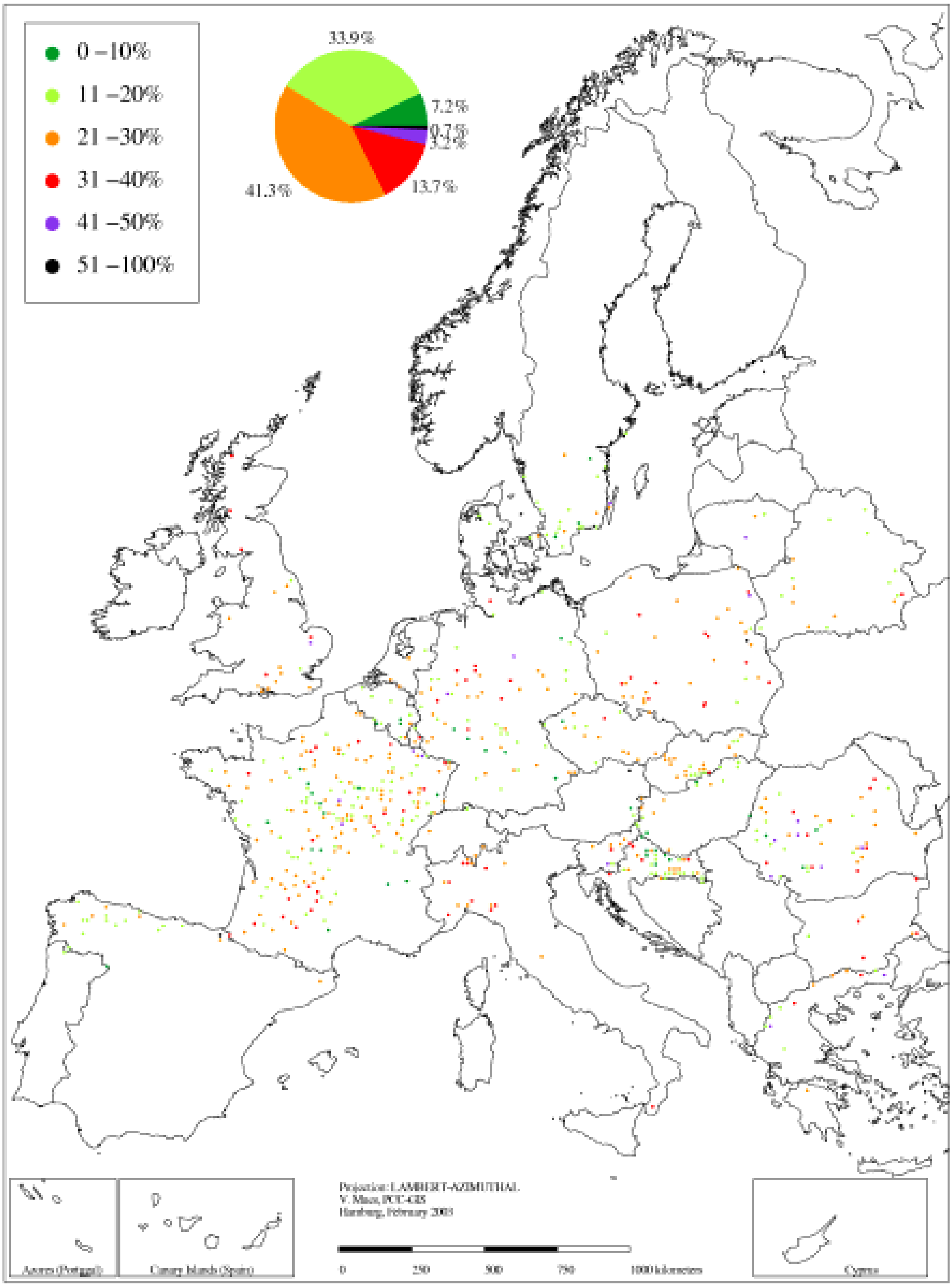


Figure 3.1.1-5: Mean plot defoliation of *Quercus robur* and *Q. petraea*.

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

The maps show large and partly well defined regions of high defoliation for the two main coniferous species, *Pinus sylvestris* and *Picea abies*. On the other hand there are also large regions of very low defoliation. 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 19.8%. 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 6.3% (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	Broadleaves	94.0	3.8	1.2	0.3	0.7	6.0	32301
	Conifers	94.7	3.5	0.9	0.2	0.7	5.3	47169
	All species	94.5	3.6	1.0	0.2	0.7	5.5	79470
Total Europe	Broadleaves	93.0	5.0	1.0	0.5	0.5	7.0	53251
	Conifers	94.2	4.0	1.0	0.3	0.5	5.8	78490
	All species	93.7	4.4	1.0	0.4	0.5	6.3	131741

3.1.2 Defoliation and identified damage types

For the sample trees the presence of the following eight different damage types 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.

These damage types are assessed, because they are often related to defoliation and discolouration. However, the confidence of the results is limited, largely due to the application of 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.

Percentages of trees for which each particular damage type was assessed are given in Table 3.1.2-1. The trees assessed are divided into those on which the respective damage type was present and those on which it was not present. The most frequently recorded damage type was insects, with 9.9% of the sample trees in total Europe being affected. Second largest was the share of trees showing fungi (6.3%), followed by abiotic agents recorded on 5.2% of all sample trees.

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 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	64.2	34.4	1.4	52.8	45.1	2.1
Insects	52.0	38.1	9.9	47.2	40.5	12.3
Fungi	53.0	40.7	6.3	48.4	45.4	6.1
Abiotic agents	53.7	41.1	5.2	48.5	44.3	7.2
Action of man	53.9	42.4	3.7	49.6	46.6	3.8
Fire	56.2	43.4	0.3	51.8	47.8	0.4
Known air pollution	59.8	38.1	2.1	58.3	41.7	0.0
Other	52.1	39.9	8.0	47.4	44.7	7.9

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 2.1% of all sample trees air pollution was identified as a cause of damage. Of these trees, 39.4% had a defoliation greater 25% (Table 3.1.2-2).

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

	Defoliation (>25%)		Discolouration (>10%)	
Damage type	Total Europe	EU	Total Europe	EU
Game/grazing	15.8	14.8	4.3	4.0
Insects	35.2	34.6	12.2	11.6
Fungi	38.8	37.8	11.7	15.1
Abiotic agents	41.8	39.5	12.0	11.6
Action of man	29.6	24.7	10.5	11.0
Fire	48.4	52.1	18.1	19.0
Known air pollution	39.4	50.0	2.2	50.0
Other	32.5	32.4	6.7	8.7
Total tree sample	21.3	19.5	6.3	5.5

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. In that 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.

For the calculation of the changes in defoliation over the last year, the sample “$CSTs_{01}$” (2001-2002) was chosen. The mid-term development was based on the sample “$CSTs_{94}$” (1994-2002), because after 1994 the tree sample remained relatively stable for several years. But in some areas this mid-term time series had to be confined to the years 1997-2002 because of changes in the assessment methods between 1994 and 1997. In future reports the $CSTs_{94}$ will be replaced by $CSTs_{97}$ having 1997 as the starting year. In order to analyse the long-term development, the sample “$CSTs_{88}$” (1988-2002) was chosen. Annex I-7 shows the spatial coverage of the three samples.

The differences in mean plot defoliation between 2000 and 2001 are mapped in Annex I-8. The sample size of the underlying 126 390 $CSTs_{01}$ corresponds to 95.9% of the total tree sample. The sample size for the $CSTs_{94}$ amounted to 61 320 trees (46.5% of the total tree sample). The $CSTs_{88}$ comprised 20 956 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. If the sample size of a species in a particular region amounts at least to 100, then the distribution of the trees over the defoliation classes is given for each year in Annex I-9 and Annex I-10. These Annexes also contain the respective information for *Abies alba* and *Picea sitchensis* because of their ecological and economical importance in some regions. For each of the six main 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 is presented 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. Also in Chapters 3.2.2-3.2.7, the trends in mean defoliation between 1994 and 2002 are mapped for each plot. Each map shows plots containing at least three trees of the given species. Trends were calculated only for those plots having at least three trees of the $CSTs_{94}$ of that species. The remaining plots are depicted in grey colour.

Between 1994 and 2002 a statistically significant increase in defoliation (deterioration) occurred on 15.8% of the plots (pie diagram in map in Figure 3.2.1-1). These plots are scattered all over Europe, but are particularly abundant in southern Finland, southern Sweden, Estonia, Latvia, western Germany, the Czech Republic, Slovenia, Romania, northern Spain and Portugal. Defoliation decreased significantly (improvement) on 11.9% of the plots, these plots being concentrated in Estonia, Poland and Romania.

Table 3.2.1-1: Number of trees common to the surveys from 1988 to 2002 (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* and *Q. rotundifolia*	*Quercus petraea* and *Q. robur*
Atlantic (North)	152	440	0	239	0	190
Atlantic (South)	0	74	229	29	24	74
Mediterranean (Higher)	0	368	192	80	464	183
Mediterranean (Lower)	0	72	894	33	1724	3
Mountainous (South)	926	480	45	766	31	79
Sub-Atlantic	1910	1087	0	1473	0	698
All regions	2988	2521	1360	2620	2243	1237
Percent of all common trees 1988-2002	14.3	12.0	6.5	12.5	10.7	5.9

Table 3.2.1-2: Number of trees common to the surveys from 1994 to 2002 (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* and *Q. rotundifolia*	*Quercus petraea* and *Q. robur*
Atlantic (North)	646	755	0	666	0	641
Atlantic (South)	0	75	340	40	24	167
Boreal	2008	2918	0	0	0	2
Boreal (Temperate)	1663	2982	0	2	0	47
Continental	254	182	0	733	1	448
Mediterranean (Higher)	52	488	306	255	617	221
Mediterranean (Lower)	16	80	1212	143	2188	276
Mountainous (North)	618	767	0	0	0	0
Mountainous (South)	2778	1081	45	1885	35	295
Sub-Atlantic	4090	8313	0	2152	0	1513
All regions	12125	17641	1903	5876	2865	3610
Percent of all common trees 1994-2002	19.8	28.8	3.1	9.6	4.7	5.9

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 3.2.1-2 and 3.2.1-3, respectively. (The graph of the CSTs$_{88}$ starts only in 1989, because defoliation scores were not made available in 5% steps by all countries before that year.) The Mediterranean species *Pinus pinaster* and *Quercus ilex* and *Q. rotundifolia* show the steepest increase in defoliation since 1988. A slight increase is revealed for *Pinus sylvestris* and *Picea abies*, with an obvious phase of recovery in the 1990s. Defoliation of *Fagus sylvatica* has been undulating around 20% for years.

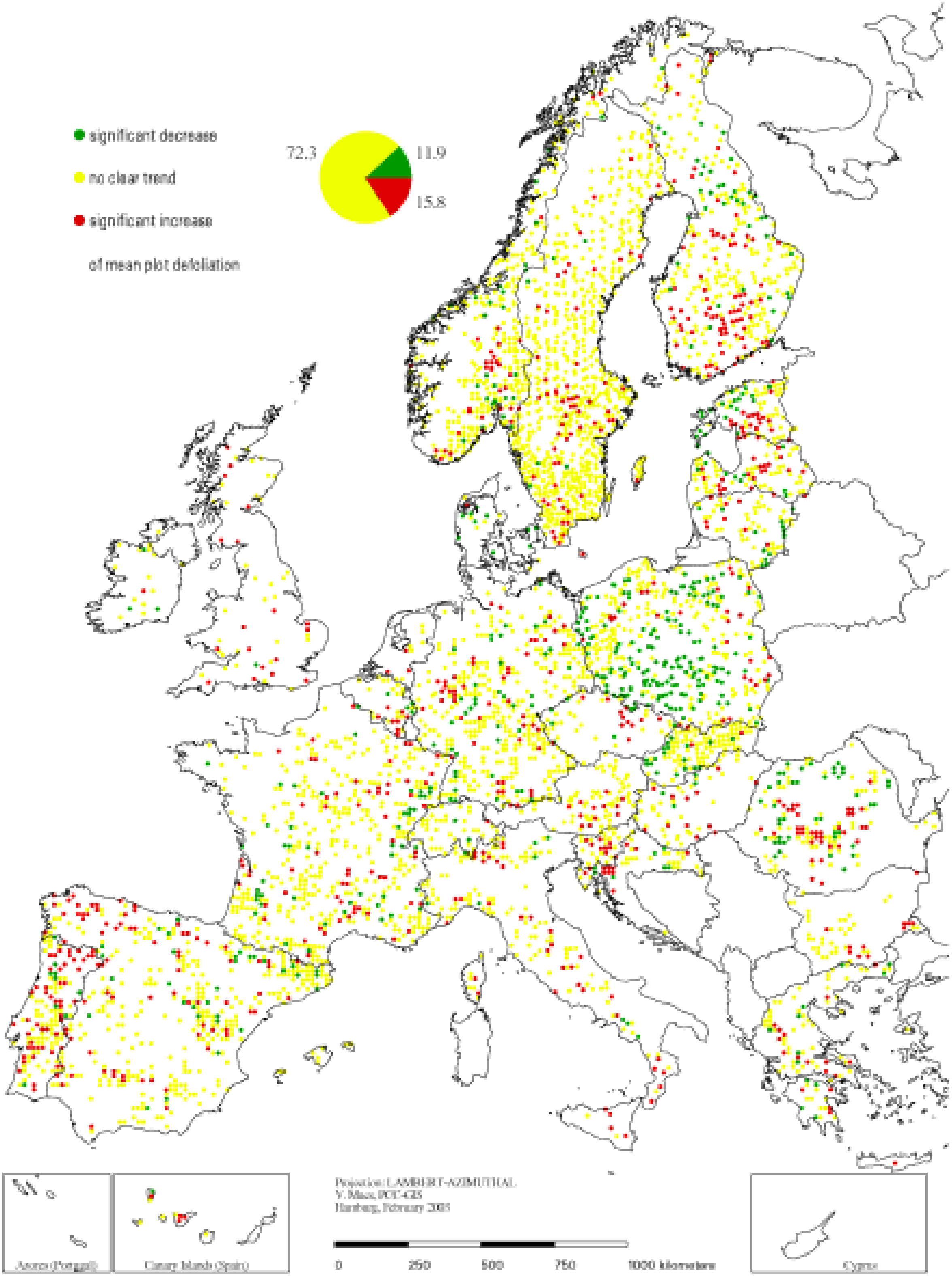


Figure 3.2.1-1: Trend of mean plot defoliation (slope of linear regression) of all species over the years 1994 to 2002 (1997 to 2002 for France and Italy due to changes in the assessment methodology and for Sweden due to changes in the sampling).

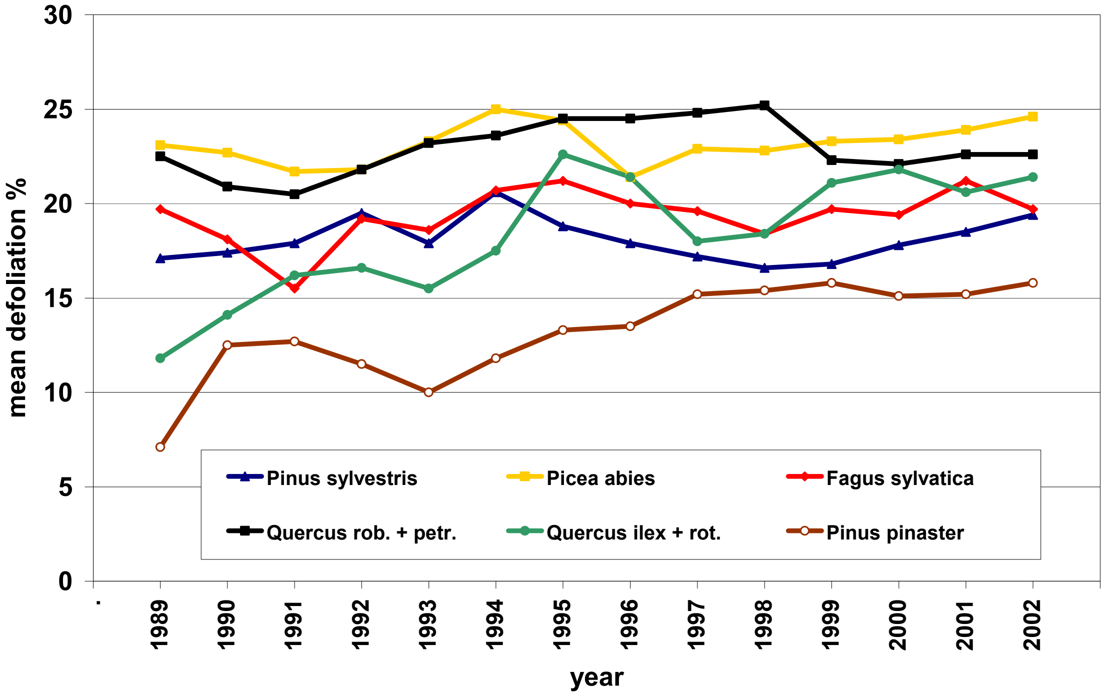


Figure 3.2.1-2: Development of mean defoliation of CSTs$_{88}$ of the 6 most frequent species. Mean defoliation could be calculated only from 1989 onwards, because in 1988 defoliation was assessed in the traditional defoliation classes instead of 5% steps. Number of trees: *Pinus sylvestris*: 2521; *Picea abies*: 2988; *Quercus robur* and *Q. petraea*: 1237; *Fagus sylvatica*: 2620; *Pinus pinaster*: 1360; *Quercus ilex* and *Q. rotundifolia*: 2243.

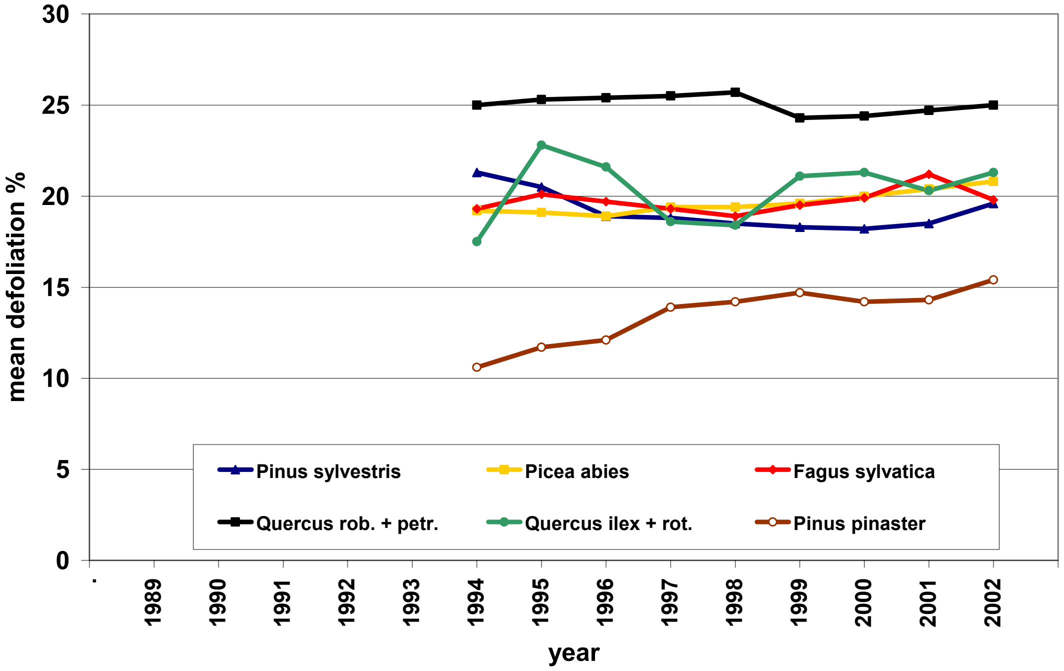


Figure 3.2.1-3: Development of mean defoliation of CSTs$_{94}$ of the 6 most frequent species. Number of trees: *Pinus sylvestris*: 17641; *Picea abies*: 12125; *Quercus robur* and *Q. petraea*: 3610; *Fagus sylvatica*:5876; *Pinus pinaster*:1903; *Quercus ilex* and Q. *rotundifolia*: 2865.

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 (47.1%) of its CSTs$_{94}$, followed by the Boreal (Temperate) and Boreal regions (16.9% and 16.5%, respectively).

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 CSTs$_{94}$ decreasing to their minima in 1999 and 2001, respectively. In 2002, however, the shares of damaged trees again increased slightly in both CSTs$_{88}$ and CSTs$_{94}$.

The defoliation patterns to a large extent varied 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 Boreal (Temperate) region the share of damaged trees showed a similar development in both CSTs$_{88}$ and CSTs94. The share of trees with 0-10% defoliation, however, distinctly changed by about 8-10 percent points between 1997 and 2001, remaining at the same low level in 2002. The recuperation observed from 1994 onwards 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 16.2% of the plots and a statistically significant deterioration on 10,6% of the plots.

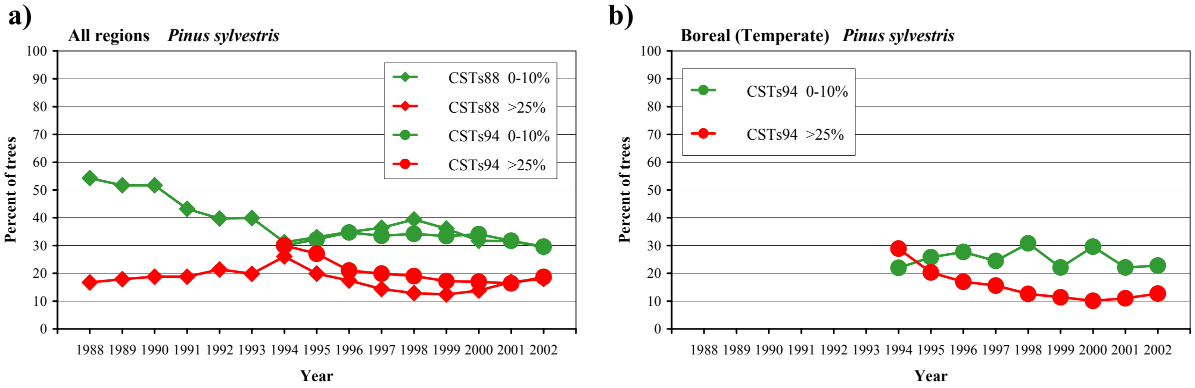


Figure 3.2.2-1: a) Sample sizes in all regions: CSTs$_{88}$ = 2521; CSTs$_{94}$ = 17641.
b) Sample sizes in the Boreal (Temperate) region: CSTs$_{94}$ = 2982.

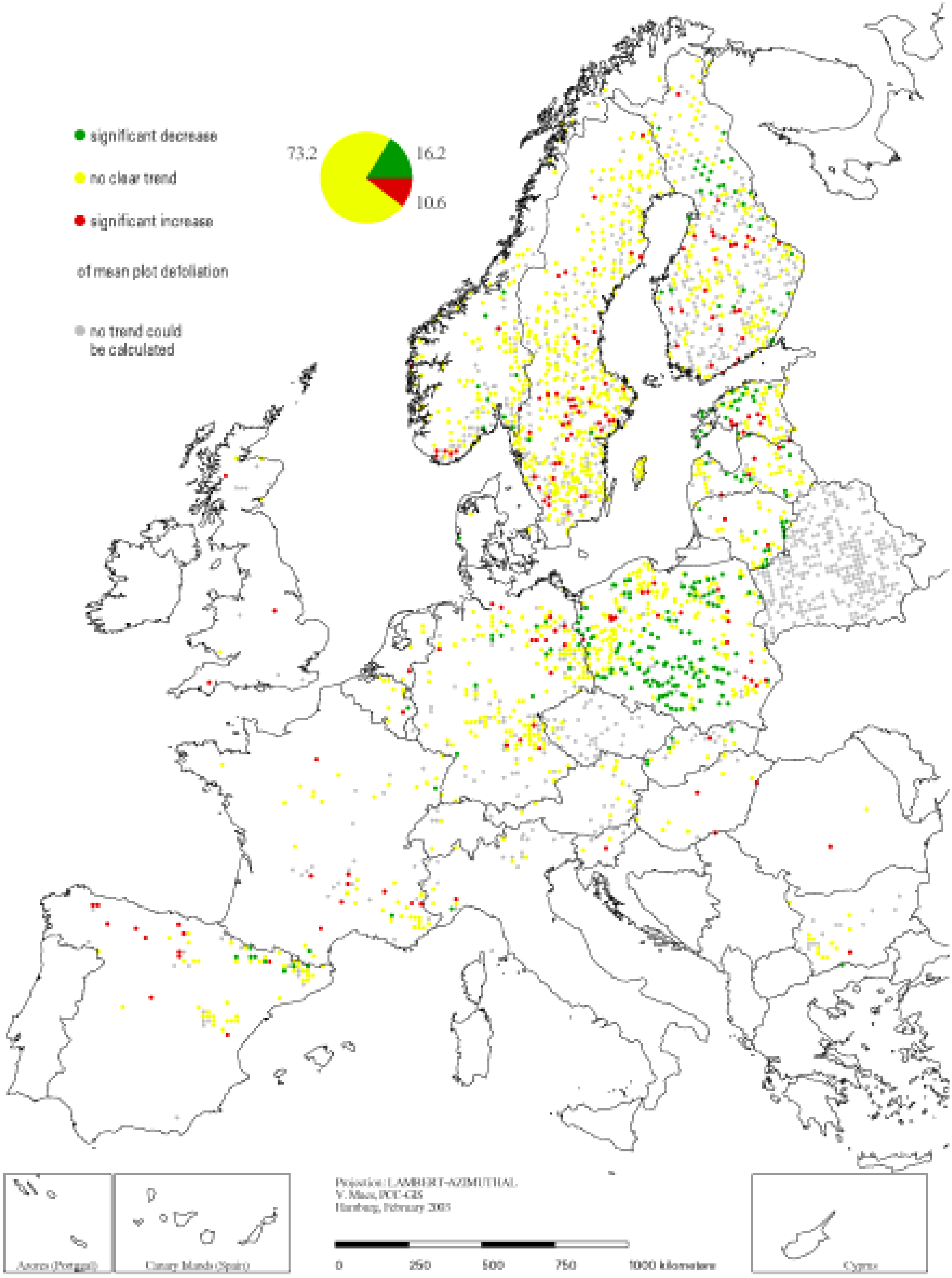


Figure 3.2.2-2: Trend of mean plot defoliation (slope of linear regression) of *Pinus sylvestris* over the years 1994 to 2002 (1997 to 2002 for France and Italy due to changes in the assessment methodology and for Sweden due to changes in the sampling; grey plots contain *Pinus sylvestris* trees for 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 contrast to the other regions, in the Boreal region the share of undamaged trees dropped from 57.7% in 1994 to 44.6% in 2002 with a minimum being recorded in 2001. The share of damaged trees increased from 13.3% in 1994 to 22.4% in 2001 and decreased again in 2002. 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 17.4% of the plots. On 7.1% of the plots an improvement was observed.

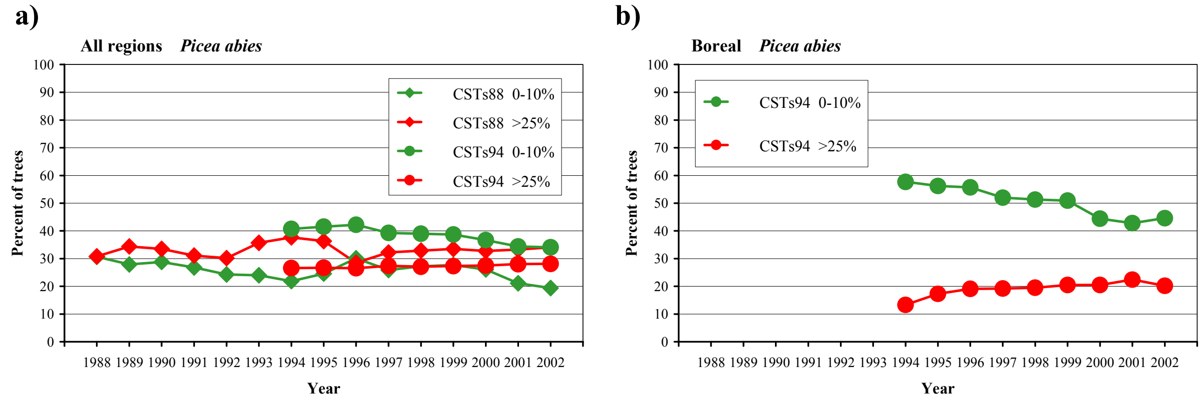


Figure 3.2.3-1: a) Sample sizes in all regions: CSTs$_{88}$ = 2988; CSTs$_{94}$ = 12125.
b) Sample size in the Boreal region: CSTs94 = 2008.

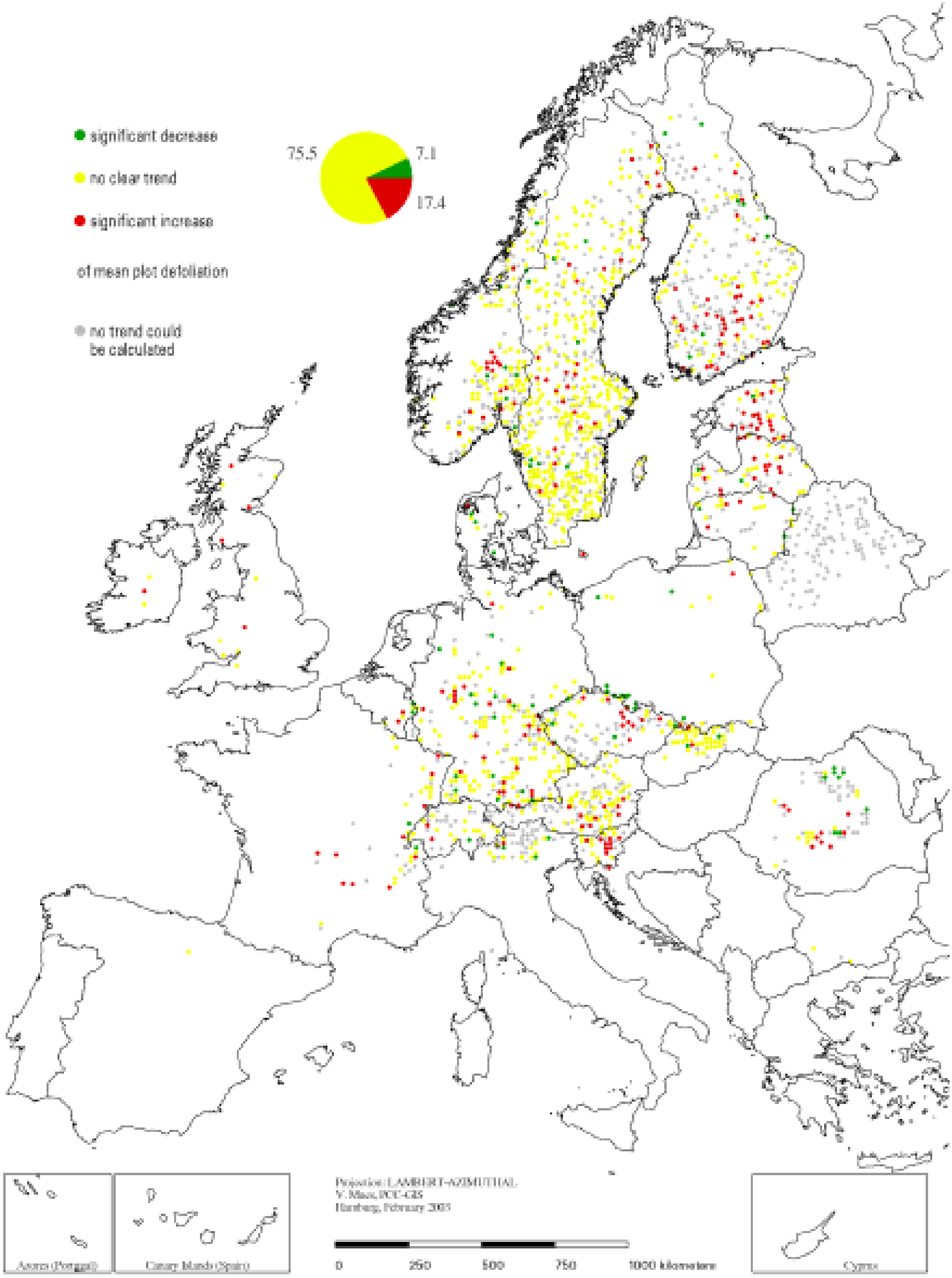


Figure 3.2.3-2: Trend of mean plot defoliation (slope of linear regression) of *Picea abies* over the years 1994 to 2002 (1997 to 2002 for France and Italy due to changes in the assessment methodology and for Sweden due to changes in the sampling; grey plots contain *Picea abies* trees for which no trends in defoliation could be calculated).

3.2.4 *Fagus sylvatica*

Fagus sylvatica was the most frequent broadleaved 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 Mountainous (South) regions where more than two thirds of the CSTs for *Fagus sylvatica* are located. The species is not represented in the Boreal region and in the Mountainous (North) region.

The crown condition of *Fagus sylvatica* has markedly recuperated over all regions after an increase in defoliation observed in 2001 (Figure 3.2.4-1a). The percentage of damaged trees decreased from 26.7% to 21.5% (CSTs$_{94}$). Thus, the defoliation on *Fagus sylvatica* has reached again the extent of the late 1990s.

About one third of the sample is located in the Mountainous (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).

According to significance tests for the plotwise medium term development in crown condition, for the major share (68.7%) of the *Fagus sylvatica* plots between 1994 and 2001 no statistically significant trend could be traced. The percentage of deteriorating plots (18.0%) is distinctly larger than the percentage of improving plots (13.3%) (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.

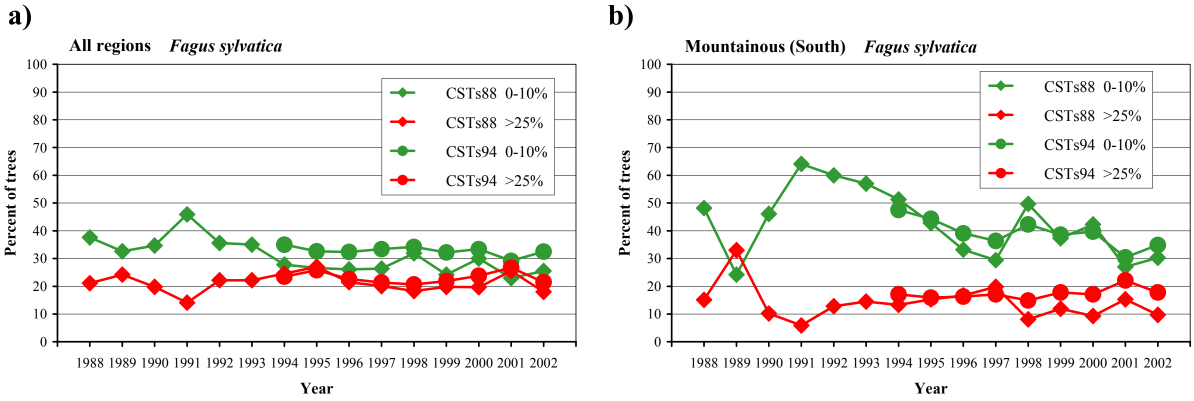


Figure 3.2.4-1: a) Sample sizes in all regions: CSTs$_{88}$ =2620; CSTs$_{94}$ = 5876.
b) Sample sizes in the Mountainous (South) region: CSTs$_{88}$ = 766; CSTs$_{94}$ = 1885.

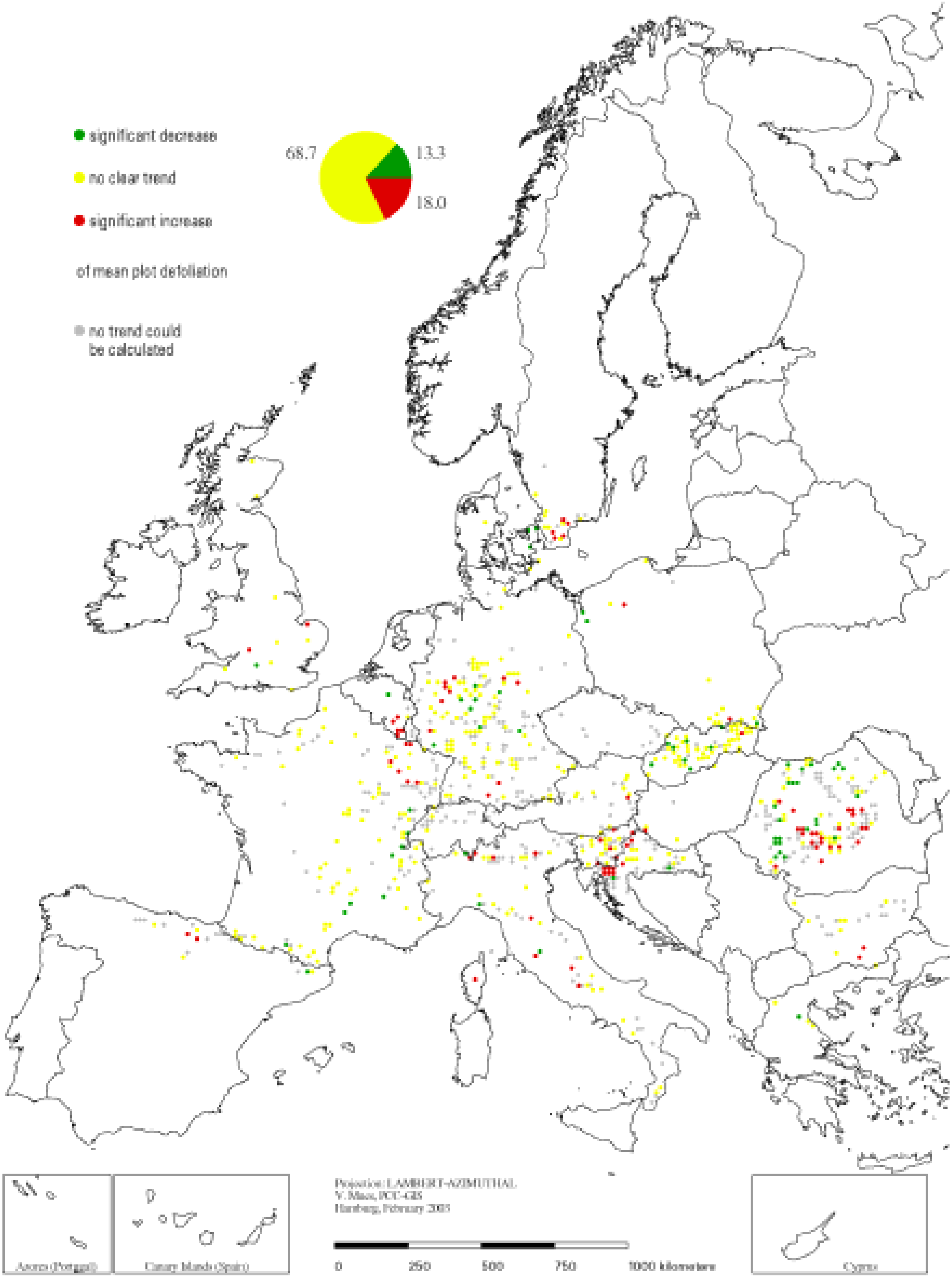


Figure 3.2.4-2: Trend of mean plot defoliation (slope of linear regression) of *Fagus sylvatica* over the years 1994 to 2002 (1997 to 2002 for France and Italy due to changes in the assessment methodology and for Sweden due to changes in the sampling; grey plots contain *Fagus sylvatica* trees for which 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 broad-leaved 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$_{88}$) and increased slightly afterwards (Figure 3.2.5-1a). For the trees in the Sub-Atlantic region, in contrast to the overall trend, a slight recuperation was observed during recent years with the shares of trees with 0-10% defoliation in both CSTs having slightly increased since 1999 (Figure 3.2.5-1b).

Changes in defoliation as recorded between 1994 and 2002, did not prove statistically significant in 76.1% of the plots (Figure 3.2.5-2). The share of improving plots (12.1%) was slightly larger than the share of plots with deteriorating crown condition (11.9%). Plots with increasing defoliation were more abundant in southernmost United Kingdom and in parts of France. Plots with decreasing defoliation were more abundant in central Germany, southern Poland and in the Slovak Republic.

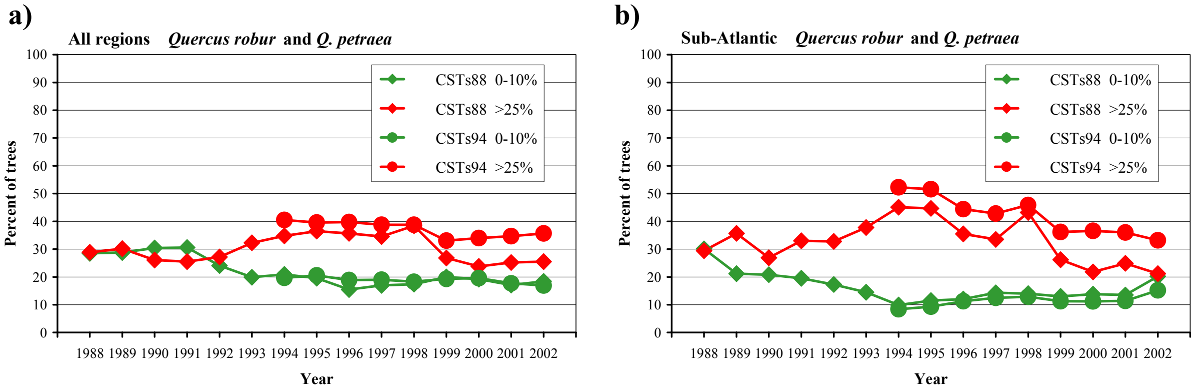


Figure 3.2.5-1: a) Sample sizes in all regions: CSTs$_{88}$ = 1237; CSTs$_{94}$ = 3610.
b) Sample sizes in the Sub-Atlantic region: CSTs$_{88}$ = 698; CSTs$_{94}$ = 1513.

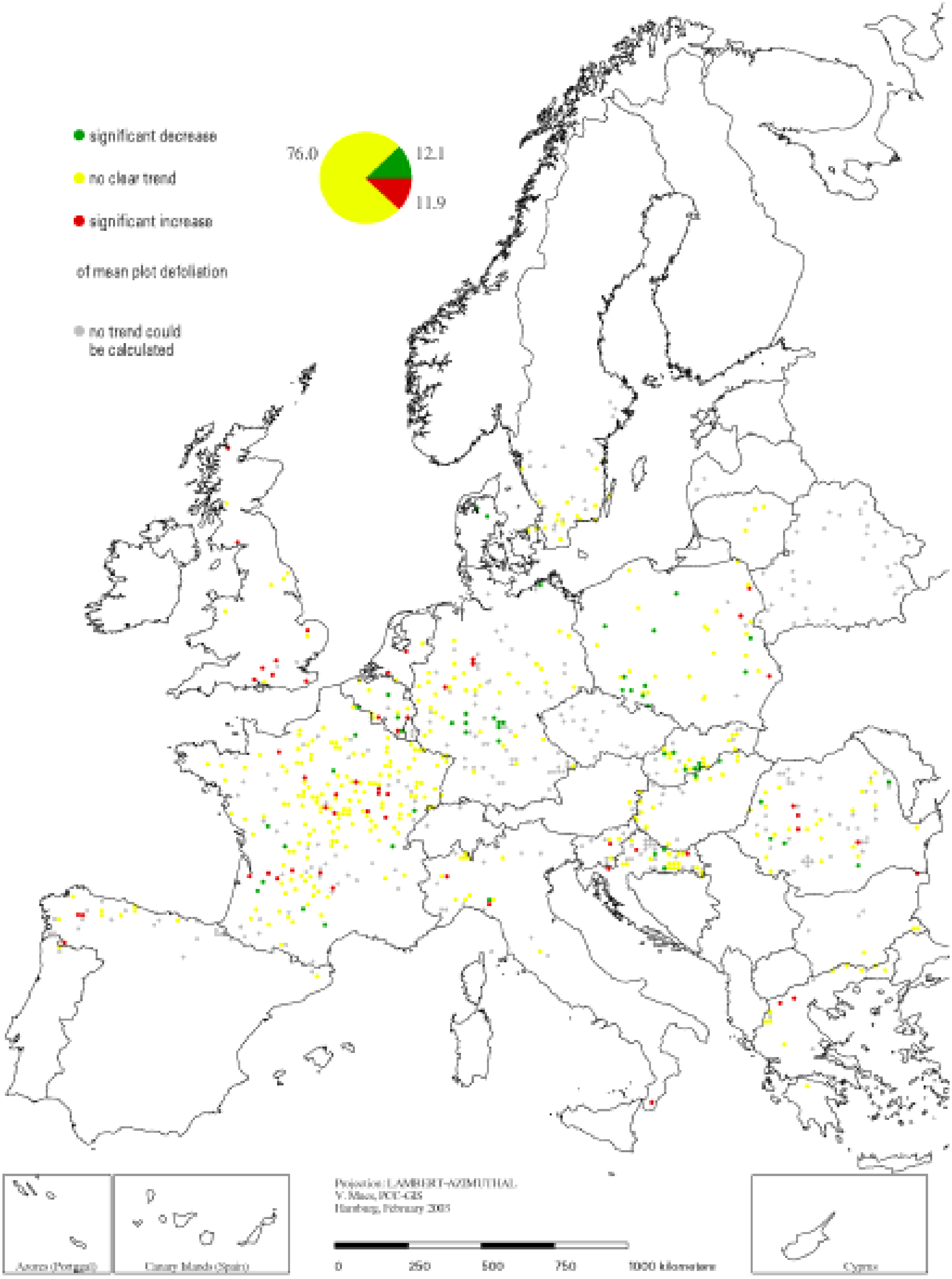


Figure 3.2.5-2: Trend of mean plot defoliation (slope of linear regression) of *Quercus robur* and *Q. petraea* over the years 1994 to 2002 (1997 to 2002 for France and Italy due to changes in the assessment methodology and for Sweden due to changes in the sampling; grey plots contain *Quercus robur* 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) representing more than three quarters of both the CSTs$_{88}$ and CSTs$_{94}$. The second most trees (CSTs$_{88}$ and CSTs$_{94}$) are located in the Mediterranean (higher) region.

The first survey years reveal a strong deterioration (Figures 3.2.6-1a and 3.2.6-1b). Only from 1988 to 1990 crown condition improved in the Mediterranean (higher) region. Afterwards, however, a marked decrease in the share of trees defoliated by 0-10% was recorded between 1991 and 1995. During the succeeding years up to 1998, improving crown condition were recorded between 1995 to 1998. Since 1999, a trend of slight decrease in the respective share was registered again. The share of trees with >25% defoliation varied distinctly by about 7 percent points during recent years.

Figure 3.2.6-2 maps the slope of the linear trend for the plots with *Quercus ilex* and *Q. rotundifolia*. Most obvious is the high share of plots without any statistically significant trend in the period from 1994 to 2002 (76.7%), reflecting the little overall change in defoliation between 1994 and 2002 shown in Figures 3.2.6-1a and 3.6.2-1b. Most of the plots with statistically significant deterioration (15.3%) are located near to the border between Portugal and Spain and in a part of southern Spain. Most plots with improving crown condition (8.0%) are located in north-eastern Spain and along the west coast of Italy.

