ISSN 1020-3729

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 for Europe

European Commission

Forest Condition in Europe

Results of the 2000 Large-scale Survey

2001 Technical Report

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

Cover photo by Martin Lorenz

ISSN 1020-3729

Printed in Germany

ISSN 1020-3729

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
for Europe

European Commission

Forest Condition in Europe

Results of the 2000 Large-scale Survey

2001 Technical Report

Prepared by: Federal Research Centre for Forestry and Forest Products

Authors

M. Lorenz (Head of PCC)

W. Seidling (Biologist, PCC)

V. Mues (Forest Scientist, PCC)

G. Becher (Forest Scientist, PCC)

R. Fischer (Forest Scientist, PCC)

Programme Coordinating Centre (PCC)
c/o Federal Research Centre for Forestry and Forest Products (BFH)
Leuschnerstr. 91
D-21031 Hamburg
Germany
Internet: http://www.icp-forests.org

Acknowledgements

33 countries supported the preparation of the present report by submission of data and reports. Several countries and the European Commission granted financial support. A complete list of the national and international institutions having contributed to the report is provided in Annex V.

Mrs. C. Lübker of PCC carried out technical and administrative work.

The United Nations Economic Commission for Europe and the European Commission wish to express their appreciation to all persons and institutions having contributed to the preparation of the report.

CONTENTS

PREFACE

Increasing forest damage in various parts of Europe and the concern that this could be caused by air pollution led to the establishment of the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) by the United Nations Economic Commission for Europe (UN/ECE) under its Convention on Long-range Transboundary Air Pollution (CLRTAP) in 1985. In 1986 the European Union (EU) adopted the 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, 38 countries including all EU-Member States, Canada and the United States of America are participating.

The monitoring programme comprises the assessment of the large-scale spatial and temporal variation of forest condition on a European-wide grid (Level I) as well as 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, also soil condition and partly the nutritional status of trees have been assessed once. At Level II, besides crown condition, soil condition and the nutritional status of trees, also increment, vegetation, depositions, soil solution, meteorology and the phenology of tree crowns are assessed.

The monitoring results contribute to the scientific basis of air pollution control policies of UN/ECE and the European Commission (EC). Fifteen years of monitoring forest condition and two decades of forest damage research have shown, however, that the discussion of recent forest damage must not be confined to the effects of air pollution alone. The comprehensive monitoring programme corresponds to the complex interrelations between natural and anthropogenic factors in forest ecosystems. Infrastructure and data of the programme are thought to be relevant for other processes of international forest policies, e.g. those on biodiversity , climate change and sustainable forest management. In this respect the monitoring pursues the objectives of Resolution S1 of the Strasbourg, Resolution H1 of the Helsinki and Resolution L2 of the Lisbon Ministerial Conference on the Protection of Forests in Europe, and contributes to global forest policies such as the United Nations Forum on Forests (UNFF).

The monitoring results obtained 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 report refers to the results of the large-scale transnational survey in the year 2000. It is the tenth in the series of Technical Reports "Forest Condition in Europe" published annually by ICP Forests and EC and presents also the results of the national crown condition surveys. The contributions to the report made by the participating countries are gratefully acknowledged.

SUMMARY

The large-scale survey of forest condition in Europe 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 (UN/ECE) and under the Scheme on the Protection of Forests against Atmospheric Pollution of the European Union (EU) started 15 years ago with the first crown condition assessment. In the year 2000, crown condition was assessed on 363 488 sample trees distributed on 18 628 plots on the different national grids in 32 of the participating 38 countries. 135 839 sample trees on 6 040 of these plots, constituting a transnational grid of 16 x 16 km in 30 countries, were evaluated for the calculation of results at the European scale.

In all parts of Europe, defoliation of various extent is observed. The mean defoliation of the 2000 total transnational tree sample is 20.0%. Of the main tree species, *Pinus sylvestris* and *Quercus robur et Quercus petraea* have the highest mean defoliation with 24.5%, followed by *Picea abies* (20.0%) and *Fagus sylvatica* (19.7%). These results are not comparable with those of previous years due to differences in the sample sizes and changes in methods in some countries. The development of defoliation, however, can be traced by means of a selection of those plots continuously observed. In recent years, the sharpest deterioration has occurred on *Pinus pinaster* and *Quercus ilex* in southern Europe. *Fagus sylvatica* deteriorated in the Subatlantic, Mountainous (south) and Continental regions. *Picea abies* deteriorated in several parts of Europe, but improved particularly in the main damage areas of central Europe. *Pinus sylvestris* recuperated in the main damage areas of central Europe from the mid 1990s on.

Defoliation was shown to reflect the impact of many different natural and anthropogenic factors. Weather conditions and biotic stressors are the ones mentioned most frequently by the countries. It is noteworthy that defoliation has been increasing in many regions and that regions of high defoliation coincide with areas of highest depositions in central Europe. Several countries mention air pollution as a predisposing, accompanying or triggering factor. However, the substantiation of cause-effect relationships needs integrative evaluations combining a larger number of parameters. As an integrative approach, general linear models were used for a country-specific description of the age-defoliation relationship for the six most frequent tree species (*Picea abies*, *Pinus sylvestris*, *Pinus pinaster, Fagus sylvatica*, *Quercus robur et petraea*, and *Quercus ilex*). The basis were values of medium-term mean defoliation (1994–2000) from all plots where at least more than two trees of the particular species were assessed in the respective period. The residuals of the models were named "preliminarily adjusted defoliation" (PAD). A geostatistic analysis with subsequent kriging of these PAD values led to maps, which show the mean defoliation adjusted for country-specific age trends. They can also be used for the detection of further variables, which cover relevant spheres of forest condition, explaining defoliation in sense of cause-effect relationships. Indices for fungi and insect infestations, calculated from the Level I data as well as first hints from a respective inquiry and extracted information from scientific literature show promising results. In future, non-linear models e.g. for the defoliation-age relationship will be applied and weighting and stratifying approaches will be developed.

1 INTRODUCTION

The present report describes the results of the large-scale transnational survey of the year 2000. The transnational survey aims to assess the spatial and temporal variation of forest condition in relation to natural and anthropogenic factors, particularly air pollution. On each of meanwhile more than 6 000 transnational sample plots, crown condition has been assessed annually for 15 years. All previous annual reports on forest condition in Europe focussed on the evaluation of crown condition. However, also soil condition and foliage chemistry was assessed on 5 300 and 1 400 of these plots, respectively, the results having been documented in separate reports. This has enabled integrative evaluations of the large-scale crown, soil and foliage data in connection with relevant large-scale data of other programmes. Aimed at contributing to the clarification of cause-effect relationships on the large-scale, the report on forest condition in Europe will no longer remain confined to the description of solely crown condition, but will from now on be extended towards evaluations utilizing the full range of large-scale data available.

The present report is outlined as follows:

Chapter 2 focuses on the methods of the large-scale surveys of crown condition, soil condition and foliage chemistry. Moreover, the quality assurance and the evaluation of crown condition data are described and the interpretability of the results is discussed.

In Chapter 3, the crown condition in 2000 and the development of crown condition over several years is described.

Chapter 4 presents a multivariate analysis of defoliation with stand age and the occurrence of insects and fungi as explanatory variables. The residuals are mapped using a geostatistical approach.

Chapter 5 consists of national reports on crown condition and its development in the individual countries, laying emphasis upon its interpretation in connection with a number of stress factors.

An interpretation of the transnational and national results is given in Chapter 6.

Maps, graphs and tables concerning the transnational and national results are provided in Annexes I and II, respectively. Annex III provides a list of tree species with their botanical names and their names in the official UN/ECE 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 2000

2.1 Background

On the Level I plots, surveys are carried out with different resolutions in time: crown condition parameters as well as the relevant stand and site characteristics are assessed annually by the participating countries, whereas the surveys of soil condition and of foliage element compounds are available from singular surveys. The methods and codes of the surveys are described in the "Manual on methods and criteria for harmonised sampling, assessment, monitoring and analysis of the effects of air pollution on forests" (UN/ECE 1998) and in Commission Regulation (EEC) No. 1996/87 and its amendments (EU 1987). In the following chapters, 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. The description of crown condition assessments includes a section on data quality assurance. Furthermore, the data evaluation is described and the interpretability of the results is commented.

2.2 Selection of sample plots

2.2.1 The transnational survey

The objective of the transnational survey is the documentation of 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.

With 6 040 plots assessed in 31 countries including all 15 EU-Member States (Table 2.2.1-1), the transnational survey of the year 2000 was the most comprehensive ever. In addition, 6 plots were assessed on the Azores and 13 plots on the Canary Islands, but excluded from the transnational evaluation as they are not located in those geoclimatic regions according to which all other plots were assigned (Annex I-1). These plots, however, are shown in the respective maps. The figures in Table 2.2.1-1 are not necessarily identical to those published in previous reports. Consistency checks and subsequent data corrections as well as new data submitted by countries may have caused rearward changes in the data base. For example, in 2000 Belarus submitted new data which dated back to 1997. Italy and Spain completed their plot sample by establishing additional plots.

Figure 2.2.1-1 shows the spatial distribution of the plots assessed in 2000. For a range of observations the plot sample is stratified according to geoclimatic regions adapted from those by WALTER et al. (1975), and WALTER and LIETH (1967). For an explanation of these regions see Annex I–1. Percentages of plots in the 10 different regions are given in Table 2.2.1-2.

Table 2.2.1-1: Number of sample plots from 1988 to 2000 according to the actual database.

Country	Number of sample plots												
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Austria			72	79	77	76	76	76	130	130	130	130	130
Belgium	33	33	29	29	29	29	29	29	29	29	29	30	29
Denmark		25	25	25	25	25	25	24	23	22	23	23	21
Finland				359	413	405	382	455	455	460	459	457	453
France	228	509	514	513	505	506	534	543	540	540	537	544	516
Germany	299	297	410	411	414	412	417	417	421	421	421	433	444
Greece	84	104	101	101	98	96	96	95	95	94	93	93	93
Ireland	22	22	22	22	22	22	21	21	21	21	21	20	20
Italy	206	204	204	206	202	212	209	207	207	181	177	239	255
Luxembourg	4	4	4	4	4	4	4	4	4	4	4	4	4
The Netherlands	14	14	14	14	14	13	13	13	12	11	11	11	11
Portugal	154	152	152	151	149	143	147	141	142	144	143	143	143
Spain	388	457	447	436	462	460	444	454	447	449	452	598	607
Sweden		60	38	45	67	59	340	726	766	758	764	764	769
United Kingdom	74	74	74	74	72	69	66	63	79	82	88	85	89
EU	1506	1955	2106	2469	2553	2531	2803	3268	3371	3346	3352	3574	3584
Belarus										409	409	401	401
Bulgaria							109	120	120	120	135	115	108
Croatia						84	88	82	83	86	89	84	83
Czech Republic	85		93	362	156	178	205	199	196	196	277	292	291
Estonia						89	90	90	91	91	91	91	90
Hungary			67	66	65	65	62	63	60	58	59	62	63
Latvia			80	101	100	101	94	94	99	96	97	98	94
Lithuania					73	74	73	73	67	67	67	67	67
Moldova						12	12	11	10	10	10	10	10
Norway					387	390	384	386	387	386	386	381	382
Poland			474	476	476	476	441	432	431	431	431	431	431
Romania					215	167	199	241	224	237	235	238	235
Russian Fed.							7	134					
Slovak Republic	111	111	111	111	111	111	111	111	110	110	109	110	111
Slovenia						34	34	42	42	42	41	41	41
Switzerland			45	45	45	45	45	47	49	49	49	49	49
Total Europe	1702	2066	2976	3630	4181	4357	4757	5393	5340	5734	5837	6044	6040