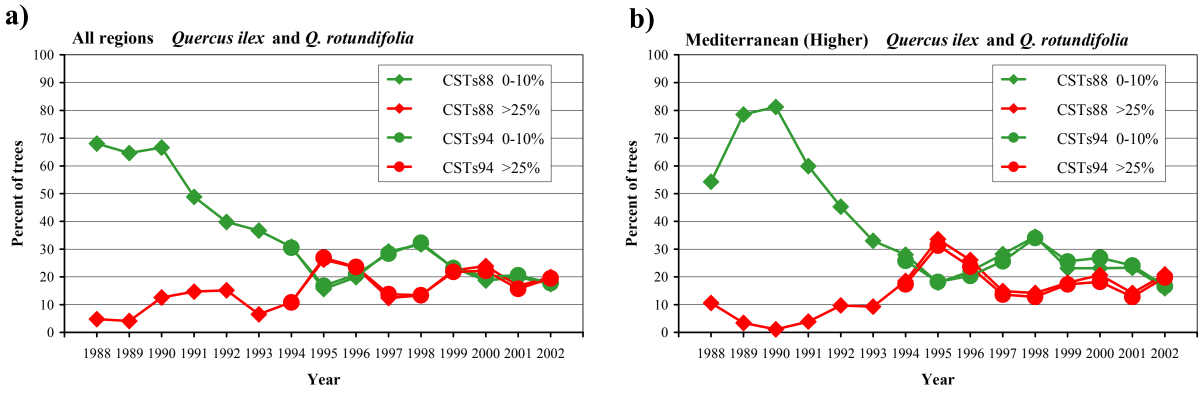


Figure 3.2.6-1: a) Sample sizes in all regions: CSTs$_{88}$ = 2243; CSTs$_{94}$ = 2865.
b) Sample sizes in the Mediterranean (Higher) region: CSTs$_{88}$ = 464; CSTs$_{94}$ = 617.

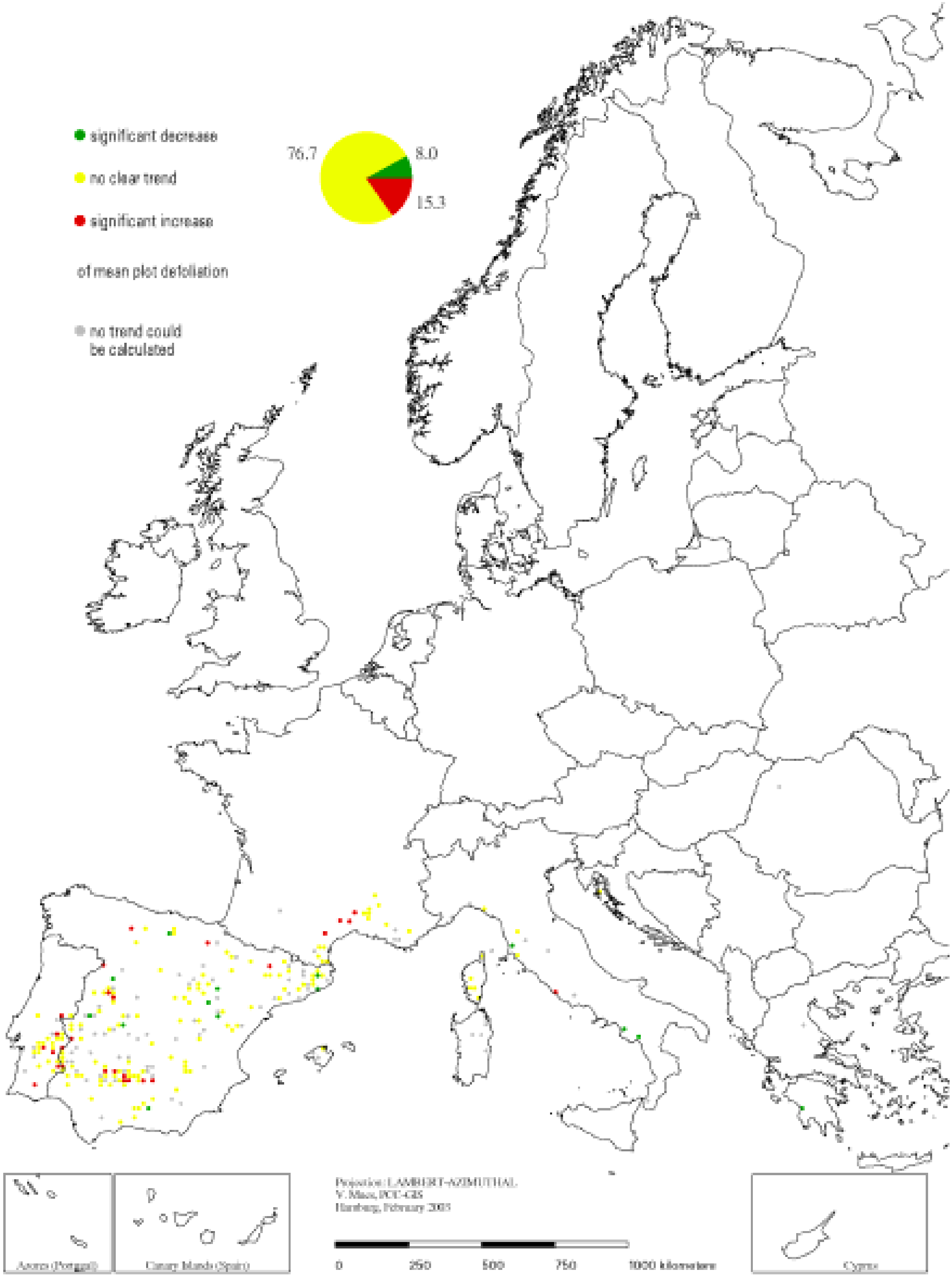


Figure 3.2.6-2: Trend of mean plot defoliation (slope of linear regression) of *Quercus ilex* and Q. *rotundifolia* over the years 1994 to 2002 (1997 to 2002 for France and Italy due to changes in the assessment methodology; grey plots contain *Quercus ilex* or *Q. rotundifolia* trees for which no trends 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 southwest of France in the Atlantic (South) region.

Over the whole observation period a marked decrease in the share of trees defoliated by 0-10% was observed (Figure 3.2.7-1a) with an intermediate recuperation recorded during the early 1990s. The proportion of trees defoliated by >25% remained much smaller than that of the undamaged trees and only slight variations in its share were observed since 1992. This indicates that increased defoliation patterns were found almost exclusively among trees defoliated moderately. In the Mediterranean (Higher) region, the proportion of undamaged trees has remained slightly higher as compared to the respective share over all regions (Figure 3.2.7-1b). However, since 1997 its share has shown a more rapid decrease in comparison with the trend in all regions. The mapped medium-term trends in defoliation development reflect these results with 24.5% of the considered plots showing statistically significant decreases in defoliation (Figure 3.2.7-2). A recuperation of crown condition could be recorded for only 11.3% of the plots.

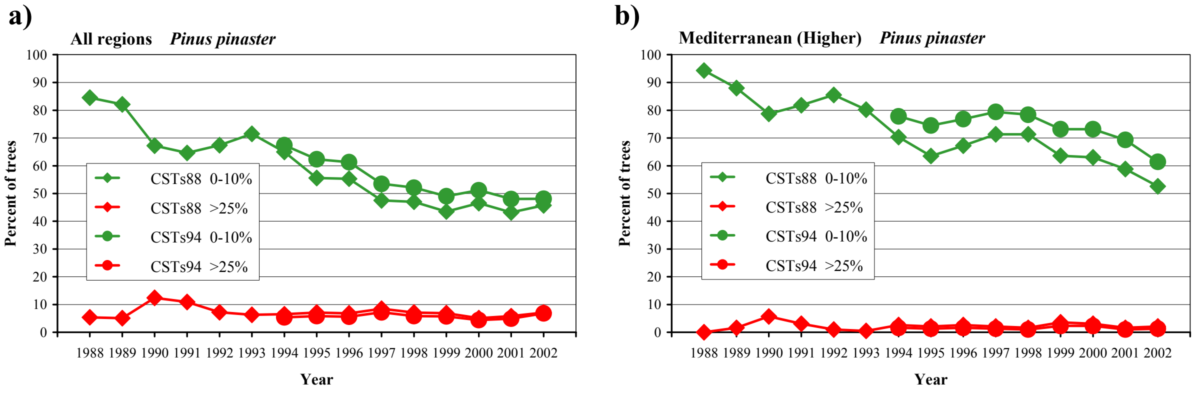


Figure 3.2.7-1: a) Sample sizes in all regions: $CSTs_{88}$ = 1360; $CSTs_{94}$ = 1903.
b) Sample sizes in the Mediterranean (Higher) region: $CSTs_{88}$ = 192; $CSTs_{94}$ = 306.

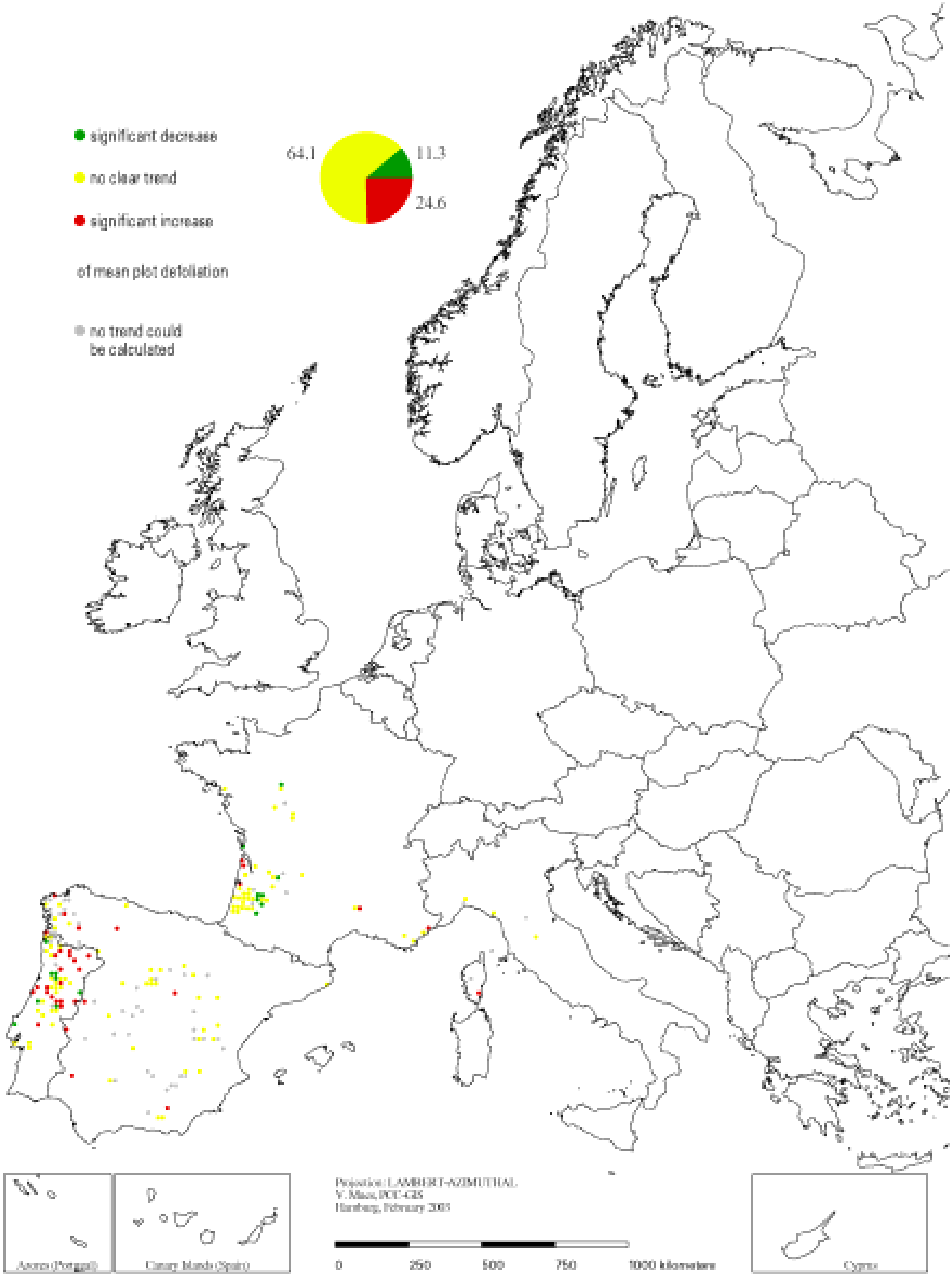


Figure 3.2.7-2: Trend of mean plot defoliation (slope of linear regression) of *Pinus pinaster* over the years 1994 to 2002 (1997 to 2002 for France and Italy due to changes in the assessment methodology; grey plots contain *Pinus pinaster* trees for which no trends in defoliation could be calculated).

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 no statistically significant relationships between crown condition in terms of defoliation and the predictor variables. Nevertheless, some plausible relationships could be detected.

The mean development of defoliation was calculated as slopes of linear regressions over the years of observation plot-wise and presented in maps. These maps are presented in colours from green (recuperation) to red (deterioration). The maps for the presentation of the preliminarily adjusted defoliation (PAD) use the same colours for depicting plots or regions, respectively, with lower (green) or higher (red) mean defoliation than the country specific model for the age effect (2.5.3). To facilitate an integrated interpretation of the development and of the relative level of defoliation the maps for the slopes were presented side by side with the maps of the PAD.

4.1 Picea abies

For the evaluation of the temporal and spatial variation of defoliation for Picea abies, 1046 plots were available with complete data for the period from 1994 to 1999. To improve the possibilities of combined interpretation of the spatial and temporal variation the maps of the mean development of defoliation (slopes of plot-wise linear regression) and the maps of the preliminarily adjusted defoliation (PAD) are presented side by side. The selected colours are used to improve the distinction between both maps. The plot wise medium term mean defoliation is presented in Figure 4.1-1.

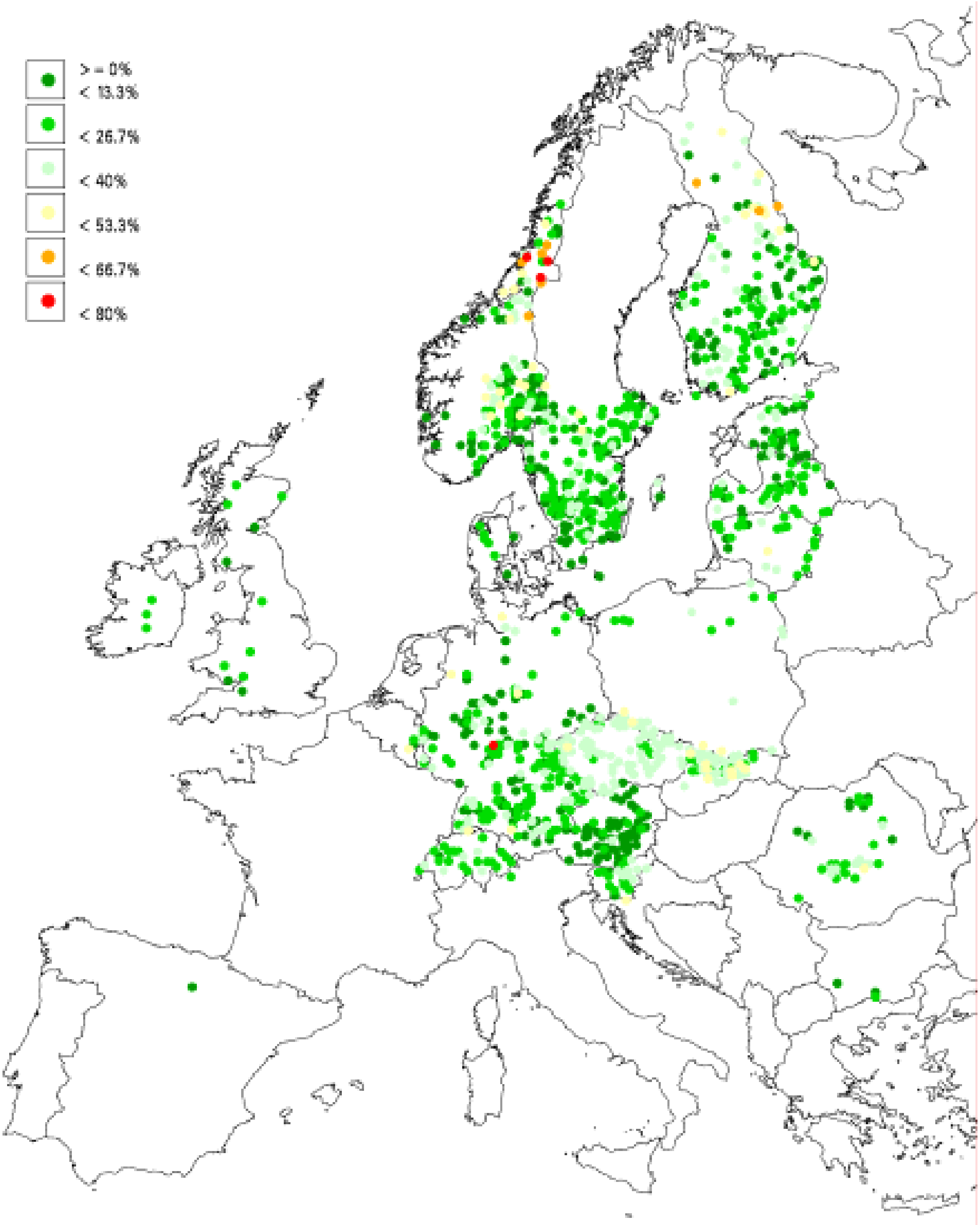


Figure 4.1-1: *Picea abies*; plot-wise presentation of medium term mean defoliation 1994 – 1999.

4.1.1 Temporal variation of defoliation

The temporal development of Picea abies was calculated as regression coefficients of a linear regression over year of observation (YEAR) according to model 4 in Table 4.1.1-1. The plot-wise calculated 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):

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

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. Additionally, the heterogeneous development in Norway, Sweden, Finland, Latvia, and Romania reveals a differentiation within the countries. Generally, the crown condition in Germany improved during the evaluation period with some exceptions in the center and the south of Germany (Figure 4.1.1-1 and Figure 4.1.1-2).

The target variable for the statistical analyses was the referenced defoliation (2.5.3). Also all predictor variables were transformed in the same way and used as referenced values. In addition to the methodology of the last year's report (UNECE, EC, 2002) also some explanatory variables were used to describe possible time lag effects. The abbreviations of those variables begin with a p indicating that the variable describes a factor observed in the **p**revious year possibly influencing defoliation in the actual year of observation. None of the evaluated predictor variables was statistically significant in the models according to the test described in section 2.5.3.

From the precipitation indices tested (sums of precipitation during varying time periods) the sum of precipitation from April to June in the year of observation and the sum of precipitation from April to September in the previous year were those with the highest explanation potential for the temporal variation of defoliation with negative regression coefficients indicating a lower defoliation in years with high precipitation in the year of observation (April to June) or the year before (April to September).

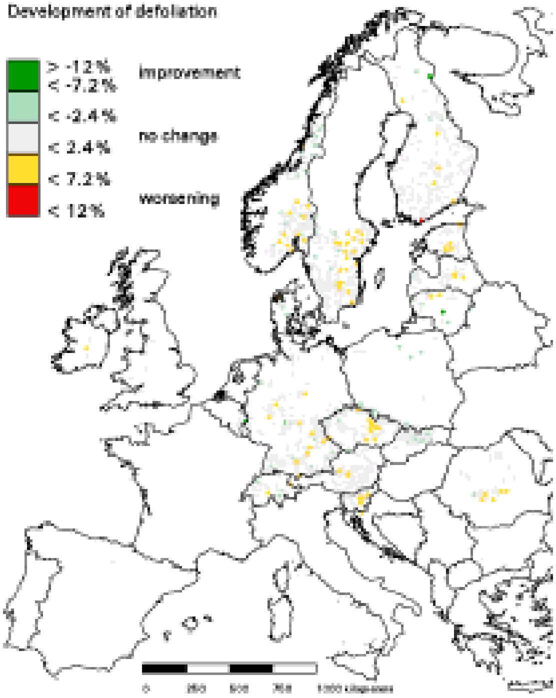


Figure 4.1.1-1: Linear temporal trend of defoliation for *Picea abies* (plot-wise presentation).

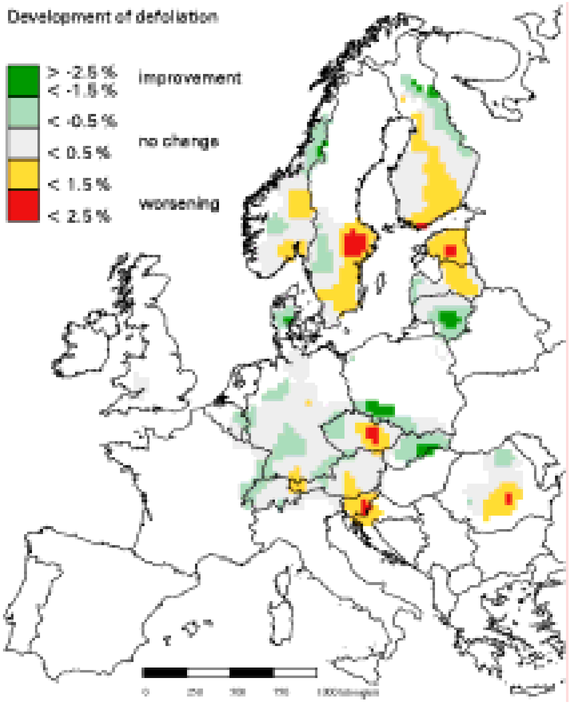


Figure 4.1.1-2: Linear temporal trend of defoliation for *Picea abies* (kriging interpolation; nugget: 2.4 sill: 1.1 range: 250 km).

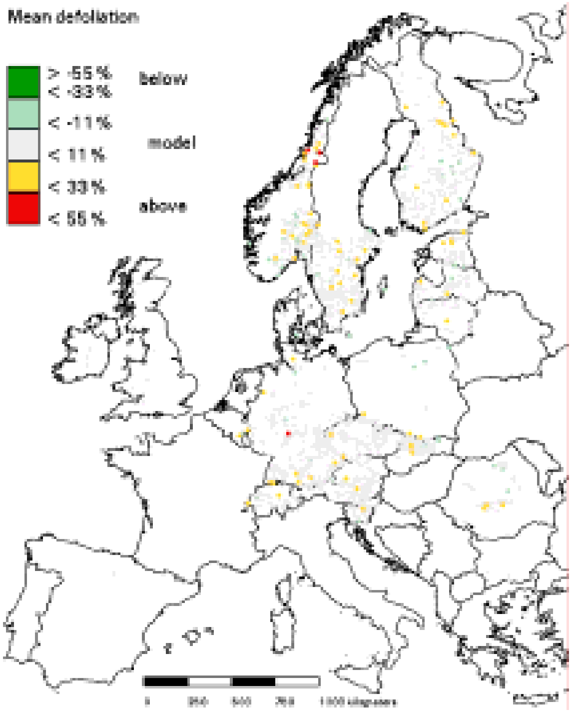


Figure 4.1.1-3: *Picea abies*; plot-wise presentation of preliminarily adjusted defoliation, deviation of medium-term mean defoliation (1994 to 1999) to country specific linear regression over age.

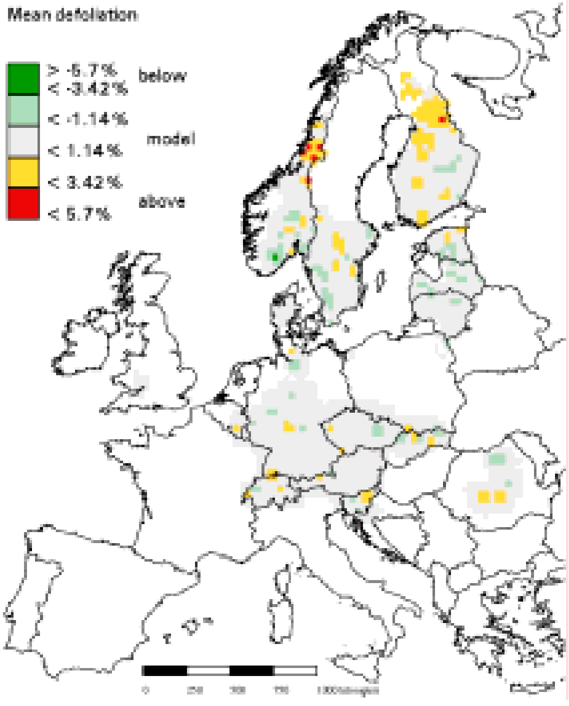


Figure 4.1.1-4: *Picea abies*; preliminarily adjusted defoliation, deviation of medium-term mean defoliation (1994 to 1999) to country specific linear regression over age (kriging interpolations; nugget: 51.2 sill: 6.7 range: 60 km).

Additionally, the regression analyses revealed a positive correlation of defoliation with the index for insect pests but a negative one with the index for fungi infestations which seems to be implausible at the first glance. Perhaps it can be explained by the difficulties with the detection of fungi infections, their late observation years after the first infection or with the fungi infestations being some kind of secondary damage.

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

model	**1**	**2**		**3**	**4**
R-square	**40.81**	**41.05**		**40.61**	**39.99**
	ßx	**ßx**	**ßx^2**	**ßx**	
prec04_06	-0.0018	-0.0037	-0.00006		
prev prec04_09	-0.0025	-0.0029	0.00001		
insect	9.09	8.54		9.12	
fungi	-0.30	-0.25			
depo S	6.52	0.99		3.36	
depo NHy	-8.64	16.36	-320.39		
depo NOx	22.88	40.68	340.79		
prev depo S	-3.63	-7.56			
prev depo NHy	-4.17	-3.75	-167.11		
prev depo NOx	-18.69	-28.99	18.91		
YEAR1)	o	o		o	o

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

The deposition of sulphur in the year of observation (depo S, Table 4.1.1-1) leads to positive regression coefficients whereas for the deposition of sulphur in the previous year (prev depo S) a negative regression coefficient was calculated. If the model 1 is expanded by adding a term for the quadratic regression over time (YEAR^2, R^2 49.3%, model not figured in Table 4.1.1-1) the regression coefficients for the other variable change only little but the regression coefficient for depo S is negative which could indicate that deviations from a linear development are due to changes in deposition of sulphur or at least that these deviations from linearity coincide with extraordinary sulphur depositions.

After the index for insect pests the deposition of sulphur is the second strongest predictor. A model with both predictor variables in addition to the plot specific linear regression over YEAR leads to a R-square value of 40.6 (model 3) which is only 0.2 percent points lower than the model with all deposition variables and the precipitation variables (model 1). On the other hand the R-square of model 3 is only 0.6 percent points higher than the model which is only describing the temporal variation by plot-wise linear regression over year of observation (YEAR, model 4).

4.1.2 Spatial variation of defoliation

The spatial variation of defoliation is presented by the preliminarily adjusted defoliation (PAD) in Figure 4.1.1-3 and Figure 4.1.1-4. Most impressing is the high within country variation of defoliation in Norway and less pronounced in Finland.

The R^2 values of all models for spatial variation of defoliation of Norway spruce are relatively high (see Table 4.1.2-1). A model only including the class variable country as predictor variable leads to a R^2 value of 23.3% (not depicted). The much higher value of model 4 (Table 4.1.2-1) which includes the country specific age trend seems to confirm the strong relationship between defoliation and age which was already described also in the Technical Report Level I 2001 (UNECE, EC, 2001) and by KLAP et al. (1997, 2000).

From the tested precipitation indices only those for differences between means in the evaluation period to the long term means lead to plausible negative regression coefficients. The distinct sums of precipitation for the evaluation period or for the long term means lead to positive regression coefficients.

Models including total nitrogen instead of separate nitrogen and nitrate components often result in implausible negative regression coefficients for deposition of sulphur which shows the difficulties in the interpretation of the regression results. Additionally, the R^2 values are slightly lower. The deposition of nitrate as one of two predictor variables is statistically significant and leads in all models to negative regression coefficients which indicates a coincidence of low defoliation values with high nitrate deposition.

The second statistically significant predictor variable is the index for insect pests. This predictor variable and the index for fungi infestation both lead to plausible positive regression coefficients (model 1 in Table 4.1.2-1).

Table 4.1.2-1: Linear regression models for spatial variation of medium-term mean defoliation of Norway spruce; statistically significant predictors shaded.

model	**1**	**2**	**3**	**4**
R-square	**58.7**	**58.6**	**58.5**	**56.8**
	ßx	**ßx**	**ßx**	
prec01_06	-0.00835	-0.00728		
insect	29.0	30.2	29.5	
fungi	3.4			
depo S	2.1			
depo NHy	4.6			
depo NOx	-25.8	-18.9	-19.1	
country	o	o	o	o
age$_{country}$	o	o	o	o

prec 01_06	difference of the 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 *Quercus robur* and *Q. petraea*

The evaluations of the spatial and temporal variation of *Quercus robur* and *Q. petraea* are based on the data from 291 plots (2.5.3). The medium term mean defoliation for the period 1994 to 1999 is presented in Figure 4.2-1 to give a first overview.

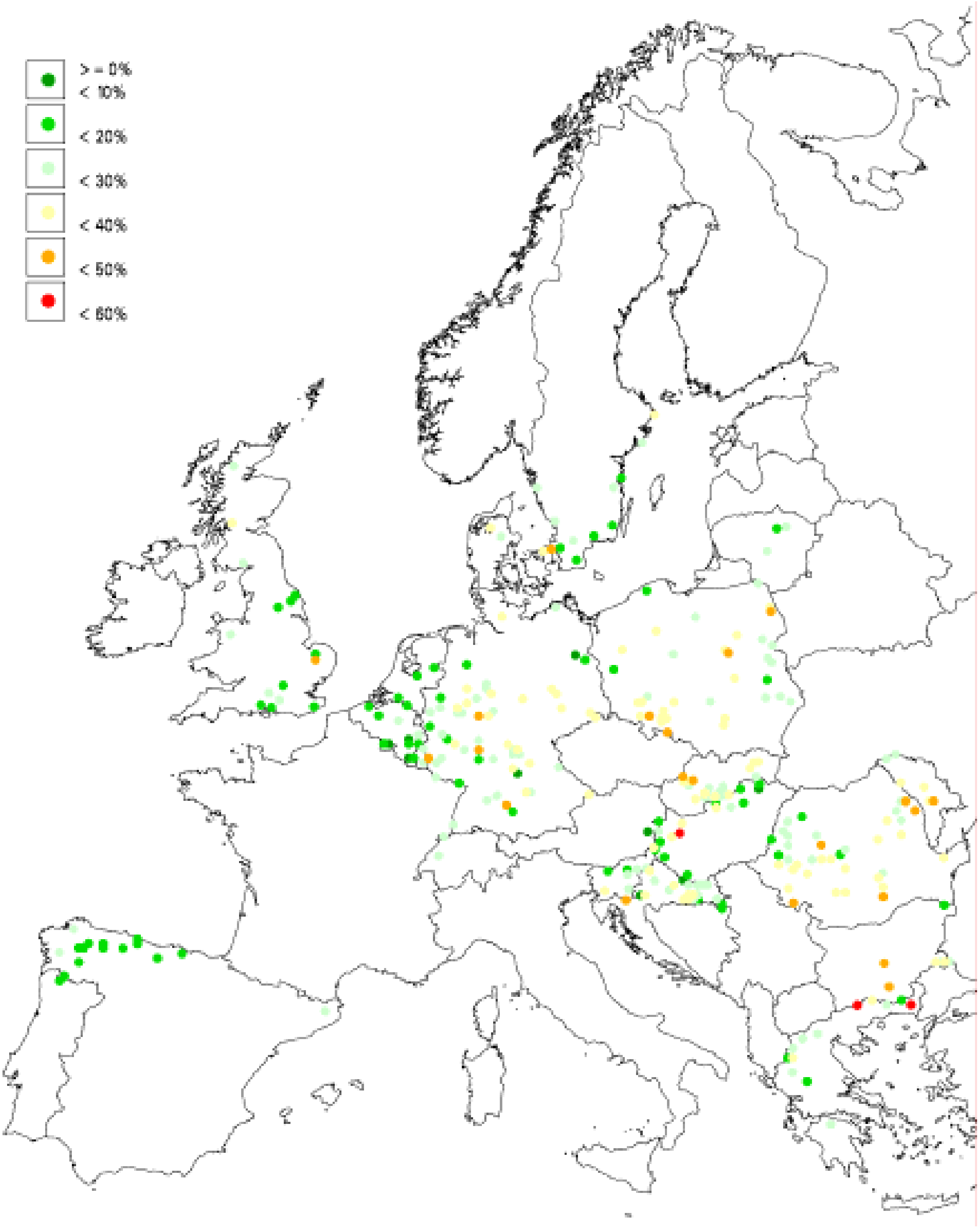


Figure 4.2-1: *Quercus robur* and *Q. petraea*; plot-wise presentation of medium term mean defoliation 1994 – 1999.

4.2.1 Temporal variation of defoliation

The temporal variation of *Quercus robur* and *Q. petraea* was analysed by multiple linear regression. The target variable annual mean defoliation as well as the predictor variables were transformed to referenced values (2.5.3). The resulting regression models are presented in Table 4.2.1-1.

No statistically significant predictor variables were found but a lot of plausible relationships were described by the models. The most simple model only including the plot-wise linear regression over the year of observation (equation (4), model 6 in Table 4.2.1-1) reaches a R-square value of 39.2%. The most comprehensive linear model 2 reaches 43.8%.

The two precipitation indices with the highest explanation potential were again the precipitation sum from April to June in the actual year and the precipitation sum from April to September in the preceding year. Both lead to plausible negative regression coefficients indicating that higher precipitation coincides with lower defoliation.

Table 4.2.1-1: models for temporal variation of defoliation of *Quercus robur* and *Q. petraea*; all models include the plot-wise calcuation of regression coefficients for the referenced year of observation

model	**1**	**2**	**3**	**4**		**5**		**6**
R-square	**43.34**	**43.82**	**43.49**	**63.57**		**43.83**		**39.16**
	ßx	**ßx**	**ßx**	**ßx**	**ßx^2**	**ßx**	**ßx^2**	
prec04_06	-0.0161	-0.0119	-0.0114	-0.0080	-0.000031	-0.0113	0.000066	
prev prec04_09	-0.0039	-0.0023	-0.0015	-0.0028	0.000003	-0.0011	-0.000026	
insect	4.85	4.82	4.94	2.79	8.42	4.17	5.76	
fungi	2.03	2.02	2.16	0.91	-1.78	2.31	-1.75	
depo S	19.30	21.50	20.13	14.84	-23.36	23.87	-1.77	
depo NHy	27.79	29.90						
depo NOx	64.11	61.38						
prev depo pS		4.51						
prev depo NHy		-30.61	-29.71	-47.21	707.93	-30.40	291.17	
prev depo NOx		13.42						
year	o	o	o	o	o	o		o

From the deposition predictor variables only the deposition of nitrate in the previous year leads to negative regression coefficients. This variable and the deposition of sulphur in the actual year are the two strongest (TYP III sum of squares) deposition predictor variables. Only the index for insect pests is of higher explanatory power. The regression coefficients for insect as well as those for fungi are in all linear models positive. Compared with the pure linear model 3 the use of quadratic functions for the predictor variable increases the R-square value only marginal (model 5). If the plot-wise regression over the year of observation is calculated quadratic (model 4) the R-square values increases by 20% points but the regression over the year of observation is only made to get an impression for unexplained plot-wise trends. The quadratic functions for the other predictor variables show that within the range of the predictor variables only deviations on a low level were modelled.

Crown condition of oak as described by the slope of a regression of annual mean defoliation over time shows the strongest deterioration in Romania, Croatia, and southern and northern Germany (Figure 4.2.1-1 and Figure 4.2.1-2). Especially for northern Germany an increase in defoliation during the evaluation period is detected for a large region. In southern Germany and Croatia the only regions were detected where crown condition deteriorated on a relatively high level of defoliation.

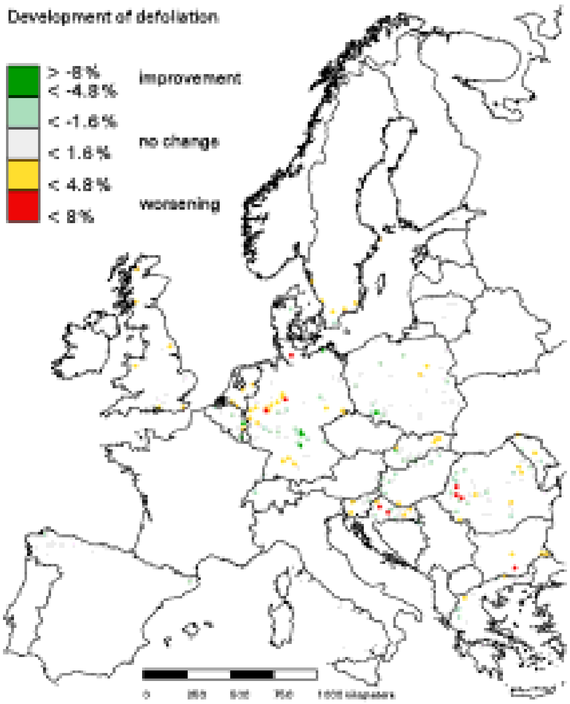


Figure 4.2.1-1: Linear temporal trend of defoliation for *Quercus robur and Q. petraea* (plot-wise presentation).

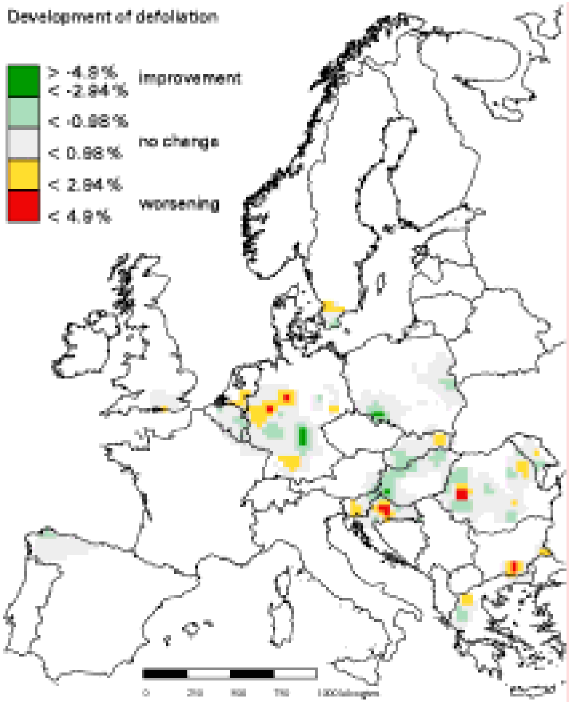


Figure 4.2.1-2: Linear temporal trend of defoliation for *Quercus robur* and *Q. petraea* (kriging interpolation; nugget: 2.2 sill: 4.6 range: 90 km).

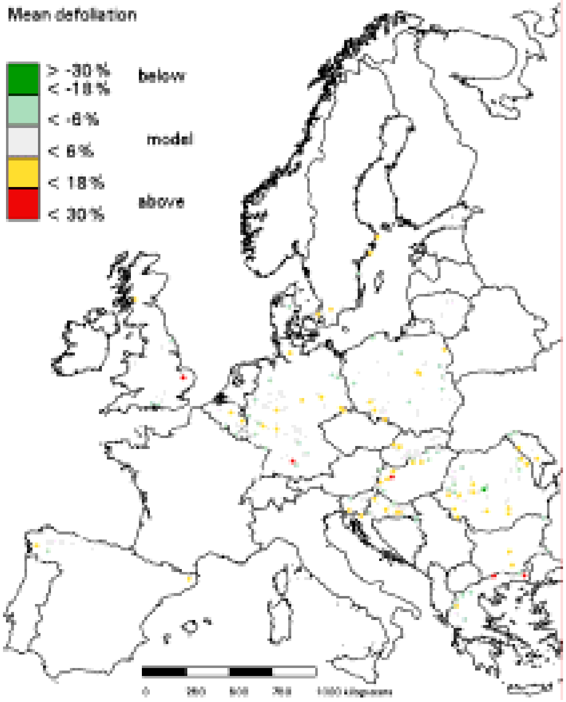


Figure 4.2.1-3: *Quercus robur* and *Q. petraea*; plot-wise presentation of preliminarily adjusted defoliation, deviation of medium-term mean defoliation (1994 to 1999) to country specific linear regression over age.

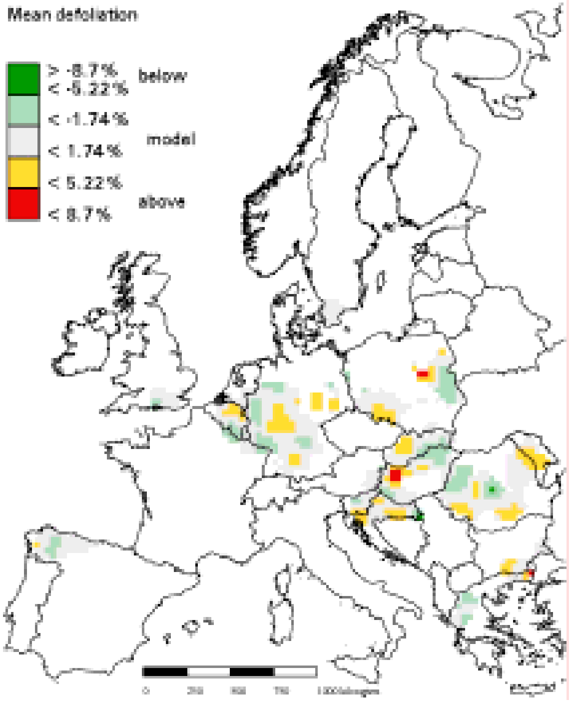


Figure 4.2.1-4: *Quercus robur* and *Q. petraea*; preliminarily adjusted defoliation, deviation of medium-term mean defoliation (1994 to 1999) to country specific linear regression over age (kriging interpolations; nugget: nugget: 34.7 sill: 22.3 range: 120 km).

For other parts of Europe an improvement of crown condition was observed. In particular, the improvement of crown condition in southern Poland has to be underlined especially when related to the high level of defoliation in this region as presented in Figure 4.2.1-3 and Figure 4.2.1-4.

4.2.2 Spatial variation of defoliation

The spatial variation in terms of the medium term mean defoliation from 1994 to 1999 (Fig. 4.2-1) was analysed by multiple linear regressions.

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

model	**1**	**2**	**3**	**4**	**5**
R-square	**43.3**	**43.1**	**42.9**	**41.7**	**40.3**
	ßx	**ßx**	**ßx**	**ßx**	
prec01_06	-0.0023	-0.0019			
insect	6	5.9	6	5.3	
fungi	-8.5	-8.5	-8.6		
depo S	-0.025	0.8			
depo NHy	-7.6	-2.5			
depo NOx	7.8				
country	o	o	o	o	o
$\text{age}_{\text{country}}$	o	o	o	o	o

prec jan-jun	difference of the 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
$\text{age}_{\text{country}}$	age of stand in years, calculated country-wise

The R^2 values of all models for spatial variation of defoliation of oak (Table 4.2.2-1) are lower than those for Norway spruce (Table 4.1.2-1). A model including only the class variable country as predictor variable leads to R^2 value of 32.0% (not depicted) the inclusion of the country specific age trend (model 5) leads to an increase to 40.3%. In addition to age and country the only significant predictor variables are insect and fungi. The negative regression coefficient for fungi is not in line with expectations. A possible explanation by inter-correlations with insects should be examined in more detail. Similar observations were made earlier for beech (UNECE, EC, 2002).

The difference of the mean sum of 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 was the strongest of the precipitation indices.

Most models including total nitrogen instead of separated nitrate and ammonium components result in plausible positive regression coefficients for deposition of sulphur (e.g. model 2 in Table 4.2.2-1). The R^2 values, however, are lower. The negative regression coefficient for the sulphur deposition when the nitrogen components are modelled separated show however that there exist strong inter-correlations among the deposition factor and here between sulphur and nitrated deposition.

4.3 Temporal and spatial variation of defoliation from 1997 to 2002

In addition to the evaluations for the period 1994 to 1999 Also the mean development of defoliation from 1997 to 2002 is presented in this section to give an impression of the recent development. Also the PAD for the period 1997 to 2002 is presented.

4.3.1 *Pinus sylvestris*

Pinus sylvestris is the most wide spread and the most frequent tree species in Europe. The temporal development of defoliation on 1956 plots shows some clear trends. Very impressive is the clear improvement of crown condition in Belarus in the evaluation period. Nearly as uniform seems to be the deterioration in Sweden, namely the south of Sweden. Other countries (Germany, Poland, Norway, and Finland) show regions of improving crown condition as well as of deteriorating crown condition. The west European countries show mostly small reactions but rather a development in direction of a higher defoliation values.

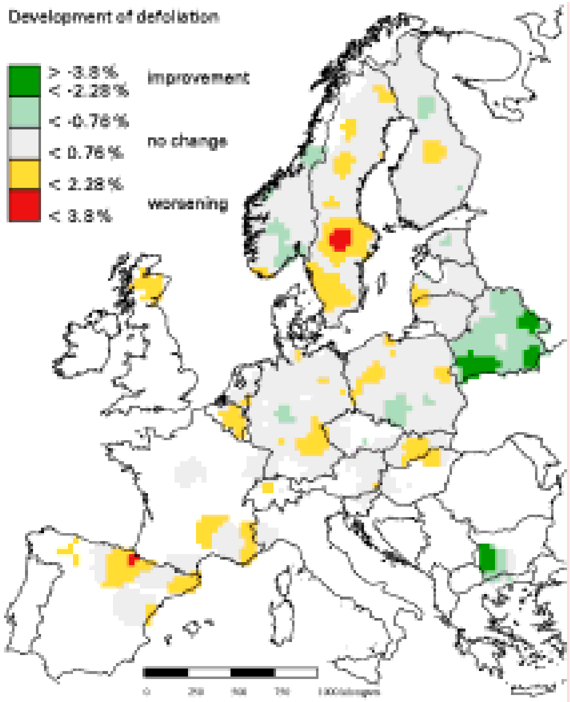


Figure 4.3.1-1: *Pinus sylvestris*; mean development of defoliation described as slope of plot specific linear regression over time from 1997 to 2002 (kriging interpolation; nugget: 1.5 sill: 0.96 range: 200 km).

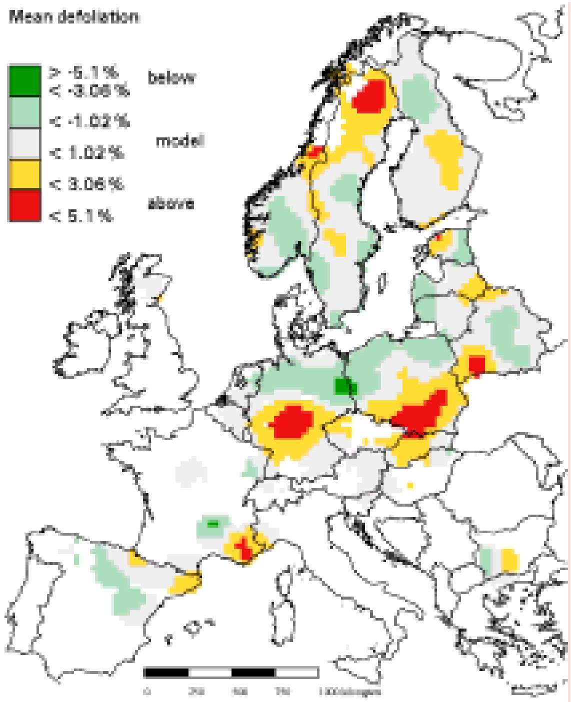


Figure 4.3.1-2: *Pinus sylvestris*; preliminarily adjusted defoliation (PAD) for the period 1997 to 2002 (kriging interpolation; nugget: 20.16 sill: 4.2 range: 300 km).

Regions of a relatively poor crown condition were observed in the North of Norway and Sweden, the central Germany, the south of Poland, the North of Estonia, the south west of Belarus and the south east of France (Figure 4.3.1-2).

4.3.2 *Picea abies*

The temporal development of *Picea abies* from 1997 to 2002 (Figure 4.3.2-1, based on 1461 plots) shows two regions of deteriorating crown condition. A region of a very high rate of deterioration is around the Baltic sea including the North of Norway. A second region of increasing defoliation reaches from the east of France through the south of Germany, Austria, and Slovakia to the south west of Romania.

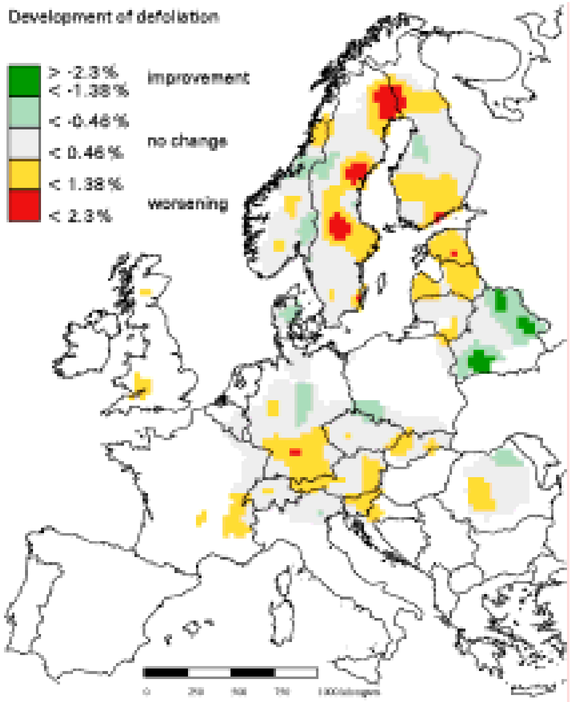


Figure 4.3.2-1: *Picea abies*; mean development of defoliation described as slope of plot specific linear regression over time from 1997 to 2002 (kriging interpolation;
nugget: 1.76 sill: 0.55 range: 210 km).

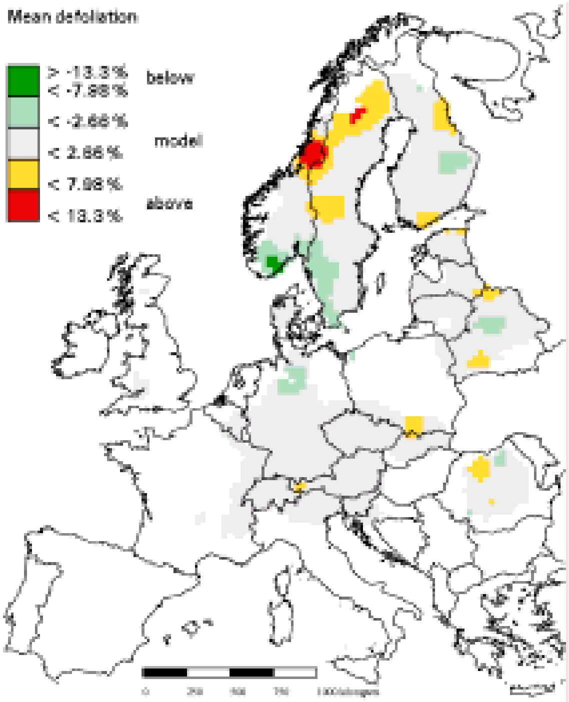


Figure 4.3.2-2: *Picea abies*; preliminarily adjusted defoliation (PAD) for the period 1997 to 2002 (kriging interpolation;
nugget: 42.7 sill: 12.8 range: 240 km).

The picture of the preliminarily adjusted defoliation (PAD; Figure 4.3.2-2) shows the relatively high defoliation in the Trøndelag region in Norway for which fungi (*Heterobasidion annosum* and *Chrysomyxa abietis*) were identified as causes (HYLEN, personal communication). But also regions in north Sweden and in north east Finland show high defoliation values compared to other regions in the respective countries.

4.3.3 *Fagus sylvatica*

The temporal development of defoliation of *Fagus sylvatica* (Figure 4.3.3-1, based on 565 plots) shows an improvement of crown condition in the south of France and less strong parts of Austria and Romania. Other regions, especially the south of Sweden show increasing defoliation values from 1997 to 2002.

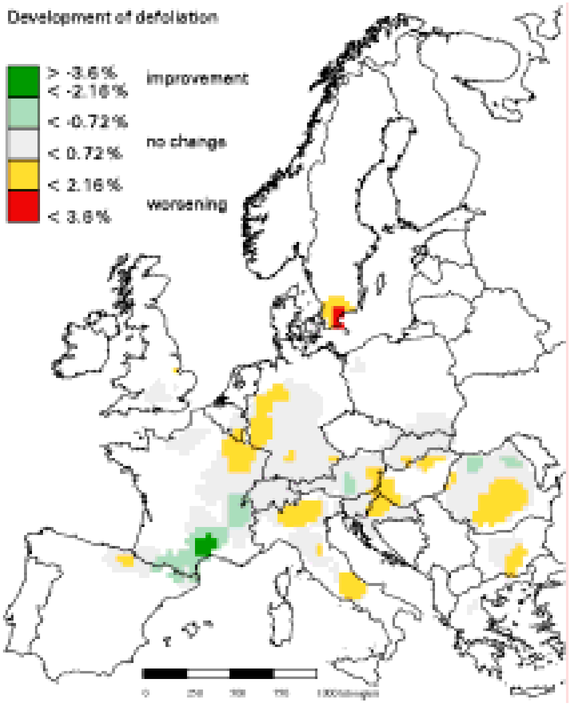


Figure 4.3.3-1: *Fagus sylvatica*; mean development of defoliation described as slope of plot specific linear regression over time from 1997 to 2002 (kriging interpolation; nugget: 2.6 sill: 1.1 range: 200 km).

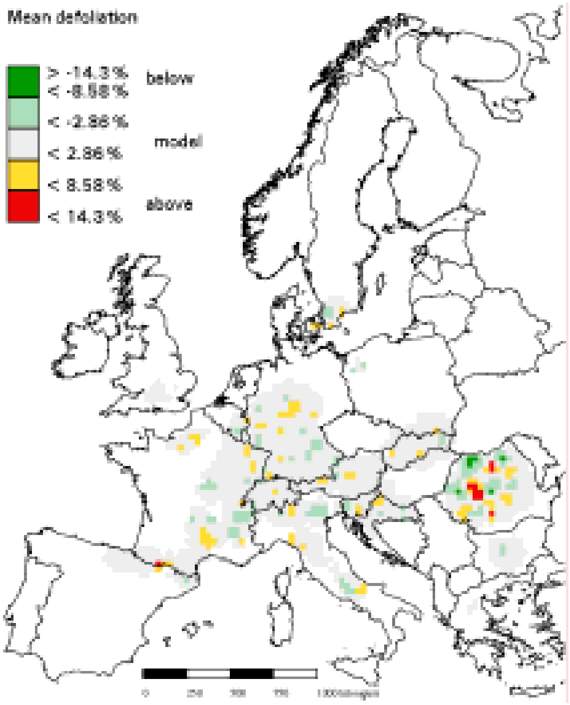


Figure 4.3.3-2: *Fagus sylvatica*; preliminarily adjusted defoliation (PAD) for the period 1997 to 2002 (kriging interpolation; nugget: 25 sill: 31 range: 70 km).

The highest within country variation is shown in Romania but also in Germany, France, and Italy defoliation is varying. Whereas in Germany and in France those regions which are of relatively high defoliation are of an improving trend the regions of very high defoliation in Romania are deteriorating and those of good crown condition are improving.

4.3.4 *Quercus robur* and *Q. petraea*

The temporal development of defoliation is of high variance (Figure 4.3.4-1, based on 503 plots). Belarus and Slovakia are of improving crown condition. Other countries show a high within country variance. for example the improving crown condition from 1997 to 2002 in central Germany (Hesse) can be explained by the bad crown condition in the mid of the 90s at least partly due to oak affecting insect pests (Paar, personal communication).

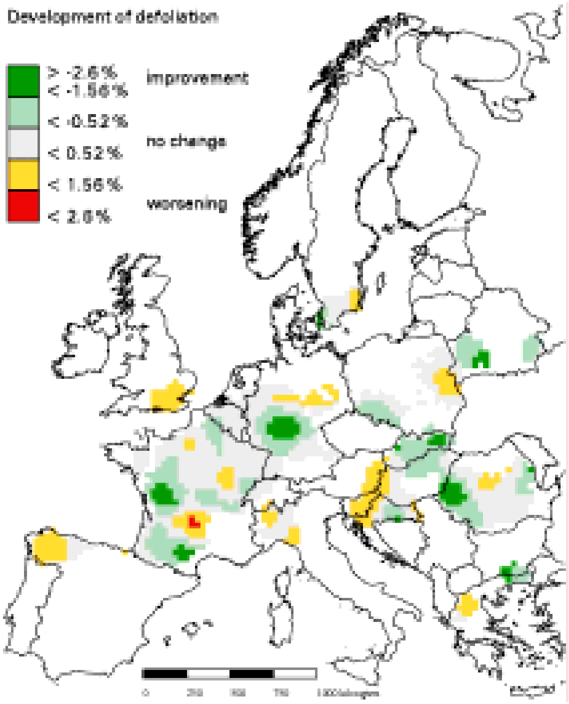


Figure 4.3.4-1: *Quercus robur* and *Q. petraea*; mean development of defoliation described as slope of plot specific linear regression over time from 1997 to 2002 (kriging interpolation; nugget: 2.2 sill: 1.4 range: 230 km).

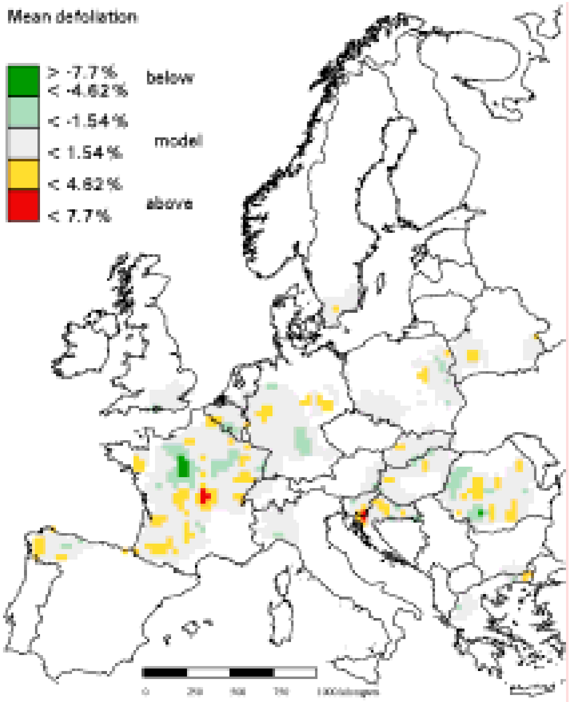


Figure 4.3.4-2: *Quercus robur* and *Q. petraea*; preliminarily adjusted defoliation (PAD) for the period 1997 to 2002 (kriging interpolation; nugget: 41.3 sill: 17.1 range: 80 km).

The within country variability of defoliation depicted as PAD in Figure 4.3.4-2 is mostly on a relative low level. In France and Slovenia the within country variation is perhaps a little more pronounced.

4.3.5 *Quercus ilex* and *Q. rotundifolia*

Figure 4.3.5-1 shows the plot-wise temporal development of defoliation based on 181 plots for *Quercus ilex* and *Q. rotundifolia*. The plot-wise presentation was used due to problems with modelling spatial autocorrelation. These problems are mainly due to high differences between the observed trends in defoliation calculated for pairs of plots which are located closely together. E.g. plots with very high improvement or deterioration of crown condition, respectively, are neighboured by those which show no meaningful trend.

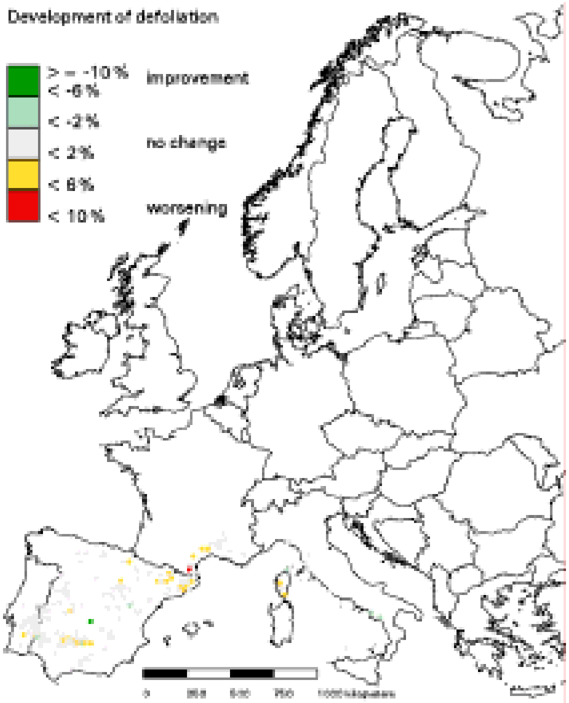


Figure 4.3.5-1: *Quercus ilex* and *Q. rotundifolia*; mean development of defoliation described as slope of plot specific linear regression over time from 1997 to 2002 (plot-wise presentation).

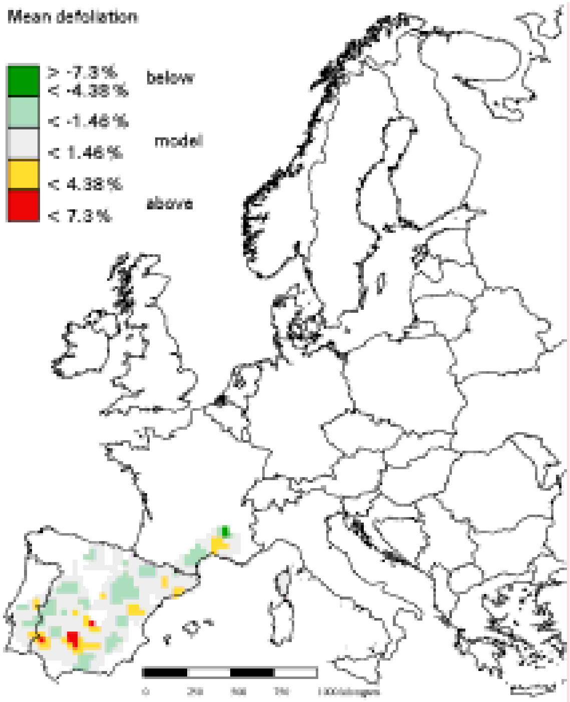


Figure 4.3.5-2: *Quercus ilex* and *Q. rotundifolia*; preliminarily adjusted defoliation (PAD) for the period 1997 to 2002 (kriging interpolation; nugget: 24.6 sill: 16.1 range: 85 km).

The map of preliminarily adjusted defoliation (PAD) shows that the defoliation values within the countries show high within country variation. Namely in the southwest of Spain a region of high defoliation is detected (compare UNECE, EC, 2001).

4.3.6 *Pinus pinaster*

Whereas the crown condition of *Pinus pinaster* is improving in the French regions of the distribution area (Figure 4.3.6-1, based on 143 plots) the regions in Spain show a deterioration even in the area of relatively high defoliation in the north west of Spain (Figure 4.3.6-2). Also in the south of Portugal a deterioration on a high level is observed whereas in the north an improvement is shown.

The level of defoliation is relatively high in the east and north of the French distribution area and in three regions at the west coast of the Iberian Penninsula (Figure 4.3.6-2).

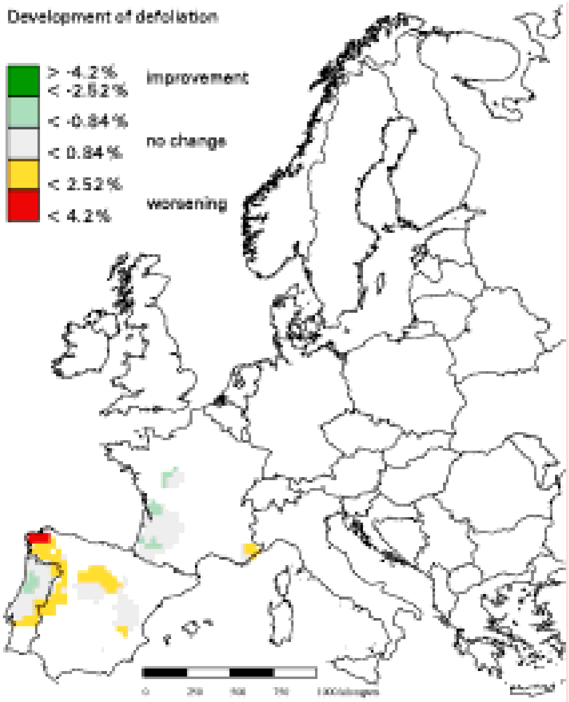


Figure 4.3.6-1: *Pinus pinaster*; mean development of defoliation described as slope of plot specific linear regression over time from 1997 to 2002 (kriging interpolation; nugget: 1.9 sill: 2.19 range: 210 km).

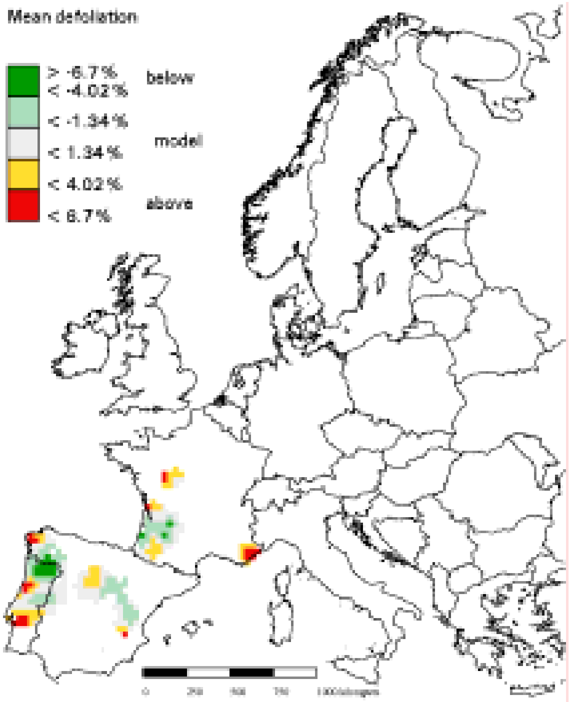


Figure 4.3.6-2: *Pinus pinaster*; preliminarily adjusted defoliation (PAD) for the period 1997 to 2002 (kriging interpolation; nugget: 19.95 sill: 20.9 range: 120 km).

5 Forest nutrition on the Finnish and Austrian Level I plots in 1987 – 2000

5.1 Introduction

Plant nutrients play an integral role in the physiological and biochemical processes of forest ecosystems. Therefore the nutritional status of trees provides an important diagnostic tool for estimating tree condition. Chemical foliar analysis is a widely used diagnostic and monitoring method in forestry and environmental studies (e.g. CAPE et al., 1990, LUYSSAERT et al., 2002). It has been used to estimate nutrient deficiencies and toxicities, and to monitor the nutritional status of trees, particularly with respect to maximising growth or evaluating mitigation measures (e.g. fertilization and liming) (e.g. MÄLKÖNEN et al., 2000). Chemical foliar analysis can also be employed when studying the impact of air pollutants and their severity on trees (e.g. ERICSSON et al., 1995). An inadequate nutrient supply may be a direct cause of low tree vitality or a factor that increases the adverse effects of air pollution (e.g. THELIN et al., 1998). High concentrations of certain elements in needle or leaf tissue may be the result of toxicity or of high emission levels. Unfavourable chemical conditions in the rooting zone of the soil may also lead to imbalances in the nutrient supply and, subsequently, to imbalanced nutrition of the trees (e.g. GEORGE and SEITH, 1998, HENDRIKS et al., 1997).

The main objectives of the foliar surveys within the ICP Forests Programme on the Level I and Level II plots are (1) to produce spatial information at regular intervals about the nutritional status of forests and the foliar chemical composition at the European level, (2) to detect deficiencies, disturbances or imbalances in tree nutrition, (3) to provide a basis for future correlative and up-scaling studies between the foliar data and other datasets, e.g. crown condition, litterfall and soil, and (4) to maintain a European-wide database and ensure the comparability of the submitted data.

The first foliar survey (1994/95) organised by ICP Forests at Level I covered only a part of Europe, because only a few European countries were able to participate in the survey. An additional problem was that the samples were collected in different countries in different years. The first evaluation of the Level I foliar data was carried out in 1997 (STEFAN et al., 1997). However, the foliar sampling on some of the Finnish and Austrian Level I plots started before the first European foliar survey. The foliar sampling in Finland started in 1987 and in Austria in 1989, and it has been repeated annually in both countries ever since.

The foliar survey at Level II is mandatory and an analysis must be carried out at least every two years. The Level II foliar survey includes 847 plots located throughout Europe, and the first survey was organised in 1995. The regularly repeated foliar survey at Level II provides good data for multivariate statistics and trend analysis of forest condition. The results of the first survey were evaluated by FIMCI in 1998 (VRIES et al., 1998).

The aim of this pilot study is to evaluate the Finnish and Austrian foliar data sets of the Level I plots collected annually since 1987. The data sets are therefore classified using fixed classification values (3rd and 5th Expert Panel Meeting), and the spatial and temporal variation is analysed. The results will be used to provide recommendations about how to strengthen and consolidate the foliar surveys carried out on the Level I and Level II plots in the ICP Forests Programme.

5.2 Material and methods

5.2.1 Finland

5.2.1.1 Sampling of tree foliage

Needle samples were collected from 36 plots of the Finnish Level I network of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests . The 36 stands, which are located throughout the country, were sampled annually between 1987 and 2000. Sixteen of the stands were dominated by Norway spruce (*Picea Abies* (Karst.) L.), and 20 by Scots pine (*Pinus sylvestris* L.). Twenty seven percent of the maximum possible number of samples (36 plots x 14 years) were missing. The needle mass was not measured in 1990, 1991, 1999 and 2000, with the result that 21% of the measurement sets were incomplete. Sampling, sample preparation and chemical analysis followed the guidelines of ICP Forest programme (UN/ECE, 1998). The samples from all sampling years were analysed in the same laboratories (the Finnish Forest Research Institute, central laboratory, Vantaa, and Parkano Research station) by the same laboratory personnel.

5.2.1.2 Validation of the analytical results

Between 1987 and 2000 the quality of the analytical methods was checked by means of method blanks, repeated measurement of internal reference samples, repeated measurements of certified reference samples and participation in inter-laboratory tests. Inter-laboratory tests (ANONYMOUS, 1994; BARTELS, 1998, 2000, 2002) showed that the relative quality, compared with other analytical laboratories working in the field of forestry, is good. During the same period the relative standard deviation or coefficient of variation (CV), respectively, based on repeated measurements of 11 different reference samples and a measure of the precision of the methods, ranged between 0.7 and 1.8% for N, 1.5 and 5.1% for S, 1.5 and 4.1% for P, 1.8 and 6.1% for K, 1.7 and 3.9% for Ca and 0.9 and 4.5% for Mg. The CV of the analytical methods is considerably smaller than the CV of the nutrient concentrations (see 5.3.1). As a consequence, the analytical methods can contribute only a minor part of the total, spatial and temporal variation.

5.2.2 Austria

5.2.2.1 Sampling of tree foliage

Needle samples were collected from 71 plots of the Austrian Level I network of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests. From 1989 until 1999 the same 71 forest plots, which were located throughout the country, were sampled annually. 66 of the stands were dominated by Norway spruce (*Picea Abies* (Karst.) L.) and 5 by Scots pine (*Pinus sylvestris* L.). A total of 770 analyses were made on the N, S, P, K, Ca and Mg concentrations in the needles. Only 1% of the possible 781 (71 plots x 11 years) analyses were missing. As the needle mass was only measured in 1995 and 1996, 82% of the measurement sets were incomplete. Sampling, sample preparation and chemical analysis followed the guidelines of ICP Forest programme (UNECE, 1998). The samples from all sampling years were analysed in the same laboratory (Bundesamt und Forschungszentrum für Wald - Pflanzenanalyse, Wien) by the same laboratory staff.

5.2.2.2 Validation of the analytical results

Between 1989 and 1999 the quality of the analytical methods was checked by means of method blanks, repeated measurement of internal reference samples, repeated measurements of certified reference samples and participation in inter-laboratory tests. Inter-laboratory tests (ANONYMOUS, 1994; BARTELS, 1998, 2000, 2002) showed that the relative quality, compared with other analytical laboratories working in the field of forestry, is good. During the period 1995-1999 the coefficient of variation (CV), based on repeated measurements of 18 different reference samples and a measure of the precision of the methods, ranged between 1.1 and 4.2% for N, 1.0 and 3.2% for S, 1.5 and 4.1% for P, 1.8 and 4.0% for K, 1.4 and 3.8% for Ca, and 1.4 and 3.5% for Mg. The CV of the analytical methods is considerably smaller than the CV of the nutrient concentrations (see 5.3.1). As a consequence, the analytical methods can contribute only a minor part of the total, spatial and temporal variation.

5.2.3 Quality control of foliar surveys

Foliar analysis can be divided into the following steps: *planning*, *representative sampling*, *sample preparation*, *instrumental analysis* and *data evaluation*. At each of these steps a quality control is needed in order to ensure that the results of foliar surveys at the European level are comparable between years and between countries (LUYSSAERT et al., 2002).

In the *planning* step the quality is controlled by means of common decisions on the objectives, frequency and number of sample plots.

At present, the quality of the *representative sampling* step is controlled by means of guidelines laid down in the ICP-Forests Manual (UN/ECE, 1998). The *representative sampling* step is known to be the source of the largest errors in the overall results of leaf analysis (LUYSSAERT et al., 2002). The effects of the sampling procedure on the final result can only be guessed. The countries involved in the program generally use their own specific sampling procedures. How the results of different sampling procedures relate to each other, and how they influence the comparability of national results for the nutrient status of forests, are not known. A system for ensuring the quality of the *representative sampling* needs to be developed.

The quality of the *sample preparation* step is controlled by means of the guidelines laid down in the ICP-Forests Manual (UN/ECE, 1998). At present, the effect of the *sample preparation* step on the final results can only be guessed. The effect of this factor could be determined by including the *sample preparation* step in a future needle/leaf inter-laboratory ring test.

The quality of the *instrumental analysis* is controlled by means of the guidelines laid down in the ICP-Forests Manual (UN/ECE, 1998). The guidelines have been improved on a number of occasions since the start of the program. These improvements are based on the results of the 5 inter-laboratory ring tests. In the first inter-laboratory ring test in 1993/1994, most of the participating 24 laboratories obtained good to excellent results for the chemical analyses of N and K, and acceptable results for Ca, Mg and P concentrations in needles and leaves. The evaluation of the results for S was problematic due to the large number of outliers. The results of subsequent ring-tests have been used to further harmonise and improve the analytical techniques. Recommendations have been made for C, N, S, P, K, Ca, Mg, Na and micro-elements (ANONYMOUS, 1994; BARTELS, 1998, 2000, 2002). Over the years, the number of participating laboratories has increased to 59 (BARTELS, 2002). The participation of new, and therefore less experienced laboratories has resulted in the reoccurrence of problems that had apparently already been solved earlier. The introduction of new equipment, e.g. CHN analysers, has on occasions been reflected in a loss of quality due to lack of experience with the new equipment (BARTELS, 2002).

The performance of the Finnish and Austrian laboratories can be compared on the basis of the 5 inter-laboratory ring tests (ANONYMOUS, 1994; BARTELS, 1996, 1998, 2000, 2002). From the start both countries have obtained good analytical results for N, S, P, K, Ca and Mg. We can therefore conclude that the analytical methods contribute only a small part of the total, spatial and temporal variation of the Finnish and Austrian results. The accuracy of the element concentrations allows unreserved comparison of the results of both countries.

Quality control in the *data evaluation* step consists of European classification values. Low, medium and high concentration values are available for classifying the foliar element concentrations. However, as these classification values have no sound scientific basis, their use is limited to classifying the element concentrations. The classes have no physiological meaning (i.e. deficient, sufficient, excess, …). A Data Accompanying Report (DAR-Q), in the form of questionnaires consisting of multiple choice and free text parts, has to be submitted together with the ICP-Forests Level II data. It is advised that the same DAR-Q forms be used at Level I. Guidelines for more complex data processing and interpretation are not yet available.

5.2.4 Statistical analyses

The total, intra-plot, inter-plot and inter-annual variation was expressed as the relative standard deviation, and calculated as the percentage ratio of the standard deviation and the average nutrient concentration. The percentage of the variance explained by the combined plot and year effect was calculated with ANOVA. The significance of the changes in nutrient concentration between the first and the last 2-year periods in the time series were tested with a paired t-test.

5.3 Results

5.3.1 Spatial and temporal variation of forest nutrition

In Finland, the total variation, expressed as the relative standard deviation, within the 36 plots and over the 14-year period was 11% for N, 12% for S, 17% for P, 16% for K, 52% for Ca, 14% for Mg, and 30% for needle mass (NM). Tree species i.e. spruce and pine, made a significant contribution to the variation in the K, Ca and Mg concentrations and NM. For these parameters the total variation within a species was lower than the total variation for both species. Sampling-year and plot effect together accounted for 60 to 90% of the observed variance. At the Finnish national level, the inter-plot CV (minimum-maximum) based on 36 plots was 5-10% for N, S and Mg, 10-20% for P, K, Ca_{pine} and NM_{pine} and NM_{spruce}, and 20-30% for Ca_{spruce}. Except for N and Ca, the differences in nutrient concentrations between the plots were not related to the location of the plot. Low N concentrations were more frequent in northern than in southern Finland (Fig. 5.3.1-1). All the high Ca concentrations occurred in southern Finland, whereas the low Ca concentrations were found in northern Finland (Fig. 5.3.1-2). In general, the high Ca concentrations were found in spruce, which is a widely occurring species in southern Finland. Apart from the years 1987 and 2000, it was not possible to calculate intra-plot variation due to the use of one composite sample to determine the element status at the plot level. The intra-plot CV (minimum-maximum) was 5-15% for N, 5-20% for S and P, 7-25% for K, 10-40% for Ca, 10-20% for Mg, and no data were available for NM. Between 1987 and 2000 the intra-plot variation significantly decreased for S in spruce (-17%) and for K in pine (-15%). As the growing environment of trees varies from year to year, this variation is likely to be reflected in the element concentrations in the needles. Medium and long-term variation in element concentrations have been associated with natural and anthropogenic changes in the growing environment. The inter-annual variation was, for all the parameters, smaller than the inter- and intra-plot variation. Based on 14 years, the CV (minimum-maximum) between the years was 5-10% for N, S, P, K and Mg, and 10-20% for Ca and NM.

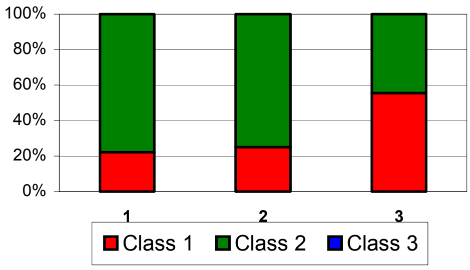


Figure 5.3.1-1: Frequency of the 14-year-average N classes in southern (1), central (2) and northern (3) Finland. Class 1 (red) has less than 12 mg N g^{-1}, class 2 (green) between 12 and 17 mg N g^{-1}, and class 3 (blue) more than 17 mg N g^{-1}.

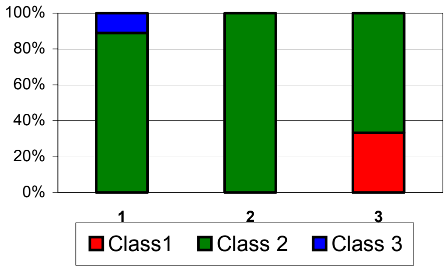


Figure 5.3.1-2: Frequency of the 14-year-average Ca classes in southern (1), central (2) and northern (3) Finland. For spruce, class 1 (red) has less than 1.5 mg Ca g^{-1}, class 2 (green) between 1.5 and 6.0 mg Ca g^{-1}, and class 3 (blue) more than 6.0 mg Ca g^{-1}. For pine, class 1 (red) has less than 1.5 mg Ca g^{-1}, class 2 (green) between 1.5 and 4.0 mg Ca g^{-1}, and class 3 (blue) more than 4.0 mg Ca g^{-1}.

In Austria, the total variation, expressed as the coefficient of variation (CV), within 71 plots and over the 11-year period was 11% for N, 13% for S, 24% for P, 23% for K, 36% for Ca, 24% for Mg, and 23% for NM $_{\text{spruce}}$. It was not possible to calculate the intra-plot variation due to the use of one composite sample to determine the element status at the plot level. Sampling-year and plot effect together accounted for 60 to 85% of the observed variance. The differences between pine and spruce contributed to the variation of N, S, Ca and Mg. At the national level, the inter-plot CV based on 71 plots was 5-10% for N and S; 10-20% for P, K, Mg and NM $_{\text{spruce}}$, and 20-30% for Ca. Austria has been divided, on the basis of the physical and chemical soil characteristics and climatic factors, into 9 so-called main growing regions (KILIAN et al., 1994) The P, Ca and N concentrations in the needles are strongly related to the growing region. In the Dolomite Alps, high soil $CaCO_3$ concentrations result in P immobilization in the soil (KILIAN, 1992). Spruce growing in the area have low P and high Ca concentrations in their needles compared to spruce in other regions. The nitrogen supply in Austria is generally low (Fig. .5.3.1-3) compared to that e.g. in Germany (BOSCH, 1986, BOSCH et al., 1983, HÜTTL, 1985, ZÖTTL, 1985). Most of the Austrian plots are suffering from nitrogen deficiency (STEFAN and FÜRST, 1998). Only the north and north-eastern regions, through which the River Danube flows, have fertile agriculture land with higher soil N concentrations. In these regions, the forests are likely to have an increased N input due to the use of fertilisers on neighbouring agricultural land. Near Linz, a fertilizer plant and dense traffic may be the cause of the higher foliar N concentrations - spruce growing in the Danube and Linz area had higher N concentration in their needles than those growing in other regions. In Austria, the Mg concentrations in the needles are usually higher than those in other countries (ZECH and POPP, 1983), the Mg concentrations being related to the soil type. In the Alps, which is a region with high Mg concentrations in the soil, most of the stands showed medium (class 2) to high (class 3) foliar Mg concentrations (Fig. 5.3.1-4). Spruce in the north and north-eastern regions, which are characterized by low soil Mg concentrations, are less likely to have high Ca concentrations. Spruce stands in the Inner-Alps are more likely to have a low K concentration in their foliage. Furthermore, the S concentrations were lower at higher altitudes (STEFAN and FÜRST, 1998). As the growing environment of trees varies from year to year, this variation is likely to be reflected in the element concentrations in the needles. Medium and long-term variation in element concentrations has been associated with natural and anthropogenic changes in the growing environment. The inter-annual variation was, for all the parameters, smaller than the inter-plot variation. Based on the 11-year period, the CV between the years was < 5% for N, S, P, K and Mg, and 5-10% for Ca and NM. The years 1992 and 1994, which had a warm and dry growing period, were characterised by abnormally lower N (1992 and 1994) and higher Ca (1992) concentrations in the needles (STEFAN and GABLER, 1998).

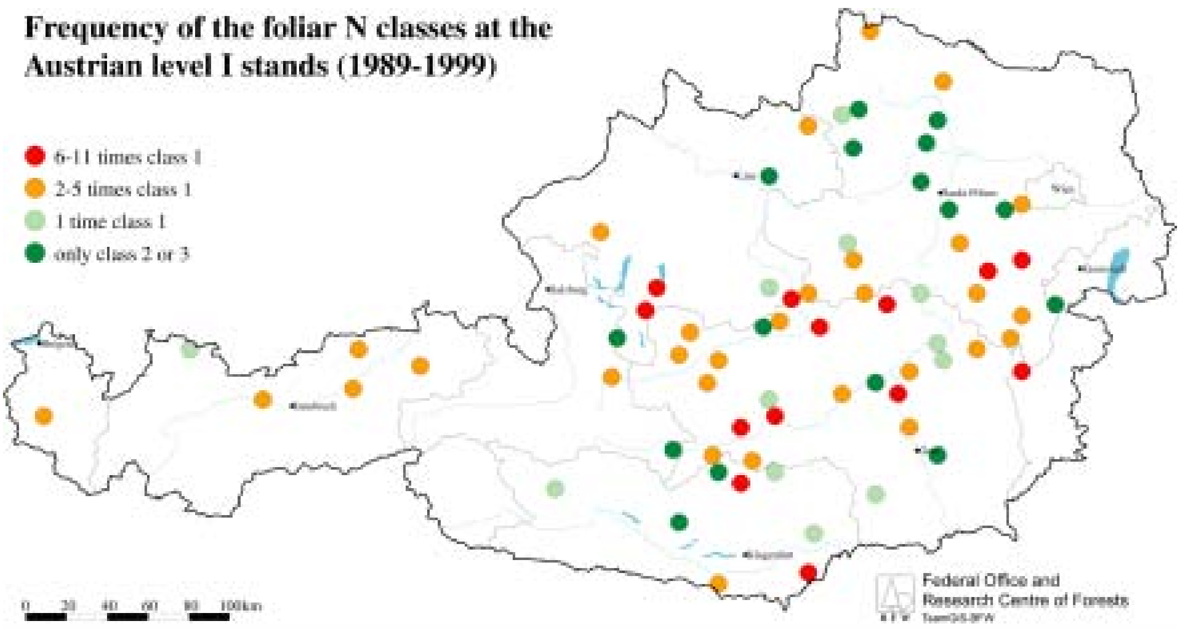


Figure 5.3.1-3: Frequency of the foliar N classes at the Austrian Level I stands. Class 1 has less than 12 mg N g^{-1}, class 2 between 12 and 17 mg N $g^{-}1$ and class 3 more than 17 mg N g^{-1}. The dominance of the red and orange dots indicates the generally low N supply in Austria.

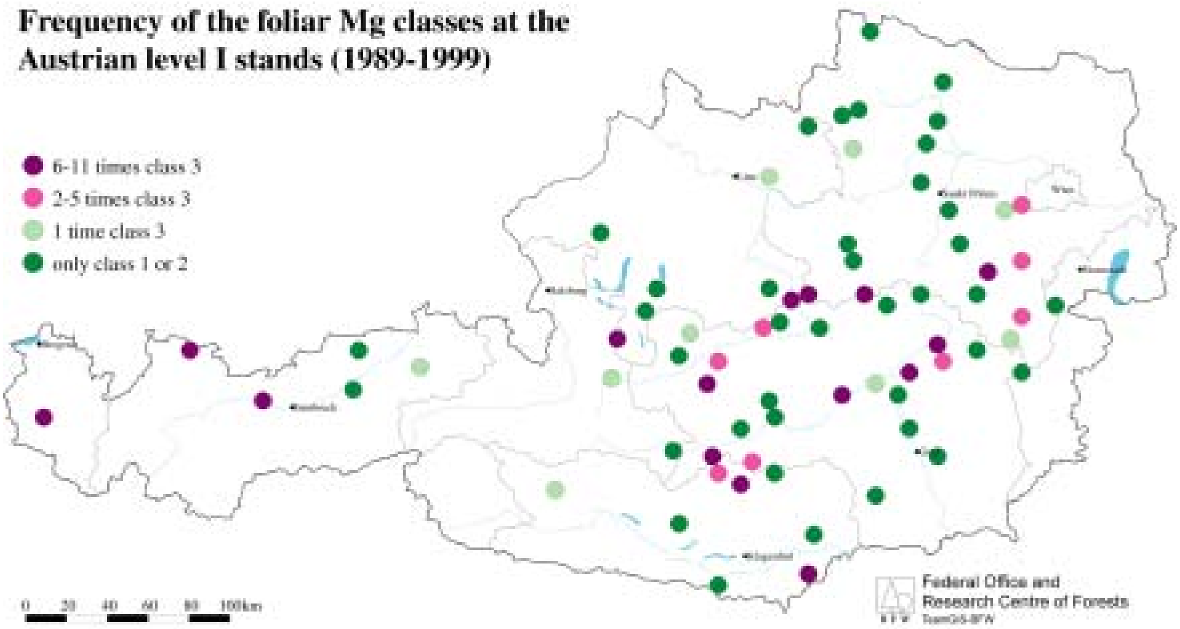


Figure 5.3.1-4: Frequency of the foliar Mg classes in the Austrian Level I stands. Class 1 has less than 0.6 Mg mg g^{-1}, class 2 between 0.6 and 1.5 Mg mg g^{-1}, and class 3 more than 1.5 Mg mg g^{-1}. The pink and purple dots mainly occur in the alpine regions.

The Finnish and Austrian values for the total CV agreed with the observed variation of the nutrient status in tree foliage in France (CROISÉ et al., 1999) and Italy (MATTEUCCI et al., 2000). It is conceivable that agreement between the CV values in different countries is a reflection of the fact that, due to the spatial and temporal dimensions of the monitoring programs, the whole range of nutrient concentrations that are likely to occur in healthy trees was observed in each country. The nutrient concentrations on a large scale might be surprisingly constant, but they often obscure strong variation on a local scale. The variation within the stands was found to equal or even exceed the variation between the stands. The same has been observed even on a larger scale; the local and regional variations in nutrient concentration equalled or exceeded the variation along transects crossing Europe from northern Sweden to Italy (BAUER et al., 1997), and from Scotland to South Germany (CAPE et al., 1990).

5.3.2 Development of forest nutrition

5.3.2.1 Finland

The mean values of the nutrient concentrations, needle mass and nutrient ratios for the 36 plots sampled in 1987-1988 and 1999-2000 are presented in Table 5.3.2.1-1. For spruce, the decrease in S (-25%), S/N (-25%), P (-14%), Mg (-10%) and NM (-24%) and the increase in N/P (+19%) and N/Mg (+12%) were significant. In pine, the nutrient concentrations of S (-24%), S/N (-25%), P (-20%), Mg (-7%) , N/P (+25%) and N/Mg (+7%) developed in a similar way as in spruce. However, there was a significant increase in NM of pine (+32%) and in N/K (+11%) due to the decreasing K (-9%) concentration. The probability that the observed precipitation during the growing season equals the long term average was calculated on the basis of the 30-year series from 32 weather stations of the Finish Metrological Institute. The probabilities were 0.98 in 1987, 0.95 in 1988, 0.06 in 1999 and 0.35 in 2000. The probabilities that the observed temperature during the growing season equals the long term average were 0.02 in 1987, 0.97 in 1988, 0.75 in 1999 and 0.60 in 2000. Thus, the period 1987-1988 was characterised by two extremely wet summers, and one of them was cold and the other hot. This may explain the increased foliar N, P, Ca and Mg concentrations (Hipelli and Branse, 1992). The period 1999-2000 was characterised by dry, warm summers, and drought may have restricted the uptake and foliar concentration of N (Mader and Thompson, 1969). The weather conditions during the period may have obscured increasing trends in forest nutrition and emphasised decreasing trends. As the dry deposition of S compounds is expected to be higher during dry periods, the weather conditions may have caused an underestimate in the decrease in foliar S concentrations.

Table 5.3.2.1-1: Mean nutrient concentrations (mg.g^{-1}), needle mass (g.1000 needles^{-1}) and nutrient ratios in **spruce** (n = 22) and **pine** (n=32) from 1987-1988 and 1999-2000 in Finland. For NM the comparison was made between 1987-1988 and 1997-1998. The significance of a change is given by its paired t-test value: (n.s.) = not significant, (**) = P < 0.05, (***) = P < 0.01. Classification values for nutrient concentrations are according to Stefan et al. (1997), and classification values for nutrient ratios according to Stefan et al. (1998).

	Mean (± SD)			Class
	1987-1988	1999-2000	Change (%)	1987-2000
Spruce				
NM	5.02 ± 0.71	4.02 ± 0.68	- 24 ***	n.a.
N	12.38 ± 1.31	12.58 ± 1.94	+ 1 $^{n.s.}$	2 – 2
S	1.10 ± 0.10	0.83 ± 0.06	- 25 ***	1 – 1
P	1.72 ± 0.35	1.48 ± 0.29	- 14 ***	2 – 2
K	6.69 ± 1.03	6.83 ± 0.48	+ 2 $^{n.s.}$	2 – 2
Ca	4.53 ± 0.92	4.84 ± 1.36	+ 7 $^{n.s.}$	2 – 2
Mg	1.27 ± 0.16	1.14 ± 0.16	- 10 ***	2 – 2
N/P	7.42 ± 1.46	8.79 ± 1.95	+ 19 ***	2 – 2
N/K	1.90 ± 0.42	1.85 ± 0.30	- 3 $^{n.s.}$	2 – 2
N/Ca	2.83 ± 0.62	2.78 ± 0.80	- 3 $^{n.s.}$	2 – 2
N/Mg	9.90 ± 1.54	11.16 ± 1.70	+ 12 ***	2 – 2
S/N	0.089 ± 0.009	0.066 ± 0.007	- 25 ***	3 – 2
Pine				
NM	10.31 ± 2.92	13.59 ± 3.70	+ 32 ***	n.a.
N	12.35 ± 1.47	12.45 ± 1.47	+ 1 $^{n.s.}$	2 – 2
S	1.07 ± 0.11	0.82 ± 0.08	- 24 ***	1 – 1
P	1.77 ± 0.21	1.41 ± 0.13	- 20 ***	2 – 2
K	5.65 ± 0.54	5.12 ± 0.56	- 9 ***	2 – 2
Ca	2.30 ± 0.61	2.17 ± 0.43	- 6 $^{n.s.}$	2 – 2
Mg	1.15 ± 0.17	1.07 ± 0.15	- 7 *	2 – 2
N/P	7.05 ± 0.90	8.81 ± 0.88	+ 25 ***	2 – 2
N/K	2.20 ± 0.31	2.44 ± 0.29	+ 11 ***	2 – 2
N/Ca	5.66 ± 1.21	5.89 ± 0.98	+ 4 $^{n.s.}$	2 – 2
N/Mg	10.93 ± 1.95	11.66 ± 1.41	+ 7 *	2 – 2
S/N	0.087 ± 0.0067	0.066 ± 0.005	- 25 ***	3 – 2

According to the classification values for nutrient concentrations (Stefan et al. 1997) and nutrient ratios (Stefan et al., 1998) in spruce and pine needles, all the average concentrations were normal (Tab. 5.3.2.1-1). No systematic deviations from this normal situation were found on the plot level. According to the classification values, the medium-term changes in the average nutrient concentrations and ratios were not meaningful except for S/N (Tab. 5.3.2.1-1). The decrease in the S/N ratio corresponded to a decrease from a high class to a well-balanced class. In 1988 a class 2 S concentration was measured on 55% of the plots, whereas 20% of the plots had a class 3 P concentration. In 2000, all the plots had a more favourable class 1 S concentration (Fig. 5.3.2.1-5), and an optimal class 2 P concentration (Fig. 5.3.2.1-6), indicating an improving environment for tree growth.

Figure 5.3.2.1-5: Development of the foliar S concentration in Finland between 1987 and 2000. Class 1 has less than 1.1 mg S g^{-1}, class 2 between 1.1 and 1.8 mg S g^{-1}, and class 3 more than 1.8 mg S g^{-1}. The foliar S concentration decreased between 1987 and 2000.

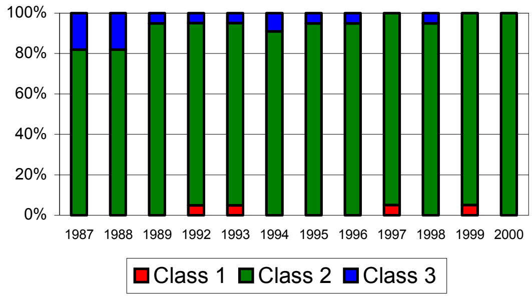


Figure 5.3.2.1-6: Development of the foliar P concentration in Finland between 1987 and 2000. Class 1 has less than 1.0 mg P g^{-1}, class 2 between 1.0 and 2.0 mg P g^{-1}, and class 3 more than 2.0 mg P g^{-1}. The foliar P concentration decreased between 1987 and 2000.