Table 2.2.1-2: Distribution of the sample plots of the year 2000 over the climatic regions.

Climatic region	Number of plots	Percentage of plots
Boreal	991	16.4
Boreal (temperate)	927	15.3
Atlantic (north)	342	5.7
Atlantic (south)	289	4.8
Sub-atlantic	1261	20.9
Continental	250	4.1
Mountainous (north)	251	4.2
Mountainous (south)	731	12.1
Mediterranean (higher)	403	6.7
Mediterranean (lower)	595	9.8
All regions	6040	100.0

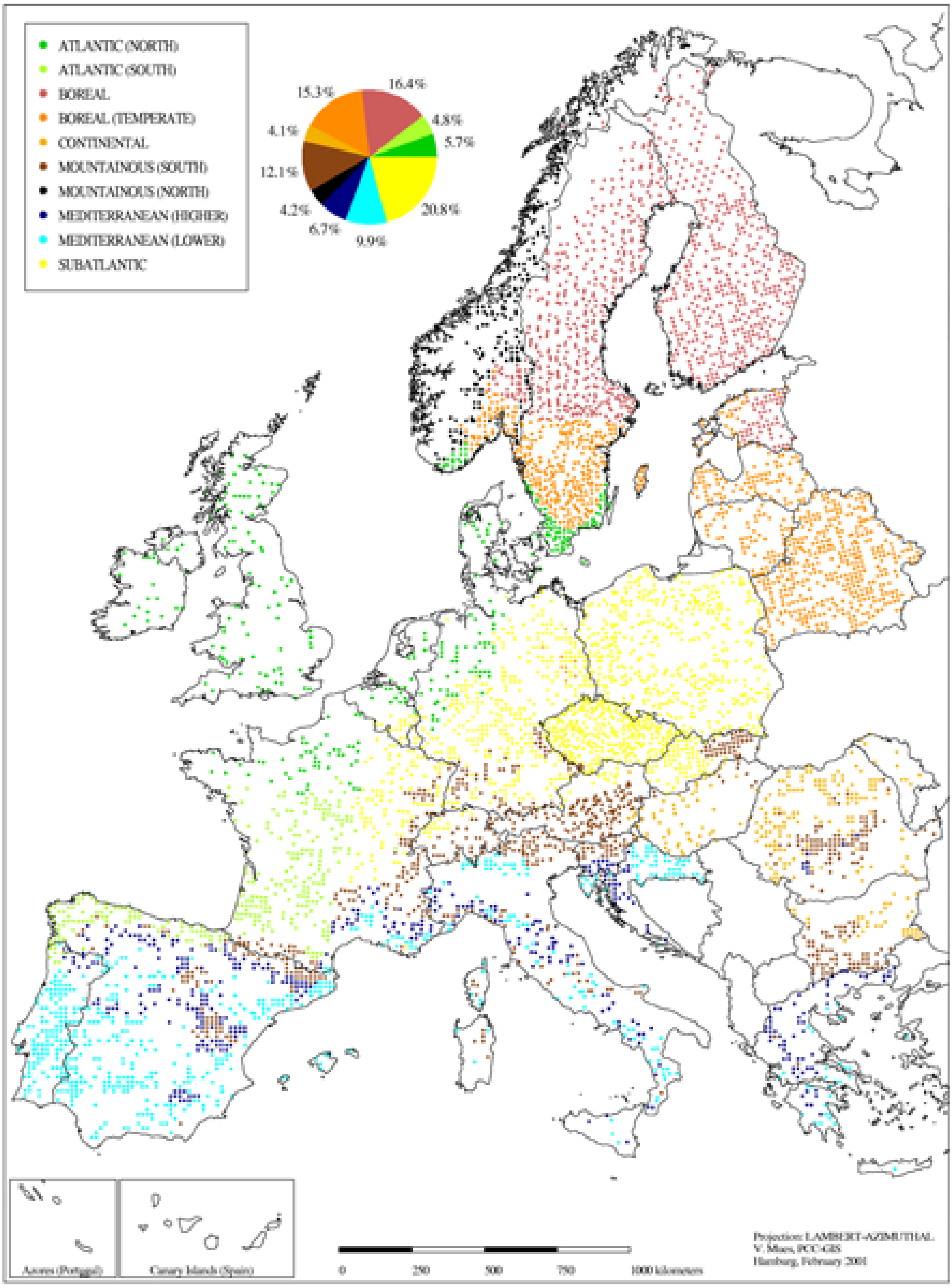


Figure 2.2.1-1: Plots according to climatic regions (2000).

2.2.2 National surveys

The national surveys aim at the documentation of the 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. 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, observations of easily identifiable damage, date of observation.