The average 1000-needle mass of spruce in Finland was 4.0 to 5.0 g, which is similar to the needle mass in France (CROISÉ et al., 1999). 14 years ago in Finland, the average 1000-needle mass for pine was 10 g, which was considerably lower than the average needle mass of 15 g for pine in France (CROISÉ et al., 1999). Due to the increase in needle mass over the 14-year period, the needle mass in Finland in 2000 had reached almost the same level as in France. The development of the needle mass were different for pine and spruce. The needle mass of pine increased by 32%, whereas that of spruce decreased by 20% between 1987-1988 and 1999-2000 (Tab. 5.3.2.1-1). To account for the changes in NM the nutrient content in 1000 needles was calculated for pine and spruce. The nutrient content of both species showed different trends (not given). In spruce the nutrient content decreased, the nutrient ratios remained at the same balanced level, and the S/N ratio decreased significantly. In pine, on the other hand, the nutrient content and ratios increased (except the S/N ratio which decreased). Comparison of the nutrient ratios for 1997-1998 and for 1999-2000 shows (not given) that the changes for spruce and pine are consistent and are still continuing. The development of the needle mass, nutrient concentration and nutrient content are simultaneously compared (Table 5.3.2.1-2). Because it is comparative it allows physiological interpretation independent of predetermined critical levels or ratios (TIMMER and STONE, 1978, HAASE and ROSE, 1995).

Table 5.3.2.1-2: Interpretation of directional shifts in nutrient concentration (Conc.), nutrient content (Cont.) and dry weight (DW) in Finland from 1987-1988 to 1999-2000. (++) > + 10%, (+) < +10%, (--) > -10% and (-) < - 10%.

	Pine				Spruce			
	DW	Conc.	Cont.	Interpretation	DW	Conc.	Cont.	Interpretation
N	++	0	++	Sufficiency	--	0	--	Excess
S	++	--	++	Dilution	--	--	--	Excess
P	++	--	++	Dilution	--	--	--	Excess
K	++	-	++	Dilution	--	0	--	Excess
Ca	++	0	++	Sufficiency	--	0	--	Excess
Mg	++	-	++	Dilution	--	--	--	Excess

The fact that N is the limiting nutrient for growth on mineral soils in Finland underlies any explanation of the development of forest nutrition in Finland (MÄLKÖNEN et al., 1990, SAARSALMI and MÄLKÖNEN, 2001). In Finland the N, P, K and Mg concentration in Scots pine needles has been found to decrease with tree age (HELMISAARI, 1992). Tree and stand ageing during the 14-year study period may partly explain the observed decreases in foliar mineral concentrations. In general, older trees have lower N, P, Ca and S concentrations in their leaves than younger trees (COLE and RAPP, 1981). The decline in leaf concentrations with age has been attributed to a decreasing supply of nutrients caused by increasing nutrient sequestration in the stem wood and litter layer (MILLER, 1984). Over the 14-year period, however, the N concentration remained constant (Table 5.3.2.1-2), which means that more N than expected was available for pine. Because N is the limiting element, a higher availability could result in a higher needle mass and higher N contents in the needles (Table 5.3.2.1-2). According to the constant concentration of N in the needles, nitrogen is still the limiting nutrient for growth. Due to increased growth the concentrations of other nutrients, except Ca, are subject to growth dilution (Table 5.3.2.1-2). We hypothesized that the development of the nutrition of pine trees results from the changed availability of N.

Decreasing nutrient concentrations due to tree and stand ageing have been observed in many species, and we can therefore expect that the N concentrations in the spruce needles would also have decreased. However, the N concentration remained constant over the 14-year period (Table 5.3.2.1-2). Both the pine and spruce stands showed signs of a higher N availability than expected. The decreasing NM of spruce indicated that the species was not able to exploit the higher availability of N to increase its needle mass. Other factors therefore obviously restricted plant growth. The drought during spring 1999 (LEINONEN, 2000), and the exceptionally high temperatures in 2000 (LEINONEN, 2001), were assumed to have contributed to the low NM. However, as drought has been reported to result in lower N concentrations (MADER and THOMPSON, 1969; HIPELLI and BRANSE, 1992), it was postulated that in some areas in Finland, the strong decrease in S has prevented spruce from utilizing the available N, leading to a decreasing needle mass. This implies that S could become a limiting element for spruce on mineral soils in Finland. If so, the development of the nutrition of spruce trees could be partly explained by changing availability of S.

5.3.2.2 Austria

The mean values of the nutrient concentrations, needle mass and nutrient ratios for the 71 plots sampled in 1989-1990 and in 1998-1999 are presented in Table 5.3.2.2-1. Over this period the decreases in S (-9%), S/N (-9%), P (-12%) and K (-8%), and increases in N/P (+15%) and N/K (+8%), were statistically significant. The probability that the observed precipitation during the growing season equals the medium term average precipitation was calculated on the basis of 7-year observations from 129 weather stations. The probabilities were 0.92 in 1989 and 0.34 in 1990. Data for 1998 and 1999 were not available. The first period (1989-1990) was characterized by an extremely wet year and a dry year. The probability that the observed temperature during the growing season equals the medium term average was 0.18 in 1989 and 0.15 in 1990. Data for 1998 and 1999 were not available. The first period (1989-1990) was thus characterised by two extremely cold summers with different precipitation regimes. The weather conditions may have resulted in improved N uptake. The weather in the first period may have obscured increasing trends, and emphasized decreasing changes in N nutrition.

Table 5.3.2.2-1: Mean nutrient concentrations (mg.g^{-1}), needle mass (NM; g.1000 needles^{-1}) and nutrient ratios from 1989-1990 and 1989-1999 for **spruce** (n = 65) and pine (n = 5) in Austria. The significance of a change is given by its paired t-test value: (n.s.) = not significant, (**) = P < 0.05, (***) = P < 0.01. Classification values for nutrient concentrations are according to Stefan et al. (1997), and classification values for nutrient ratios according to Stefan et al. (1998).

	Mean (± SD)			Class
	1989-1990	1998-1999	Change (%)	1987-2000
Spruce				
N	13.07 ± 1.19	13.09 ± 1.50	+ 0$^{n.s.}$	2 – 2
S	1.03 ± 0.12	0.93 ± 0.11	- 9***	2 – 2
P	1.61 ± 0.38	1.41 ± 0.36	- 12***	2 – 2
K	6.14 ± 1.34	5.63 ± 1.17	- 8***	2 – 2
Ca	4.18 ± 1.23	4.28 ± 1.54	+ 2$^{n.s.}$	2 – 2
Mg	1.27 ± 0.30	1.29 ± 0.30	+ 1$^{n.s.}$	2 – 2
NM	n.a.	n.a.	n.a.	n.a.
N/P	8.52 ± 1.91	9.78 ± 2.21	+ 15***	2 – 2
N/K	2.24 ± 0.57	2.44 ± 0.64	+ 9***	2 – 2
N/Ca	3.46 ± 1.25	3.52 ± 1.51	+ 2$^{n.s.}$	2 – 2
N/Mg	10.83 ± 2.51	10.63 ± 2.52	- 2$^{n.s}$	2 – 2
S/N	0.079 ± 0.009	0.072 ± 0.008	- 9***	3 – 2
Pine				
N	13.71 ± 1.36	13.96 ± 1.73	+ 2$^{n.s.}$	2 – 2
S	1.11 ± 0.09	1.06 ± 0.09	- 4$^{n.s.}$	2 – 2
P	1.54 ± 0.17	1.33 ± 0.11	- 13***	2 – 2
K	6.06 ± 1.15	6.19 ± 0.54	+ 2$^{n.s.}$	2 – 2
Ca	3.68 ± 0.49	3.56 ± 0.42	- 3$^{n.s.}$	2 – 2
Mg	1.11 ± 0.21	1.13 ± 0.16	+ 2$^{n.s.}$	2 – 2
NM	n.a.	n.a.	n.a.	n.a.
N/P	9.03 ± 1.38	10.52 ± 1.33	+ 16**	2 – 3
N/K	2.33 ± 0.48	2.28 ± 0.38	- 2$^{n.s}$	2 – 2
N/Ca	3.81 ± 0.72	3.96 ± 0.56	+ 4$^{n.s.}$	2 – 2
N/Mg	12.64 ± 2.21	12.50 ± 2.10	- 1$^{n.s.}$	2 – 2
S/N	0.081 ± 0.008	0.077 ± 0.007	- 6$^{n.s.}$	3 – 3

According to the classification values for nutrient concentrations (Stefan et al., 1997) and nutrient ratios (Stefan et al., 1998) in spruce and pine needles, the medium-term changes in the average nutrient concentrations and ratios were not meaningful except for S/N (Table5.3.2.2-1). The decrease in the S/N ratio corresponded to a change from a high class to a well-balanced class. However, meaningful changes occurred at the plot level. No class 3 S concentrations were observed during the period. In 1989, 30% of the plots had a class 2 S concentration. However, by 1999 the S concentration in the needles had decreased (Fig. 5.3.2.2-1). As a consequence, less than 10% of the plots were classified as class 2. The changes in the S concentrations were related to the location of the plots. Decreases were observed in areas exposed to Austrian emission sources; however, these decreases were compensated by increases near the Slovenian and Hungarian borders. Along the Czech border the pollution stress has remained relatively constant up until 1999 (Fürst, 2000).

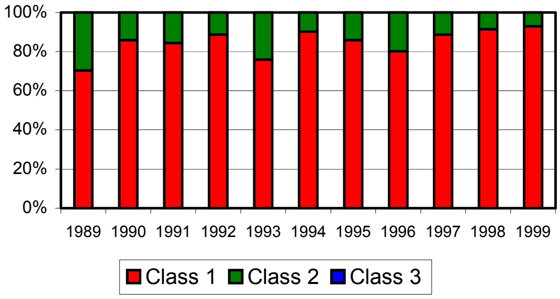


Figure 5.3.2.2-1: Development of the foliar S concentration in Austria between 1989 and 1999. Class 1 has less than 1.1 mg S g^{-1}, class 2 between 1.1 and 1.8 mg S g^{-1}, and class 3 more than 1.8 mg S g^{-1}. The foliar S concentration decreased between 1989 and 1999.

The existence of different growth regions is important in understanding the changes in nutrient status in Austria (STEFAN and FÜRST, 1998). In some regions, especially in the south of Austria, N deficiency is common, while in other regions (northern part of Austria and near the River Danube) the amount of plant available N is, according to the average values along the European transect (BAUER et al., 1997, values not given), sufficient. In other regions (the Dolomitic Alps) P is deficient (value not given). When the main growth regions are utilized in data interpretation, each region has to be sampled to a sufficient extent. The 71-plot network in Austria is too sparse to allow valid data analysis for each growth region. Pine and spruce react differently to the same changes in the growing environment (Tables 5.3.2.2-1). The number of pine forests is too small to allow valid interpretation of their nutrient status. If the aim is to evaluate the temporal changes in regional differences in forest nutrition, then a dense sampling network (e.g. all Level I plots) should be sampled at regular intervals.

For Austria the needle mass was only available in 1995 and 1996. Therefore it was not possible to formulate a physiological interpretation of the changes in nutrient status. However, there was a significant change in the S, P and K concentrations in spruce needles. A decrease in the N concentration due to ageing of the trees and the stands was expected for pine as well as for spruce (5.3.2.1, HELMISAARI, 1992, COLE and RAPP, 1981). The absence of such a decrease indicates that more N became available for tree growth in Austria. The forests were able to take up the N, but we have no information about the effects of this on the needle mass and nutrient content. The available data do not allow to determine the reasons of the increased N-availability.

6 NATIONAL SURVEY REPORTS in 2002

In 2002, 32 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 33 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 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 the broad-leaved trees in Annex II-7. Graphical presentations of the results are given in Annex II-8. It has to be taken into account, however, that it is not possible to directly compare the national 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 differences in the samples or survey methods occurred e.g. due to changes in the grid.

6.1 Northern Europe

6.1.1 Estonia

The 2002 forest condition survey in Estonia was performed on 89 Level I permanent sample plots. Nine tree species were covered by the assessments including 1 450 *Pinus sylvestris*, 608 *Picea abies* trees, as well as specimens of *Betula pendula*, *B. pubescens*, *Populus tremula*, *Alnus glutinosa*, *A. incana*, *Ulmus glabra*, *Fraxinus excelsior* and *Acer platanoides*. The highest defoliation was observed in *Pinus sylvestris* after a significant improvement of its crown condition between 1995 and 2000. In 2002, the share of healthy *Pinus sylvestris* amounted to 49.1% or 12 percent points lower as compared to 2000. However, only 5.2% of *Pinus sylvestris* trees were in defoliation classes 2-4.

The permanent increase in defoliation observed in *Picea abies* between 1995 and 2001, stopped in 2002. However, warm and dry weather in 1999 and the second half of the 2001 summer as well as the extremely dry summer 2002 might have caused drought stress and the infestation with bark beetles. Another cause for damage to *Picea abies* were strong winds. In 2002, the share of not defoliated *Picea abies* was 3 percent points higher as compared to 2001, but still 14 percent points higher as compared to 1995. Of defoliated *Picea abies*, only 9.6% were in defoliation classes 2-4. Mechanical and wind damage, bark browsing by moose, root rot and bark beetles largely contributed to damage and death observed in *Picea abies*.

The crown condition of broad-leaved tree species was distinctly better than for conifers. Yet the share of damaged trees was significantly higher than in 1999. Considerable differences were observed in the regional distribution of defoliation in Estonia. The regions with highest defoliation remained the same as compared to previous years. Several plots with high levels of defoliated *Picea abies* were located close to local sources of air pollution in North-eastern Estonia. Most severe defoliation in *Pinus sylvestris* was recorded in North-western Estonia.

6.1.2 Finland

The 2002 forest condition survey in Finland was conducted on 457 sample plots on 24 x 32 km and 16 x 16 km grids. No changes were observed in the average defoliation level of any tree species between 2001 and 2002. Of the 8 595 trees assessed, 54% of the conifers and 56% of the broad-leaved species were not suffering from defoliation. The proportion of slightly defoliated (11-25% defoliation) conifers was 34%, and about 12% of the conifers were moderately defoliated. In the broad-leaved species, the respective shares were 35% and 9%. Average defoliation in *Pinus sylvestris* was 9.3% (9.0% in 2001), 18.8% in *Picea abies* (18.4% in 2001), and 11.7% (11.5% in 2001) in broad-leaved species, mainly *Betula* spp. A total of 32 trees (0.4%) died during 2001-2002 (0.2% between 2000 and 2001).

On *Pinus sylvestris*, the share of discolouration of more than 10% remained unchanged in comparison to 2001 with less than 1% of the trees. In *Picea abies*, discolouration of more than 10% decreased from 6% to 4.5%. However, in broad-leaved species discolouration increased from 0.4% to 1.4%. In conifers, most frequent discolouration symptoms were needle tip and needle yellowing, mainly in needles older than two years. Moreover, the share of slightly discoloured broad-leaved trees (1-10% discolouration) was higher than in the previous year. The most significant cause for forest damage in 2002 were the heavy storms in July with a volume of about 1 million m^3 timber broken or felled *Pinus sylvestris* in Southern Finland. Due to drought in the early year starting already in April, fungal diseases were less common in 2002 as in 2001.

No correlation was found between defoliation patterns of conifers or broad-leaved trees and modelled sulphur and nitrogen deposition (1993) at the national level in 2002.

6.1.3 Latvia

The forest condition survey in Latvia was carried out on 364 permanent sample plots on the national 8 x 8 km grid net. Main tree species assessed in Latvia are *Pinus sylvestris*, *Picea abies*, and *Betula* spp. No significant changes were observed in the mean defoliation of these species. In *Pinus sylvestris* mean defoliation was 20.5% (21.0% in 2001). The share of not defoliated trees increased by 2.3 percent points as compared to 2001. The trend of improving crown condition in *Pinus sylvestris* has been observed since 1993. In *Picea abies*, mean defoliation remained unchanged at 20.8%. A deterioration in crown condition of this species has been observed since 1996, reaching 21.5% in 2000. A slight improvement by 2.1 percent points was observed in 2002. The crown condition of *Betula pendula* showed a slight improvement since 2000, when the highest level in defoliation of this species was recorded. Damage symptoms were identified on 6.5% of *Pinus sylvestris*, on 10.7% of *Picea abies*, and on 12.2% of *Betula* spp. The most frequent damage types were adverse abiotic factors (30% of all damaged trees), fungi (22.4%), and insects (22.1%).

6.1.4 Lithuania

The forest condition survey 2002 in Lithuania was carried out on 220 plots on a 8 x 8 km grid net. A total of 5 162 trees was assessed, representing 11 tree species. When considering all tree species, 16.4% of the sample trees were not defoliated. 12.7% were rated defoliated (defoliation classes 2-4). The mortality rate was calculated as 0.8%. The average defoliation of all species was 20.4% (19.9% in 2001). In *Fraxinus excelsior*, a constant deterioration in crown condition has been observed since 1996. Its mean defoliation reached 45.9%, and the share of damaged trees increased up to 60.8%. The proportion of discoloured trees (classes 1-4) remained the same as in 2001 with less than 1%. At 8.8% of the assessed trees damage symptoms were assessed. Most important damage types were fungi (3.8% of all trees) and insects (2.6%). The main factor influencing the forest condition in 2002 was the dry summer, affecting broad-leaved trees more frequently than conifers.

6.1.5 Norway

With respect to all assessed tree species, 35.0% of all trees were not defoliated. The mortality rate was 0.3%. Average crown density was 81.1%, showing a slight decrease by 0.4 percent points as compared to 2001. In *Picea abies*, average crown density increased from 80.7% to 81.1% in 2002, in *Pinus sylvestris* the average crown density remained unchanged with 82.4% in 2002. In *Betula* spp. a decrease by 1.0 percent points was recorded to 78.9% in 2002. Of the coniferous trees, 38.0% were rated not defoliated, representing an increase by 1.4 percent points in comparison to 2001. At the same time, a decrease in not defoliated *Betula* spp. by 3.1 percent points was observed to 24.4% in 2002. 16.3% of *Picea abies* showed signs of discolouration, after 23.9% in 2001. Of *Pinus sylvestris*, 7.4% were rated discoloured, reflecting a decrease by 4.0 percent points as compared to 2001. In *Betula* spp., an increase in discoloured trees was observed from 4.2% in 2001 to 10.4% in 2002. The main damage symptom identified in 2002 was related to infestation by the fungus *Melampsoridium betulinum*. In general, the observed crown condition results from an interaction between climate, pests, pathogens and general stress. The results of the 2002 assessments confirm the forest vitality status recorded over the last few years.

It should be noted that the national survey design in Norway was changed in 2001. The survey now is conducted on selected plots of a 9 x 9 km grid net for *Picea abies* and *Pinus sylvestris*. Also included are sample trees of the national forest inventory on a 3 x 3 km grid net, remeasured every five years. The sampling scheme for *Betula* spp. remained the same as in previous years.

6.1.6 Russia

The 2002 forest condition survey in Russia was carried out in five regions: Moscow, Kaliningrad, Leningrad, Novgorod and Pskov regions. A total number of 3 500 trees was assessed, representing 11 tree species. *Pinus sylvestris* as most sensitive indicator for air pollution was assessed in all regions. Furthermore, *Picea abies*, *Quercus robur*, *Tilia* *cordata*, *Ulmus glabra*, *Fraxinus excelsior*, *Alnus glutinosa*, *Betula pendula*, *Betula pubescens,* and *Fagus sylvatica* were assessed.

55% of *Pinus sylvestris* trees younger than 60 years were not defoliated, 40% were slightly defoliated, 5% moderately and another 0.2% severely defoliated. 0.1% of *Pinus sylvestris* were assessed as dead. In *Pinus sylvestris* trees older than 60 years, defoliation patterns were the same as in 2001. In five regions, 38% of *Pinus sylvestris* trees were not defoliated, in 50.4% slight defoliation was observed, 10.8% were moderately and 0.3% severely defoliated. In the Kaliningrad region, defoliation was higher as in the Moscow region. No major changes in defoliation were observed in the Leningrad, Pskov, and Novgorod regions between 2001 and 2002.

6.1.7 Sweden

The results from the national forest condition survey concern only forest of thinning age or older. An improvement in the tree health on the main tree species *Picea abies* and *Pinus silvestris* are observed in Northern Sweden. The improvement is most likely related to the extraordinary long and warm summer in 2002. In Southern Sweden small differences in the tree health are noticed. The share of discoloured *Picea abies* trees has decreased. *Pinus sylvestris* discolouration is still rare. About 3% of all pine trees are discoloured.

The excessive outbreak of *Gremmeniella abietina,* which arose in 2001, continued to strongly affect tree health in 2002. New infection was, however, only about 20% of the total amount of the observed symptoms. Most affected areas are in mid Sweden and the central part of Southern Sweden. Nearly 5% of the *Pinus sylvestris* forest were slightly affected and severe damage (with more than 60% of *Pinus sylvestris* showing defoliation exceeding 25%, and more than 20% with defoliation exceeding 60%) was observed on 40 000 ha of the *Pinus sylvestris* forest. Other fungi damage (root rot excluded) and insect damage were observed on less than 2% of the main conifer species. Most common of these are pine blister rust and *Neodiprion sertifer.*

An observed increase in dead trees to 0.5% was attributed to an increased number of wind throw after the stormy weather in the winter season of 2001 and 2002. About 50% of all dead trees were wind thrown.

The forest damage level as well as its annual variation were interpreted as an effect of natural stress factors. Air pollution inflicts and interacts with these factors.

6.2 Central Europe

6.2.1 Austria

Due to an ascertained increase in forest area, eight new plots were established on the national grid in 2002. Of the sample trees 2.8% have been removed by thinning operations or clearcut since last year's survey. The mortality rate of 0.17%., i.e. the ratio of trees died since last year and remaining in the forest is the highest since 1994. The mortality rate could be higher as some dead trees may have been removed between surveys.

The 2002 crown condition survey in Austria did not show remarkable changes in defoliation as compared to the previous year. Among the most common coniferous tree species, *Picea abies* changed imperceptibly only. The crown condition of *Larix decidua* and *Abies alba* slightly deteriorated. The crown condition of *Pinus sylvestris* improved remarkably with the proportion of not defoliated sample trees increasing by 10.7 percent points. The crown condition of the most common broad-leaved tree species, *Fagus sylvatica* and *Quercus* spp. revealed different trends. The crown condition of *Fagus sylvatica* obviously improved, whereas the crown condition of *Quercus* spp. remarkably deteriorated. The proportion of not defoliated trees of *Fagus sylvatica* increased by 9.1 percent points, whereas the proportion of not defoliated *Quercus* spp. decreased by 20.1 percent points.

Discolouration was only found on 0.6% of the sample trees. On about 47% of the sample trees mechanical damage to stem or crown was recorded. Most frequent damage was caused by snow, storm or ice (49%), and by human activities like felling or logging (23%). Herbal parasites (*Viscum album*, *Loranthus europaeus*) infested about 7% of *Abies alba* trees, 9% of *Pinus sylvestris* and 11% of *Quercus* spp. Tree crowns with herbal parasites revealed a significantly higher defoliation as compared to not infested specimens.

6.2.2 Croatia

The forest condition survey in Croatia was carried out on 80 plots on the 16 x 16 km grid in 2002. The share of slightly to severely defoliated trees (defoliation classes 2-4) decreased by 4.4 percent points as compared to 2001. In broad-leaved trees, a decrease by 4.3 percent points to 14.4% was observed, whereas in conifers the respective share remained almost constant with 63.5%. The high share of moderately to severely defoliated conifers does not show up in the results, because their number (241) is strongly outnumbered by the 1 669 broad-leaved trees.

Abies alba remains the most strongly defoliated species with 81.2% of trees in defoliation classes 2-4 after 84.5% in 2001. Its lowest defoliation scores date back to 1988 with 36.6% trees in these defoliation classes. The least affected species is *Quercus robur* with 16.7% in 2001 and a further decrease by 0.5 percent points in 2002. In *Fagus sylvatica*, the share of trees in defoliation classes 2-4 decreased again to 4.8% after an intermediate increase to 12.5% in 2001. The exceptionally wet summer of 2002 positively affected the crown condition in Croatia as main ecological agent influencing defoliation patterns.

6.2.3 Czech Republic

In the Czech Republic, a moderate increase in defoliation was observed in *Picea abies*, *Pinus sylvestris* and *Quercus* spp. independent of age as compared to 2001. Mainly a shift from defoliation class 1 to defoliation class 2 was observed. The shares of trees in defoliation classes 2-4 increased from 52.1% to 53.4% in 2002. A distinct decrease in defoliation was observed only in *Fagus sylvatica* in both age classes.

Forest stands were particularly affected by hailstorm and destructive wind including tornado events during the summer season between May and August. Especially in central and Eastern Bohemia and Moravia, damage was mainly caused by downburst and hailstorm. Even relatively stable broad-leaved forest stands were damaged. Biotic damage in Northern Moravian *Picea abies* stands was caused by *Armillaria ostoyae*. *Meloderma desmazieriessii* affected *Pinus strobus*, e.g. in the Elbe Sandstone National Park, where this tree species is harvested in order to stop the extension of the pest.

In 2002, the continued decrease of air pollution was less distinct as compared to previous years. The deposition of nitrogen has slightly increased during recent years. In 2001, the exposure index for ozone (AOT40) in forests exceeded the critical value of 10,000 ppb h in 94.5% of the territory of the Czech Republic. In comparison to 2000, the AOT40 decreased; in 2001 the highest values were measured in Southern Moravia.

6.2.4 Germany

The crown condition assessment conducted in Germany in 2002 shows that over all tree species 21% of forest areas display visible defoliation (defoliation classes 2 - 4), a situation that has remained virtually unchanged since 1995. The percentage of visible defoliation peaked in 1991 (30%), then dropped to 23% until 1995. Since stabilization in 1995, there have been no major improvements.

This situation is also reflected by the most important tree species: 26% of the area covered by spruce, 13% of the area covered by pine and 32% of the area covered by beech display visible defoliation with minor changes only.

A substantial improvement only occurred for oak, the most severely affected principal tree species so far: the percentage of trees with visible leaf loss has dropped to 29% (2002) since its peak in 1996/97 (47%). However, defoliation is still three times as high as at the beginning of the crown condition assessment (1984: 9%).

While there have been major cuts in air pollution emissions, they are still too high measured by the ecosystem resilience. This applies especially to acidifying and eutrophying air pollution (notably nitrogen oxides and ammonia). The cumulative sulphur and nitrogen inputs into forest soils over decades will remain a critical burden of the past for a long time to come. The profound impact of air pollution on forest ecosystems is becoming increasingly evident: sulphur and nitrogen inputs persisting over decades have caused changes to forest soils, for example, that will have long-term effects. Many forest soils have lost large amounts of their nutrients. They are acidifying as a result and also emit pollutants into the soil solution.

6.2.5 Poland

The forest condition survey in Poland was carried out on 1 229 permanent observation plots on the national network, including 433 plots of the transnational 16 x 16 km grid net. The assessments covered as main tree species: *Pinus sylvestris*, *Picea abies*, *Abies alba*, *Betula* spp., *Fagus sylvatica* and *Quercus* spp.. The forest condition remained more or less the same as compared to 2001. 8.8% of all sample trees were rated not defoliated, indicating a decrease by 1.1 percent points from previous year‘s results. The proportion of damaged trees (defoliation classes 2-4) increased by 2.1 percent points to a current share of 32.7% of all trees. The share of trees defoliated by more than 25% increased by 2.2 percent points for coniferous and by 1.7 percent points for broad-leaved tree species. For conifers

32.6% were assessed in defoliation classes 2-4. For broad-leaved trees, the respective share was 33.1%.

A slightly improving crown condition was observed in *Abies alba* stands, with the share of trees defoliated more than 25% decreasing by 9 percent points. Still *Abies alba* remained the coniferous tree species with the highest share of trees, 58.4%, in defoliation classes 2-4. In stands of *Betula* spp., a slight worsening of crown condition was recorded with an increase by 3.5 percent points of trees defoliated by more than 25%. Of the broad-leaved tree species, *Quercus* spp. was the most severely damaged tree species with a share of 42.6% in defoliation classes 2-4. Discolouration (classes 1-4) was observed in 0.9% of coniferous, and in 0.6% of broad-leaved species.

6.2.6 Slovak Republic

The crown condition survey in the Slovak Republic was carried out on 111 Level I plots of the 16 x 16 km grid net. The assessment covered 5 076 trees, 4 207 of which being assessed as dominant or co-dominant trees according to Kraft. Of these, 24.8% were damaged (defoliation classes 2-4). The respective shares were 40.4% in conifers and 14.4% in broad-leaved trees. In comparison to 2001, the share of trees defoliated by more than 25% decreased by 6.9 percent points.

Overall defoliation was 22.2% with 26.9% in conifers and 19.0% in broad-leaved trees. There was no significant deterioration in crown condition as compared to 2001. However, in *Carpinus betulus*, *Acer* spp., and *Fagus sylvatica*, a distinct improvement was observed, crown condition of the latter species recovered after a strong fructification in 2001. In the medium term, the lowest levels of damage were observed in *Fagus sylvatica* and *Carpinus betulus*. The most severely damaged species were *Abies alba*, *Picea abies*, and *Robinia pseudoacacia*. A statistically significant improvement in crown condition was observed for broad-leaved as well as for coniferous trees.

Identified damage types were assessed as part of the crown condition assessments. 15.7% of all 5 076 trees had some kind of known damage symptoms. Most frequent damage was caused by fungi (5.8%) as consequence of stem damage. Logging damage and insect attacks each occurred on 4.0% of the trees, and abiotic agents were recorded on 2.6% of trees. The most severe damage was caused by epiphytes. 69% of the assessed trees had defoliation of more than 25%. Also logging and game had strong impacts on defoliation patterns.

6.2.7 Slovenia

The crown condition survey in Slovenia covered a total of 936 trees on 39 sample plots. Mean defoliation of all tree species was 23.2%. The proportion of trees with more than 25% unexplained defoliation reached 30.2%. An increase in damaged trees between 2001 and 2002 did not prove statistically significant. As in previous years, the crown condition of conifers and broad-leaved trees revealed distinct differences. In conifers, 28.3% were defoliated by less than 10%, 40.3% of the conifers were slightly defoliated (10%- 25%) and 26.6% were moderately defoliated (>25-60%), and 4.8% severely defoliated or dead.

As for broad-leaved trees, 34.9% were not defoliated, slight defoliation was observed in 39.2%, moderate defoliation occurred in 22.5%, and severe defoliation in 3.4%.

On the species level, mean defoliation of *Picea abies* remained almost the same as in 2001, while the share of damaged trees (defoliated by more than 25%) increased by 5.8 percent points. This change was found statistically significant. The crown condition of *Fagus sylvatica* remained unchanged as compared to 2001.

6.2.8 Switzerland

In 2002, 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 the previous years. Defoliation of unknown causes remained unchanged compared to 2001, while total defoliation increased slightly but not significantly. In 2002, 18.6% of the trees had more than 25% unexplained defoliation (i.e. subtracting the known causes such as insect damage, or frost damage), and 30.2% of the trees had more than 25% total defoliation. Overall, the weather conditions in 2002 were quite favourable with above average precipitation during the vegetation period. 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. Despite the continuation of the out-break of *Ips typographus* on *Picea abies* following the December 1999 storms, tree removal on the plots has not increased (1.5%). On the plots of the 16 x 16 km grid no bark beetle attacks were observed, indicating that the grid density is too low to capture the bark beetle calamity.

6.3 Southern Europe

6.3.1 Cyprus

The forest condition survey in Cyprus included 300 trees of *Pinus brutia*, 36 *Pinus nigra*, and 24 *Cedrus brevifolia* trees. 30.8% of the assessed trees were not defoliated, 66.4% were slightly defoliated, moderate defoliation was observed in 2.8% of the trees. No discolouration was observed. In comparison to the 2001 assessments, an improvement was observed with regard to defoliation as well as to discolouration. The improving crown condition was mainly attributed to favourable weather conditions.

In *Pinus brutia*, 26.3% of the sample was not defoliated, 70.3% were in defoliation class 1 (slightly defoliated), and another 3.3% was in defoliation class 2 (moderately defoliated). As compared to the 2001 results, an increase in the share of not defoliated trees by 7.0 percent points was observed, mainly accompanied by a decrease in defoliation class 2. In *Pinus nigra*, 26.3% were not defoliated, 47.2% showed slight defoliation. A slight deterioration was observed as compared to the 2001 results with a shift by 22.2 percent points from not defoliated to slightly defoliated trees. In *Cedrus brevifolia* 54.2% of the sample was not defoliated, slight defoliation was observed in 45.8%, reflecting a recuperation by 20.9 percent points in comparison to the 2001 results.

On 31.6% of the assessed trees, insect attacks were observed. 5.3% of the sample showed signs of other agents (lichens). In comparison to 2001, a decrease by 27.3 percent points was observed with respect to insect attacks.

6.3.2 Greece

The 2002 forest condition survey in Greece revealed that 79.1% of all trees were not or slightly defoliated, 16.6% were moderately and 2.3% of the trees were severely defoliated. Another 2.0% of the assessed trees were rated dead. In conifers, 48.2% were not defoliated, 35.7% were slightly, 11.9% were moderately, and 1.3% severely defoliated. 2.9% of the conifers were dead. In broad-leaved trees, 35.2% were not defoliated, 38.2% were slightly and 22.1% were moderately defoliated. Furthermore, 3.3% broad-leaved trees were severely defoliated and 1.1% of the broad-leaved trees were recorded dead.

Taking into account all species, a decrease by 2.5 percent points in slightly defoliated trees was observed. Moderately defoliated trees decreased by 0.5 percent points and severely defoliated trees decreased by 0.7 percent points corresponding with an increase in not defoliated trees by 3.3 percent point. In conifers, a high increase in not defoliated trees by 5.1 percent points was observed with corresponding decreases by 4.0 percent points of slightly defoliated trees, 1.1 percent points of moderately defoliated trees and 0.6 percent points of severely defoliated trees. In broad-leaved species, slight increases by 1.1 percent points of not defoliated and of 0.5 percent points for moderately defoliated trees were observed, corresponding to decreases of slightly defoliated trees (1.0 percent points) and severely defoliated trees (0.9 percent points). In comparison to previous years, a slight improvement in crown condition was observed in both broad-leaved and coniferous tree species.

Of the assessed trees, about 15.2% showed signs of insect attacks; in 9.6% abiotic stress, in 2.5% human and in 12.8% other agents caused damage to trees. No damage was attributed to known air pollution. The year 2002 was rainy with heavy winter and an exceptionally wet and humid summer.

6.3.3 Italy

The 2002 crown condition assessment was carried out on 7 165 sample trees on 265 Level I plots of the 16 x 16 km transnational grid. In comparison to 2001, the number of assessed plots was reduced by 7 plots because data were transmitted delated and trees were cut. Considering the total tree sample, the share of damaged trees (defoliation classes 2-4) was 37.3%. With 20.5% of trees in defoliation classes 2-4, conifers showed less defoliation than broad-leaved trees with a share of 44.6% trees in these classes.

With regard to age classes and tree species, 36.6% of *Pinus sylvestris* trees younger than 60 years were in defoliation classes 2-4, whereas *Picea abies* trees performed distinctly better with only 2.4% in defoliation classes 2-4. 15.9% of *Pinus sylvestris*, 22.1% of *Larix decidua* and 23.7% of *Pinus halepensis* younger than 60 years were in defoliation classes 2-4. Among the conifers older than 60 years, *Pinus sylvestris* showed the worst crown condition with a share of 43.2% trees in defoliation classes 2-4, followed by *Larix decidua* with 33.2% trees in the respective classes, whereas *Pinus cembra*, *Picea abies* and

Abies alba showed less defoliation with 11.8% to 23.7% trees in defoliation classes 2-4. For broad-leaved trees in the age class below 60 years, 67.5% of the assessed *Quercus pubescens* and 64.9% of *Castanea sativa* were in defoliation classes 2-4; other broad-leaved species showed lower defoliation: *Ostrya carpinifolia* 27.9%, *Quercus cerris* 28.6%, *Quercus ilex* 32.7%, and *Fagus sylvatica* 35.3% trees in defoliation classes 2-4.

Analyzing 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, 35.8% of the conifers and 73.4% of the broad-leaved trees. The most frequently observed damage types were insects, fungi and climatic stress.

Compared to the survey results of 2001, defoliation was slightly lower for all species in 2002: in 2001, 38.4% were in defoliation classes 2-4, and in 2002 37.3%.

6.3.4 Portugal

The 2002 forest condition survey in Portugal was carried out on 145 plots including 4 350 trees, 72% of them being younger than 60 years. The results of the assessments indicate a trend of improving crown condition since 1990. In both broad-leaved and coniferous species a decrease in the shares of damaged trees was observed between 1990 and 2002. The share of trees in defoliation class 1 slightly decreased by 1 percent point between 2001 and 2002 to currently 42.6%. This decrease was mainly attributed to conifers with an improvement in crown condition from 43.7% in 2001 to 38.6% in 2002. In broad-leaved trees, however, the share of trees in defoliation class 1 slightly increased by 1.1 percent points in the same time interval. For some trees a shift from the warning stage (defoliation class 1) to defoliation class 0 was observed. Also, the share of trees in defoliation classes 2-4 slightly decreased from 10.1% in 2001 to currently 9.6%. This recuperation was found in both coniferous and broad-leaved tree species.

The observed trend of improving crown condition has been observed since 1990 (30.8% damaged trees) and 1994 with 5.7% damaged trees; during recent years the share of damaged trees has remained relatively stable with about 9.6%.

The most severe decline in crown condition was observed for *Quercus suber*, reaching its peak in 1991 with 52.7%. The maximum defoliation for *Quercus ilex* was recorded in 1991 as well, reaching 46.2%. The crown condition of *Pinus pinaster* remained distinctly better with a maximum share of damaged trees in 1990 with 26.3%. The maximum share of damaged trees of *Eucalyptus globulus* was 7.3% in 1991. Defoliation was mainly attributed to fungi and insect attacks as well as forest fires, triggered by a sequence of extremely dry years (1989-1991).

6.3.5 Spain

In the crown condition assessments in Spain 83.5% of the assessed trees were considered healthy, whereas slightly above 14% of the trees were assessed in defoliation classes 2 and 3. These figures showed a slight deterioration in crown condition as compared to 2001. Deterioration of crown condition has been observed between 1987 and 2002 for broad-leaved and coniferous trees, taking into account defoliation as well as discolouration. In the latter, deterioration obviously is slightly stronger as compared to the broad-leaved trees. Conifers showed a stronger deterioration than broad-leaved trees. The share of dead trees remained unchanged between 2001 and 2002.

Defoliating insects such as *Lymantria* spp., *Thaumetopoea pytiocampa*, and wood-boring insects are of importance. In *Eucalyptus* forests, also *Gonipterus scutellatus* was recorded. Broad-leaved trees were affected by *Altica quercetorum*, together with the widespread occurrence of *Viscum album* in conifers. Obviously the *Quercus* spp. decline occurring throughout the Mediterranean, has continued to increase in several *Quercus ilex* and *Quercus suber* forests in Spain. One important agent affecting *Quercus* spp. mainly in some areas inside the Balearic Islands, Extremadura, and Andalucia is the wood borer *Cerambyx* spp.. Also fungi caused damage to trees, among others *Microsphaera alphitoides* and *Sirococcus conigenum*.

6.3.6 Serbia and Montenegro

The 2002 forest condition survey was carried out on 46 sample plots representing 1 104 trees on the transnational 16 x 16 km grid net in Montenegro. The assessment did include 313 conifers (*Abies alba*, *Picea abies*, *Pinus nigra*, *P. leucodermis*, *Cupressus sempervirens*, *Juniperus oxicedrus*) and 791 broad-leaved trees of the species *Quercus cerris*, *Q. pubescens*, Q. *petraea*, *Fagus sylvatica*, *Fraxinus ornus*, *Carpinus betulus*, *C. orientalis*, *Ostrya carpinifolia*, and *Corylus avelana*. The observations indicate that broad-leaved trees are less endangered than conifers.

6.4 Western Europe

6.4.1 Belgium

Wallonia

In Wallonia, average defoliation in 2002 slightly decreased for *Fagus sylvatica* and *Quercus petraea* for the first time since 1999. As in other parts of Europe, the crown condition of these species continued to be the worst as during previous years. In *Quercus robur* and *Picea abies*, an increase in average defoliation was observed. Identifiable damage types were observed on only 9.4% of trees. Insects, fungi and abiotic agents could significantly explain annual changes in defoliation in 2002. The special problem which occurred on *Fagus sylvatica* in the Ardennes during 2000 and 2001 obviously stabilized in 2002. Only few additional trees exhibited damage caused by Scolytidae (mainly *Trypodendron signatum* and *T. domesticum*) and fungi (mainly *Fomes fomentarius*).

A slight increase in discolouration was observed for broad-leaved species, especially for *Fagus sylvatica* older than 60 years with 21.1% of trees discoloured by more than 25%. Water availability was good in 2001 and 2002 with very high rainfall (the second highest ever since 1833) in spring and in September 2001, and in February and summer 2002.

Flanders

The 2002 crown condition survey in Flanders was carried out on 72 plots on a 4 x 4 km grid net with 10 plots coinciding with the transnational 16 x 16 km grid. Considering all tree species together, only minor changes in defoliation were observed as compared to the 2001 crown condition survey. The share of trees with moderate to severe defoliation decreased from 22.1% to 21.7%. Discolouration increased from 5.4% to 7.3%. The crown condition of coniferous tree species deteriorated, whereas an improvement of crown condition was observed for broad-leaved tree species. The share of damaged broad-leaves decreased to 19.9%, whilst the proportion of damaged conifers amounted to 25.4%. Discolouration increased in both broad-leaves and conifers.

A slight increase in defoliation of *Fagus sylvatica* was partly due to the intense fructification in 2002. Similar observations of increased defoliation coinciding with fructification had been recorded e.g. in 1987, 1991, 1995 and 2000. 14.7% of the trees were damaged. In *Quercus robur*, crown condition improved as compared to 2001 with 20.7% of trees in defoliation classes 2-4. Insect damage on *Quercus robur* was lower than in 2001. In *Quercus rubra*, a slight improvement in crown condition was observed in 2002 with 24.1% of trees rated damaged. Crown condition of *Populus* spp. improved, yet still 36% of the trees exhibited more than 25% defoliation. As in 1997 and 1999, *Populus* spp. suffered from serious rust infestation (*Melampsora* spp.).

In *Pinus nigra* ssp. *laricio*, about 47.5% of trees were rated damaged with the fungus *Sphaeropsis sapinea* identified as main cause of damage. Crown condition of *Pinus sylvestris* slightly deteriorated with a share of damaged trees increasing to 19.6%.

6.4.2 Denmark

The Danish level I forest condition survey in 2002 showed a satisfying condition for all tree species, based on both EU/ICP Forests plots (22) and national plots (28), in total 1200 trees. The crown condition survey showed reduced defoliation for oak and Norway spruce compared to 2001. The defoliation of beech was at the same level as in 2001. Generally, other tree species are also in good health.

The results of the crown condition survey in 2002 showed that 76% of all coniferous trees and 57% of all deciduous trees were undamaged. 18% of all conifers and 36% of all deciduous trees showed warning signs of damage, and 6% of all conifers and 7% of all deciduous trees were damaged. This is the highest number of undamaged trees since the beginning of the survey.

The health condition of Norway spruce (*Picea abies*) improved from 2001 to 2002 after three years of stable health. The mean defoliation improved from 11 to 8%, and the share of damaged trees decreased from 6% to 5%. This was probably due to favourable growth conditions in the past 2 years, especially in relation to precipitation.

The mean defoliation for beech (*Fagus sylvatica*) remained at 13% in 2002, in spite of a huge mast production in many older stands. However, the share of damaged trees slightly increased from 7% to 8%. This was mainly due to higher defoliation in stands older than 70 years, most probably in connection with high mast production.

The condition of oak (*Quercus robur* and *Q. petraea*) in Denmark is strongly influenced by attacks of defoliators and subsequent attacks by *Armillaria* sp. In the previous years since the crown condition survey started, the level of defoliation in oak was high compared to the other tree species. However, in 2002 the defoliation of oak was comparable with the level of beech. This is the result of at least 4 years of steady improvement, due to the absence of major insect attacks and also due to very favourable growth conditions in the past 2 years. In 2002 the mean defoliation decreased to 14% (from 19% in 2001), and the share of damaged trees decreased from 14% in 2001 to 8% in 2002.

The Danish report may be seen via the internet on http://data.fsl.dk/FFlevel1/index.htm

6.4.3 France

The forest condition survey in France included 10 355 trees on 518 permanent sample plots. After three consecutive years of continuous decrease in defoliation (1998-2000), an increase in defoliation for most species was observed starting in 2001, and continuing in 2002. Broad-leaved trees still showed a distinctly higher defoliation than conifers. As regards discolouration, fluctuations for the different species could be observed which, however, in general remained on a very low level with about 10% of discoloured trees. Mortality has remained stable on a very low level over the last ten years (0.2%). These nation-wide trends, however, conceal a very broad regional variety. In comparison with 2001, species with high defoliation were *Quercus pubescens* in the South-west, *Fagus sylvatica* in the North-east, and *Pinus halepensis* in the South-east.

For six years, damage due to abiotic and biotic factors has been assessed when obviously affecting crown condition. Since 2000 the level of damage has also been indicated. The increase in defoliation observed in 2001 most probably was caused by the buprestid beetle *Coroebus bisfasciatus* on *Quercus pubescens* and *Rhynchaenus fagi* on *Fagus sylvatica*. Despite the deterioration of *Pinus halepensis*, the frequency of assessed redness caused by the pine canker *Crumenulopsis sororia* markedly decreased. Only few climatic peculiarities can be recorded as the particularly dry spring in the South-west, a cloudy summer with high amounts of precipitation in the Midi-Pyrenees and in the South-east. Damage by leaf-eating insects was of minor importance, although an augmentation of the pine processionary moth *Thaumetopoea pityocampa* was reported for the South-west. Also an important desiccation of oak crowns by *Coroebus bisfasciatus* was detected in 2002.

6.4.4 Ireland

The annual assessment of crown condition was conducted on the Level I plots in Ireland between July and September 2002. Overall mean percent defoliation and discolouration was 16.3% and 6.6% respectively. This represents a disimprovement in crown condition of Irish forests between the 2001 and 2002 survey of 0.5% points for defoliation and of 1.7% points for discolouration. Defoliation levels recorded in 2002 were greater than the 12-year average of 15.8% and discolouration in 2002 was also above the 12 year average of 5.2% points. In terms of species, defoliation decreased in the order of Norway spruce > lodgepole pine > Sitka spruce while the trend in discolouration was in the order of lodgepole pine > Sitka spruce > Norway spruce. These results do not vary significantly from those recorded in the 2001 survey despite the relative increase in discolouration scores.

The trends in crown density among species are similar to last years survey. In 2002, Norway spruce had the highest defoliation levels as was observed in 2000 and 2001 also. This was the result of a combination of defoliation levels decreasing in lodgepole pine and increasing somewhat in both spruce species. Lodgepole pine had the highest discolouration levels of the three species in 2002, which was also the observation in last years survey.