On the plots of the transnational survey, the parameters reported in Tab. 2.3.1.-1 are additionally to defoliation and discolouration given.

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

Registry and location	country	state where the plot is assessed [code numbers]
	plot number	identification of each plot
	plot coordinates	latitude and longitude [degrees, minutes, seconds] (geographic)
	date	day, month and year of observation
Geomorphology	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]
	easily identifiable damage	treewise observations concerning damage caused by game and grazing, insects, fungi, abiotic agents, direct action of man, fire, known regional pollution, and other factors

Nearly all countries submitted data on **water availability**, **humus type**, **altitude**, **aspect**, and **mean age**. The numbers of plots for which these site parameters were reported increased distinctively since the 1998 survey (Table 2.3.1-2). The data set is now almost complete for altitude, aspect and mean age. For **soil type**, the coverage is much lower than for the other parameters. Several countries, including one EU-Member State, did not submit soil type data. These variables are available for more than 5000 plots, partially surveyed from 1987 onwards.

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

Country	Number of plots	Number of plots per site parameter					
		Water	Humus	Altitude	Aspect	Age	Soil
Austria	130	130	128	130	130	130	130
Belgium	29	29	29	29	29	29	10
Denmark	21	21	21	21	21	21	21
Finland	453	453	453	453	453	453	453
France	516	516	516	516	516	516	466
Germany	444	444	444	444	444	444	409
Greece	93	93	91	93	93	93	93
Ireland	20	20	20	20	20	20	20
Italy	255	255	255	255	255	255	0
Luxembourg	4	4	4	4	4	4	4
The Netherlands	11	11	11	11	11	11	11
Portugal	143	143	143	143	143	143	137
Spain	607	607	607	607	607	607	431
Sweden	769	624	756	769	769	769	561
United Kingdom	89	89	89	89	89	89	89
EU	3584	3439	3567	3584	3584	3584	2857
Percent of EU plot sample		99.95	99.53	100.0	100.0	100.0	79.12
Belarus	401	400	0	0	401	401	0
Bulgaria	108	108	0	108	108	108	108
Croatia	83	83	83	83	83	83	57
Czech Republic	291	291	95	291	291	291	95
Estonia	90	90	90	90	90	90	90
Hungary	63	63	41	63	63	63	63
Latvia	94	94	94	94	94	94	94
Lithuania	67	67	1	67	67	67	67
Rep. of Moldova	10	10	10	10	10	10	0
Norway	382	0	369	382	382	382	365
Poland	431	431	0	431	431	431	30
Romania	235	235	235	235	235	235	227
Slovak Republic	111	0	111	111	111	111	111
Slovenia	41	41	41	41	41	41	41
Switzerland	49	0	0	49	49	49	46
Total Europe	6040	5352	4737	5639	6040	6040	4251
Percent of total plot sample		88.61	78.43	93.36	100.0	100.0	70.38

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 5289 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, however the most were surveyed in the years from 1993 to 1995 (2498 plots). An overview is given in Table 2.3.2-1.

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

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

[1)] 12 of them belonging to Canary islands

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

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

Besides this general information the database 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, or - 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 (UN/ECE 1998) - between 10 and 30 cm. Resulting codes together with those for the organic layer are listed in Table 2.3.2-2. Combinations of the listed layers are often grouped country-wise. Deviations of sampling depths occur due to national approaches, which have been performed before the manual has been adopted.

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

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

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

Systematic differences between the participating laboratories were tested and estimated by ring tests. The resulting mean errors for the most relevant parameters are 23% for pH, 10% for total N, and 10% for base saturation, which can with respect to particular cases be quite considerable. Furthermore, reported data violating one or more integrity rules outlined in VANMECHELEN et al. (1997: 6f), 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 1497 plots from 17 European countries (Table 2.3.3-1). The survey was carried out using a standardised methodology (STEFAN et al. 2000).

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

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

Data from the foliage survey are available from 1987 to 1998 with highest frequency in the years from 1992 to 1997 (1317 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.

Table 2.3.3-2: Parameters stored within the foliar data base (according to STEFAN et al. 2000).

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
Geomorphology	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]

The comparability of the data was checked along with the annual Level II surveys by means of four interlaboratory analytical tests, which resulted in a significant improvement in analytical quality, especially for the element sulphur which was in the beginning classified as 'fairly problematic' but now (4th interlaboratory test 1999/2000; BARTELS 2000) reaches variances below 10% between all laboratories.

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 standardized 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 (UN/ECE, 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 losses of foliage caused by stressors including air pollutants and which are not explainable by 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 (UN/ECE, 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 from the beginning on. Should mechanical damage occur to a sample tree, any resulting loss of foliage is not counted as defoliation. In this 6way, 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 2.4). Discolouration is reported both in the transnational and in the national surveys using the traditional classification.

2.3.4.2 Defoliation assessment in 2000

The total numbers of trees assessed from 1988 to 2000 in each country are shown in Table 2.3.4.2-1. The figures are not necessarily identical to those published in previous reports for the same reasons explained in Chapter 2.2.1.

The 2000 tree sample represented 112 species. 64.2% of the plots were dominated by conifers, 35.5% 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 26.5%, followed by *Picea abies* with 20.9%, *Fagus sylvatica* with 8.9% and *Quercus robur* with 3.8% of the total tree sample (Annex I-6).

Table 2.3.4.2-1: Number of sample trees from 1988 to 2000 according to the actual database.

Country	Number of sample trees												
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Austria			2132	2244	2167	2121	2107	2101	3670	3604	3577	3535	3506
Belgium	792	791	684	686	673	685	684	678	684	683	692	696	686
Denmark		600	600	600	600	600	600	576	552	528	552	552	504
Finland				3899	4545	4427	4261	8754	8732	8788	8758	8662	8576
France	4464	10170	10280	10255	10093	10118	10672	10851	10800	10800	10740	10883	10317
Germany	7913	7853	10558	10662	10767	10729	10866	10907	11002	10990	13178	13466	13722
Greece	1980	2463	2392	2392	2320	2272	2272	2248	2248	2224	2204	2192	2192
Ireland	461	462	458	458	460	462	441	441	441	441	441	417	420
Italy	5468	5635	5701	5741	5643	5884	5791	5703	5836	4873	4939	6710	7128
Luxembourg	96	96	96	96	95	95	93	96	96	96	96	96	96
Netherlands	280	278	279	280	280	260	260	257	237	220	220	225	218
Portugal	4620	4569	4563	4585	4508	4308	4414	4230	4260	4319	4290	4290	4290
Spain	9260	10968	10728	10462	11088	11040	10656	10896	10728	10776	10848	14352	14568
Sweden		234	146	265	300	311	3989	10310	10925	10910	11044	11135	11361
United Kingdom	1775	1776	1776	1770	1728	1656	1584	1512	1896	1968	2112	2039	2136
EU	37109	45895	50393	54395	55267	54968	58690	69560	72107	71220	73691	79250	79720
Belarus										9814	9736	9585	9602
Bulgaria							4370	4812	4789	4788	5389	4379	4197
Croatia						2016	2150	1970	1974	2030	2066	2015	1991
Czech	2125		2325	8971	3882	4423	5087	4933	4853	4844	6905	7300	7275
Estonia						2136	2159	2160	2184	2184	2184	2184	2160
Hungary			1351	1371	1348	1361	1322	1342	1298	1257	1383	1470	1488
Latvia			1920	2424	2396	2420	2257	2262	2368	2297	2326	2348	2256
Lithuania					1768	1843	1760	1776	1643	1634	1616	1613	1609
Moldova						288	288	263	236	253	234	259	234
Norway					4001	4016	3942	3905	3948	4028	4069	4052	4051
Poland			9476	9520	9520	9520	8820	8640	8620	8620	8620	8620	8620
Romania					5155	4004	4776	5688	5375	5687	5637	5712	5640
Russian Fed.							183	3180					
Slovak	5441	5382	5333	5296	5251	5144	5115	5091	5018	5033	5094	5063	5157
Slovenia						816	816	1008	1008	1008	984	984	984
Switzerland			479	487	488	500	509	824	854	880	868	857	855
Total Europe	44675	51277	71277	82464	89076	93455	102244	117414	116275	125577	130802	135691	135839

2.3.4.3 Data quality and interpretability of results

The quality of crown condition data is crucial to the interpretation of the assessment results. Assessment errors are inherent to the monitoring design, the field assessments, the data evaluation and the reporting of results. The reliability of the results depends strongly on the measures undertaken to keep errors within tolerable limits during each phase of the monitoring programme. Referring to CLINE and BURKMAN (1989), DURRANT et al.(1999) examine four main measures aimed at keeping the quality of data at high level in the monitoring of crown condition: “Quality management” (QM) concerning the monitoring design, “Quality assurance” (QA) concerning the precise definition of standards and procedures of the field assessments, “Quality control” (QC) aimed at calibration, training, independent reassessments and plausibility checks of data, as well as “Quality evaluation” (QE) assessing the accuracy of the data by means of statistical methods. Some of these measures have been an integral part of crown condition monitoring ever since, whilst others remain to be implemented (COZZI and FERRETTI, 2000). In the following, the consequences of the different implementation of these measures for the quality of the existing Level I crown condition database are discussed.

The sampling of trees and plots has been largely harmonized among the participating countries. The results of an inquiry by COZZI, FERRETTI AND LORENZ (2001) among 20 participating countries indicate that huge effort is made in Europe to document the design and the methods and to promote and ensure quality control of crown condition data. With respect to the monitoring system, the inquiry indicates a good agreement in objectives and a good documentation of the design of the monitoring system at national level. The monitoring plots were always permanent, selected according to a probabilistic design and located according to a systematic grid. In many cases the transnational Level I grid is a sub-sample of national networks designed to provide data also for other purposes. In this light, potential problems in comparability of data and for defoliation statistics come from the different frame attributes used to represent the target population (e.g. different basis for sample selection) and from differences in plot shape and nature. This has so far prevented precise quantifications of the reliability with which the tree sample represents all trees or the total forest area of Europe, as it would be expected from a transnational QM approach. A further problem is that changes in e.g. forest area (e.g. afforestation) are not always taken into account. This may cause a loss of representativity of the sample as the target population may change in extension and age.

The assessment of defoliation is subject to a number of QA measures, the most important being the standards and procedures defined in the Manual of ICP Forests (UN/ECE 1998) and in photoguides. In the inquiry (COZZI, FERRETTI AND LORENZ 2001) the Manual was found almost always adopted as basic reference document, and in many cases it was supplemented by national guidelines. In these cases, it was found that different reference standards and different solutions for specific assessement condition were adopted at national level, and this may have caused methodological “deviations” between countries.