Exposure continued to be the greatest single cause of damage to the sample trees in 2002, however, the instances of observed aphid damage were significantly greater than 2001. Indeed damage to the spruce species, Sitka in particular, by the green spruce aphid *Elatobium abietinum* (Hemiptera: Aphididae) was the single greatest biotic cause of damage in the 2002 survey. This appears to be the result of particularly favourable climatic conditions for spruce aphid which prevailed during 2002. 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 again 2002, recorded on the young spruce trees at Ballinglen. No instances of damage directly attributable to atmospheric deposition were recorded in the 2002 survey.

6.4.5 The Netherlands

The annual assessment of the 11 plots on the national grid net shows a very slight increase in the overall defoliation with 21.7% of the trees in defoliation classes 2-4. Considerable differences on the species level were observed. *Pinus sylvestris* generally is in good condition, with little discolouration and only 5% of trees in defoliation classes 2-4. *Quercus* spp. is affected by both discolouration and defoliation on four plots. Almost 30% of the trees were in defoliation classes 2-4 after 18.5% in 2001. For *Pseudotsuga menziesii*, the share of trees in defoliation class 2 has always been relatively high; the percentage of trees in defoliation classes 2-4 decreased from 84% in 2001 to 76% in 2002.

6.4.6 United Kingdom

Climatic conditions during the 2002 season were favourable for tree growth, being mild and generally wet until late August. In spite of this all of the surveyed species, namely *Picea abies*, *Pinus sylvestris*, *Picea sitchensis*, *Quercus robur* and *Fagus sylvatica*, displayed some deterioration in condition with respect to last year. Considering all species together, crown condition was markedly poorer than in 2001 thus continuing the gradual trend for reduction in crown density which has been evident since 1995.

A distinct deterioration in the condition of *Fagus sylvatica* was largely attributable, as in previous cases of similar change in 1995 and 2000, to abundant fruiting. A marked reduction in the mean crown density of *Quercus robur* in 2002 reflected a minor change in the condition of the majority of surveyed trees: when compared with their condition last year, 33% of the sample population displayed a decrease in crown density of only 5-10%. The incidence of insect damage to oak was similar to that recorded in 2001 but an increase in fungal damage, particularly that caused by the powdery mildew pathogen *Microsphaera alphitoides*, was noted this year.

Among the conifers, *Picea sitchensis* displayed the greatest change in condition with severe defoliation occurring in certain parts of the country due to attack by the green spruce aphid *Elatobium abietinum* which commenced early in the year following a mild winter. *Picea abies* was not similarly affected. As in 2001 heavy male flowering, particularly in the upper crowns of trees, has contributed to a slight deterioration in the condition of *Pinus sylvestris* this year.

6.5 South-eastern Europe

6.5.1 Bulgaria

The annual crown condition survey in Bulgaria was carried out on 141 plots on grid nets of 16 x 16 km, 8 x 8 km and 4 x 4 km with a total 5 303 sample trees being assessed, representing 2 876 conifers and 2 427 broad-leaved trees. In comparison to 2001, the share of slightly to severely damaged and dead trees increased by 7.5 percent points. The share of trees without visible symptoms of defoliation decreased from 31.5% in 2001 to 24.1% in 2002. The share of damaged trees (defoliation classes 2-4) slightly increased by 3.3 percent points.

Among coniferous trees, the share of not defoliated trees decreased by 11.2 percent points; the share of moderately to severely defoliated trees increased by 4.9 percent points. In *Pinus sylvestris* trees younger than 60 years, the share of not defoliated trees decreased by 12 percent points, and the share of slightly to moderately defoliated *Pinus sylvestris* significantly increased. Also in *Abies alba*, a significant increase in moderately defoliated trees was observed. For conifers older than 60 years, the share of not defoliated trees significantly decreased for all species. The share of moderately defoliated conifers increased with an exception for *Abies alba*.

In broad-leaved trees, no significant change was observed in 2002. However, in *Fagus sylvatica* younger than 60 years, the share of moderately defoliated trees substantially increased by 10.2 percent points as compared to 2001. In *Quercus* spp. of the same age class, an increase in moderately defoliated trees by 8.6 percent points was observed. The condition of *Pinus nigra*, *P. sylvestris*, *Fagus sylvatica* and *Quercus* spp. was affected by a number of natural and anthropogenic stress factors including *Cecidomyia fagi*, *Rhynchaenus fagi*, *Dryomia circinuans*, *Gnomonia quercina*, *Neuroterus numismalis*, *Microsphaera alphitoides*, *Nectria* sp, *Lophodermium* sp., *Cenangium* sp., *Heterobasidion annosum*, and Aphididae.

6.5.2 Hungary

In contrast to the preceding forest condition surveys in Hungary, the dry and hot summer had no considerably negative effect on the overall crown condition. Although the average temperatures were about 2° C higher and the precipitation was about 30% lower in the first nine months of the year as compared to the long-term average, defoliation patterns remained the same as in 2001 with 21.2% of trees in defoliation classes 2-4. *Robinia pseudoacacia* remained the species with the highest defoliation (31.1%) in defoliation classes 2-4. Of *Quercus robur* and *Q. petraea*, 26.3% and 26.4%, respectively, were rated in defoliation classes 2-4. In *Pinus sylvestris*, the respective share was 25.9%. Defoliation of conifers and of *Robinia pseudoacacia* increased, while improving crown condition was observed in *Quercus robur*, *Quercus cerris*, *Fagus sylvatica*, and *Carpinus betulus*. Defoliation attributed to insects and fungi was slightly higher as compared to 2001, but lower than during the 15 years of forest condition surveys. *Robinia pseudoacacia* was severely attacked by leaf mining insects (*Parectopa robiniella* and *Phillonoricter robiniella*). *Quercus robur* and *Carpinus betulus* were damaged by various leaf eating insects. Rainfall in August increased the occurrence of mildew (*Microsphaera alphitoides*) on *Quercus petraea*.

6.5.3 Romania

The crown condition survey in Romania covered as main tree species *Picea abies*, *Fagus sylvatica*, *Abies alba*, *Robinia pseudoacacia* and several *Quercus* spp. A total of 104 366 trees was assessed, with 13.5% being assessed in defoliation classes 2-4. The respective shares in conifers were 9.9% and in broad-leaved trees 14.8%. The lowest defoliation was observed in *Picea abies* with 8.4% in defoliation classes 2-4, 10.2% in *Fagus sylvatica*, and 13.9% in *Abies alba*. Highest defoliation was observed in *Quercus frainetto* (42.5%), *Quercus pubescens* and *Q. pedunculiflora* (31.1%), *Robinia pseudoacacia* (28.9%), *Quercus robur* (23.6%) and *Quercus cerris* (22.9%).

In *Picea abies* and *Abies alba* crown condition remained unchanged as compared to 2001. In *Fagus sylvatica* a slight improvement by 1.1 percent points was observed. However, defoliation of tree species in Southern and South-eastern Romania, slightly increased due to intense drought. In these regions, the intense leef/needle losses succeeding the excessive droughts of 2000 and autumn 2001, could not recuperate despite the high amounts of precipitation of 2002. *Quercus pubescens* and *Q. petraea* did not follow these regional trends.

6.6 Eastern Europe

6.6.1 Belarus

In Belarus, the crown condition design in 2002 changed in comparison to previous years. Defoliation assessments were carried out only in trees not shaded out by other tree crowns. 80% of all stands and 77% of the sample trees were younger than 60 years. About 9.5% of the assessed trees were rated severely damaged (defoliation classes 2-4), and 55.6% were rated slightly damaged. For *Pinus sylvestris* and *Picea abies* the shares of trees in defoliation classes 2-4 were 9% and 11%, respectively. For *Picea abies*, an annual mortality of about 2.5 – 2.9% was observed between 2000 and 2002. In *Picea abies*, damage most frequently was attributed to *Ips typographus* and to climatic factors. The annual mortality rate in *Pinus sylvestris* reached 0.8 - 1.0%.

In *Quercus robur* and *Populus tremula* about 22% and 11%, respectively, where rated severely damaged (defoliation classes 2-4). On *Quercus robur*, main damage was caused by biotic (45%) and abiotic agents (4%). Between 1999 and 2001, an annual mortality rate of 0.9% was observed for *Quercus robur* that strongly increased to 1.6% in 2002. In *Populus tremula*, 39% of damage was attributed to biotic, and about 4% to abiotic factors. In 2002, the share of dead *Populus tremula* increased by 1.8%. In *Fraxinus excelsior, Betula pendula*, *Alnus glutinosa* and other broad-leaved tree species, low shares of defoliated trees (defoliation classes 2-4) were observed. Damage in these tree species was attributed to various stress factors with varying percentages below 15%.

6.6.2 Republic of Moldova

The forest condition survey in the Republic of Moldova covered 11 489 trees on 480 sample plots. The main species assessed included *Robinia pseudoacacia*, *Quercus robur*, *Populus* sp., and *Fraxinus excelsior*. 57.4% of the assessed trees were recorded as defoliated in defoliation classes 2-4. On the species level, 55% of *Robinia pseudoacacia* were in defoliation classes 2-4, the respective shares in *Quercus robur* and *Populus* sp. were 53.9%, and 47.2%, respectively. Of *Fraxinus excelsior*, 40.5% were assessed in defoliation classes 2-4. 3 000 trees of the total sample were damaged by insects, 1 444 of which (48.7%) were in defoliation classes 2-4. 500 trees were affected by abiotic agents, 300 trees were affected by cryptogrammic fungi. More than 700 trees suffered from multiple damage.

6.6.3 Ukraine

The forest condition survey in the Ukraine covered 49 plots with 1 204 trees. The assessments included as main tree species *Pinus sylvestris*, *P. pallasiana*, *Quercus robur*, and *Fraxinus excelsior*. The plots were located in the Eastern and Southern Ukraine, where the natural conditions are unfavourable to forest growth, and air pollution levels are highest in the country. Mean defoliation was 19.2% in conifers and 27.1% in broad-leaved trees. In general, a slightly improved crown condition was observed as compared to 2001 with the share of not defoliated trees increasing by 2.8 percent points in 2002. At the same time, the share of moderately to severely damaged trees considerably decreased from 38.9% to 25.6%. This might be, however, due to a reduced sample size.

For the Common Sample Trees (CSTs), a slight tendency of improving crown condition was observed. Mean defoliation of all trees decreased by 1.3 percent points to 25.4% in 2002. This observation, however, did not prove statistically significant. The shares of trees in defoliation classes 2 and 3 decreased, whereas increasing shares of trees were observed in defoliation classes 1 and 4. A slight improvement was recorded for *Quercus robur*. Statistically significant changes were observed in defoliation class 2 with a decrease by 10.1 percent points, with accompanying increases in the other defoliation classes. For *Fraxinus excelsior*, a statistically significant increase was observed in defoliation class 1 with decreasing shares observed in the other defoliation classes. The same trends were observed in *Pinus sylvestris*, and *P. pallasiana*. However, for these species the changes did not prove statistically significant. Spring frosts, continuous summer drought, and high temperatures are considered the main factors affecting the forest condition in the Ukraine in 2002.

7 DISCUSSION

7.1 Development of defoliation

Of all sample trees observed continuously over the last 9 years, the share of trees classified as damaged increased from 21.9% in 2001 to 22.9% in 2002. This confirms the finding of last years' reports that the deterioration of crown condition has resumed after a transient recuperation in the mid 1990s and a subsequent period of steady state. The main causes for the spatial and temporal variation of defoliation across Europe quoted by the participating countries were biotic and climatic factors and differed greatly between regions and species.

For *Pinus sylvestris* a recuperation observed from 1994 on especially in eastern Germany, Poland and parts of the Baltic states had been attributed to reduced air pollution especially in Poland and Lithuania. The deterioration from 2001 to 2002 occurred mainly in Finland and in central and southern Sweden, where it was explained by heavy storms and by an outbreak of *Gremmeniella abietina*, respectively.

The high defoliation of *Picea abies* reflects partly its poor crown condition in the main damage areas of central and eastern Europe, where it had been noticed well before the first defoliation survey (ARDÖ et al., 1997) and had been explained as an effect of air pollution (e.g. SCHULZE, 1989, GOBOLD and HÜTTERMANN, 1994, FREER-SMITH, 1998). In the Boreal region *Picea abies* recovered partly from fungal diseases and storm damage experienced in 2001. Increasing defoliation in 2002 can be partly explained by severe storm and drought with subsequent bark beetle attack in Estonia and an outbreak of *Armillaria ostoyae* in the Czech Republic. Also in 2002, however, a recuperation of *Picea abies* due to increased precipitation was observed in Denmark.

Fagus sylvatica recuperated from its 2001 peak in defoliation which had partly reflected a deterioration in the Mountainous (South) region partly due to hail and storm. Other plots showing a recovery were found in Germany and Romania. Increasing defoliation was explained by *Rhynchaenus fagi* in France and by abundant fruiting in the United Kingdom.

Quercus robur and *Quercus petraea* recovered in 1998 from severe defoliation explained by a complex of several stressors including insects (FISCHER, 1999) and weather extremes (LANDMANN et al., 1993, MATHER et al., 1995). The defoliation surveys of the subsequent years revealed a steady state.

Among the main tree species in Europe *Pinus pinaster* as well as *Quercus ilex and Quercus rotundifolia* show the steepest increase in defoliation since the beginning of the survey. Summer heat and drought are the main causes quoted by Spain and Portugal. While *Pinus pinaster* is still the least defoliated of the main tree species in Europe, the defoliation of *Quercus ilex* and *Quercus rotundifolia* now exceeds that of *Pinus sylvestris* and *Fagus sylvatica*. The increase in defoliation in 2002 and earlier years was partly attributed to the wood borer *Cerambyx cerdo* in some areas of Spain.

Atmospheric depositions were only rarely mentioned as a cause of defoliation by the participating countries, because the link between both stands out from the effects of the other factors only in cases of severe local air pollution. The impact of air pollution and other factors upon defoliation was analysed by means of integrative evaluations.

7.2 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 integrative evaluation of the Technical Report on Level I 2001 (PAD; UNECE, CEC, 2001). The new evaluation method of integrative evaluations in the following year's report was 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 linear regression models with the predictor variable year of observation. The analyses of the spatial and temporal variation using the distributions of predictor variables for precipitation, deposition and biotic infestations for building statistical models is presented for *Picea abies* and *Quercus robur* and *Q. petraea* in this year's report (4.1 and 4.2) after the presentation of results for *Pinus sylvestris* and *Fagus sylvatica* in the last year's report (UNECE, EC, 2002). 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. Due to a lack of predictor variables especially for the deposition after 1999 the evaluation period was limited to the years 1994 to 1999. For the six main tree species (*Pinus sylvestris*, *Picea abies*, *Fagus sylvatica*, *Quercus robur* and *Q. petraea*, *Quercus ilex* and *Q. rotundifolia*, and *Pinus pinaster*) the respective information about spatial and temporal variation of defoliation were calculated and mapped in 4.3 for the more recent period 1997 to 2002.

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). For the respective analyses 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. 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.

For many cause-effect relationships a time lag between observed impact and observation of response can be expected (e.g. acidification processes). The possibility of time lags between impact and response was tried to be found by including values from the previous year.

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 under process.

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.The chosen methodology does not recognise the temporal auto-correlation. 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. Future evaluations should regard on this aspect. In this year's report the same methodology as in the last year's report was chosen to produce comparable results. Analyses using the SAS procedure MIXED seem to be a promising task for the future because spatial and temporal aspects can be modelled together. Because of the high complexity of the underlying principles it could not be applied during the presented analyses but for future analyses it could also be a sharper statistical tool for the detection of significant correlations than the applied error model has been.

The evaluation of the spatial variation of defoliation emphasised the importance of a correction of the defoliation values for country specific age trend. The maps of the uncorrected medium-term mean defoliation values reveal border effects among some countries. The values of the preliminarily adjusted defoliation (PAD) depict reasonable regions of relatively high/low defoliation without those comparably strong inconsistencies at national borders. Due to the possible loss of 'real' differences in mean defoliation between neighbouring countries because of the calculation of the PAD it seems preferable to substitute the underlying statistical relationships by empirical relationships based on results from future 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 *Picea abies* and *Quercus robur* and *Q. petraea*. Thus, mean values of defoliation calculated for large regions of Europe or even total Europe must be interpreted with care.

Whereas the analyses for *Picea abies* revealed mostly negative correlations of depositions with defoliation the opposite was found for *Quercus robur* and *Q. petraea*. This could be an indication for an effect of differences in the nutrition of the tree species and possible dependencies from depositions.

7.2.1 ***Picea abies***

The maps of the mean development of defoliation (Fig. 4.1.1-1 and Fig. 4.1.1.-2) reveal some trends which were described as well by the national reports (6). Thus the mean increase in defoliation in Estonia during the period 1994 to 1999 was underlined by the Estonian report. Nevertheless, more information can be gained in connection with the presentation of the more recent development (4.3).

It was no significant predictor variable found in the multiple linear models in 4.1.1. Nevertheless many plausible correlations were found and could explain 40.8% of the temporal variation of defoliation which was described by the referenced defoliation (2.5.3). Also the integration of non-linear effects into the model did not lead to much higher R-square values.

The deposition of sulphur in the year of observation (depS) led to positive regression coefficients in all models. This factor was after the index for insect pests (s. below) the second strongest predictor variable. In contrast to the positive correlation of depS with the sulphur deposition in the previous year (p depS) was negatively correlated with referenced defoliation. Also the deposition of nitrate and ammonium in the previous year were negatively correlated. Perhaps, this could be an indication for the nutrition effects of these depositions or of co-deposited nutrients for which no information was available.

Of the precipitation indices the sums of precipitation for April to June in the actual year and from April to September in the previous year were the strongest predictors and showed consistently negative regression coefficients which seems to be plausible. As expected were the positive regression coefficients for the index for insect pests (the higher the share of trees which are infected by insects the higher the mean plot defoliation in this year).

Not expected was the negative regression coefficients for fungi. When higher values of this index – the share of trees which is infected by fungi – are observed one should expect that the defoliation is increased too. The opposite was observed. A temporal lag between the main negative influence of fungi on crown condition and the real observation by the field teams seems to be a plausible explanation for this effect which was also found for *Pinus sylvestris* in the last year's report (UNECE, EC, 2002) but also the fungi being a secondary damage after an other strong damaging effect could be a possible explanation.

The spatial variation of defoliation in terms of the medium-term mean defoliation could be explained by nearly 58.5% by the available predictor variables. A model with both significant variables ammonium and insect reaches a R-square value of 58.5%. Compared with a model only describing the country specific age trend this is an increase of 1.7%.

Of all predictors the precipitation index and the deposition of nitrate were the only predictors which led to negative regression coefficients indicating a better crown condition in areas with high mean precipitation and high nitrate deposition. Areas with high medium-term values for insect pests and fungi infestations as well as for the depositions of sulphur and ammonium showed on average higher defoliation values.

7.2.2 *Quercus robur* and *Q. petraea*

The mean development of defoliation from 1994 to 1999 shows a high variability (Fig. 4.2.1-1 and Fig. 4.2.1-2). The largest area of increasing defoliation is in north Germany and the South of the Netherlands. Also in the north of Croatia, in Bulgaria, and in Romania a strong deterioration was observed during the evaluation period.

For the temporal variation of defoliation expressed by the referenced defoliation of *Quercus robur* and *Q. petraea* no predictor variables were found to be significant. The most comprehensive model reaches a R-square value of 43.8%. The reduction of the all deposition factors but the two strongest ones – the deposition of sulphur in the actual and that of ammonium in the previous year – led to a marginally lower value of 43.5%.

The regression coefficients of all predictor variables but the precipitation indices and ammonium deposition in the previous year are positive indicating higher defoliation in years with higher deposition or impact of fungi or insects, respectively. High precipitation and a high deposition of ammonium in the previous year coincide with lower values of defoliation.

The spatial variation of defoliation could be explained by 43.3% by a model including all available variables. A reduction to the significant ones, the indices for insect and fungi infestations, led to a R-square value 42.9% which is only 0.4% lower. These two predictor variables led to an increase compared with a pure country specific age model of 2.6%.

Models including the deposition predictor variables revealed negative regression coefficients for the deposition of sulphur if both nitrogen components (nitrate and ammonium) are used in the model instead of the total deposition of nitrogen. This indicates high inter-correlation between the deposition factors and reduces the possibilities for a clear interpretation of the found regression coefficients.

7.3 Foliar analyses

Foliar analysis can be divided into the following steps: *planning*, *representative sampling*, *sample preparation*, *instrumental analysis* and *data evaluation*. In order to ensure that the results of foliar surveys at the European level are comparable between years and between countries, the quality of all the steps has to be controlled. At present, the quality of most steps is controlled by means of guidelines laid down in the ICP-Forests Manual. Since 1995, the quality of the chemical analysis within the ICP-Forests Program was guarded, controlled and improved by 5 inter-laboratory ring-tests. However, the quality of foliar survey within the ICP-Forests Program would benefit from a tighter quality control of the *representative sampling* and *data evaluation* steps.

In Finland and Austria, 60 to 85% of the variation in the foliar nutrient concentrations was explained by the combined plot-year effect. In Finland and Austria, as well as in France (CROISÉ et al., 1999), Italy (MATTEUCCI et al., 2000) and along a European transect (CAPE et al., 1990), the variation between the stands was larger than the variation between the different sampling years. Thus, over a 10- to 15-year period and within the same tree species, the local conditions such as soil type, deposition regime, altitude, latitude, provenance etc. cause more variation in the foliar nutrient concentrations than the temporal conditions such as weather, ageing, variation in the deposition regime, long-term climatic changes etc. As a consequence, more replicate samples are needed to characterise the regional nutrient concentrations in needles than are needed to resample the same region several years in succession. We can conclude that repeated sampling during the monitoring of long-term changes benefits from this relatively low temporal variation. However, when the effect of a long-term change on the nutrient concentration is measured in the short or medium term, the effect is likely to be very small. Aiming at a very small effect size (or very high precision) will inflate the sample size (FOSTER, 2001). In the short and medium term, complete time series are available and the use of powerful statistics is possible, i.e. the use of a paired t-test instead of an unpaired t-test. As shown by the Finnish data set, management, harvesting, storms etc result in the loss of plots from the time series. Complete time series will therefore become rare in the long term, which means that only less powerful statistics can be used to analyse the data. As a result, networks for monitoring long-term changes may need to sample more plots than is necessary to describe the actual variation between plot and year.

In general, the variation between stands is greater than the variation between successive sampling years. Due to the high intra- and inter-plot variation, a dense network is required to evaluate the regional differences in forest nutrition within Europe. A one-year European survey of all Level I plots is suitable to evaluate the regional differences in forest nutrition within Europe. Due to the relatively low temporal variation, the temporal changes on a European scale could be evaluated on the basis of annual or bi-annual foliar surveys of the Level II network. Whether the surveys are annual or bi-annual is irrelevant when evaluating changes in forest nutrition. However, at the present state of understanding of forest ecosystems, the results from bi-annual surveys are more difficult or even impossible to use in correlative and up-scaling studies. The results of bi-annual surveys may prove to be less suitable for increasing our understanding of the functioning of forest ecosystems.

The results of this pilot study for Finland illustrate the strength and diversity of foliar surveys; although the environmental conditions are similar for spruce and pine (some plots are located very close together, experienced the same weather, decrease in S-deposition, ozone, CO_2, etc.), the reaction of the individual tree species is different. Due to these species-specific reactions, foliar analysis is expected to be a valuable tool for detecting the effects of global change on forest ecosystems and for monitoring changes in functional biodiversity2). Irrespective of whether a foliar survey is used to evaluate forest nutrition, global change or functional biodiversity, needle mass is a key parameter in interpreting the results of the survey. To allow interpretation of the foliar data independent of predetermined critical levels or ratios the needle mass and element concentration have to be determined. Threshold values allow a fast but approximate classification of the results. Owing to the fact that classification values were accepted by the 3rd and 5th meeting of the Expert Panel on Foliar Analysis for being applied to the whole of Europe, only large changes and extreme conditions could be detected. Given the lack of a sound scientific basis to the classification values, the use of classification values as a tool for data interpretation should be limited to data exploration. Whatever method is used, the results from a foliar survey should be analysed on an individual species basis (see also HENDRIKS et al., 1997).

The amount of data used in this analysis is limited; only 4 out of the 14 years were used in interpreting the changes in nutrient status. Therefore the results may be sensitive to subjective choices and random variation. The analyses presented above may also be biased owing to our choice of the start and end point of the time series. These shortcomings could be avoided by using the whole time series. Because the shifts in nutrient concentration, nutrient content and needle mass should be the basis of any evaluation of forest nutrition, suitable data analysis methods are needed to simultaneously process the element concentrations, contents and needle mass. Limiting the evaluation to only one of these parameters can obscure important changes. In addition, the methods that were used in this study only reveal changes on the national level; changes on the plot level can be masked. The analyses are here based on the analysis of individual nutrients, whereas in fact trees

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2) Functional biodiversity is the term used for diversity which is not biological but adds to the biological diversity. For further reading see DIAZ et al. (2003)

react to the relationships between the elements. Nutrient ratios can simulate these relationships but are not able to capture more than two elements. New methods are being developed to utilize the potential of foliar analysis to its full extent. These methods are based on artificial neuron networking, and they are therefore able to analyse the development of the relationships between several elements on the plot level. In addition to providing an insight into the development of forest nutrition, these methods are expected to increase the efficiency and quality of the data analysis. The methods are now being tested on the Finnish Level I data. In order to further tailor these methods for the ICP Forests programme, the Level II data should be evaluated using these new methods.

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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 2002, 16.8% 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. 15.1% 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*. 5.8% 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 **Sub-Atlantic** 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 18.9% 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.* In 2002, 4.1% of the sample plots were located in this region.

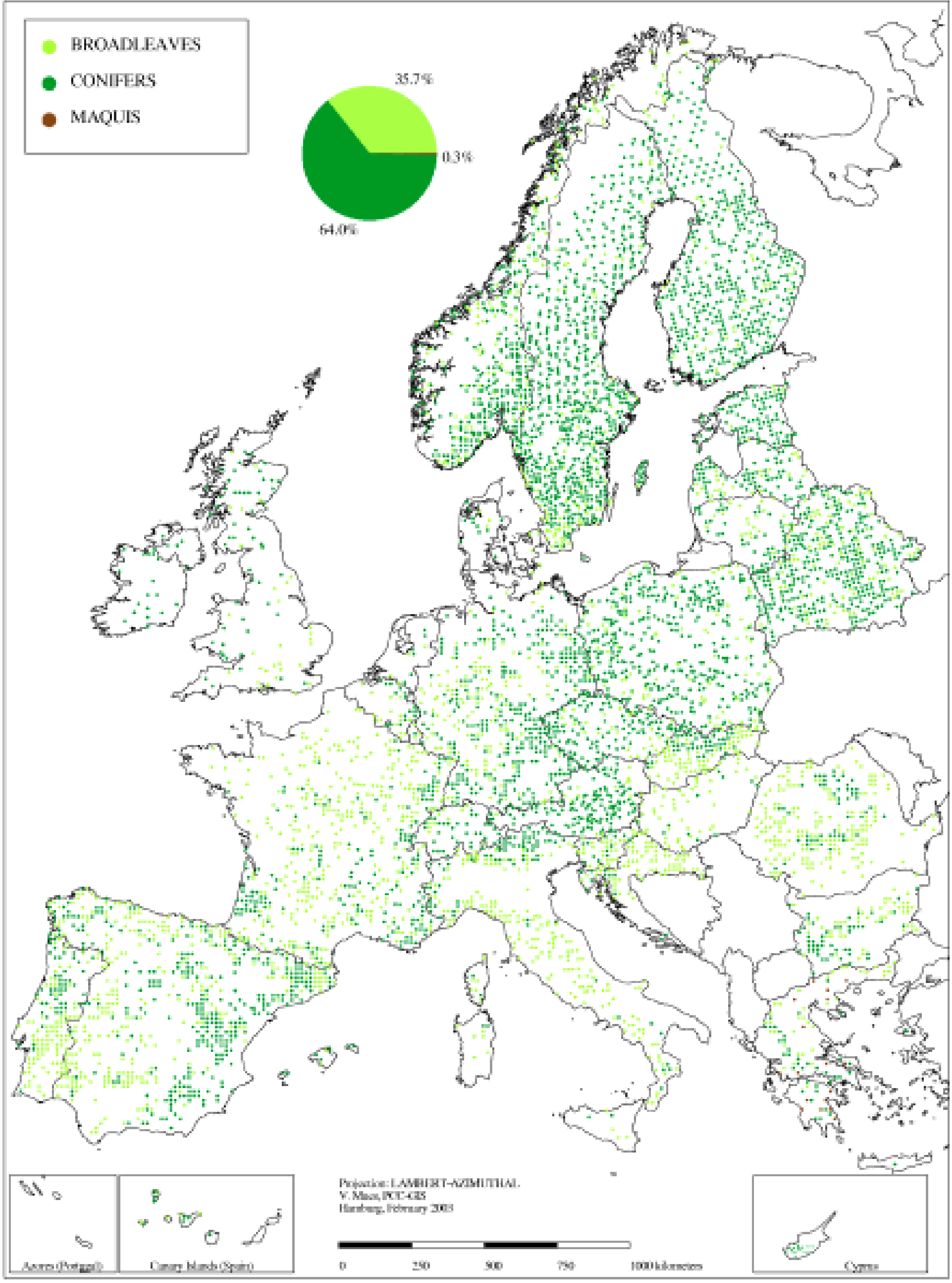
The **Mountainous (South)** region comprises plots on several mountain ridges. They share steep climatic gradients and consequently complex geobotanical structures, depending on altitude and exposition. They comprise the Alpine system (Pyrenees, Alps, Tatras, Carpathians and the Balkan), the Appenin, 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*. This climatic region comprises 12.0% 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.* 4.6% 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 (6.7% 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 (10.4% 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

Broad-leaves and conifers (2002)



Annex I-3
Species assessed (2002)

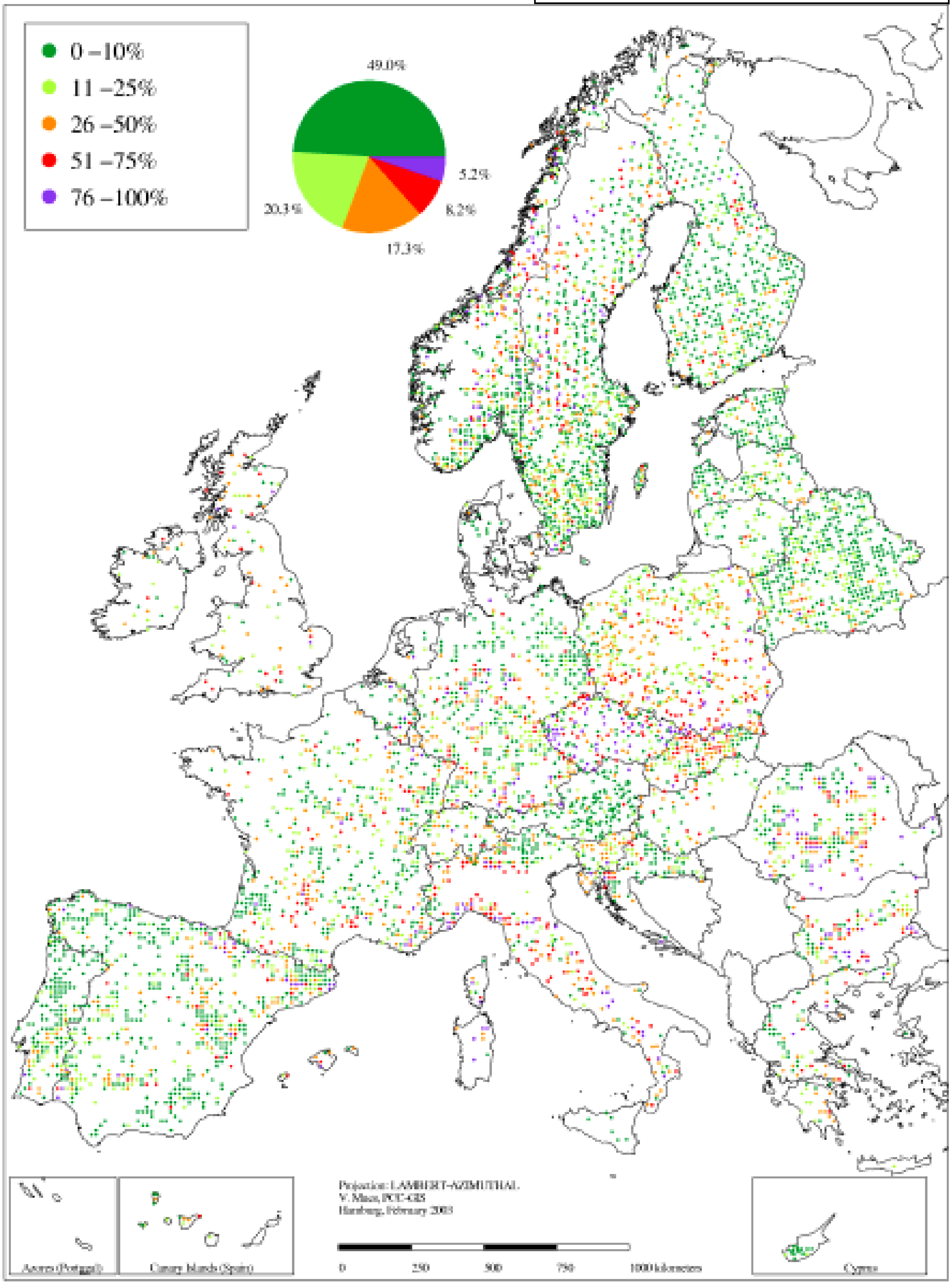
Species	Observed trees Number	%	Observed plots Number	%
Pinus sylvestris	35194	26.71	1824	17.80
Picea abies	26353	20.00	1479	14.43
Fagus sylvatica	11911	9.04	669	6.53
Quercus robur	4903	3.72	435	4.25
Quercus ilex	3869	2.94	226	2.21
Betula pubescens	3840	2.91	630	6.15
Pinus pinaster	3785	2.87	190	1.85
Betula pendula	3699	2.81	649	6.33
Quercus petraea	3353	2.55	350	3.42
Pinus nigra	2841	2.16	159	1.55
Pinus halepensis	2617	1.99	134	1.31
Abies alba	2086	1.58	205	2.00
Quercus pubescens	1928	1.46	160	1.56
Carpinus betulus	1741	1.32	233	2.27
Quercus suber	1678	1.27	100	0.98
Quercus cerris	1663	1.26	129	1.26
Eucalyptus spp.	1644	1.25	75	0.73
Castanea sativa	1365	1.04	154	1.50
Larix decidua	1266	0.96	190	1.85
Populus tremula	1110	0.84	255	2.49
Alnus glutinosa	977	0.74	139	1.36
Fraxinus excelsior	975	0.74	189	1.84
Quercus pyrenaica	970	0.74	56	0.55
Picea sitchensis	943	0.72	47	0.46
Robinia pseudoacacia	872	0.66	68	0.66
Quercus frainetto	830	0.63	44	0.43
Quercus rotundifolia	661	0.50	38	0.37
Pseudotsuga menziesii	573	0.43	50	0.49
Acer pseudoplatanus	531	0.40	161	1.57
Pinus pinea	511	0.39	39	0.38
Populus hybrides	426	0.32	21	0.20
Quercus faginea	399	0.30	50	0.49
Pinus brutia	377	0.29	19	0.19
Other broadleaves	364	0.28	77	0.75
Ostrya carpinifolia	358	0.27	60	0.59
Pinus radiata	329	0.25	18	0.18
Tilia cordata	307	0.23	67	0.65
Juniperus thurifera	302	0.23	23	0.22
Abies cephalonica	269	0.20	13	0.13
Alnus incana	241	0.18	45	0.44
Quercus coccifera	224	0.17	17	0.17
Prunus avium	223	0.17	104	1.02
Abies borisii-regis	179	0.14	10	0.10
Olea europaea	177	0.13	20	0.20
Pinus contorta	176	0.13	13	0.13
Acer campestre	167	0.13	66	0.64
Quercus rubra	162	0.12	22	0.21

Species	**Observed trees** **Number**	**%**	**Observed plots** **Number**	**%**
Pinus uncinata	146	0.11	13	0.13
Fagus moesiaca	121	0.09	6	0.06
Fraxinus angustifolia	119	0.09	13	0.13
Populus nigra	117	0.09	11	0.11
Fraxinus ornus	114	0.09	40	0.39
Acer platanoides	107	0.08	38	0.37
Tilia platyphyllos	104	0.08	19	0.19
Pinus cembra	97	0.07	10	0.10
Alnus cordata	88	0.07	5	0.05
Platanus orientalis	88	0.07	5	0.05
Sorbus aucuparia	74	0.06	29	0.28
Larix kaempferi	68	0.05	8	0.08
Pinus strobus	64	0.05	8	0.08
Arbutus unedo	57	0.04	11	0.11
Populus canescens	51	0.04	4	0.04
Salix caprea	50	0.04	33	0.32
Juniperus oxycedrus	50	0.04	18	0.18
Sorbus aria	49	0.04	30	0.29
Ulmus glabra	49	0.04	24	0.23
Acer monspessulanum	46	0.03	13	0.13
Juniperus phoenicea	46	0.03	10	0.10
Acer opalus	44	0.03	17	0.17
Populus alba	44	0.03	10	0.10
Juniperus communis	43	0.03	7	0.07
Other conifers	41	0.03	9	0.09
Phillyrea latifolia	40	0.03	9	0.09
Salix spp.	39	0.03	11	0.11
Cupressus sempervirens	36	0.03	5	0.05
Cedrus atlantica	32	0.02	4	0.04
Salix alba	28	0.02	4	0.04
Sorbus torminalis	25	0.02	21	0.20
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
Corylus avellana	19	0.01	10	0.10
Quercus fruticosa	19	0.01	1	0.01
Ulmus minor	18	0.01	8	0.08
Fagus orientalis	15	0.01	1	0.01
Pinus leucodermis	11	0.01	1	0.01
Pyrus communis	10	0.01	6	0.06
Pistacia terebinthus	10	0.01	1	0.01
Sorbus domestica	9	0.01	8	0.08
Tsuga spp.	9	0.01	1	0.01
Ilex aquifolium	8	0.01	5	0.05
Juglans regia	8	0.01	4	0.04
Ceratonia siliqua	8	0.01	3	0.03
Cercis siliquastrum	8	0.01	1	0.01
Cupressus lusitanica	8	0.01	1	0.01
Alnus viridis	7	0.01	1	0.01

Species	**Observed trees** **Number**	**%**	**Observed plots** **Number**	**%**
Ulmus laevis	6	0.00	3	0.03
Carpinus orientalis	5	0.00	1	0.01
Cedrus deodara	4	0.00	1	0.01
Quercus trojana	3	0.00	2	0.02
Abies grandis	3	0.00	1	0.01
Pinus mugo	3	0.00	1	0.01
Thuja spp.	3	0.00	1	0.01
Juglans nigra	2	0.00	2	0.02
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
Taxus baccata	1	0.00	1	0.01
All species	131741	100.00	10246	100.00

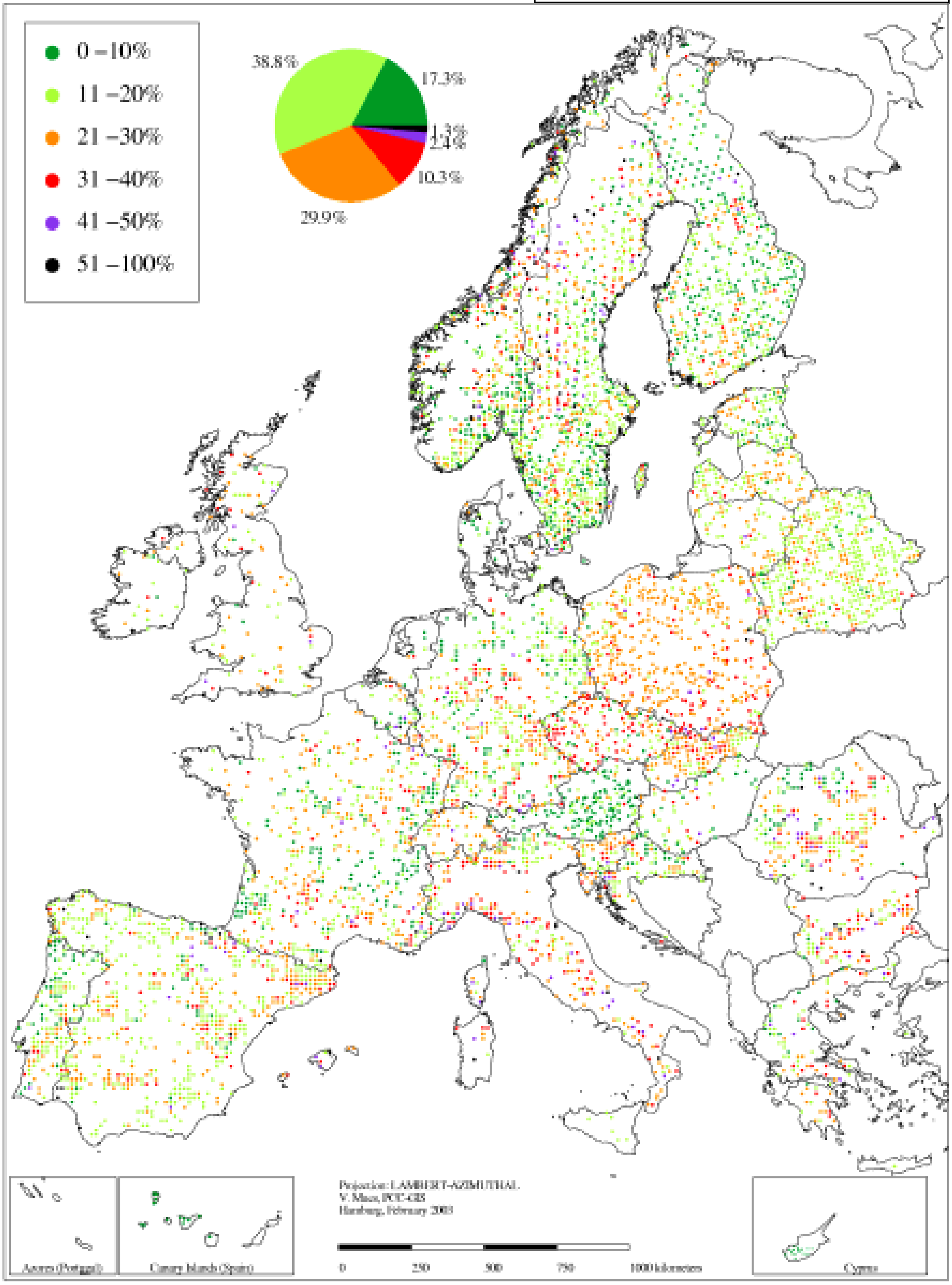
Annex I-4
Percentage of trees damaged (2002)

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.



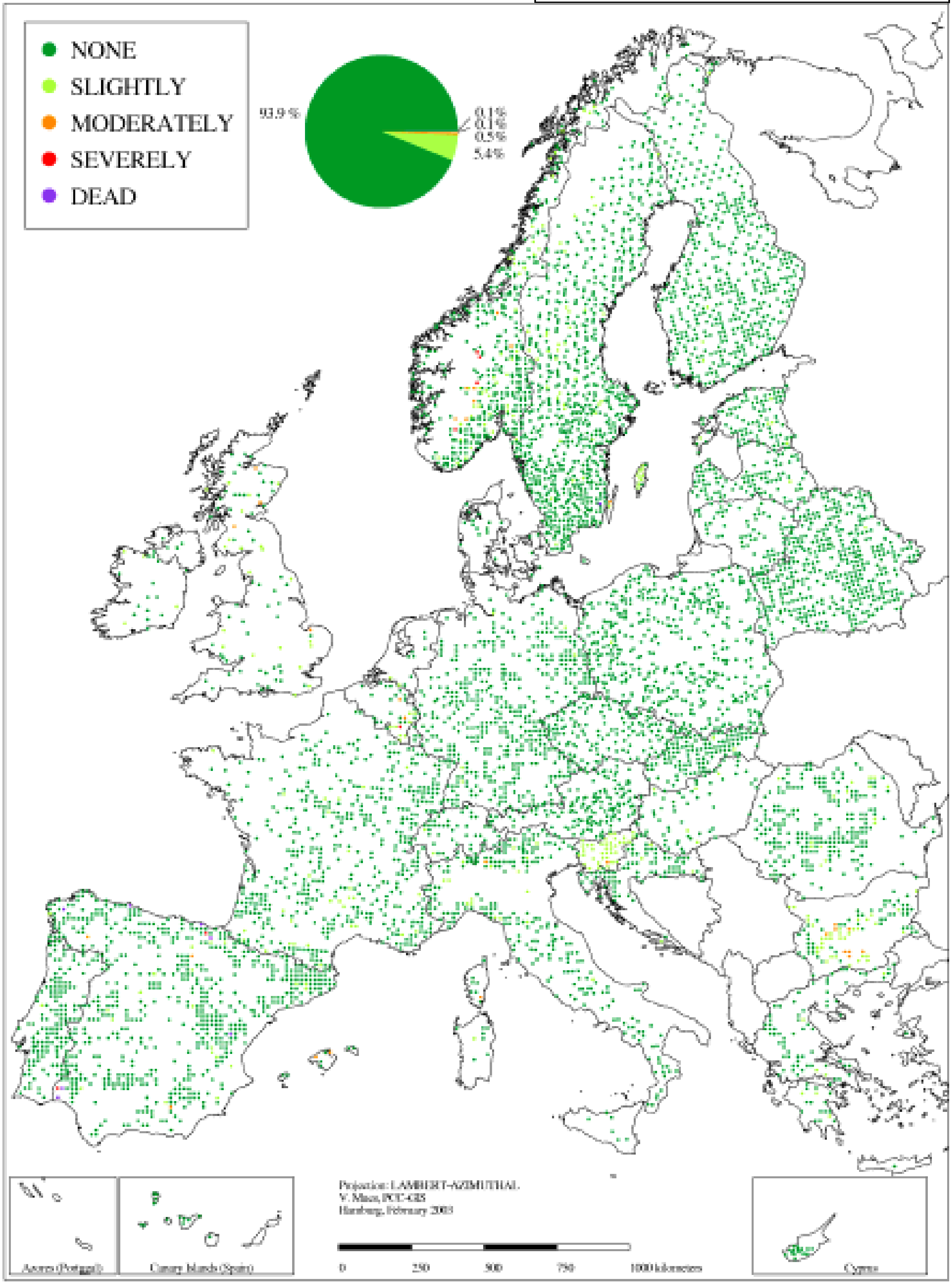
Annex I-5
Mean plot defoliation of all species (2002)

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.