Some standards and procedures specified in the Manual leave room for interpretations or are not applicable in all cases. This applies both to the use of references and to the way in which the assessments are performed, and raises difficulties in the spatial and temporal comparability of results. Spatial patterns of defoliation in a given year may be distorted if references (photos or reference trees) differ between regions despite similar ecological conditions. This is not so much a problem if spatial patterns of trends over several years are analyzed. But also trends in defoliation can be biased, for instance if one and the same reference tree is used over the years of observation, although its defoliation is changing. Besides the references, the methods of defoliation assessment may differ between countries. This applies mainly to the definition of the assessable crown and the assessment of transparency alternatively to defoliation.

There are two possibilities of coping with the above mentioned deficits in QA. One consists in further reaching QA measures such as more precise definitions of standards and descriptions of procedures. This solution, however, might imply methodological changes in some countries, thus creating a conflict with the countries’ interest to keep methods constant in order to produce consistent time series. The other possibility consists in identifying and quantifying existing bias by means of QC and QE, thus permitting subsequent corrections during the evaluation of the data.

Aimed to minimize observer bias and country bias, several QC measures have been implemented in the crown condition monitoring programme. As regards the keeping observer bias within tolerable limits, a high standard of training is a precondition for reliable assessments. This precondition is usually met in the participating countries. At the national level, observer bias can be estimated by analyzing training and test results as well as results of control assessments (SCHADAUER 1991, KÖHL 1991 and 1992). Therefore, at the national level the accuracy of defoliation assessments on individual trees is known for the most abundant tree species. For individual species, the reliability of the defoliation assessments has been shown (e.g. EICHHORN and ACKERBAUER 1987, DOBBERTIN et al. 1997).

The inquiry by COZZI, FERRETTI AND LORENZ (2001) shows that in larger countries, dozens of teams are involved in the annual surveys. In some instances the use of many field crews offers considerable logistic advantages. This means that the European-wide harmonization of crown condition data rests on the harmonization between hundreds of observers, and – at country level, the high number of field crews may cause problems in providing adequate training and field checks. In any case, the results suggest the importance to manage the data about the field crews. Changes in field crews may be strong drivers of changes in reported scores for crown condition and it is therefore important to link the field crews to the plot assessed in order to take into account the actual or potential bias of the crews.

Country bias is more difficult to estimate and eliminate than observer bias. The main benefit of previous international intercalibration courses consisted in preventing that methods deviated more and more between the countries over the years. The results of international intercalibration courses, however, were so far of limited use for quantifying country bias, as they were normally not designed for this purpose. A recently suggested concept for future international intercalibration courses aims to derive country bias with a given confidence level from the scores of the participating national team leaders (FERRETTI 1998). The new concept includes international control assessments, as they have been performed successfully at the national level. An auxiliary QC tool for intercalibration could be species specific sets of photographs covering the full range of possible defoliation values, including morphological differences. Assessments of these photographs by different observers would permit the quantification of observer and country bias.

Large efforts in QC have been made ever since with respect to data validation. At the national level and at the international level the annual sets of crown condition data have to pass stringent tests of their completeness and correctness. Whilst these validation procedures are still mainly performed in the laboratory, increasing use of hand held computers for data acquisition in the field will help to avoid wrong entries into the database.

The results of statistical analyses of the comparability of crown condition data in the sense of QE performed at the international level have proven helpful for detecting country bias (GOSH et al. 1997). QE and QC measures alike lay the basis for future homogenizations of the crown condition data prior to the search for their statistical relationships with the wide range of predictor variables.

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 significantly (UN/ECE, CEC 1994).

2.4 Evaluation and presentation of the survey results

2.4.1 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.

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 2.4-1) is a practical convention, as real physiological thresholds cannot be defined.

Table 2.4.1-1: Defoliation and discolouration classes according to UN/ECE 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

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 its trees (expressed as percentages) falls into class 2 or higher. Otherwise the sample point is considered as "undamaged".

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). Additionally attention must be called to the fact that *Quercus robur* and *Quercus petraea* are evaluated together and noted as *Quercus robur et petraea*. For this reason the actual results are not fully comparable with the corresponding ones from the last reports.

The development of defoliation over time is expressed either as changes in the shares of trees of a particular defoliation class or as changes in mean defoliation. 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.

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 2000.

2.4.2 Integrative Evaluations

2.4.2.1 Generalized Linear Models

Generalized linear models (GLM, SAS 1990) are used to explore the most important statistical relationships of tree crown condition in Europe. The evaluated tree species are *Pinus sylvestris*, *Picea abies*, *Pinus pinaster, Fagus sylvatica*, *Quercus robur et petraea*, and *Quercus ilex*. Only plots which were annually assessed from 1994 to 2000 and which contained more than 2 trees on average of the respective species were taken into consideration.

As dependent (target, response) variable the medium-term mean defoliation averaged over the annual plot means from 1994 to 2000 is used. In addition, models with medium-term mean discolouration over the same period as target variable are evaluated.

Some fundamental explanatory variables are used within the statistical models. Since methodological differences between countries are highly probable (e.g. KLAP et al. 1997, 2000) country is introduced as a classification variable. The most important continuous (numeric) variable used as a covariate within the models, is stand age. Stand age classes given in the Level I data base were transformed into mean ages of the respective classes beforehand and uneven aged stands (class 8) were set to age class 6 (= 110 y). Further covariates used in additional runs are indices for the mean-term infestation rates by insects or fungi. They were calculated as the averages of the annual share of trees per plot which were observed to be infested by insects and/or fungi respectively.

GLM allows mixed approaches, including class and continuous variables. The model of the basic form

$$y = f(C1, X1) \tag{1}$$

used in this approach, is an analysis-of-covariance model, where "y" denotes the target variable (e.g. mean defoliation), "C_1" a class variable (e.g. country), and "X_1" a continuous numeric variable (e.g. age). This type of evaluation combines features of regression analysis and analysis of variance.

Linear regression models describe the relationship between the target variable and explaining metric variables (predictors) as linear functions:

$$y_i = ß_0 + ß_1 \bullet X_{1i} + ß_2 \bullet X_{2i} + \ldots + r_i \tag{2}$$

The mean crown condition "y" of the plot "i" can be explained by the model with the error "r_i", the so called residuum. This residuum can be used as a basis for further analyses. The intercept "$ß_0$" gives the value of the target variable for the value 0 of the metric explanatory variable (e.g. age). The regression coefficients "$ß_1$", "$ß_2$" ... accomplish the statistical model.

Categorical variables "C" like country are added according to equation (3):

$$y_{ij} = ß_0 + C_{1j} + ß_1 \bullet X_{1i} + ß_2 \bullet X_{2i} + \ldots + r_i \tag{3}$$

The value "C_{1j}" of a categorical variable describes the differences between the target variable level of the plots of country "j" and the mean of a system selected reference country. This is comparable with an analysis of variance.

An extended model additionally considers the so-called interactions between a class variable C (e.g. country) and a numeric variable X (e.g. age). The specific model with C_1 and X_1 reads

$$y_{ij} = ß_0 + C_{1j} + ß_1 \bullet X_{1i} + (X_1 * C_1)_j \bullet X_{1i} + r_i \tag{4}$$

with "$X_1 * C_1$" expressing an interaction term of country "j". This is called a homogeneity-of-slopes model.

The additional inclusion of further numeric parameters like the occurrences of insect and fungi (X_2, X_3) and their interactions with country is done in the same way.

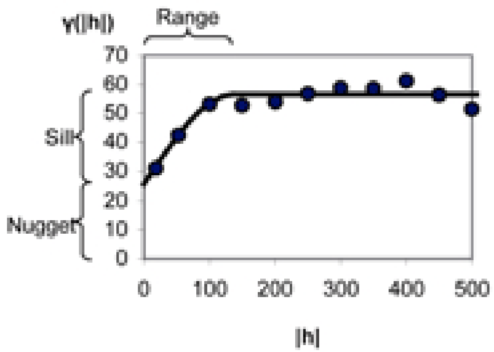
The modelled mean level of defoliation is calculated for each country setting for comparison reasons age = 90 years and included in the particular tables of model results.

2.4.2.2 Geostatistics

Level I data are assessed within a systematic gridnet allover most of Europe and may therefore be objects of geostatistical evaluations. One of its aims is the estimation of values of the regionalized variable for unobserved points or for the area of the concerning region respectively.

The fundamental assumption of geostatistics is, that a regionalized 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 regionalized 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 preliminarily adjusted defoliation (regionalized variable) can be described by an empirical semivariogram which expresses the dissimilarity increasing with distance h between (sample) points x_i and $x_i + h$ (Fig. 2.4.5.2-1). Each point in the empirical semivariogram is calculated using equation (5) for the particular distance or class (lag) of distance h. The semivariance is the mean squared difference between i pairs of values of the regionalized variable from i pairs of points/locations within the spatial distance h.



$$\gamma(\mathrm{h}) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(x_i) - z(x_i + h)]^2 \quad (5)$$

$N(h)$ – number of point pairs with distance h
$z(x_i)$ – regionalized variable at sample point x_i

Figure 2.4.5.2-1: 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 variogram: 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 regionalized variable. Mainly two conditions lead to a nugget value greater than zero:

A) The underlying measurement gridnet has a too low density, so that the spatial structure/autocorrelation could not be detected completely.
B) The underlying spatial structures are covered by inaccuracies of data assessment or other reasons of "noise".

The sill is quantifying the autocorrelative component of the regionalized 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 γ(h) and the higher is – in general – the (kriging-) weight of this plot for the interpolation (kriging) of the regionalized variable at any estimation point $z^*(x_i)$.

The result of modelling, the empirical semivariogram, is the so-called theoretical semivariogram. A popular function of the theoretical semivariogram is the spherical model, defined by the following equation:

$$\gamma(h) = \begin{cases} \text{nugget} & ; 0 = h \\ \text{nugget} + \text{sill} \cdot \left\{ 1{,}5 \left(\frac{h}{\text{range}} \right) - 0{,}5 \left(\frac{h}{\text{range}} \right)^3 \right\} & ; 0 < h < \text{range} \\ \text{nugget} + \text{sill} & ; h \geq \text{range} \end{cases} \quad (6)$$

Spherical semivariograms are used in the present study due to their good interpretability and in order to increase the comparability between the examined tree species. If better adapted models are found, they are mentioned in the particular chapters. General introductions to applied geostatistics are given by e.g. RIPLEY (1981) or CRESSIE (1991).

Geostatistics and particularly semivariography are used for a spatial analysis of the residuals from a model, in which age, country and their interaction term age*country are used for a statistical explanation of the variance of mean defoliation. This model is assumed to explain most of the systematical part of the deterministic component of the variance of defoliation. Thus the residuals – here the regionalized variables – roughly quantify the defoliation, corrected for systematical differences between countries and ages. This purely statistical type of country correction is mainly applied due to missing objectively assessed correction factors. Thus the residuals can be described as “preliminarily adjusted defoliation” (PAD). Using the kriging interpolation for the model residuals maps of PAD in Europe are produced. Inter-country relations should however be interpreted with care.

Only for those points a value of the regionalized 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.