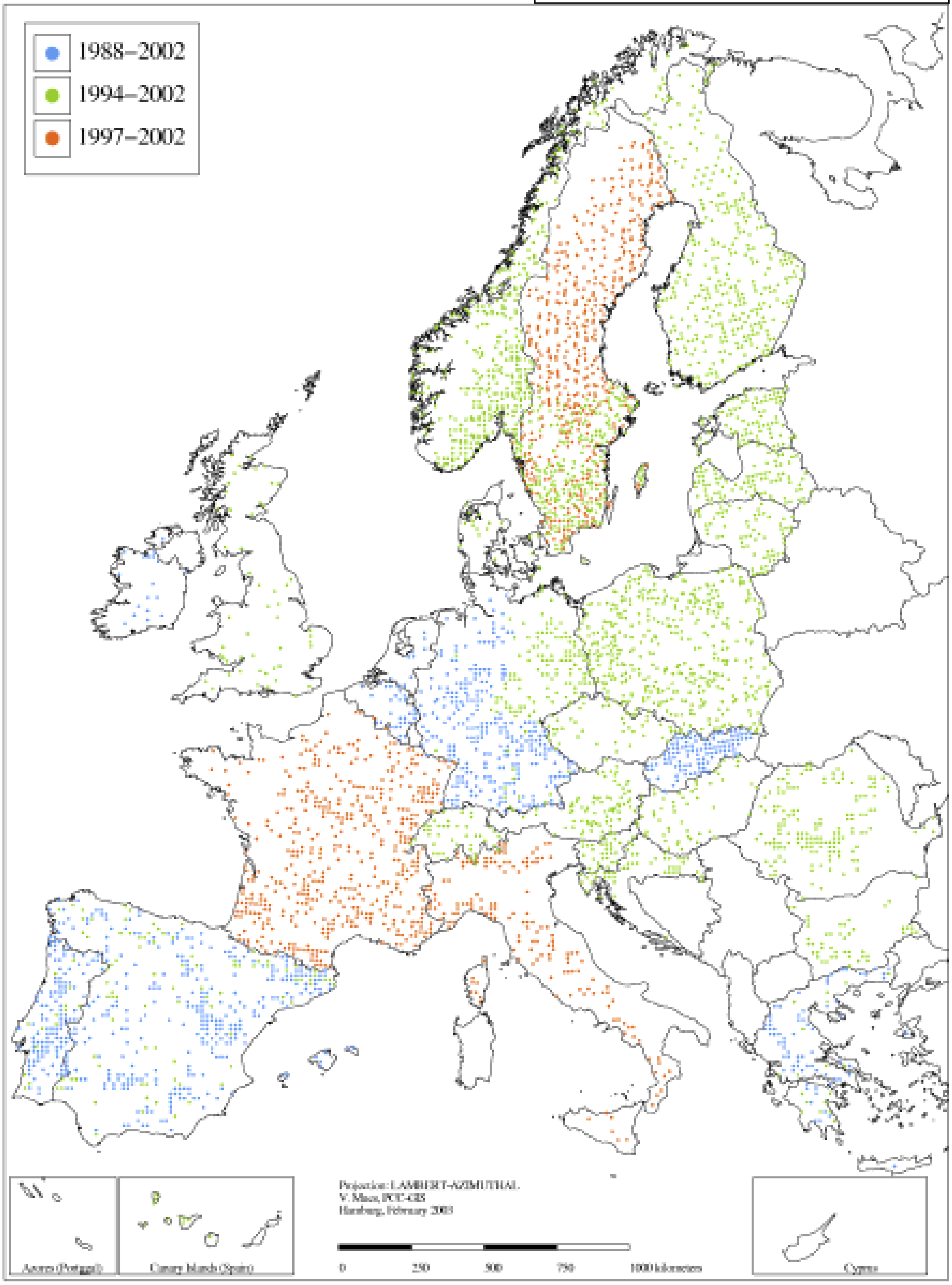
Annex I-6
Plot discolouration (2002)

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.



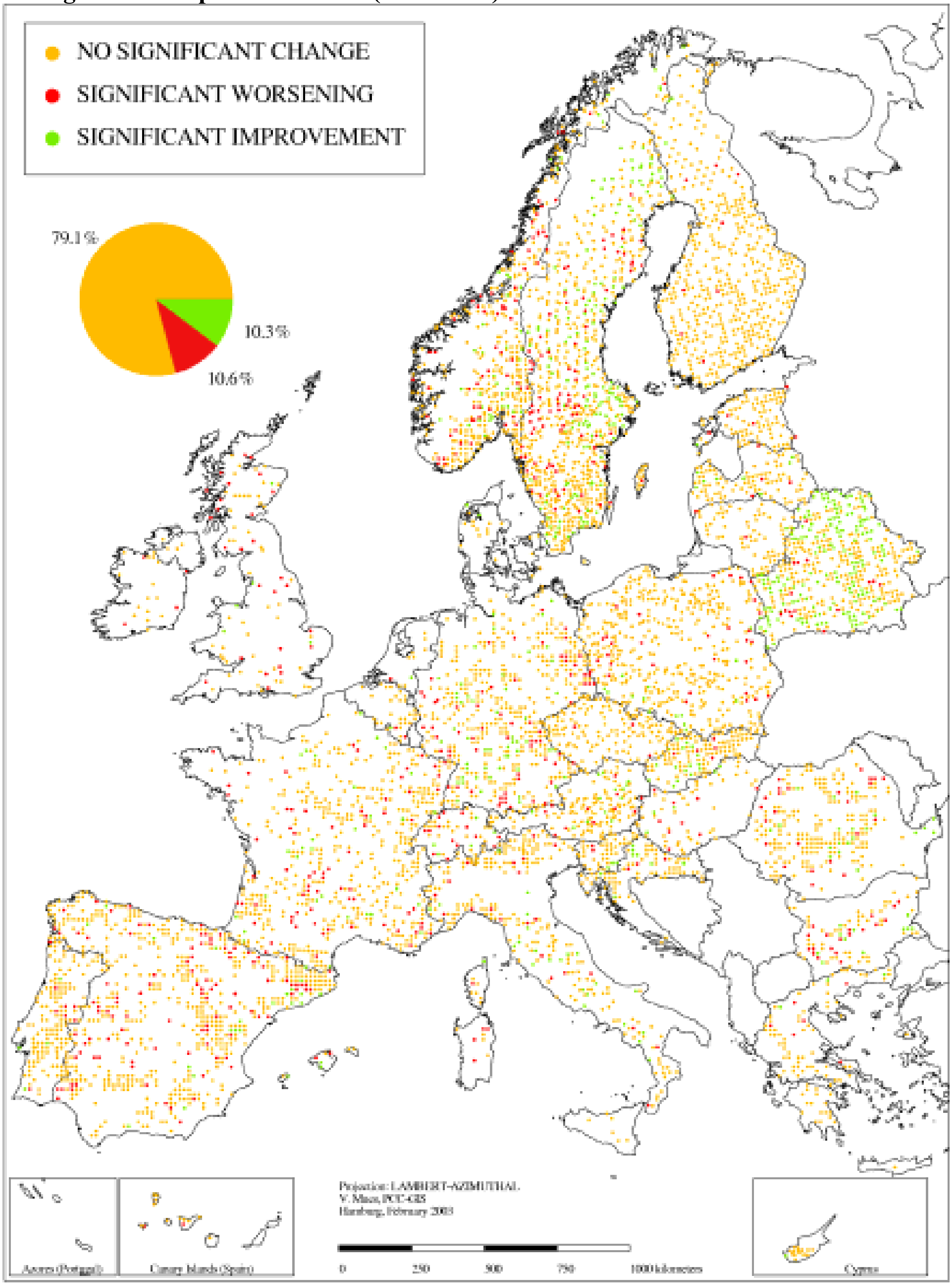
Annex I-7
Distribution of plots of the CSTs_{88}, CSTs_{94}, and CSTs_{97}

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 (2001-2002)



Annex I-9

Development of defoliation of most common species (1988-2002).

Picea abies

ATLANTIC (NORTH)	0-10%	>10-25%	>25%	SUB-ATLANTIC	0-10%	>10-25%	>25%	MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%
1988	55.9	25.0	19.1	1988	30.2	37.3	32.5	1988	27.4	43.2	29.4
1989	48.7	34.2	17.1	1989	28.4	37.9	33.7	1989	23.4	37.9	38.7
1990	46.0	31.6	22.4	1990	27.8	38.6	33.6	1990	28.2	36.7	35.1
1991	45.4	32.9	21.7	1991	27.6	41.7	30.7	1991	22.0	44.6	33.4
1992	38.2	48.0	13.8	1992	29.1	44.9	26.0	1992	12.1	46.4	41.5
1993	40.1	34.9	25.0	1993	26.5	39.9	33.6	1993	16.1	42.2	41.7
1994	38.2	37.5	24.3	1994	23.6	40.1	36.3	1994	15.9	41.4	42.7
1995	42.1	35.5	22.4	1995	24.9	36.9	38.2	1995	21.0	44.4	34.6
1996	44.1	30.9	25.0	1996	30.5	42.5	27.0	1996	27.0	40.8	32.2
1997	42.2	28.9	28.9	1997	25.8	41.6	32.6	1997	23.5	44.5	32.0
1998	44.7	29.6	25.7	1998	27.3	40.2	32.5	1998	24.1	41.0	34.9
1999	48.7	19.7	31.6	1999	26.1	38.6	35.3	1999	27.4	42.5	30.1
2000	40.2	24.3	35.5	2000	24.7	40.0	35.3	2000	26.9	45.9	27.2
2001	41.5	26.3	32.2	2001	22.1	43.1	34.8	2001	15.4	54.1	30.5
2002	44.8	28.9	26.3	2002	20.1	43.5	36.4	2002	13.9	55.3	30.8

ALL REGIONS	0-10%	>10-25%	>25%
1988	30.7	38.5	30.8
1989	27.9	37.7	34.4
1990	28.8	37.7	33.5
1991	26.8	42.1	31.1
1992	24.3	45.5	30.2
1993	24.0	40.3	35.7
1994	21.9	40.4	37.7
1995	24.6	39.1	36.3
1996	30.1	41.4	28.5
1997	25.9	41.9	32.2
1998	27.2	39.9	32.9
1999	27.7	38.8	33.5
2000	26.1	41.1	32.8
2001	21.1	45.6	33.3
2002	19.4	46.5	34.1

Pinus sylvestris

ATLANTIC (NORTH)	0-10%	>10-25%	>25%	SUB-ATLANTIC	0-10%	>10-25%	>25%	MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%
1988	68.7	26.1	5.2	1988	32.0	40.2	27.8	1988	55.4	26.9	17.7
1989	58.4	33.9	7.7	1989	28.1	40.8	31.1	1989	58.3	27.3	14.4
1990	53.9	39.1	7.0	1990	28.6	37.5	33.9	1990	63.8	23.3	12.9
1991	55.0	38.2	6.8	1991	17.3	50.0	32.7	1991	47.5	37.1	15.4
1992	60.9	30.5	8.6	1992	18.1	49.1	32.8	1992	37.5	41.9	20.6
1993	53.6	39.1	7.3	1993	25.9	47.5	26.6	1993	33.8	45.2	21.0
1994	49.6	42.0	8.4	1994	12.0	51.2	36.8	1994	24.6	45.2	30.2
1995	47.3	45.7	7.0	1995	19.0	49.6	31.4	1995	27.7	58.3	14.0
1996	41.6	50.0	8.4	1996	23.2	50.2	26.6	1996	36.0	50.5	13.5
1997	47.7	47.3	5.0	1997	23.8	52.3	23.9	1997	34.0	56.2	9.8
1998	57.1	37.7	5.2	1998	25.8	54.1	20.1	1998	38.3	51.1	10.6
1999	47.1	44.3	8.6	1999	20.8	60.7	18.5	1999	42.5	47.7	9.8
2000	47.5	40.5	12.0	2000	14.3	65.8	19.9	2000	33.1	55.0	11.9
2001	42.7	46.2	11.1	2001	18.3	54.6	27.1	2001	31.7	56.2	12.1
2002	44.1	45.0	10.9	2002	18.1	59.0	22.9	2002	21.7	57.3	21.0

Pinus sylvestris

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1988	86.5	11.1	2.4
1989	90.7	8.2	1.1
1990	89.9	8.2	1.9
1991	86.1	12.0	1.9
1992	72.0	17.9	10.1
1993	62.8	20.9	16.3
1994	62.7	22.6	14.7
1995	55.5	29.6	14.9
1996	51.7	38.0	10.3
1997	51.4	41.3	7.3
1998	52.4	40.8	6.8
1999	53.6	41.8	4.6
2000	55.2	41.8	3.0
2001	51.4	45.1	3.5
2002	49.4	40.8	9.8

ALL REGIONS	0-10%	>10-25%	>25%
1988	54.3	29.0	16.7
1989	51.7	30.4	17.9
1990	51.7	29.5	18.8
1991	43.2	38.0	18.8
1992	39.7	38.9	21.4
1993	39.9	40.3	19.8
1994	31.2	42.7	26.1
1995	33.0	47.1	19.9
1996	34.9	47.7	17.4
1997	36.4	49.2	14.4
1998	39.4	47.7	12.9
1999	36.1	51.5	12.4
2000	31.7	54.5	13.8
2001	31.6	51.5	16.9
2002	29.4	52.6	18.0

Fagus sylvatica

ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1988	40.6	45.6	13.8
1989	34.7	49.0	16.3
1990	18.4	41.9	39.7
1991	36.0	44.3	19.7
1992	21.3	46.9	31.8
1993	20.1	49.8	30.1
1994	25.9	49.4	24.7
1995	15.5	52.3	32.2
1996	15.9	51.9	32.2
1997	22.6	48.1	29.3
1998	25.9	46.9	27.2
1999	10.5	61.0	28.5
2000	8.8	40.6	50.6
2001	17.2	41.4	41.4
2002	13.4	43.1	43.5

SUB-ATLANTIC	0-10%	>10-25%	>25%
1988	31.4	43.5	25.1
1989	34.3	42.5	23.2
1990	28.2	49.1	22.7
1991	35.6	46.3	18.1
1992	21.5	51.3	27.2
1993	23.1	50.2	26.7
1994	12.6	55.2	32.2
1995	16.6	49.8	33.6
1996	19.5	56.6	23.9
1997	22.3	57.9	19.8
1998	20.8	55.6	23.6
1999	15.7	60.5	23.8
2000	23.9	54.5	21.6
2001	17.9	51.9	30.2
2002	22.3	58.7	19.0

MOUNTAINOUS (SOUTH)	0-10%	>10-25%	>25%
1988	48.2	36.7	15.1
1989	24.2	42.8	33.0
1990	46.1	43.7	10.2
1991	64.1	30.0	5.9
1992	60.0	27.2	12.8
1993	57.0	28.5	14.5
1994	51.3	35.4	13.3
1995	42.8	41.9	15.3
1996	33.2	50.1	16.7
1997	29.4	50.8	19.8
1998	49.7	42.2	8.1
1999	37.3	50.8	11.9
2000	42.3	48.4	9.3
2001	27.0	57.7	15.3
2002	30.3	60.0	9.7

ALL REGIONS	0-10%	>10-25%	>25%
1988	37.6	41.3	21.1
1989	32.6	43.2	24.2
1990	34.7	45.5	19.8
1991	45.9	40.0	14.1
1992	35.6	42.2	22.2
1993	35.0	42.8	22.2
1994	27.8	47.6	24.6
1995	26.6	46.4	27.0
1996	26.1	52.4	21.5
1997	26.4	53.5	20.1
1998	31.9	49.8	18.3
1999	24.2	56.0	19.8
2000	30.0	50.3	19.7
2001	23.0	51.5	25.5
2002	25.5	56.5	18.0

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	54.3	35.1	10.6	1988	71.9	25.1	3.0	1988	68.0	27.2	4.8
1989	78.5	18.1	3.4	1989	60.1	35.5	4.4	1989	64.6	31.3	4.1
1990	81.2	17.7	1.1	1990	63.1	22.0	14.9	1990	66.6	20.8	12.6
1991	59.9	36.2	3.9	1991	45.7	36.3	18.0	1991	48.8	36.5	14.7
1992	45.3	45.0	9.7	1992	38.4	45.6	16.0	1992	39.8	45.0	15.2
1993	33.0	57.7	9.3	1993	37.8	56.6	5.6	1993	36.7	56.8	6.5
1994	28.0	53.5	18.5	1994	32.5	58.6	8.9	1994	30.8	58.3	10.9
1995	17.9	48.5	33.6	1995	15.3	59.8	24.9	1995	15.6	58.2	26.2
1996	22.0	51.9	26.1	1996	19.4	57.3	23.3	1996	19.9	56.7	23.4
1997	28.2	56.9	14.9	1997	28.9	59.0	12.1	1997	29.1	58.5	12.4
1998	34.5	51.3	14.2	1998	30.4	56.4	13.2	1998	31.7	55.0	13.3
1999	23.1	59.0	17.9	1999	22.6	53.3	24.1	1999	23.3	54.4	22.3
2000	23.1	56.2	20.7	2000	17.0	57.7	25.3	2000	18.7	57.4	23.9
2001	23.3	62.5	14.2	2001	19.3	63.4	17.3	2001	19.9	63.3	16.8
2002	15.9	63.2	20.9	2002	18.1	62.5	19.4	2002	17.4	62.7	19.9

Pinus pinaster

ATLANTIC (SOUTH)	0-10%	>10-25%	>25%	MEDITERR. (HIGHER)	0-10%	>10-25%	>25%	MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1988	83.9	15.7	0.4	1988	94.3	5.7	0.0	1988	81.7	10.1	8.2
1989	85.5	11.4	3.1	1989	88.0	10.4	1.6	1989	79.1	14.3	6.6
1990	46.3	14.8	38.9	1990	78.7	15.6	5.7	1990	68.5	23.8	7.7
1991	46.8	23.1	30.1	1991	81.8	15.1	3.1	1991	64.2	27.6	8.2
1992	63.7	24.9	11.4	1992	85.5	13.5	1.0	1992	63.4	28.9	7.7
1993	63.8	27.5	8.7	1993	80.2	19.3	0.5	1993	71.2	21.8	7.0
1994	64.6	27.1	8.3	1994	70.3	27.1	2.6	1994	64.1	28.9	7.0
1995	60.2	34.1	5.7	1995	63.5	34.4	2.1	1995	51.9	39.4	8.7
1996	61.6	33.2	5.2	1996	67.2	30.2	2.6	1996	50.0	41.9	8.1
1997	62.0	33.2	4.8	1997	71.3	26.6	2.1	1997	37.0	51.9	11.1
1998	56.8	38.4	4.8	1998	71.3	27.1	1.6	1998	37.8	53.0	9.2
1999	54.6	41.5	3.9	1999	63.6	32.8	3.6	1999	34.8	56.5	8.7
2000	55.1	43.2	1.7	2000	63.0	33.9	3.1	2000	39.5	53.9	6.6
2001	41.5	52.4	6.1	2001	58.8	39.6	1.6	2001	39.1	54.2	6.7
2002	43.2	45.4	11.4	2002	52.6	45.3	2.1	2002	44.3	48.4	7.3

Pinus pinaster

ALL REGIONS	0-10%	>10-25%	>25%
1988	84.5	10.1	5.4
1989	82.1	12.8	5.1
1990	67.2	20.4	12.4
1991	64.6	24.5	10.9
1992	67.4	25.4	7.2
1993	71.5	22.2	6.3
1994	65.0	28.5	6.5
1995	55.6	37.3	7.1
1996	55.3	37.9	6.8
1997	47.5	44.0	8.5
1998	47.0	45.9	7.1
1999	43.5	49.6	6.9
2000	46.5	48.4	5.1
2001	43.2	51.0	5.8
2002	45.7	47.2	7.1

Quercus suber

MEDITERR. (LOWER)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1988	92.1	7.1	0.8	1988	92.3	6.9	0.8
1989	64.8	28.4	6.8	1989	63.2	27.7	9.1
1990	36.9	20.5	42.6	1990	36.4	20.2	43.4
1991	25.1	31.5	43.4	1991	25.1	31.1	43.8
1992	26.6	38.2	35.2	1992	26.4	37.7	35.9
1993	48.5	43.4	8.1	1993	49.9	42.2	7.9
1994	40.6	48.8	10.6	1994	42.3	47.4	10.3
1995	20.8	56.6	22.6	1995	22.9	55.2	21.9
1996	33.0	52.4	14.6	1996	34.0	51.8	14.2
1997	35.6	52.4	12.0	1997	37.3	51.0	11.7
1998	26.0	61.1	12.9	1998	27.3	60.2	12.5
1999	22.6	57.8	19.6	1999	23.9	57.0	19.1
2000	21.5	61.1	17.4	2000	22.9	60.2	16.9
2001	21.3	61.7	17.0	2001	21.6	61.7	16.7
2002	22.3	59.8	17.9	2002	22.5	59.9	17.6

Quercus robur and *Q. petraea*

ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1988	31.6	43.1	25.3
1989	44.7	47.4	7.9
1990	71.5	27.4	1.1
1991	54.7	40.0	5.3
1992	32.1	55.8	12.1
1993	28.9	52.2	18.9
1994	46.3	40.5	13.2
1995	51.1	38.4	10.5
1996	24.2	45.8	30.0
1997	24.7	54.2	21.1
1998	26.3	50.5	23.2
1999	32.1	37.9	30.0
2000	35.3	42.6	22.1
2001	27.4	50.0	22.6
2002	19.5	51.0	29.5

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1988	13.1	61.2	25.7
1989	32.2	52.0	15.8
1990	19.7	55.7	24.6
1991	28.4	47.6	24.0
1992	32.2	40.5	27.3
1993	14.8	53.0	32.2
1994	27.9	43.1	29.0
1995	13.1	44.8	42.1
1996	15.3	43.7	41.0
1997	16.9	42.1	41.0
1998	15.3	45.4	39.3
1999	26.8	51.9	21.3
2000	23.5	50.8	25.7
2001	19.7	54.6	25.7
2002	13.1	53.6	33.3

SUB-ATLANTIC	0-10%	>10-25%	>25%
1988	30.1	40.5	29.4
1989	21.2	43.1	35.7
1990	20.8	52.3	26.9
1991	19.5	47.5	33.0
1992	17.3	49.9	32.8
1993	14.5	47.7	37.8
1994	9.9	45.0	45.1
1995	11.5	43.8	44.7
1996	12.0	52.5	35.5
1997	14.3	52.2	33.5
1998	14.0	42.8	43.2
1999	13.0	60.8	26.2
2000	13.8	64.4	21.8
2001	13.5	61.6	24.9
2002	20.2	58.6	21.2

ALL REGIONS	0-10%	>10-25%	>25%
1988	28.5	42.6	28.9
1989	28.8	41.0	30.2
1990	30.4	43.5	26.1
1991	30.6	43.9	25.5
1992	24.1	48.7	27.2
1993	19.9	47.8	32.3
1994	20.9	44.3	34.8
1995	19.6	43.9	36.5
1996	15.5	48.8	35.7
1997	17.0	48.4	34.6
1998	17.4	44.2	38.4
1999	20.0	53.2	26.8
2000	19.2	57.0	23.8
2001	17.1	57.7	25.2
2002	18.4	56.1	25.5

Abies alba

MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%
1988	26.0	26.5	47.5
1989	16.0	29.0	55.0
1990	21.5	31.5	47.0
1991	25.5	34.0	40.5
1992	15.5	42.5	42.0
1993	12.5	31.5	56.0
1994	15.0	42.5	42.5
1995	15.0	41.0	44.0
1996	12.5	34.0	53.5
1997	11.5	42.5	46.0
1998	14.5	38.0	47.5
1999	12.0	43.5	44.5
2000	13.5	45.5	41.0
2001	11.5	43.0	45.5
2002	8.5	51.0	40.5

ALL REGIONS	0-10%	>10-25%	>25%
1988	23.5	27.3	49.2
1989	15.6	27.7	56.7
1990	19.4	29.4	51.2
1991	22.5	30.8	46.7
1992	14.9	35.6	49.5
1993	12.8	29.4	57.8
1994	13.5	37.4	49.1
1995	14.5	36.3	49.2
1996	13.5	31.5	55.0
1997	14.5	37.4	48.1
1998	18.3	32.5	49.2
1999	13.1	40.1	46.8
2000	14.9	39.8	45.3
2001	12.5	38.1	49.4
2002	11.1	42.9	46.0

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
2002	50.6	32.7	16.7	2002	50.6	32.7	16.7

All species

ATLANTIC (NORTH)	0-10%	>10-25%	>25%	ATLANTIC (SOUTH)	0-10%	>10-25%	>25%	SUB-ATLANTIC	0-10%	>10-25%	>25%
1988	59.6	30.3	10.1	1988	84.2	11.7	4.1	1988	32.8	39.4	27.8
1989	50.3	39.0	10.7	1989	86.7	10.1	3.2	1989	29.1	39.8	31.1
1990	54.4	32.8	12.8	1990	67.5	14.2	18.3	1990	26.8	41.5	31.7
1991	51.0	37.0	12.0	1991	63.2	19.5	17.3	1991	27.6	44.3	28.1
1992	45.3	40.0	14.7	1992	70.3	21.1	8.6	1992	23.3	46.0	30.7
1993	40.7	41.4	17.9	1993	63.2	27.1	9.7	1993	23.5	44.0	32.5
1994	41.3	42.9	15.8	1994	64.0	29.1	6.9	1994	16.0	45.6	38.4
1995	40.7	41.8	17.5	1995	61.3	32.1	6.6	1995	19.2	43.4	37.4
1996	37.7	43.4	18.9	1996	57.1	37.5	5.4	1996	22.6	49.4	28.0
1997	41.7	42.2	16.1	1997	59.8	35.4	4.8	1997	23.5	49.9	26.6
1998	46.0	38.3	15.7	1998	54.7	39.4	5.9	1998	23.3	47.3	29.4
1999	42.3	39.7	18.0	1999	55.8	39.1	5.1	1999	20.6	52.3	27.1
2000	40.9	36.1	23.0	2000	50.7	43.0	6.3	2000	21.7	51.7	26.6
2001	39.9	38.5	21.6	2001	43.9	47.2	8.9	2001	19.4	48.9	31.7
2002	34.4	42.9	22.7	2002	38.2	49.6	12.2	2002	20.5	51.8	27.7

MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%	MEDITERR. (HIGHER)	0-10%	>10-25%	>25%	MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1988	45.6	34.5	19.9	1988	61.1	29.4	9.5	1988	77.1	18.5	4.4
1989	40.7	30.9	28.4	1989	67.9	25.3	6.8	1989	71.5	24.2	4.3
1990	46.6	32.3	21.1	1990	66.5	25.6	7.9	1990	62.5	21.9	15.6
1991	46.8	35.2	18.0	1991	61.3	28.5	10.2	1991	53.7	28.9	17.4
1992	35.8	39.2	25.0	1992	52.6	34.2	13.2	1992	45.8	37.1	17.1
1993	34.1	39.1	26.8	1993	47.0	40.0	13.0	1993	50.5	41.3	8.2
1994	30.4	42.4	27.2	1994	43.9	40.6	15.5	1994	44.5	43.8	11.7
1995	28.5	48.3	23.2	1995	35.8	41.6	22.6	1995	28.5	50.7	20.8
1996	30.0	46.1	23.9	1996	38.2	42.8	19.0	1996	32.3	50.9	16.8
1997	29.2	47.0	23.8	1997	41.6	42.8	15.6	1997	33.6	55.6	10.8
1998	36.1	42.6	21.3	1998	45.4	41.4	13.2	1998	33.9	54.4	11.7
1999	34.1	46.4	19.5	1999	42.2	46.0	11.8	1999	29.0	54.9	16.1
2000	32.1	49.8	18.1	2000	40.2	47.1	12.7	2000	27.4	56.0	16.6
2001	22.8	56.0	21.2	2001	36.0	49.9	14.1	2001	27.2	58.1	14.7
2002	21.4	56.5	22.1	2002	34.4	48.0	17.6	2002	26.7	56.8	16.5

ALL REGIONS	0-10%	>10-25%	>25%
1988	55.6	29.5	14.9
1989	52.6	30.6	16.8
1990	49.7	30.4	19.9
1991	46.3	34.6	19.1
1992	39.5	39.3	21.2
1993	39.2	41.0	19.8
1994	34.3	43.0	22.7
1995	28.9	45.5	25.6
1996	31.2	47.5	21.3
1997	32.7	48.9	18.4
1998	34.5	46.8	18.7
1999	31.3	49.7	19.0
2000	30.2	50.5	19.3
2001	27.0	52.1	20.9
2002	26.2	52.7	21.1

Annex I-10

Development of defoliation of most common species (1994-2002).

Picea abies

BOREAL	0-10%	>10-25%	>25%	BOREAL (TEMPERATE)	0-10%	>10-25%	>25%	ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1994	57.7	29.0	13.3	1994	43.4	39.6	17.0	1994	58.2	26.9	14.9
1995	56.2	26.5	17.3	1995	49.5	35.9	14.6	1995	54.5	31.3	14.2
1996	55.7	25.2	19.1	1996	40.3	42.6	17.1	1996	55.6	28.5	15.9
1997	52.0	28.8	19.2	1997	39.7	43.3	17.0	1997	58.5	26.2	15.3
1998	51.3	29.2	19.5	1998	38.7	45.1	16.2	1998	52.8	33.0	14.2
1999	50.9	28.6	20.5	1999	33.4	45.9	20.7	1999	54.2	30.8	15.0
2000	44.4	35.1	20.5	2000	36.6	44.7	18.7	2000	56.5	28.5	15.0
2001	42.8	34.8	22.4	2001	33.3	47.5	19.2	2001	57.7	26.8	15.5
2002	44.6	35.2	20.2	2002	36.2	47.2	16.6	2002	55.6	27.1	17.3

SUB-ATLANTIC	0-10%	>10-25%	>25%	CONTINENTAL	0-10%	>10-25%	>25%	MOUNTAINOUS (NORTH)	0-10%	>10-25%	>25%
1994	21.8	37.0	41.2	1994	43.3	28.0	28.7	1994	48.2	20.4	31.4
1995	23.6	34.5	41.9	1995	43.7	29.1	27.2	1995	46.0	21.5	32.5
1996	26.8	34.0	39.2	1996	44.0	28.0	28.0	1996	44.6	18.0	37.4
1997	22.2	36.0	41.8	1997	40.6	31.1	28.3	1997	44.5	20.7	34.8
1998	22.7	37.0	40.3	1998	42.5	29.9	27.6	1998	44.9	19.7	35.4
1999	22.9	36.2	40.9	1999	44.1	35.0	20.9	1999	47.2	22.7	30.1
2000	21.1	37.6	41.3	2000	41.7	37.0	21.3	2000	44.7	27.5	27.8
2001	18.4	40.4	41.2	2001	41.7	39.0	19.3	2001	48.2	21.4	30.4
2002	18.4	38.9	42.7	2002	42.9	38.2	18.9	2002	39.3	28.8	31.9

MOUNTAINOUS (SOUTH)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1994	47.8	29.8	22.4	1994	40.7	32.7	26.6
1995	48.3	31.5	20.2	1995	41.5	31.8	26.7
1996	51.8	29.0	19.2	1996	42.2	31.3	26.5
1997	49.0	31.2	19.8	1997	39.3	33.3	27.4
1998	49.1	29.8	21.1	1998	39.0	33.9	27.1
1999	50.1	30.9	19.0	1999	38.7	34.0	27.3
2000	47.2	31.9	20.9	2000	36.7	35.8	27.5
2001	43.2	35.7	21.1	2001	34.4	37.6	28.0
2002	41.4	37.1	21.5	2002	34.1	37.8	28.1

Pinus sylvestris

BOREAL	0-10%	>10-25%	>25%	BOREAL (TEMPERATE)	0-10%	>10-25%	>25%	ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1994	68.3	27.1	4.6	1994	22.0	49.1	28.9	1994	50.3	40.4	9.3
1995	72.1	23.4	4.5	1995	25.8	53.9	20.3	1995	48.0	43.4	8.6
1996	72.8	23.0	4.2	1996	27.7	55.3	17.0	1996	42.9	48.8	8.3
1997	70.1	26.1	3.8	1997	24.5	59.9	15.6	1997	50.7	42.1	7.2
1998	70.2	26.1	3.7	1998	30.8	56.6	12.6	1998	51.6	40.9	7.5
1999	70.0	26.2	3.8	1999	22.1	66.5	11.4	1999	46.5	43.2	10.3
2000	71.2	26.0	2.8	2000	29.6	60.3	10.1	2000	47.0	42.4	10.6
2001	68.0	28.4	3.6	2001	22.1	66.9	11.0	2001	37.0	49.9	13.1
2002	64.5	31.2	4.3	2002	22.8	64.5	12.7	2002	41.5	44.9	13.6

SUB-ATLANTIC	0-10%	>10-25%	>25%	CONTINENTAL	0-10%	>10-25%	>25%	MOUNTAINOUS (NORTH)	0-10%	>10-25%	>25%
1994	12.6	42.6	44.8	1994	55.0	28.0	17.0	1994	52.6	34.4	13.0
1995	15.8	41.9	42.3	1995	64.3	9.9	25.8	1995	53.8	33.9	12.3
1996	20.4	49.4	30.2	1996	56.6	13.7	29.7	1996	52.8	34.8	12.4
1997	20.0	51.8	28.2	1997	54.4	15.4	30.2	1997	47.8	36.8	15.4
1998	19.4	54.0	26.6	1998	58.8	14.3	26.9	1998	44.4	39.6	16.0
1999	19.9	56.2	23.9	1999	57.7	23.6	18.7	1999	48.1	38.1	13.8
2000	19.0	55.9	25.1	2000	57.7	22.0	20.3	2000	52.6	37.0	10.4
2001	17.7	58.1	24.2	2001	57.2	33.5	9.3	2001	51.9	37.8	10.3
2002	15.6	58.1	26.3	2002	50.0	36.3	13.7	2002	47.4	40.0	12.6

MOUNTAINOUS (SOUTH)	0-10%	>10-25%	>25%	MEDITERR. (HIGHER)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1994	33.4	41.3	25.3	1994	53.7	33.2	13.1	1994	30.0	40.0	30.0
1995	26.5	50.2	23.3	1995	47.8	39.5	12.7	1995	32.2	40.7	27.1
1996	30.5	41.0	28.5	1996	48.0	43.4	8.6	1996	34.7	44.3	21.0
1997	27.3	43.3	29.4	1997	47.5	45.7	6.8	1997	33.5	46.6	19.9
1998	27.6	36.4	36.0	1998	45.3	48.8	5.9	1998	34.2	46.8	19.0
1999	35.5	33.0	31.5	1999	48.2	46.9	4.9	1999	33.4	49.4	17.2
2000	26.8	45.3	27.9	2000	53.7	42.8	3.5	2000	34.1	48.9	17.0
2001	34.4	44.8	20.8	2001	51.9	43.4	4.7	2001	31.7	51.9	16.4
2002	26.9	43.8	29.3	2002	47.8	43.2	9.0	2002	29.6	51.7	18.7

Fagus sylvatica

ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1994	35.9	45.0	19.1
1995	24.3	45.2	30.5
1996	27.6	43.9	28.5
1997	35.4	42.8	21.8
1998	30.8	47.3	21.9
1999	24.9	51.2	23.9
2000	18.6	45.4	36.0
2001	30.8	44.0	25.2
2002	23.7	48.1	28.2

SUB-ATLANTIC	0-10%	>10-25%	>25%
1994	14.7	51.5	33.8
1995	16.5	46.5	37.0
1996	19.4	52.7	27.9
1997	22.1	52.4	25.5
1998	20.5	51.7	27.8
1999	18.4	54.1	27.5
2000	22.1	49.6	28.3
2001	18.4	48.9	32.7
2002	21.8	52.4	25.8

CONTINENTAL	0-10%	>10-25%	>25%
1994	44.2	33.2	22.6
1995	39.7	37.2	23.1
1996	33.4	39.2	27.4
1997	41.0	34.9	24.1
1998	39.3	38.7	22.0
1999	43.3	33.2	23.5
2000	45.3	28.0	26.7
2001	41.2	30.0	28.8
2002	50.4	30.4	19.2

MOUNTAINOUS (SOUTH)	0-10%	>10-25%	>25%
1994	47.5	35.4	17.1
1995	44.3	39.8	15.9
1996	39.1	44.6	16.3
1997	36.4	46.5	17.1
1998	42.3	42.8	14.9
1999	38.6	43.6	17.8
2000	39.7	43.2	17.1
2001	30.4	47.5	22.1
2002	34.9	47.3	17.8

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1994	60.8	29.8	9.4
1995	53.3	31.4	15.3
1996	69.4	23.1	7.5
1997	55.7	25.1	19.2
1998	58.1	33.7	8.2
1999	57.3	33.7	9.0
2000	58.8	31.8	9.4
2001	50.2	36.1	13.7
2002	52.6	38.4	9.0

MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1994	79.7	11.9	8.4
1995	75.5	20.3	4.2
1996	86.0	9.8	4.2
1997	81.1	14.0	4.9
1998	81.1	14.7	4.2
1999	87.4	9.8	2.8
2000	83.9	11.2	4.9
2001	66.4	16.1	17.5
2002	84.6	9.1	6.3

ALL REGIONS	0-10%	>10-25%	>25%
1994	35.0	41.5	23.5
1995	32.6	41.6	25.8
1996	32.4	45.0	22.6
1997	33.4	45.2	21.4
1998	34.2	45.1	20.7
1999	32.2	45.9	21.9
2000	33.4	42.8	23.8
2001	29.2	44.1	26.7
2002	32.5	46.0	21.5

Quercus ilex and *Q. rotundifolia*

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1994	25.8	56.9	17.3
1995	18.2	50.5	31.3
1996	20.4	55.9	23.7
1997	25.6	60.8	13.6
1998	34.0	53.2	12.8
1999	25.6	57.1	17.3
2000	26.9	54.9	18.2
2001	24.1	63.1	12.8
2002	16.7	63.5	19.8

MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1994	32.6	58.4	9.0
1995	16.7	56.9	26.4
1996	21.1	54.8	24.1
1997	28.8	57.1	14.1
1998	31.4	54.9	13.7
1999	21.9	54.5	23.6
2000	17.8	58.3	23.9
2001	19.8	63.8	16.4
2002	18.3	62.5	19.2

ALL REGIONS	0-10%	>10-25%	>25%
1994	30.5	58.7	10.8
1995	16.8	56.3	26.9
1996	20.9	55.5	23.6
1997	28.4	57.8	13.8
1998	32.3	54.3	13.4
1999	23.2	55.0	21.8
2000	20.1	57.7	22.2
2001	20.6	63.7	15.7
2002	17.8	62.7	19.5

Pinus pinaster

ATLANTIC (SOUTH)	0-10%	>10-25%	>25%
1994	65.6	27.6	6.8
1995	61.8	33.2	5.0
1996	62.4	33.2	4.4
1997	65.3	30.6	4.1
1998	57.7	38.5	3.8
1999	56.8	39.7	3.5
2000	56.1	41.8	2.1
2001	42.9	52.7	4.4
2002	46.5	42.6	10.9

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1994	77.8	20.6	1.6
1995	74.5	24.2	1.3
1996	76.8	21.6	1.6
1997	79.4	19.3	1.3
1998	78.4	20.6	1.0
1999	73.2	24.5	2.3
2000	73.2	24.5	2.3
2001	69.3	29.7	1.0
2002	61.4	37.3	1.3

MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1994	65.5	28.5	6.0
1995	58.9	33.8	7.3
1996	56.5	36.6	6.9
1997	42.7	47.6	9.7
1998	42.9	49.3	7.8
1999	39.7	52.9	7.4
2000	43.5	50.7	5.8
2001	43.4	50.6	6.0
2002	44.8	48.1	7.1

ALL REGIONS	0-10%	>10-25%	>25%
1994	67.4	27.2	5.4
1995	62.3	31.9	5.8
1996	61.3	33.1	5.6
1997	53.5	39.3	7.2
1998	52.1	42.1	5.8
1999	49.0	45.3	5.7
2000	51.2	44.4	4.4
2001	48.0	47.1	4.9
2002	48.1	45.1	6.8

Quercus suber

MEDITERR. (LOWER)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1994	41.4	47.0	11.6	1994	43.0	45.7	11.3
1995	20.3	56.1	23.6	1995	22.4	54.6	23.0
1996	32.0	53.8	14.2	1996	33.1	53.1	13.8
1997	34.8	52.7	12.5	1997	36.4	51.5	12.1
1998	27.8	59.0	13.2	1998	29.2	57.9	12.9
1999	24.5	56.2	19.3	1999	25.7	55.5	18.8
2000	22.9	59.3	17.8	2000	24.3	58.4	17.3
2001	22.2	59.6	18.2	2001	22.7	59.5	17.8
2002	23.5	58.0	18.5	2002	23.9	57.9	18.2

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	39.3	39.5	21.2	1994	58.7	31.7	9.6	1994	8.4	39.3	52.3
1995	37.6	44.1	18.3	1995	46.7	46.1	7.2	1995	9.3	39.1	51.6
1996	28.5	40.6	30.9	1996	41.3	53.9	4.8	1996	11.3	44.3	44.4
1997	25.4	46.4	28.2	1997	40.7	55.1	4.2	1997	12.5	44.7	42.8
1998	23.4	47.4	29.2	1998	40.7	52.7	6.6	1998	12.9	41.2	45.9
1999	23.1	48.4	28.5	1999	46.1	48.5	5.4	1999	11.3	52.5	36.2
2000	29.5	49.0	21.5	2000	39.5	52.7	7.8	2000	11.2	52.2	36.6
2001	20.3	48.5	31.2	2001	27.5	62.9	9.6	2001	11.4	52.6	36.0
2002	16.4	45.8	37.8	2002	26.3	65.9	7.8	2002	15.2	51.6	33.2

MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%	CONTINEN-TAL	0-10%	>10-25%	>25%	MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1994	9.8	50.9	39.3	1994	18.3	35.7	46.0	1994	25.8	41.6	32.6
1995	16.9	43.4	39.7	1995	24.8	31.9	43.3	1995	15.4	44.8	39.8
1996	10.2	33.2	56.6	1996	23.4	31.3	45.3	1996	15.8	44.4	39.8
1997	14.6	26.8	58.6	1997	22.5	37.3	40.2	1997	16.7	39.8	43.5
1998	13.9	38.3	47.8	1998	24.8	39.0	36.2	1998	16.7	43.5	39.8
1999	17.3	37.3	45.4	1999	29.0	33.0	38.0	1999	27.1	49.4	23.5
2000	16.3	38.6	45.1	2000	26.3	23.2	50.5	2000	23.1	50.2	26.7
2001	16.3	41.0	42.7	2001	27.2	25.7	47.1	2001	20.4	50.6	29.0
2002	12.5	43.4	44.1	2002	22.5	26.1	51.4	2002	12.7	52.5	34.8

MEDITERR. (LOWER)	0-10%	>10-25%	>25%	ALL REGIONS	0-10%	>10-25%	>25%
1994	19.9	39.1	41.0	1994	19.7	39.8	40.5
1995	25.7	33.3	41.0	1995	20.6	39.8	39.6
1996	29.7	37.7	32.6	1996	18.9	41.3	39.8
1997	24.6	36.6	38.8	1997	19.0	42.2	38.8
1998	17.0	42.4	40.6	1998	18.3	42.9	38.8
1999	19.6	48.9	31.5	1999	19.3	47.6	33.1
2000	16.3	48.6	35.1	2000	19.6	46.4	34.0
2001	20.3	48.9	30.8	2001	17.7	47.6	34.7
2002	17.8	51.4	30.8	2002	16.9	47.4	35.7

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	7.5	22.4	70.1	1994	30.0	37.1	32.9	1994	21.9	29.6	48.5
1995	8.1	27.5	64.4	1995	27.4	38.2	34.4	1995	20.1	34.2	45.7
1996	8.8	31.2	60.0	1996	26.1	31.8	42.1	1996	18.3	32.0	49.7
1997	11.2	31.2	57.6	1997	24.3	35.7	40.0	1997	17.8	32.9	49.3
1998	12.2	28.5	59.3	1998	20.2	37.3	42.5	1998	16.3	32.6	51.1
1999	9.2	32.5	58.3	1999	19.5	41.0	39.5	1999	15.5	35.2	49.3
2000	9.2	29.5	61.3	2000	18.4	39.9	41.7	2000	13.6	34.3	52.1
2001	10.2	27.5	62.3	2001	22.6	40.8	36.6	2001	16.8	34.3	48.9
2002	11.2	26.8	62.0	2002	22.4	44.0	33.6	2002	17.8	35.0	47.2

Picea sitchensis

ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1994	38.7	42.8	18.5
1995	44.3	37.2	18.5
1996	45.5	39.3	15.2
1997	50.3	33.3	16.4
1998	42.5	39.3	18.2
1999	53.2	30.1	16.7
2000	48.2	31.3	20.5
2001	48.2	33.6	18.2
2002	37.2	37.5	25.3

ALL REGIONS	0-10%	>10-25%	>25%
1994	38.7	42.8	18.5
1995	44.3	37.2	18.5
1996	45.5	39.3	15.2
1997	50.3	33.3	16.4
1998	42.5	39.3	18.2
1999	53.2	30.1	16.7
2000	48.2	31.3	20.5
2001	48.2	33.6	18.2
2002	37.2	37.5	25.3

All species

BOREAL	0-10%	>10-25%	>25%
1994	63.4	27.9	8.7
1995	65.2	24.7	10.1
1996	65.2	24.3	10.5
1997	62.4	27.2	10.4
1998	61.9	27.7	10.4
1999	61.9	27.2	10.9
2000	59.1	30.6	10.3
2001	57.0	31.5	11.5
2002	55.9	33.3	10.8

BOREAL (TEMPERATE)	0-10%	>10-25%	>25%
1994	32.8	44.9	22.3
1995	37.9	45.1	17.0
1996	35.7	48.4	15.9
1997	32.6	52.8	14.6
1998	35.3	51.6	13.1
1999	28.2	57.9	13.9
2000	31.7	54.6	13.7
2001	26.4	59.5	14.1
2002	27.7	58.2	14.1

ATLANTIC (NORTH)	0-10%	>10-25%	>25%
1994	45.2	38.9	15.9
1995	41.9	40.0	18.1
1996	40.0	40.5	19.5
1997	44.3	38.5	17.2
1998	41.8	40.9	17.3
1999	40.4	41.5	18.1
2000	40.4	39.4	20.2
2001	39.1	40.8	20.1
2002	35.1	41.5	23.4

ATLANTIC (SOUTH)	0-10%	>10-25%	>25%
1994	65.6	28.6	5.8
1995	61.7	32.7	5.6
1996	58.2	37.2	4.6
1997	61.0	33.9	5.1
1998	54.3	40.2	5.5
1999	54.6	40.2	5.2
2000	50.6	43.2	6.2
2001	41.9	50.3	7.8
2002	38.0	50.8	11.2

SUB-ATLANTIC	0-10%	>10-25%	>25%
1994	15.3	41.4	43.3
1995	17.6	40.2	42.2
1996	21.4	45.2	33.4
1997	20.9	47.0	32.1
1998	20.5	47.4	32.1
1999	20.3	50.0	29.7
2000	20.0	49.4	30.6
2001	18.2	50.7	31.1
2002	17.6	51.1	31.3

CONTINEN-TAL	0-10%	>10-25%	>25%
1994	35.6	35.1	29.3
1995	36.7	33.1	30.2
1996	35.3	34.2	30.5
1997	36.6	34.9	28.5
1998	36.3	35.8	27.9
1999	40.4	33.2	26.4
2000	41.5	25.7	32.8
2001	40.3	30.1	29.6
2002	39.9	30.3	29.8

MOUNTAIN-OUS (NORTH)	0-10%	>10-25%	>25%
1994	46.5	29.9	23.6
1995	45.5	29.0	25.5
1996	44.8	28.9	26.3
1997	42.2	35.1	22.7
1998	40.9	34.8	24.3
1999	42.4	35.5	22.1
2000	45.0	37.1	17.9
2001	46.5	34.7	18.8
2002	40.1	38.5	21.4

MOUNTAIN-OUS (SOUTH)	0-10%	>10-25%	>25%
1994	40.0	36.0	24.0
1995	37.9	39.6	22.5
1996	38.2	37.6	24.2
1997	37.5	38.0	24.5
1998	39.2	35.6	25.2
1999	39.6	36.4	24.0
2000	36.5	38.9	24.6
2001	33.0	42.1	24.9
2002	32.0	42.3	25.7

MEDITERR. (HIGHER)	0-10%	>10-25%	>25%
1994	42.0	41.5	16.5
1995	35.2	42.4	22.4
1996	38.5	42.7	18.8
1997	40.8	42.4	16.8
1998	43.7	41.6	14.7
1999	41.1	44.3	14.6
2000	39.8	45.7	14.5
2001	35.1	49.0	15.9
2002	33.4	47.6	19.0

MEDITERR. (LOWER)	0-10%	>10-25%	>25%
1994	44.9	41.8	13.3
1995	31.8	46.7	21.5
1996	35.3	47.1	17.6
1997	35.6	51.5	12.9
1998	36.3	50.2	13.5
1999	31.3	52.1	16.6
2000	29.7	53.7	16.6
2001	28.4	55.8	15.8
2002	28.0	54.5	17.5

ALL REGIONS	0-10%	>10-25%	>25%
1994	35.8	38.7	25.5
1995	34.2	39.4	26.4
1996	35.7	41.0	23.3
1997	35.4	42.9	21.7
1998	35.7	42.7	21.6
1999	34.3	44.5	21.2
2000	33.6	44.7	21.7
2001	31.1	47.0	21.9
2002	30.1	47.0	22.9

	CSTs$_{88}$			**CSTs$_{94}$**		
Year	**No. of trees** N	**Mean defoliation** $\bar{x}$	**Standard error** $s_{\bar{x}} = s\sqrt{N}$	**No. of trees** N	**Mean defoliation** $\bar{x}$	**Standard error** $s_{\bar{x}} = s\sqrt{N}$
Pinus sylvestris						
1989	2521	17.1	0.32			
1990	2521	17.4	0.33			
1991	2521	17.9	0.27			
1992	2521	19.5	0.31			
1993	2521	17.9	0.26			
1994	2521	20.6	0.27	17641	21.3	0.10
1995	2521	18.8	0.25	17641	20.5	0.10
1996	2521	17.9	0.23	17641	18.9	0.09
1997	2521	17.2	0.23	17641	18.8	0.09
1998	2521	16.6	0.22	17641	18.5	0.09
1999	2521	16.8	0.21	17641	18.3	0.09
2000	2521	17.8	0.22	17641	18.2	0.09
2001	2521	18.5	0.24	17641	18.5	0.09
2002	2521	19.4	0.28	17641	19.6	0.10
Picea abies						
1989	2988	23.1	0.31			
1990	2988	22.7	0.31			
1991	2988	21.7	0.26			
1992	2988	21.8	0.24			
1993	2988	23.3	0.27			
1994	2988	25.0	0.29	12125	19.2	0.15
1995	2988	24.4	0.30	12125	19.1	0.15
1996	2988	21.4	0.28	12125	18.9	0.15
1997	2988	22.9	0.28	12125	19.4	0.14
1998	2988	22.8	0.29	12125	19.4	0.14
1999	2988	23.3	0.30	12125	19.6	0.14
2000	2988	23.4	0.29	12125	20.0	0.14
2001	2988	23.9	0.28	12125	20.4	0.14
2002	2988	24.6	0.29	12125	20.8	0.15
Quercus robur* and *Q. petraea						
1989	1237	22.5	0.46			
1990	1237	20.9	0.42			
1991	1237	20.5	0.40			
1992	1237	21.8	0.38			
1993	1237	23.2	0.39			
1994	1237	23.6	0.40	3610	25.0	0.24
1995	1237	24.5	0.43	3610	25.3	0.25
1996	1237	24.5	0.39	3610	25.4	0.25
1997	1237	24.8	0.43	3610	25.5	0.26
1998	1237	25.2	0.42	3610	25.7	0.26
1999	1237	22.3	0.38	3610	24.3	0.25
2000	1237	22.1	0.38	3610	24.4	0.25
2001	1237	22.6	0.39	3610	24.7	0.25
2002	1237	22.6	0.40	3610	25.0	0.25
Fagus sylvatica						
1989	2620	19.7	0.27			
1990	2620	18.1	0.24			
1991	2620	15.5	0.23			
1992	2620	19.2	0.27			
1993	2620	18.6	0.25			
1994	2620	20.7	0.25	5876	19.3	0.17
1995	2620	21.2	0.25	5876	20.1	0.18
1996	2620	20.0	0.22	5876	19.7	0.18
1997	2620	19.6	0.22	5876	19.3	0.18
1998	2620	18.4	0.23	5876	18.9	0.18
1999	2620	19.7	0.21	5876	19.5	0.18
2000	2620	19.4	0.24	5876	19.9	0.19
2001	2620	21.2	0.24	5876	21.2	0.19
2002	2620	19.7	0.24	5876	19.8	0.19

CSTs$_{88}$

CSTs$_{94}$

Year	No. of trees	Mean defoliation	Standard error	No. of trees	Mean defoliation	Standard error
	N	$\overline{x}$	$s_{\overline{x}} = s\sqrt{N}$	N	$\overline{x}$	$s_{\overline{x}} = s\sqrt{N}$
Pinus pinaster						
1989	1360	7.1	0.26			
1990	1360	12.5	0.35			
1991	1360	12.7	0.32			
1992	1360	11.5	0.27			
1993	1360	10.0	0.29			
1994	1360	11.8	0.29	1903	10.6	0.24
1995	1360	13.3	0.30	1903	11.7	0.24
1996	1360	13.5	0.30	1903	12.1	0.25
1997	1360	15.2	0.30	1903	13.9	0.25
1998	1360	15.4	0.27	1903	14.2	0.23
1999	1360	15.8	0.26	1903	14.7	0.22
2000	1360	15.1	0.25	1903	14.2	0.21
2001	1360	15.2	0.25	1903	14.3	0.20
2002	1360	15.8	0.34	1903	15.4	0.29
Quercus ilex* and *Q. rotundifolia						
1989	2243	11.8	0.16			
1990	2243	14.1	0.28			
1991	2243	16.2	0.25			
1992	2243	16.6	0.21			
1993	2243	15.5	0.17			
1994	2243	17.5	0.22	2865	17.5	0.19
1995	2243	22.6	0.25	2865	22.8	0.24
1996	2243	21.4	0.24	2865	21.6	0.23
1997	2243	18.0	0.22	2865	18.6	0.21
1998	2243	18.4	0.24	2865	18.4	0.22
1999	2243	21.1	0.26	2865	21.1	0.24
2000	2243	21.8	0.25	2865	21.3	0.22
2001	2243	20.6	0.24	2865	20.3	0.20
2002	2243	21.4	0.23	2865	21.3	0.20

Annex II

National Surveys

Annex II-1

Forests and surveys in European countries (2002)

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	10x10		
Austria	8385	3878	2683	798	3481	8.7 x 8.7	264	7029
Belarus	20760	7845	4728	3117	7845	16 x 16	407	9690
Belgium	3035	691	281	324	691	4^2 / 8^2	132	3079
Bulgaria	11100	3314	1172	2142	3314	$4^2/8^2/16^2$	141	5303
Croatia	5654	2061	321	1740	1175	16 x 16	80	1910
Cyprus	925	298	172	0	138	16x16	15	360
Czech Republic	7886	2630	2057	573	2630	$8^2/16^2$	140	7013
Denmark	4300	468	294	174	468	$7^2/16^2$	20	480
Estonia	4510	2249	1177	1072	2249	16 x 16	93	2169
Finland	30460	20032	18089	1663	15006	16^2 / 24x32	457	8593
France	54926	14591	9228	4058	13100	16 x 16	518	10355
Germany	35562	10264	6869	3395	10264	16^2 / 4^2	447	13534
Greece	12890	2512	954	1080	2512	16 x 16	75	1768
Hungary	9300	1804	251	1553	1804	4 x 4	1143	26921
Ireland	6889	436	399	37	399	16 x 16	21	424
Italy	30128	8675	1735	6940	7699	16 x 16	258	7165
Latvia	6459	2902	1596	1199	1902	8 x 8	364	8682
Liechtenstein	16	8	6	2	no survey in 2002			
Lithuania	6520	1858	1144	714	1858	8x8/16x16	220	5162
Luxembourg	259	89	30	54	no survey in 2002			
Rep. of Moldova	3376	318	6	312	318	2 x 2	480	11489
The Netherlands	3482	334	158	52	210	16 x 16	11	231
Norway	32376	12000	6800	5200	12000	$3^2/9^2$	1504	7421
Poland	31268	8756	6786	1970	6901	varying	1229	24580
Portugal	8893	3234	1081	2153	3233	16 x 16	145	4350
Romania	23750	6244	1929	4315	6244	4 x 4	4028	104366
Russian Fed.	11100	8125			6315	varying	183	4144
Serbia and Montenegro						16 x 16	46	1104
Slovak Republic	4901	1961	815	1069	1961	16 x 16	111	4207
Slovenia	2027	1099	410	688	1099	16 x 16	39	936
Spain	50471	11588	5910	4056	11588	16 x 16	620	14880
Sweden	41000	23400	19600	900	20600	varying	4180	16671
Switzerland	4129	1186	818	368	1186	16 x 16	49	1064
Turkey	77945	20199	9426	10773	no survey in 2002			
Ukraine	60350	9316	3969	5347	643	16 x 16	49	1204
United Kingdom	24100	2156	1520	636	2156	random	356	8532
TOTAL	744180	200611	112314	71172	152272	varying	17825	324816

Greece: Excluding maquis.
Russian Feder.: Only regional surveys in north-western and Central European parts of Russia.
Serbia and Montenegro: Montenegro only.

Annex II-2

Defoliation of all species by classes and class aggregates (2002)

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						
Austria	3481	7029	60.2	29.6	8.5	1.7	10.2
Belarus	7845	9690	34.9	55.6	8.2	1.3	9.5
Belgium	691	3079	38.7	43.5	16.1	1.7	17.8
Bulgaria	3314	5303	24.1	38.8	29.9	7.2	37.1
Croatia	1175	1910	38.4	41.0	18.6	2.0	20.6
Cyprus	138	360	30.8	66.4	2.8	0.0	2.8
Czech Republic	2630	7013	11.6	35.0	52.7	0.7	53.4
Denmark	468	480	61.5	29.8	7.3	1.4	8.7
Estonia	2249	2169	45.9	46.5	6.6	1.0	7.6
Finland	15006	8593	54.6	33.9	10.5	1.0	11.5
France	13100	10355	40.1	38.0	20.3	1.6	21.9
Germany	10264	13534	35.1	43.5	20.0	1.4	21.4
Greece	2512	1768	42.1	37.0	16.6	4.3	20.9
Hungary	1804	26921	38.1	40.7	16.0	5.2	21.2
Ireland	399	424	43.9	35.4	16.0	4.7	20.7
Italy	7699	7165	20.3	42.4	33.4	3.9	37.3
Latvia	2902	8682	19.8	66.4	12.0	1.8	13.8
Liechtenstein			no survey in 2002				
Lithuania	1858	5162	16.4	70.8	9.6	3.2	12.8
Luxembourg	84		no survey in 2002				
Rep. of Moldova	318	11489	25.2	32.3	32.6	9.9	42.5
The Netherlands	210	231	57.1	21.2	20.4	1.3	21.7
Norway	12000	7421	35.0	39.5	22.0	3.5	25.5
Poland	6868	24580	8.8	58.5	30.7	2.0	32.7
Portugal	3233	4350	47.8	42.6	8.9	0.7	9.6
Romania	6244	104366	62.7	23.8	12.0	1.5	13.5
Russian Fed.	6315	4144	37.9	51.2	10.2	0.7	10.9
Serbia and Montenegro		1104	80.8	15.3	3.7	0.2	3.9
Slovak Republic	1961	4207	17.3	57.9	23.3	1.5	24.8
Slovenia	1099	936	32.3	39.6	24.2	3.9	28.1
Spain	11588	14880	24.2	59.4	13.2	3.2	16.4
Sweden	20600	16671	49.2	35.0	13.4	2.4	15.8
Switzerland	1186	1064	23.4	58.0	11.7	6.9	18.6
Turkey			no survey in 2002				
Ukraine	1285	1204	8.9	63.4	23.8	3.9	27.7
United Kingdom	2156	8532	27.3	45.4	25.7	1.6	27.3

Greece: Excluding maquis.
Russian Feder.: Only regional surveys in north-western and Central European parts of Russia.
Serbia and Montenegro: Montenegro only.

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 (2002)

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						12.4
Austria	2683	6101	60.7	29.2	8.5	1.6	10.1
Belarus	4728	7086	33.0	57.3	8.5	1.2	9.7
Belgium	281	1118	40.0	40.3	18.1	1.6	19.7
Bulgaria	1172	2876	16.7	39.3	36.0	8.0	44.0
Croatia	321	241	8.3	28.2	54.8	8.7	63.5
Cyprus	172	360	30.8	66.4	2.8	0.0	2.8
Czech Republic	2057	5858	9.1	30.8	59.3	0.8	60.1
Denmark	294	292	78.4	17.1	2.8	1.7	4.5
Estonia	1177	2058	44.2	47.9	6.9	1.0	7.9
Finland	18089	7339	54.3	33.8	11.0	0.9	11.9
France	9228	3604	55.3	29.5	13.8	1.4	15.2
Germany	6869	9358	35.8	44.4	18.5	1.3	19.8
Greece	954	944	48.2	35.7	11.9	4.2	16.1
Hungary	236	3931	37.6	39.6	18.0	4.8	22.8
Ireland	399	424	43.9	35.4	16.0	4.7	20.7
Italy	1735	2162	41.8	37.7	17.7	2.8	20.5
Latvia	1596	6371	17.9	67.8	12.4	1.9	14.3
Liechtenstein	6		no survey in 2002				
Lithuania	1073	3327	15.4	75.3	7.5	1.8	9.3
Luxembourg	30		no survey in 2002				
Rep. of Moldova	6		only broadleaves assessed				
The Netherlands	158	150	71.2	11.3	17.5	0.0	17.5
Norway	6800	5755	38.0	37.9	20.4	3.7	24.1
Poland	5384	18720	7.8	59.7	30.4	2.1	32.5
Portugal	1081	1434	57.8	38.6	3.3	0.3	3.6
Romania	1929	25944	68.4	21.7	8.8	1.1	9.9
Russian Fed.	5800	3500	39.1	50.9	9.3	0.7	10.0
Serbia and Montenegro		313	71.5	21.2	6.9	0.4	7.3
Slovak Republic	815	1686	7.9	51.7	37.8	2.6	40.4
Slovenia	410	375	28.3	40.3	26.6	4.8	31.4
Spain	5910	7532	28.7	55.7	12.2	3.4	15.6
Sweden	13090	14838	48.5	34.7	14.3	2.5	16.8
Switzerland	818	755	20.0	60.1	13.2	6.7	19.9
Turkey	9426		no survey in 2002				
Ukraine	3969	487	10.3	75.1	14.0	0.6	14.6
United Kingdom	1520	4932	29.3	45.6	23.5	1.6	25.1

Greece: Excluding maquis.
Russian Feder.: Only regional surveys in north-western and Central European parts of Russia.
Serbia and Montenegro: Montenegro only.

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 (2002)

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						
Austria	798	928	56.8	31.9	9.2	2.1	11.3
Belarus	3117	2604	40.3	50.7	7.6	1.4	9.0
Belgium	324	1961	37.9	45.1	15.0	2.0	17.0
Bulgaria	2142	2427	32.8	38.2	22.6	6.4	29.0
Croatia	1740	1669	42.8	42.8	13.4	1.0	14.4
Cyprus			only conifers assessed				
Czech Republic	573	1155	24.0	56.1	19.5	0.4	19.9
Denmark	174	188	35.1	49.5	14.4	1.0	15.4
Estonia	1072	111	76.6	20.7	1.8	0.9	2.7
Finland	1663	1254	56.1	35.1	7.8	1.0	8.8
France	4058	6751	32.0	42.5	23.8	1.7	25.5
Germany	3395	4176	33.6	41.7	23.0	1.7	24.7
Greece	1080	824	35.2	38.3	22.1	4.4	26.5
Hungary	1462	22990	38.3	40.9	15.6	5.2	20.8
Ireland	37		only conifers assessed				
Italy	6940	5003	11.0	44.4	40.1	4.5	44.6
Latvia	1199	2311	24.8	62.4	10.9	1.9	12.8
Liechtenstein	2		no survey in 2002				
Lithuania	701	1835	18.1	62.9	13.5	5.5	19.0
Luxembourg	54		no survey in 2002				
Rep. of Moldova		11489	25.2	32.3	32.6	9.9	42.5
The Netherlands	52	81	30.9	39.5	25.9	3.7	29.6
Norway	5200	1666	24.4	45.2	27.7	2.7	30.4
Poland	1517	5860	12.1	54.8	31.7	1.4	33.1
Portugal	2153	2916	42.9	44.5	11.7	0.9	12.6
Romania	4315	78422	60.6	24.6	13.1	1.7	14.8
Russian Fed.	510	644	31.4	52.6	15.4	0.6	16.0
Serbia and Montenegro		791	90.9	9.4	0.6	0.0	0.6
Slovak Republic	1069	2521	23.5	62.1	13.6	0.8	14.4
Slovenia	688	561	34.9	39.2	22.5	3.4	25.9
Spain	4056	7348	19.5	63.2	14.3	3.0	17.3
Sweden	900	1833	52.2	39.2	6.8	1.8	8.6
Switzerland	368	309	30.7	53.3	8.4	7.6	16.0
Turkey	10773		no survey in 2002				
Ukraine	5347	717	7.9	55.4	30.5	6.2	36.7
United Kingdom	636	3600	24.6	45.1	28.7	1.6	30.3

Greece: Excluding maquis.
Russian Federation: Only regional surveys in north-western and Central European parts of Russia.
Sweden, *Norway*: Special study on birch.
Serbia and Montenegro: Montenegro only.

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 (1991-2002)

Participating countries	All species defoliation classes 2-4												change % points
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2001/ 2002
Albania								9.8	9.9	10.1	10.2		
Austria	7.5	6.9	8.2	7.8	6.6	7.9	7.1	6.7	6.8	8.9	9.7	10.2	0.5
Belarus		29.2	29.3	37.4	38.3	39.7	36.3	30.5	26.0	24.0	20.7	9.5	-11.2
Belgium	17.9	16.9	14.8	16.9	24.5	21.2	17.4	17.0	17.7	19.0	17.9	17.8	-0.1
Bulgaria	21.8	23.1	23.2	28.9	38.0	39.2	49.6	60.2	44.2	46.3	33.8	37.1	3.3
Croatia		15.6	19.2	28.8	39.8	30.1	33.1	25.6	23.1	23.4	25.0	20.6	-4.4
Cyprus											8.9	2.8	-6.1
Czech Rep.	45.3	56.1	51.8	57.7	58.5	71.9	68.6	48.8	50.4	51.7	52.1	53.4	1.3
Denmark	29.9	25.9	33.4	36.5	36.6	28.0	20.7	22.0	13.2	11.0	7.4	8.7	1.3
Estonia	only conifers assessed							8.7	8.7	7.4	8.5	7.6	-0.9
Finland	16.0	14.5	15.2	13.0	13.3	13.2	12.2	11.8	11.4	11.6	11.0	11.5	0.5
France	7.1	8.0	8.3	8.4	12.5	17.8	25.2	23.3	19.7	18.3	20.3	21.9	1.6
Germany	25.2	26.4	24.2	24.4	22.1	20.3	19.8	21.0	21.7	23.0	21.9	21.4	-0.5
Greece	16.9	18.1	21.2	23.2	25.1	23.9	23.7	21.7	16.6	18.2	21.7	20.9	-0.8
Hungary	19.6	21.5	21.0	21.7	20.0	19.2	19.4	19.0	18.2	20.8	21.2	21.2	0.0
Ireland	15.0	15.7	29.6	19.7	26.3	13.0	13.6	16.1	13.0	14.6	17.4	20.7	3.3
Italy	16.4	18.2	17.6	19.5	18.9	29.9	35.8	35.9	35.3	34.4	38.4	37.3	-1.1
Latvia		37.0	35.0	30.0	20.0	21.2	19.2	16.6	18.9	20.7	15.6	13.8	-1.8
Liechtenstein		16.0											
Lithuania	23.9	17.5	27.4	25.4	24.9	12.6	14.5	15.7	11.6	13.9	11.7	12.8	1.1
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	42.5	5.6
The Netherlands	17.2	33.4	25.0	19.4	32.0	34.1	34.6	31.0		21.8	19.9	21.7	1.8
Norway	19.7	26.2	24.9	27.5	28.8	29.4	30.7	30.6	28.6	24.3	27.2	25.5	-1.7
Poland	45.0	48.8	50.0	54.9	52.6	39.7	36.6	34.6	30.6	32.0	30.6	32.7	2.1
Portugal	29.6	22.5	7.3	5.7	9.1	7.3	8.3	10.2	11.1	10.3	10.1	9.6	-0.5
Romania	9.7	16.7	20.5	21.2	21.2	16.9	15.6	12.3	12.7	14.3	13.3	13.5	0.2
Russian Fed.				10.7	12.5						9.8	10.9	1.1
Serbia and Monten.	9.8					3.6	7.7	8.4	11.2	8.4	14.0	3.9	-10.1
Slovak Rep.	28.5	36.0	37.6	41.8	42.6	34.0	31.0	32.5	27.8	23.5	31.7	24.8	-6.9
Slovenia	15.9		19.0	16.0	24.7	19.0	25.7	27.6	29.1	24.8	28.9	28.1	-0.8
Spain	7.4	12.3	13.0	19.4	23.5	19.4	13.7	13.6	12.9	13.8	13.0	16.4	3.4
Sweden	only conifers assessed				14.2	17.4	14.9	14.2	13.2	13.7	17.5	15.8	-1.7
Switzerland	16.1	12.8	15.4	18.2	24.6	20.8	16.9	19.1	19.0	29.4	18.2	18.6	0.4
Turkey													
Ukraine	6.4	16.3	21.5	32.4	29.6	46.0	31.4	51.5	56.2	60.7	39.6	27.7	-11.9
United Kingdom	56.7	58.3	16.9	13.9	13.6	14.3	19.0	21.1	21.4	21.6	21.1	27.3	6.2

Czech Republic: Only trees older than 60 years assessed until 1997. *France*: Due to methodological changes, only the time series 1990-94 and 1997-2002 are consistent, but not comparable to each other. *Germany*: For 1990, only data for former Federal Republic of Germany. *Greece*: Excluding maquis. *Italy*: Due to methodological changes, only the time series 1989-96 and 1997-2002 are consistent, but not comparable to each other. *Russian Feder.*: Only regional surveys in north-western and Central European parts of Russia. *United Kingdom*: The difference between 1992 and subsequent years is mainly due to a change of assessment method in line with that used in other States. *Serbia and Montenegro*: Montenegro only.

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 (1991-2002)

Participating countries	Conifers Defoliation classes 2-4												change % points
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2001/ 2002
Albania								12.0	12.1	12.3	12.4		
Austria	7.0	6.6	8.2	7.9	6.6	7.3	6.3	6.3	6.4	9.1	9.6	10.1	0.5
Belarus		33.7	33.8	44.0	43.9	43.1	41.2	33.9	28.9	26.1	23.4	9.7	-13.7
Belgium	23.4	23.0	18.3	21.2	21.0	25.8	19.2	13.5	15.5	19.5	17.5	19.7	2.2
Bulgaria	26.5	25.5	26.9	25.0	41.4	46.5	53.5	69.8	48.9	46.4	39.1	44.0	4.9
Croatia		26.2	33.9	39.3	57.5	57.0	68.7	45.8	53.2	53.3	65.1	63.5	-1.6
Cyprus											8.9	2.8	-6.1
Czech Rep.	46.3	57.9	51.5	59.0	60.7	74.9	71.9	54.6	57.4	58.3	58.1	60.1	2.0
Denmark	31.4	28.6	37.0	38.7	34.8	23.2	15.9	17.0	9.9	8.8	6.7	4.5	-2.2
Estonia	28.0	29.5	21.2	16.0	14.2	14.6	11.4	9.0	9.1	7.5	8.8	7.9	-0.9
Finland	17.2	15.2	15.6	13.1	13.7	13.7	12.8	12.2	11.9	12.0	11.4	11.9	0.5
France	6.7	7.1	8.2	8.2	9.2	13.5	16.2	16.8	14.1	12.0	14.0	15.2	1.2
Germany	24.8	23.8	21.4	21.6	18.3	16.7	15.4	19.0	19.2	19.6	20.0	19.8	-0.2
Greece	7.2	12.3	13.9	13.2	13.6	14.4	13.8	12.9	13.5	16.5	17.2	16.1	-1.1
Hungary	17.8	20.1	20.1	21.2	18.7	17.8	17.4	18.7	17.6	21.5	19.5	22.8	3.3
Ireland	15.0	15.7	29.6	19.7	26.3	13.0	13.6	16.1	13.0	14.6	17.4	20.7	3.3
Italy	13.8	17.2	15.1	15.0	19.4	25.1	28.1	25.5	23.1	19.2	19.1	20.5	1.4
Latvia		45.0	41.0	34.0	23.0	24.8	21.9	18.9	20.6	20.1	15.8	14.3	-1.5
Liechtenstein		18.0											
Lithuania	27.8	17.5	29.2	26.3	26.6	12.9	13.9	13.6	11.5	12.0	9.8	9.3	-0.5
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	34.7	30.6	27.7	45.4	43.5	45.3	43.2		23.5	20.7	17.5	-3.2
Norway	19.0	23.4	20.9	22.4	24.0	25.1	28.5	27.5	24.3	21.8	25.1	24.1	-1.0
Poland	46.9	50.3	50.8	55.6	54.5	40.5	36.8	34.6	30.6	32.1	30.3	32.5	2.2
Portugal	19.8	11.3	7.1	5.4	6.6	5.6	7.8	6.6	6.0	4.3	4.3	3.6	-0.7
Romania	6.9	10.9	16.6	15.5	15.2	10.4	10.3	9.0	9.1	9.8	9.6	9.9	0.3
Russian Fed.	4.2	5.4	4.5	9.4	10.1	9.4					9.8	10.0	0.2
Serbia and Monten.	15.9					4.4	7.9	6.0	9.2	10.0	21.3	0.4	-20.9
Slovak Rep.	38.5	44.0	49.9	50.3	52.0	41.0	42.2	40.3	40.2	37.9	38.7	40.4	1.7
Slovenia	31.3		27.0	19.0	33.6	26.0	32.5	36.7	38.0	34.5	32.2	31.4	-0.8
Spain	7.3	13.5	14.7	19.1	18.1	18.1	11.5	12.9	9.8	12.0	11.6	15.6	4.0
Sweden	12.3	16.9	10.6	16.2	14.5	16.9	15.9	15.0	13.6	13.5	18.4	16.8	-1.6
Switzerland	18.0	14.1	17.4	19.6	23.2	21.4	19.9	19.7	18.3	33.0	19.1	19.9	0.8
Turkey													
Ukraine	6.4	13.8	21.7	34.8	25.7	45.8	32.7	64.9	50.0	47.3	16.8	14.6	-2.2
United Kingdom	51.5	52.7	16.8	15.0	13.0	13.9	17.0	19.8	20.1	20.2	20.6	25.1	4.5

Czech Republic: Only trees older than 60 years assessed until 1997. *France*: Due to methodological changes, only the time series 1990-94 and 1997-2002 are consistent, but not comparable to each other. *Germany*: For 1990, only data for former Federal Republic of Germany. *Greece*: Excluding maquis. *Italy*: Due to methodological changes, only the time series 1989-96 and 1997-2002 are consistent, but not comparable to each other. *Russian Feder.*: Only regional surveys in north-western and Central European parts of Russia. *United Kingdom*: The difference between 1992 and subsequent years is mainly due to a change of assessment method in line with that used in other States. *Serbia and Montenegro*: Montenegro only.

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 (1991-2002)

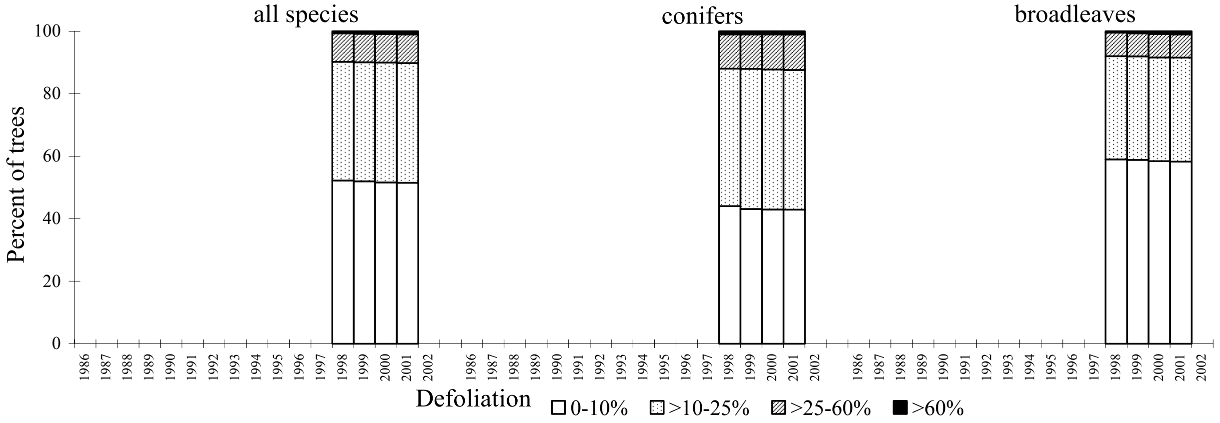
Participating countries	Broadleaves Defoliation classes 2-4												change % points
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2001/ 2002
Albania								8.0	8.1	8.4	8.4		
Austria	11.1	9.3	7.7	7.4	6.5	11.6	12.2	9.6	9.4	7.6	10.4	11.3	0.9
Belarus		14.8	16.6	18.6	22.9	29.2	23.0	19.3	17.0	16.9	13.3	9.0	-4.3
Belgium	13.5	11.8	11.7	12.8	26.6	18.5	16.1	19.2	19.1	18.8	18.3	17.0	-1.3
Bulgaria	15.3	18.0	16.6	34.4	32.7	33.0	43.9	48.4	35.9	45.8	26.0	29.0	3.0
Croatia		13.6	15.6	26.4	35.2	26.0	27.8	21.9	16.8	18.3	18.7	14.4	-4.3
Cyprus	only conifers assessed												
Czech Rep.	37.6	29.2	54.4	48.0	30.6	34.0	26.5	13.5	17.1	21.4	21.7	19.9	-1.8
Denmark	27.3	21.2	27.0	32.4	39.7	36.1	28.4	30.1	18.8	13.9	8.5	15.4	6.9
Estonia		0.0	1.1	2.0	1.1	5.3	7.4	1.0	1.1	9.5	2.1	2.7	0.6
Finland	7.7	10.1	12.8	12.0	11.0	10.3	8.4	9.4	8.6	9.9	8.8	8.8	0.0
France	7.4	8.5	8.4	8.4	14.3	20.1	29.9	26.9	22.9	21.6	23.6	25.5	1.9
Germany	26.5	32.0	29.9	30.1	29.9	30.8	28.6	25.2	26.9	29.9	25.4	24.7	-0.7
Greece	28.5	25.0	29.8	35.0	38.2	34.6	34.9	31.7	20.2	20.2	26.6	26.5	-0.1
Hungary	19.9	21.8	21.2	21.8	20.2	19.5	19.7	19.0	18.2	20.8	21.5	20.8	-0.7
Ireland	only conifers assessed												
Italy	17.1	18.5	18.3	20.7	18.5	31.2	38.0	38.9	39.3	40.5	46.3	44.6	-1.7
Latvia		19.0	17.8	15.0	10.0	11.4	11.3	13.6	14.2	22.2	14.8	12.8	-2.0
Liechtenstein		8.0											0.0
Lithuania	14.9	17.6	23.8	23.3	20.8	12.2	15.9	19.7	11.8	17.7	16.3	19.0	2.7
Luxembourg	33.9	30.5	31.0	46.8	51.4	49.8	41.8	33.3		33.5			0.0
Rep. of Moldova			50.9	21.9	40.5	41.1	30.0		41.4	29.2	36.9	42.5	5.6
The Netherlands	9.4	31.1	13.1	5.1	10.8	19.2	17.8	14.0		18.8	18.5	29.6	11.1
Norway	25.1	38.9	42.1	47.6	47.4	45.0	38.9	42.2	44.8	34.0	33.7	30.4	-3.3
Poland	34.8	40.4	45.6	51.5	46.7	37.4	35.8	34.8	31.1	32.0	31.4	33.1	1.7
Portugal	36.6	29.1	7.5	5.8	10.4	8.3	8.6	12.0	13.7	13.2	12.8	12.6	-0.2
Romania	10.4	18.4	21.4	22.9	18.0	18.7	16.9	13.3	14.0	15.8	14.7	14.8	0.1
Russian Fed.				39.4	34.4							16.0	
Serbia and Monten.	8.2					3.5	7.4	10.1	13.0	6.7	6.7	0.6	-6.1
Slovak Rep.	21.1	30.0	29.1	35.6	35.8	28.0	23.3	27.0	19.3	13.9	26.9	14.5	-12.4
Slovenia	5.8		11.0	13.0	19.3	15.0	21.4	21.7	23.2	18.4	26.7	25.9	-0.8
Spain	7.4	11.2	11.4	19.6	28.7	20.7	15.8	14.4	16.1	15.7	14.4	17.3	2.9
Sweden	only conifers assessed				7.9	20.7	6.1	7.4	8.7	7.5	14.1	8.6	-5.5
Switzerland	13.3	11.1	12.7	16.2	27.0	19.8	12.5	18.1	20.4	22.1	16.3	16.0	-0.3
Turkey													0.0
Ukraine	6.4	20.2	21.6	29.9	33.0	46.2	30.7	43.2	59.7	69.6	53.3	36.7	-16.6
United Kingd.	65.6	67.8	17.1	12.4	14.5	15.0	22.0	22.9	23.2	23.8	21.9	30.3	8.4

Czech Republic: Only trees older than 60 years assessed until 1997. *France*: Due to methodological changes, only the time series 1990-94 and 1997-2002 are consistent, but not comparable to each other. *Germany*: For 1990, only data for former Federal Republic of Germany. *Greece*: Excluding maquis. *Italy*: Due to methodological changes, only the time series 1989-96 and 1997-2002 are consistent, but not comparable to each other. *Russian Feder.*: Only regional surveys in north-western and Central European parts of Russia. *United Kingdom*: The difference between 1992 and subsequent years is mainly due to a change of assessment method in line with that used in other States. *Serbia and Montenegro*: Montenegro only.

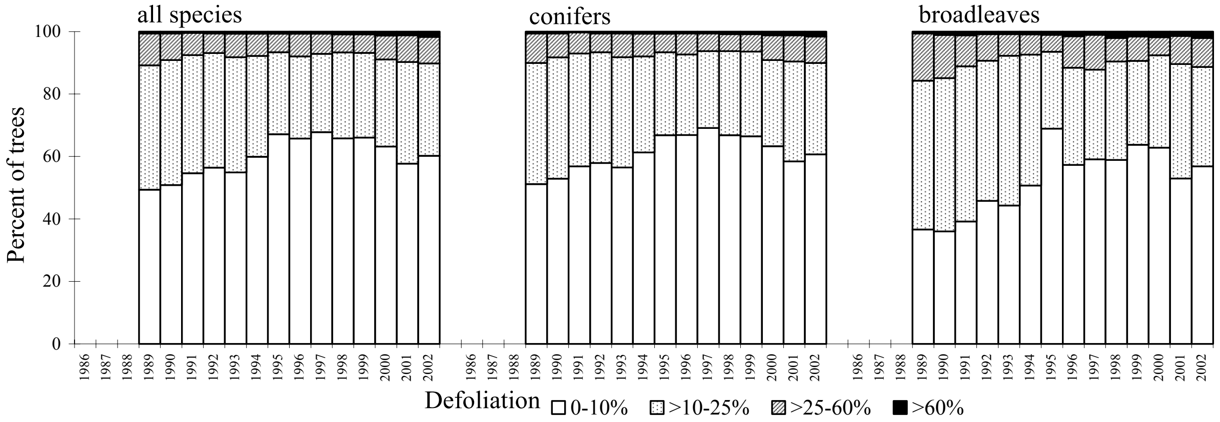
Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time..

Annex II-8
Changes in defoliation (1986-2002)

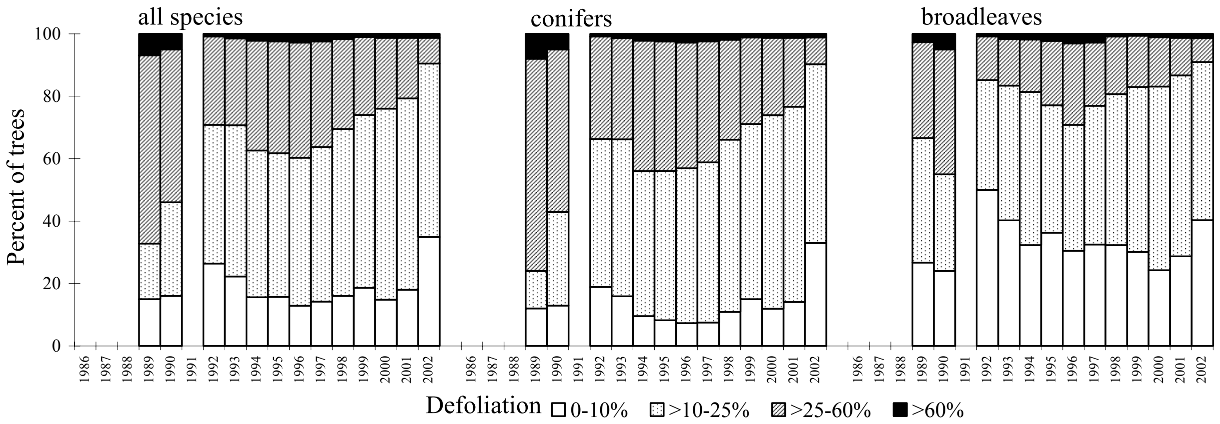
Albania



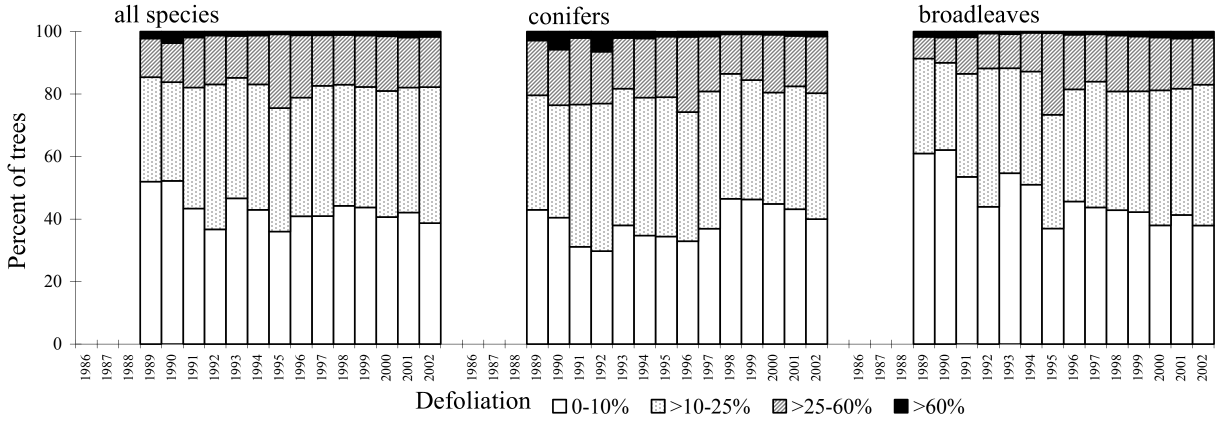
Austria



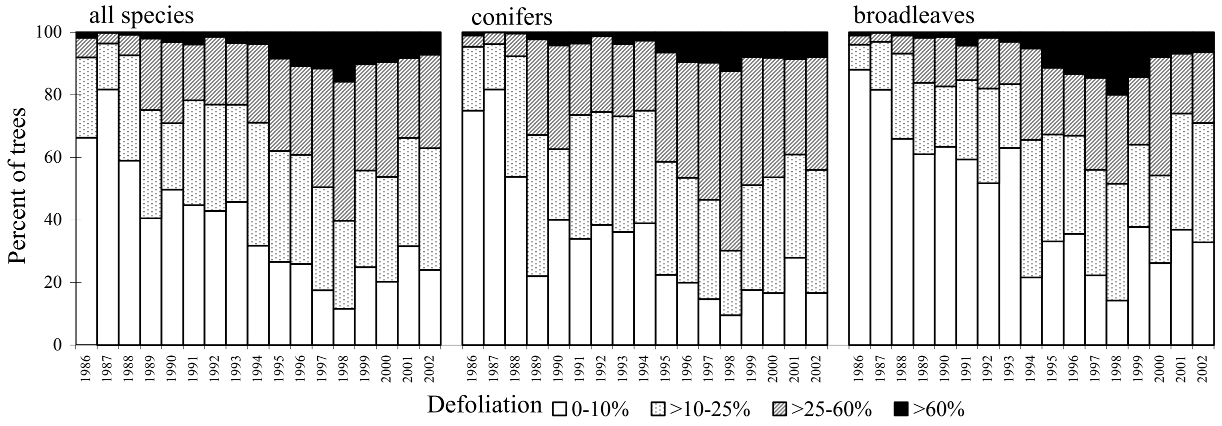
Belarus



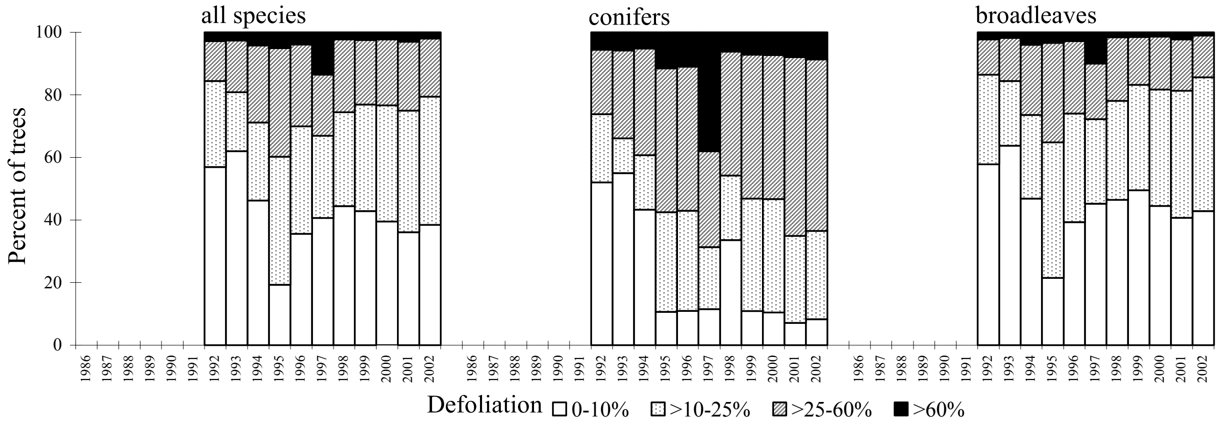
Belgium



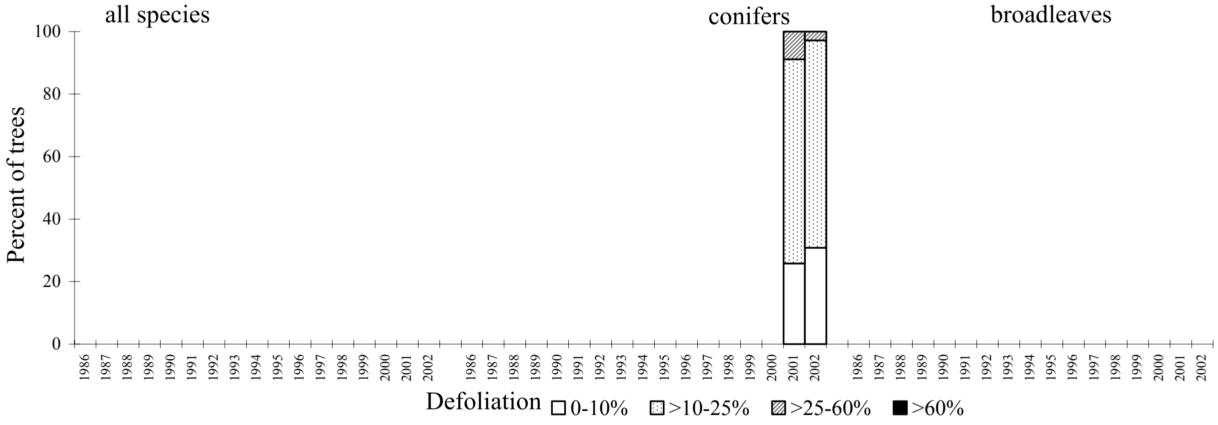
Bulgaria



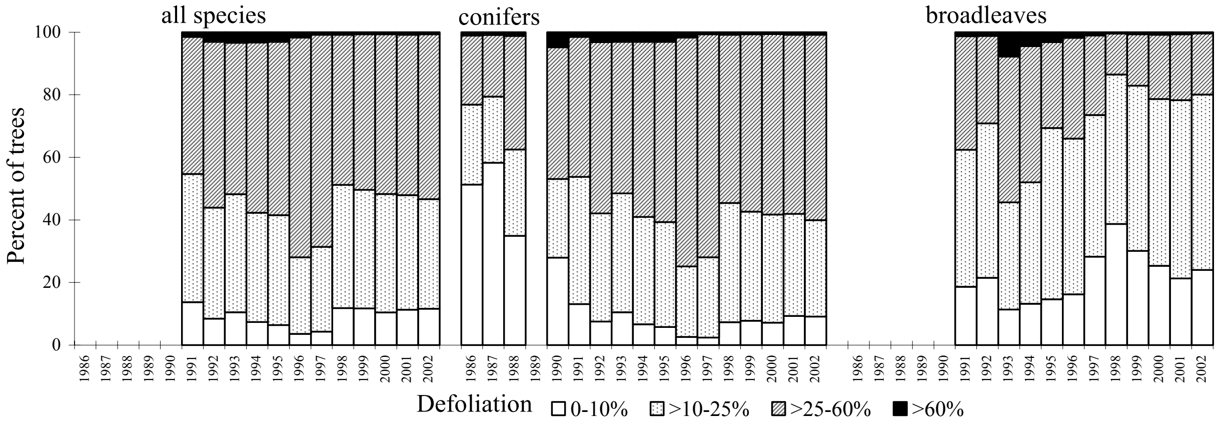
Croatia



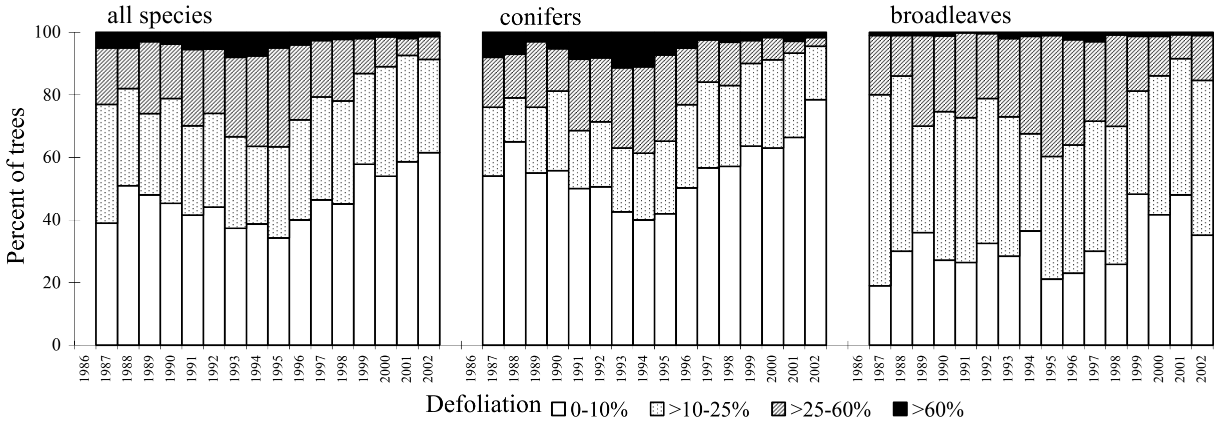
Cyprus



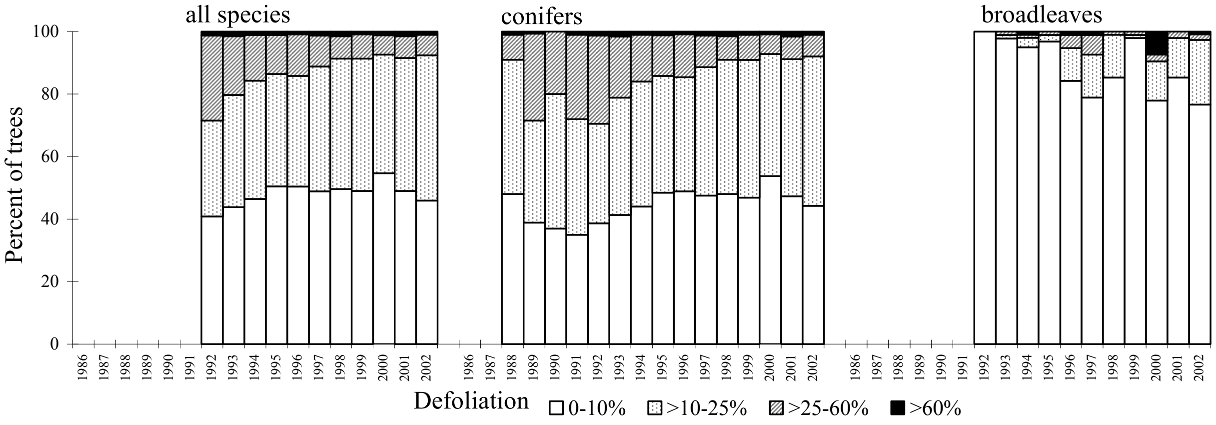
Czech Republic



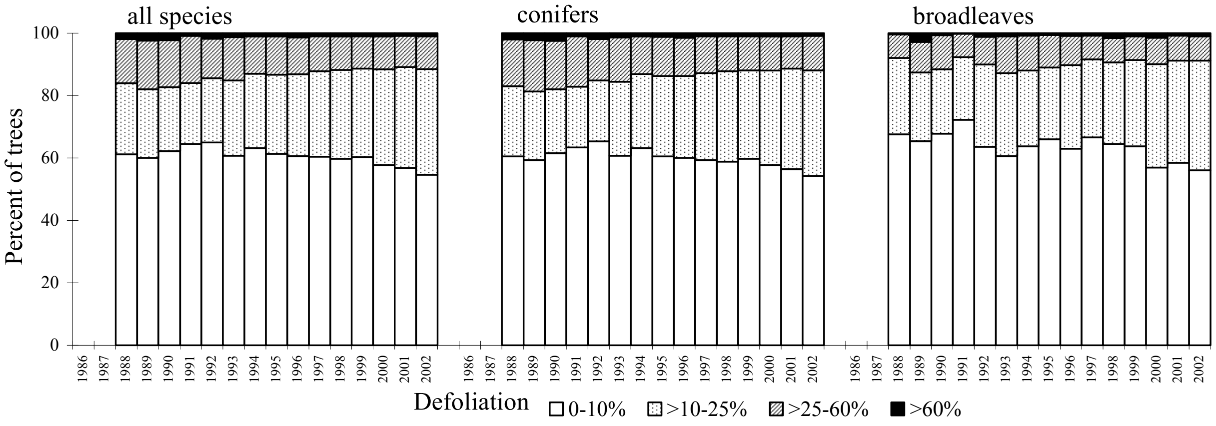
Denmark



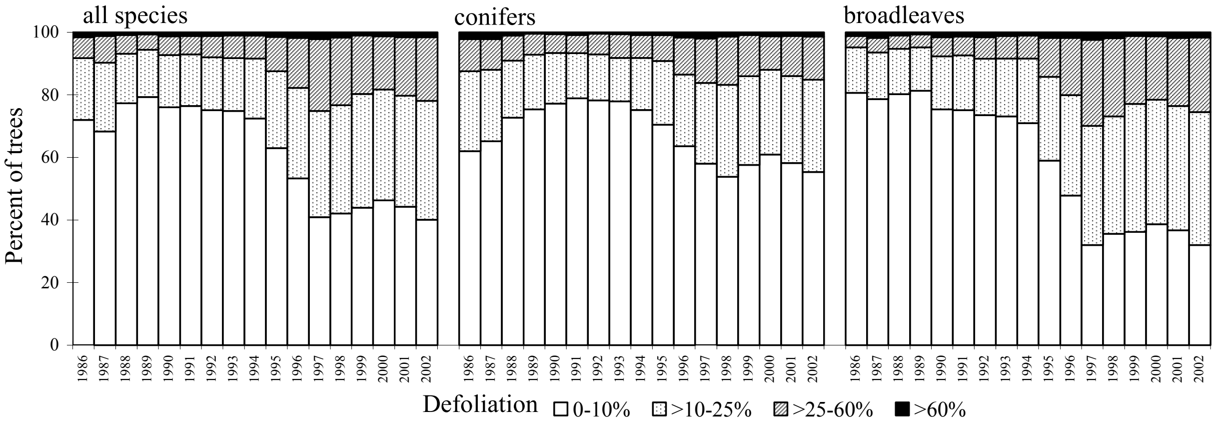
Estonia



Finland

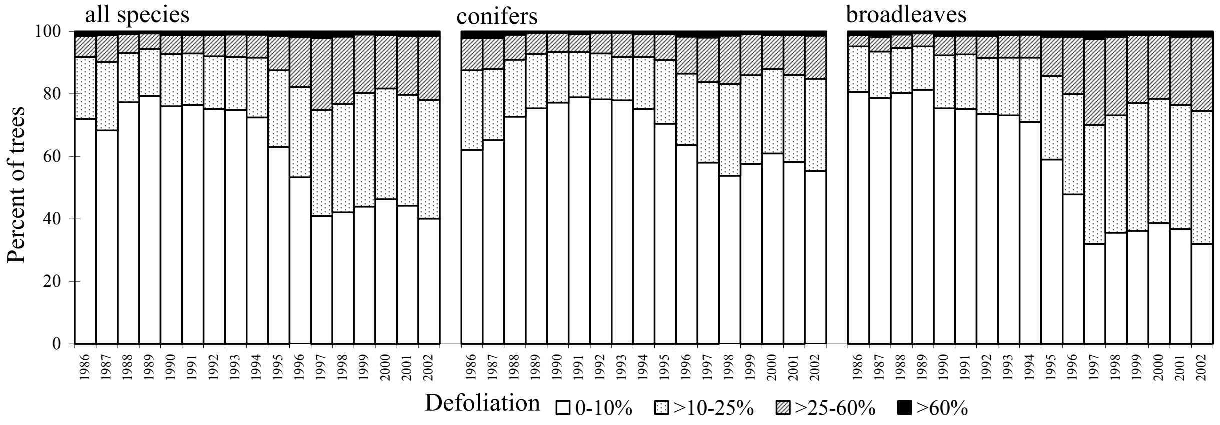


France *



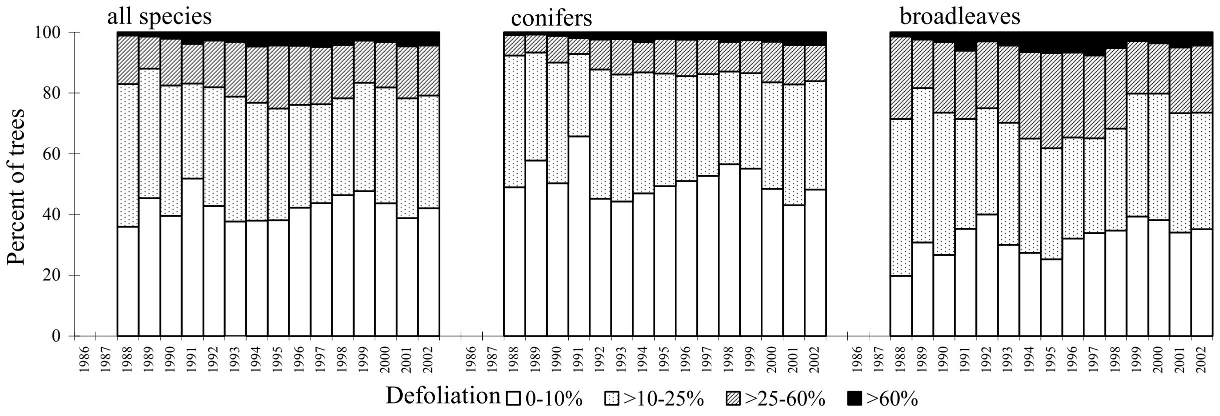
*** due to methodological changes, only the time series 1988-94 and 1997-99 are consistent, but not comparable to each other.**

Germany

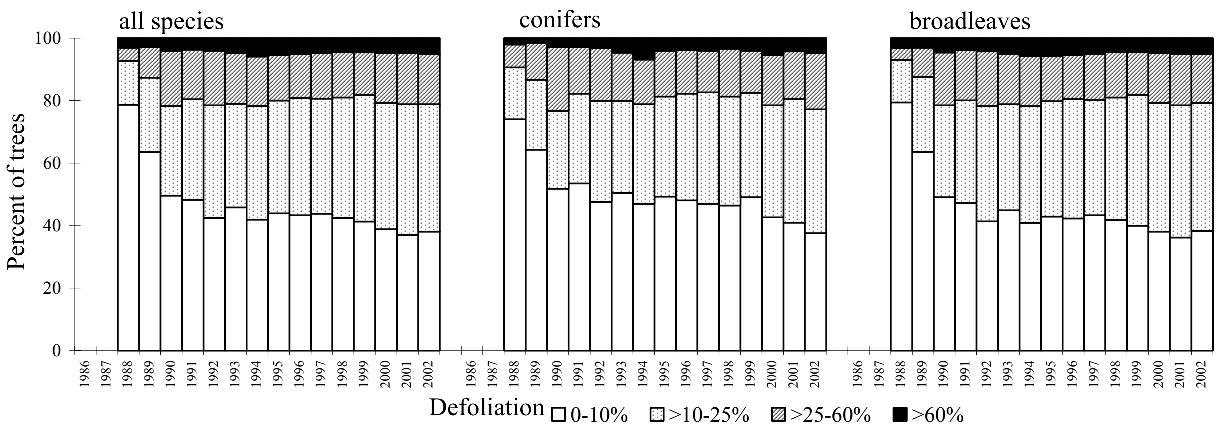


*** since 1991 with former GDR**

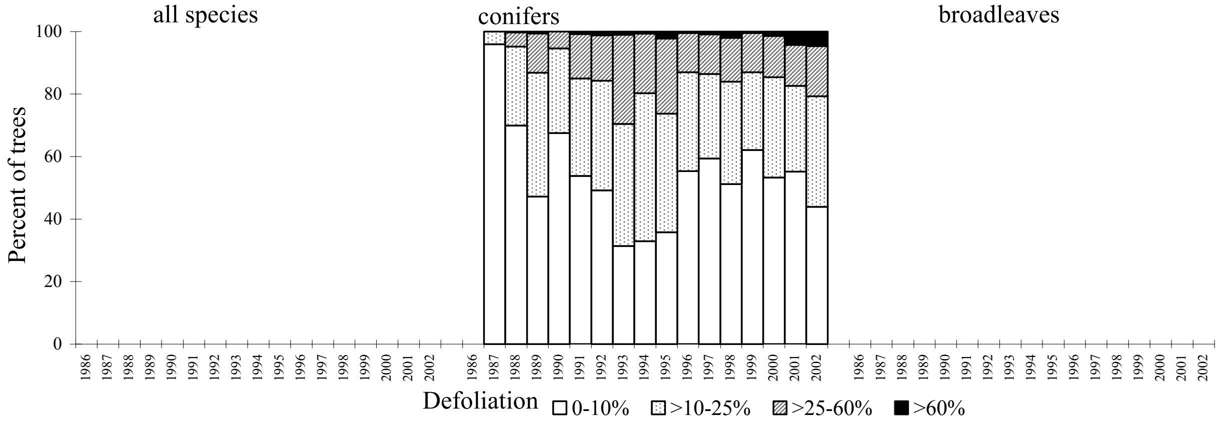
Greece



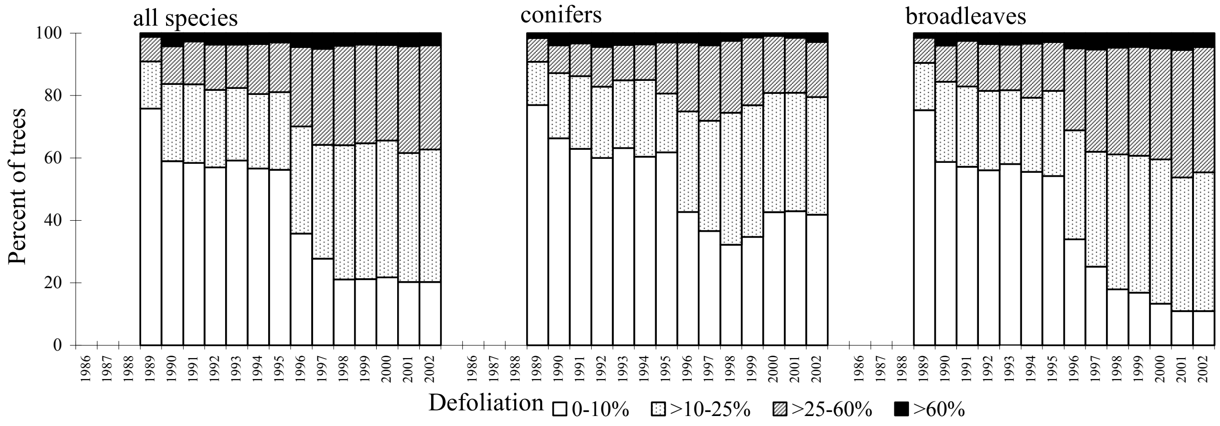
Hungary



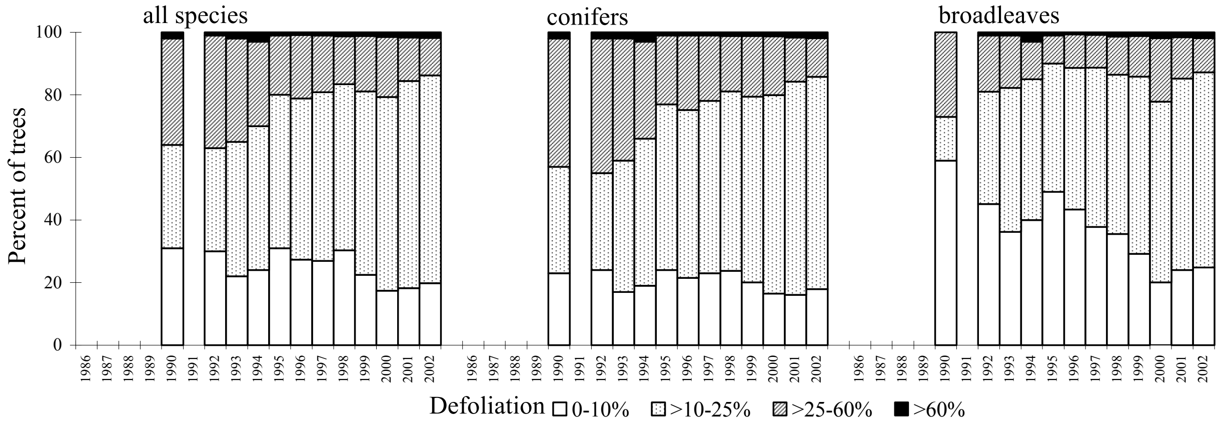
Ireland



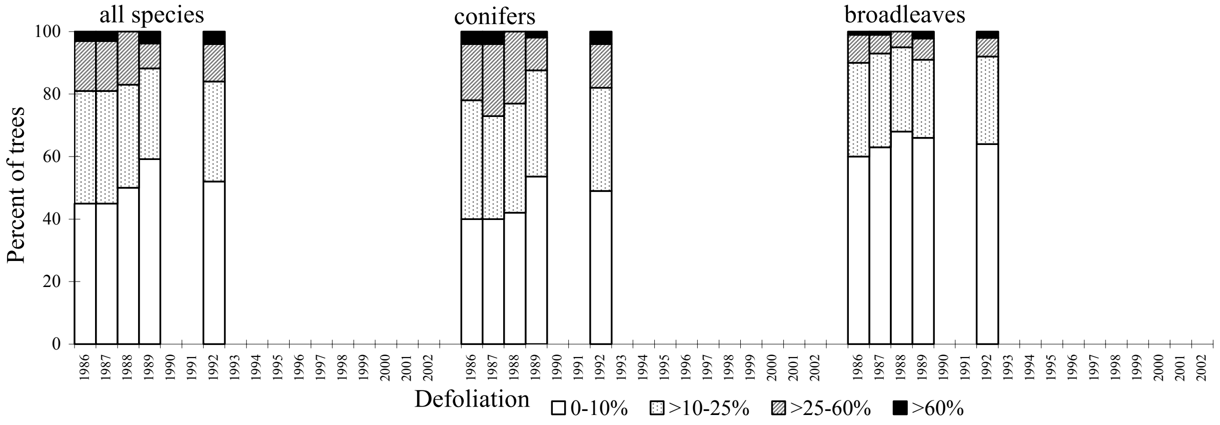
Italy



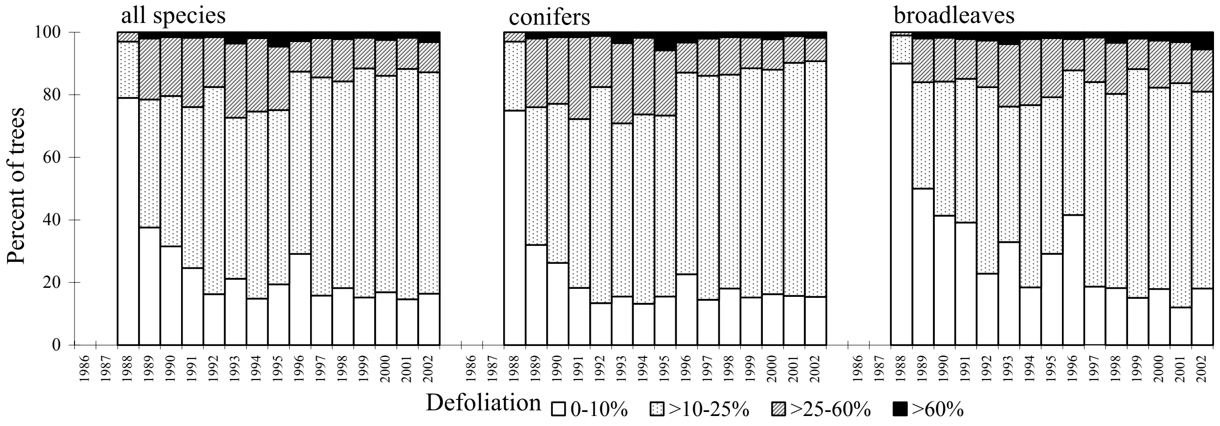
Latvia



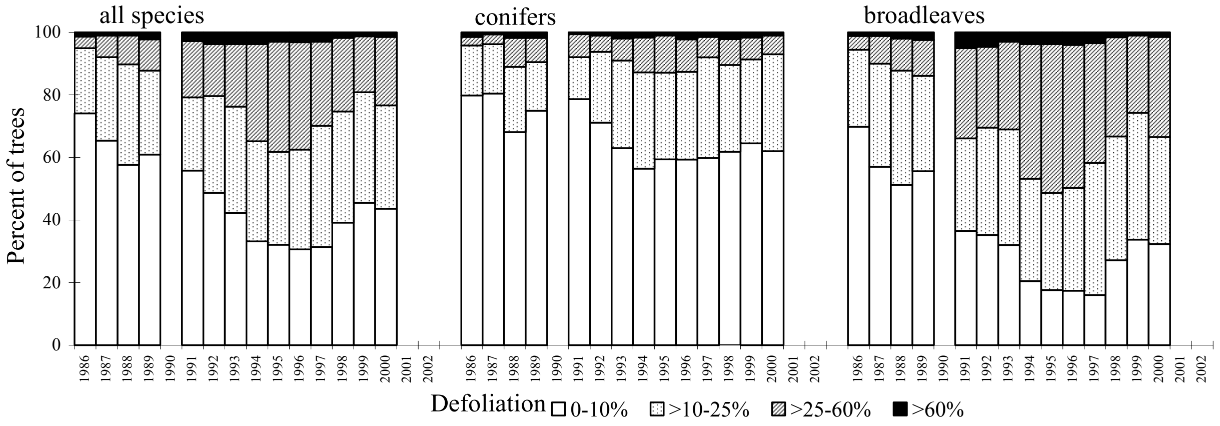
Liechtenstein



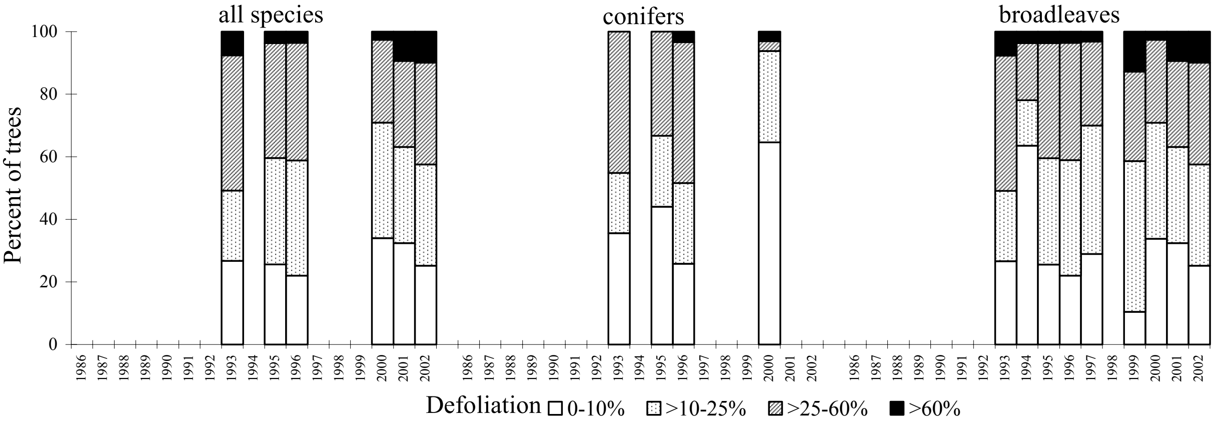
Lithuania



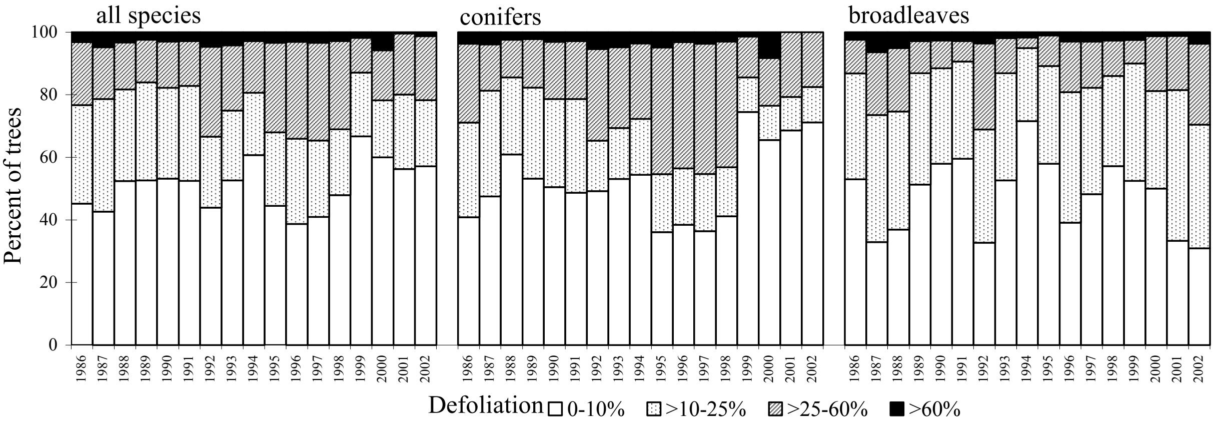
Luxembourg



Republic of Moldova

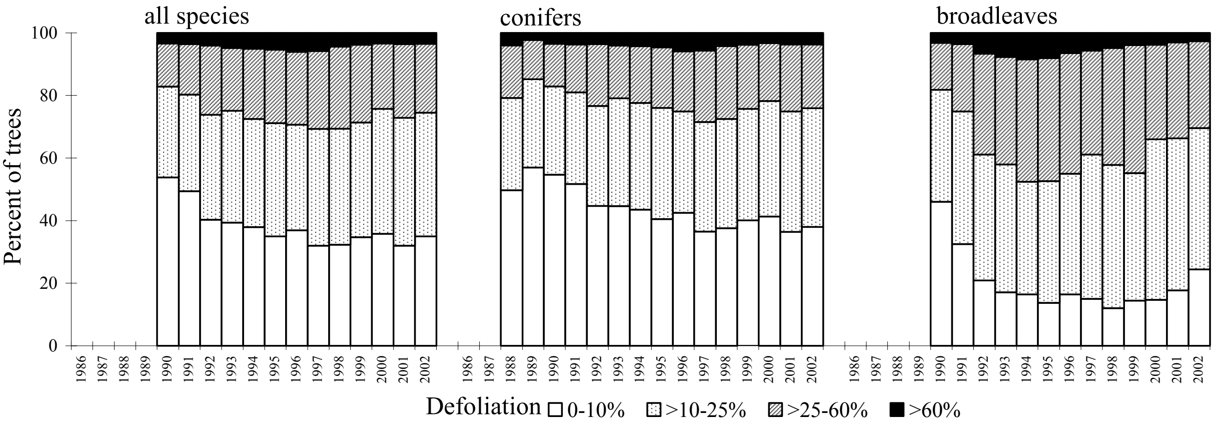


The Netherlands

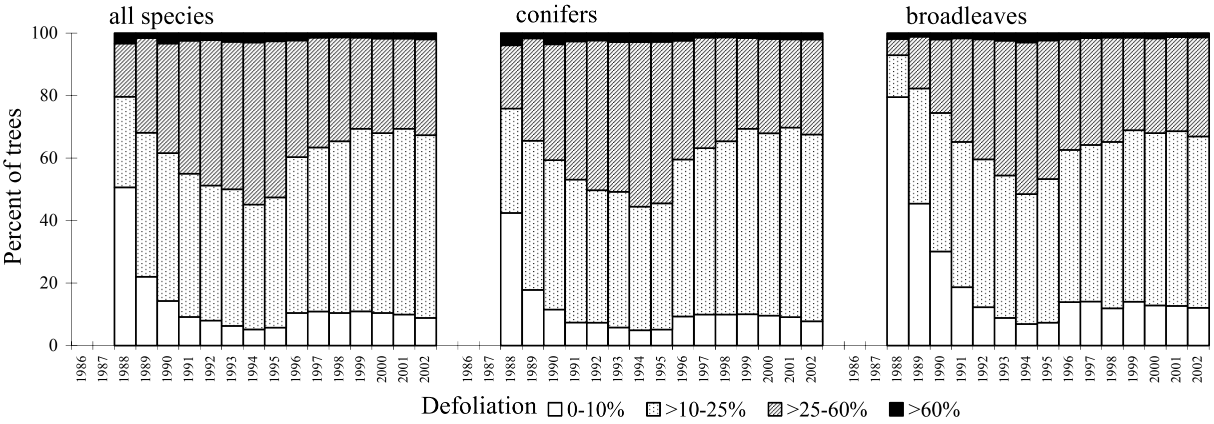


1989-1994: 1500 plots, 1995-1998: 200 plots, since 1999: 11 plots

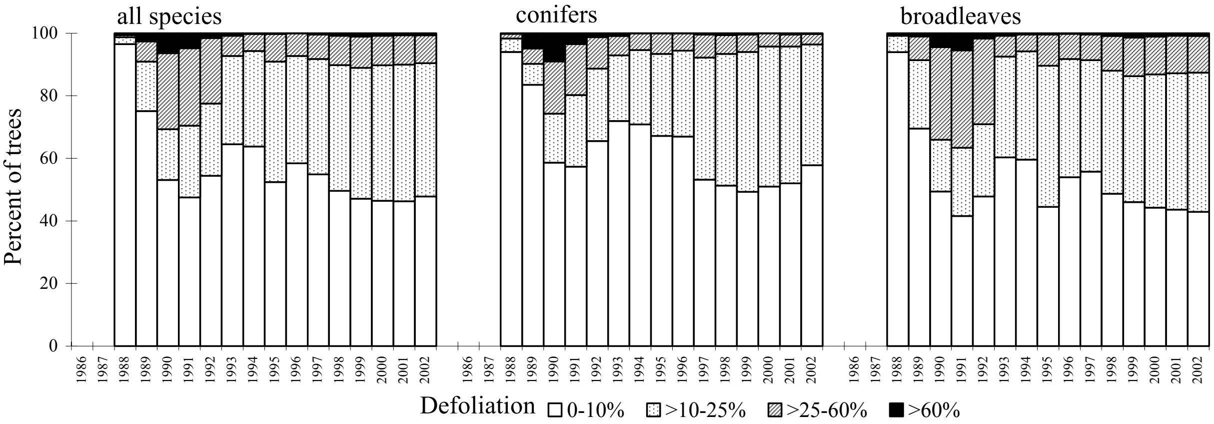
Norway



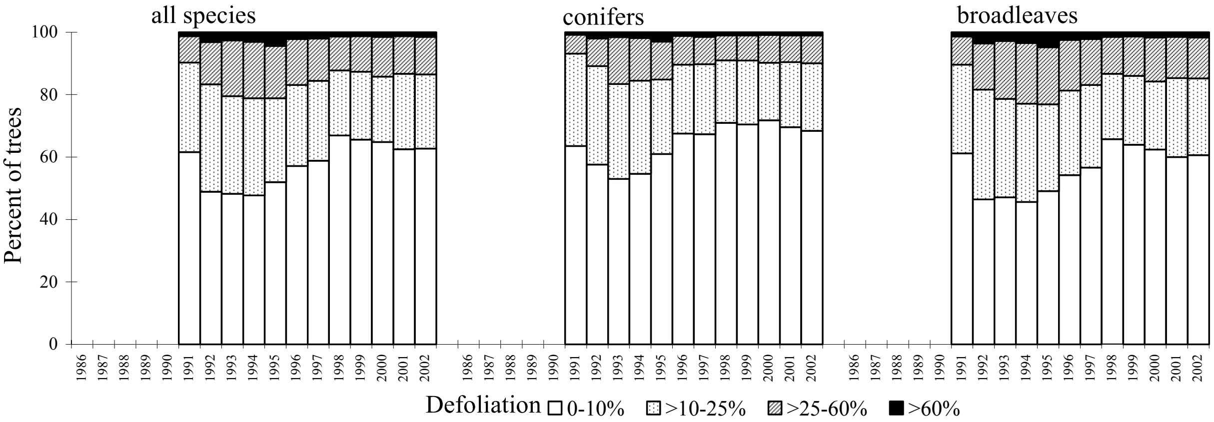
Poland



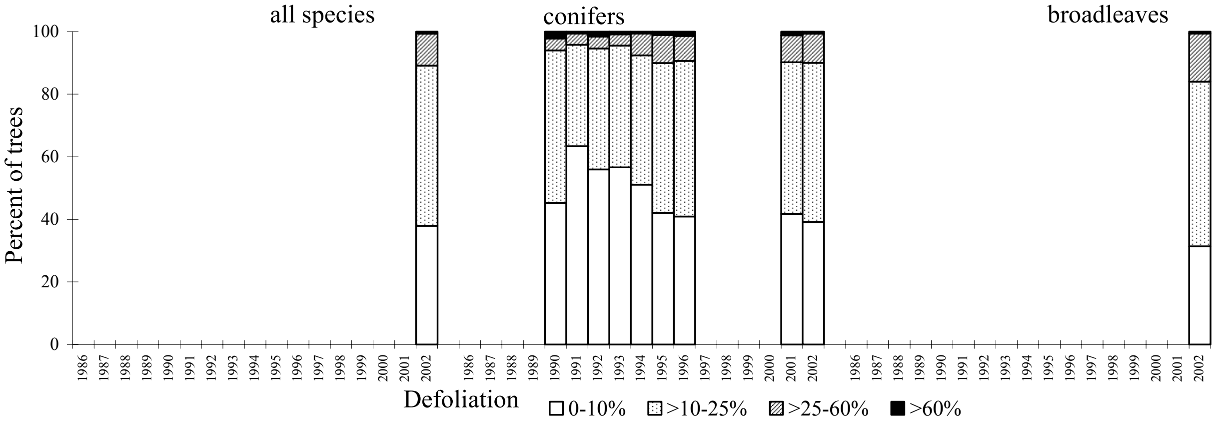
Portugal



Romania

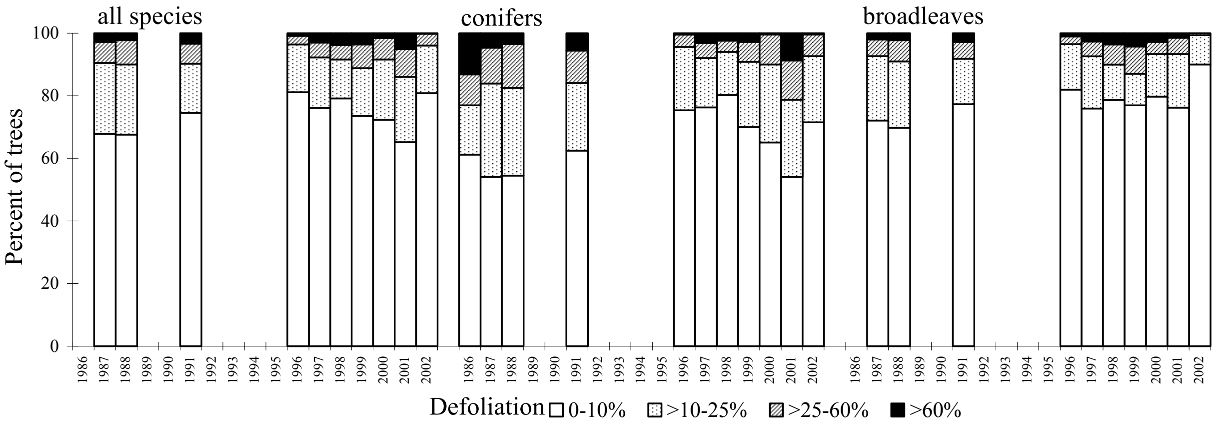


Russian Federation *

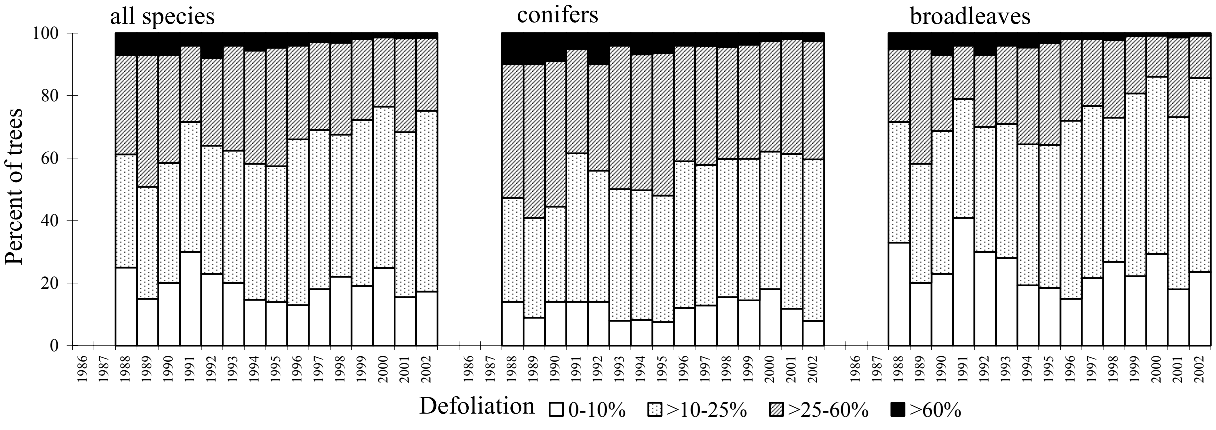


*** Only regional surveys in north-western and Central European parts of Russia.**

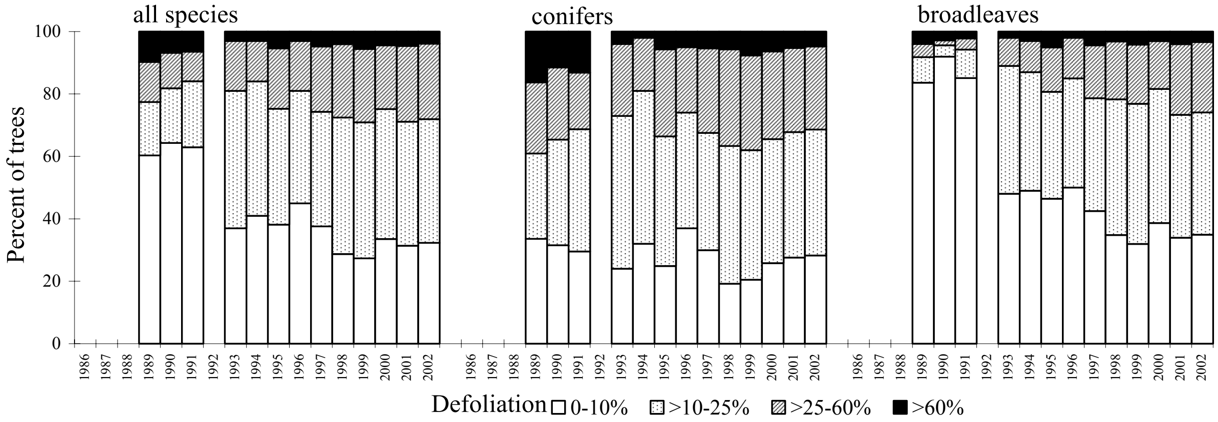
Serbia and Montenegro



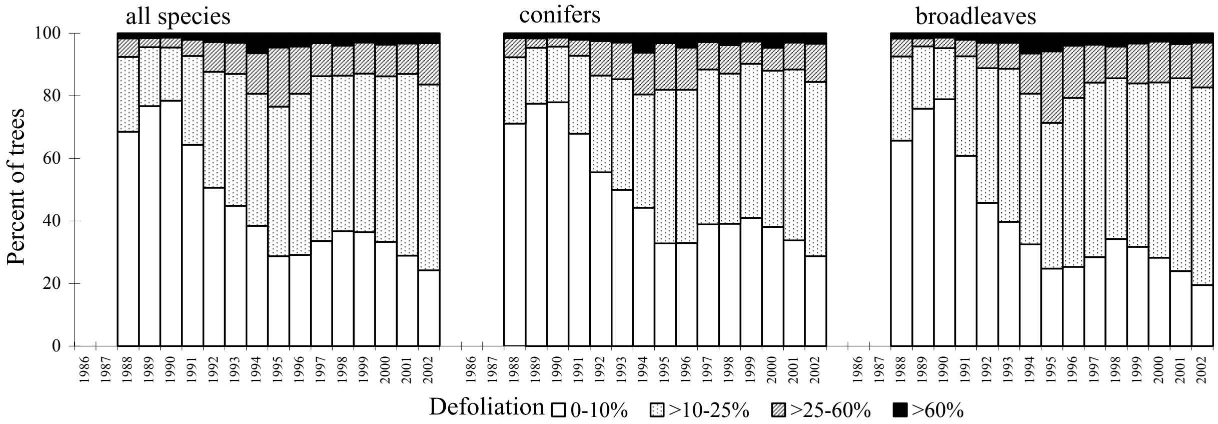
Slovak Republic



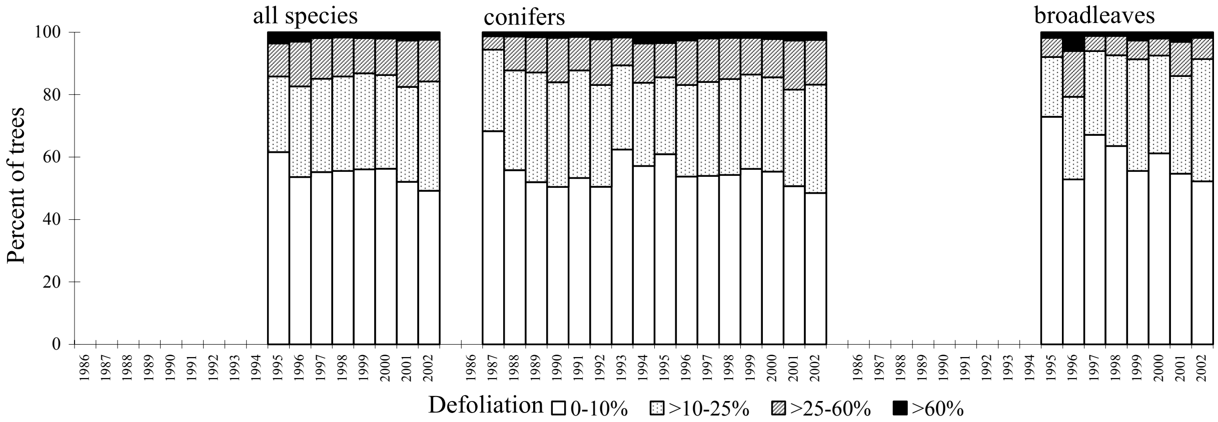
Slovenia



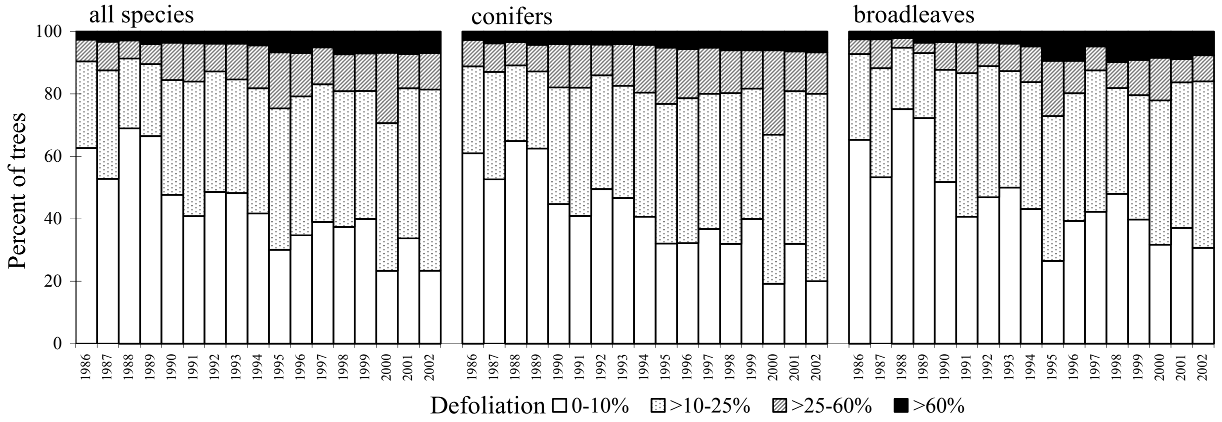
Spain



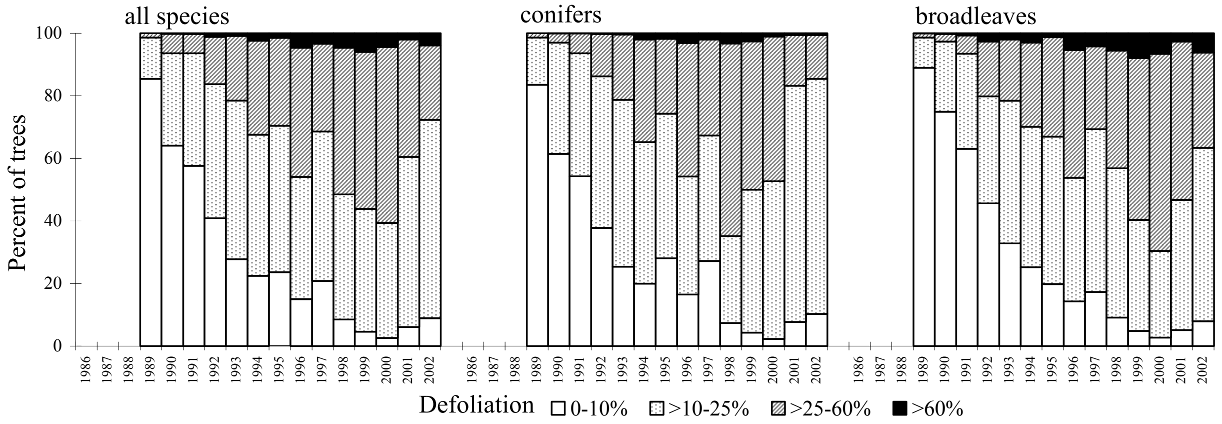
Sweden



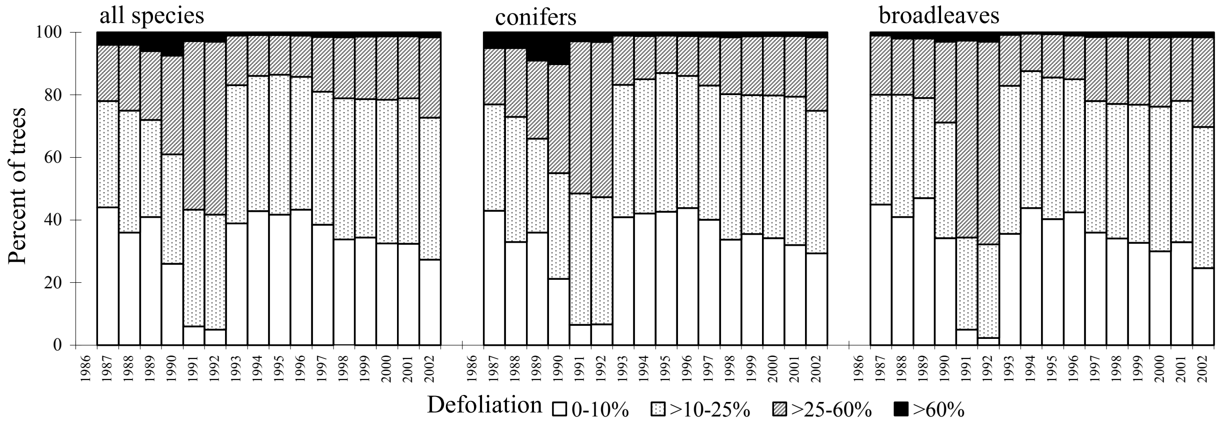
Switzerland



Ukraine



United Kingdom



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

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:

$$t = \frac{\left| \bar{x}_{2002} - \bar{x}_{2001} \right| \sqrt{N}}{s_d}$$

where $\bar{x}_{2002} - \bar{x}_{2001}$ is the difference in mean plot defoliation between the assessments in 2001 and 2002,

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 pair wise assigned differences in tree defoliation for both years of assessment

$$d_i = x_{2002(i)} - x_{2001(i)}, \qquad i = 1,2,3,...,N$$

with N - number of trees per plot.

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

$$s_d = \sqrt{s_{2001}^2 + s_{2002}^2 - 2r_{2001,2002} s_{2001} s_{2002}}$$

with standard deviations s_{2001}, s_{2002} and $r_{2001,2002}$ derived from the pairs of defoliation scores for the years 2001 and 2002.

The latter equation reveals that a high correlation between the two damage assessments as quantified by the correlation coefficient $r_{2001,2002}$ 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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