Another application of semivariography is the detection of outliers. Plots with residuals, which do not fit to the spatial pattern lead to very high variogram values and can be identified e.g. by calculating so called variogram clouds. Possible reasons for extremely high or low residuals at certain points or areas should be discussed with the particular National Focal Centres and can lead to the design of new explanatory variables.

3 RESULTS OF THE TRANSNATIONAL SURVEY IN 2000

3.1 Crown condition in 2000

3.1.1 Defoliation and discolouration by region and species

In the transnational survey of the year 2000 the defoliation of 135 839 trees are available in the actual database. Of this total tree sample, 22.8% had a defoliation greater than 25%, i.e. were rated as "damaged". The share of damage broadleaves is with 23.6% slightly larger than the share of damaged conifers with 22.3%. In the EU-Member States the share of damaged trees was with 17.6% distinctively lower than in total Europe, because areas with higher defoliation are mainly located in the non-EU countries, namely in parts of central and eastern Europe. However, in the EU-Member States the share of the damaged broadleaves (22.1%) is markedly higher than the respective share of the conifers (14.5%) (Table 3.1.1-1).

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

	Species type	Percentage of trees in defoliation class							Defoliation		No. of trees
		0-10%	>10-25%	0-25%	>25-60%	>60%	dead	>25%	Mean	Median	
EU	Broadleaves	34.2	43.7	77.9	19.6	1.8	0.7	22.1	20.1	15	32319
	Conifers	48.7	36.8	85.5	12.5	1.0	1.0	14.5	16.2	15	47401
	All species	42.8	39.6	82.4	15.4	1.3	0.9	17.6	17.8	15	79720
Total Europe	*Fagus sylv.*	35.7	42.1	77.8	19.9	1.7	0.6	22.2	19.7	15	12067
	Qu. petraea et *robur*	21.1	45.2	66.3	30.6	2.0	1.1	33.7	24.5	20	9067
	Broadleaves	32.7	43.7	76.4	20.8	1.9	0.9	23.6	20.7	15	54345
	Picea abies	38.0	34.6	72.6	25.2	1.6	0.6	27.4	20.0	20	28380
	Pinus sylv.	33.6	47.3	80.9	17.5	1.0	0.6	19.1	24.5	15	36055
	Conifers	36.2	41.5	77.7	20.0	1.3	1.0	22.3	19.6	15	81494
	All species	34.8	42.4	77.2	20.3	1.5	1.0	22.8	20.0	15	135839

For all plots, the percentage of damaged trees is mapped in Annex I-3. Plots with a share of damaged trees larger than 25% occur throughout Europe, but are more concentrated in central and eastern Europe. Plots with an average defoliation higher than 50% are highly abundant in the Czech Republic, are clustered in the Slovak Republic and in the mountainous parts of Romania and Bulgaria, and are frequent in Italy, Norway, northern Sweden, southern Poland and central Germany. Regions with small percentages of trees classified as damaged are situated especially in Austria, Belarus, southern Sweden, southern Finland, eastern Germany, parts of the Baltic states and several parts of the Iberian Peninsula.

In order to avoid bias due to the use of defoliation classes (Chapter 2), frequency distributions of trees in 5%-defoliation steps were calculated. In Figures 3.1.1-1a and 3.1.1-1b, the frequency distributions for the total of all trees, broadleaved and coniferous trees are shown for each climatic region as well as for the total of all regions. Along with each frequency distribution, the number of trees, the mean defoliation and the median are 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 et Quercus petraea*. For each of the species related maps each plot had to be checked whether it would qualify as a plot representing this species. This was considered to be the case whenever the number of trees of the given species was at least three.

Mean defoliation for the total of all regions is 20.0%, and conifers show slightly lower defoliation than broadleaves. The three largest regions (Sub-atlantic, Mountainous and Boreal temperate) together with the Boreal region comprise about three quarters of all coniferous sample trees. In these regions, the coniferous trees have mostly slightly higher defoliation than the broadleaves, this being due to the large numbers of defoliated plots of *Pinus sylvestris* and *Picea abies* in the Czech Republic, the Slovak Republic and Poland (Figures 3.2.1-2 and 3.2.1-3).

In the remaining regions (Atlantic north, Atlantic south, Mountainous north, Continental, Mediterranean higher and Mediterranean lower), the broadleaved trees outnumber the coniferous trees and have mostly higher defoliation.

Among the four main species in Europe, *Pinus sylvestris and Quercus robur et Quercus petraea* had the highest mean defoliation (24.5%), followed by *Picea abies* (20.0%) and *Fagus sylvatica* (19.7%).

The survey results for discolouration are shown in Table 3.1.1-2 and in Annex I-4. In total Europe, 7.3 % of the trees of all species had a discolouration greater 10% (i.e. were regarded as discoloured). The broadleaves show with 8.3% a higher amount of discoloured trees than the conifers with 6.7%.

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

	Species type	Discolouration						No. of trees
		0-10%	>10-25%	>25-60%	>60%	dead	>10%	
EU	Broadleaves	92.6	4.9	1.3	0.5	0.7	7.4	32319
	Conifers	93.8	4.1	0.9	0.2	1.0	6.2	47401
	All species	93.4	4.4	1.0	0.3	0.9	6.6	79720
Total Europe	Broadleaves	91.7	5.7	1.5	0.5	0.6	8.3	54345
	Conifers	93.3	4.3	1.3	0.3	0.8	6.7	81494
	All species	92.7	4.8	1.4	0.4	0.7	7.3	135839

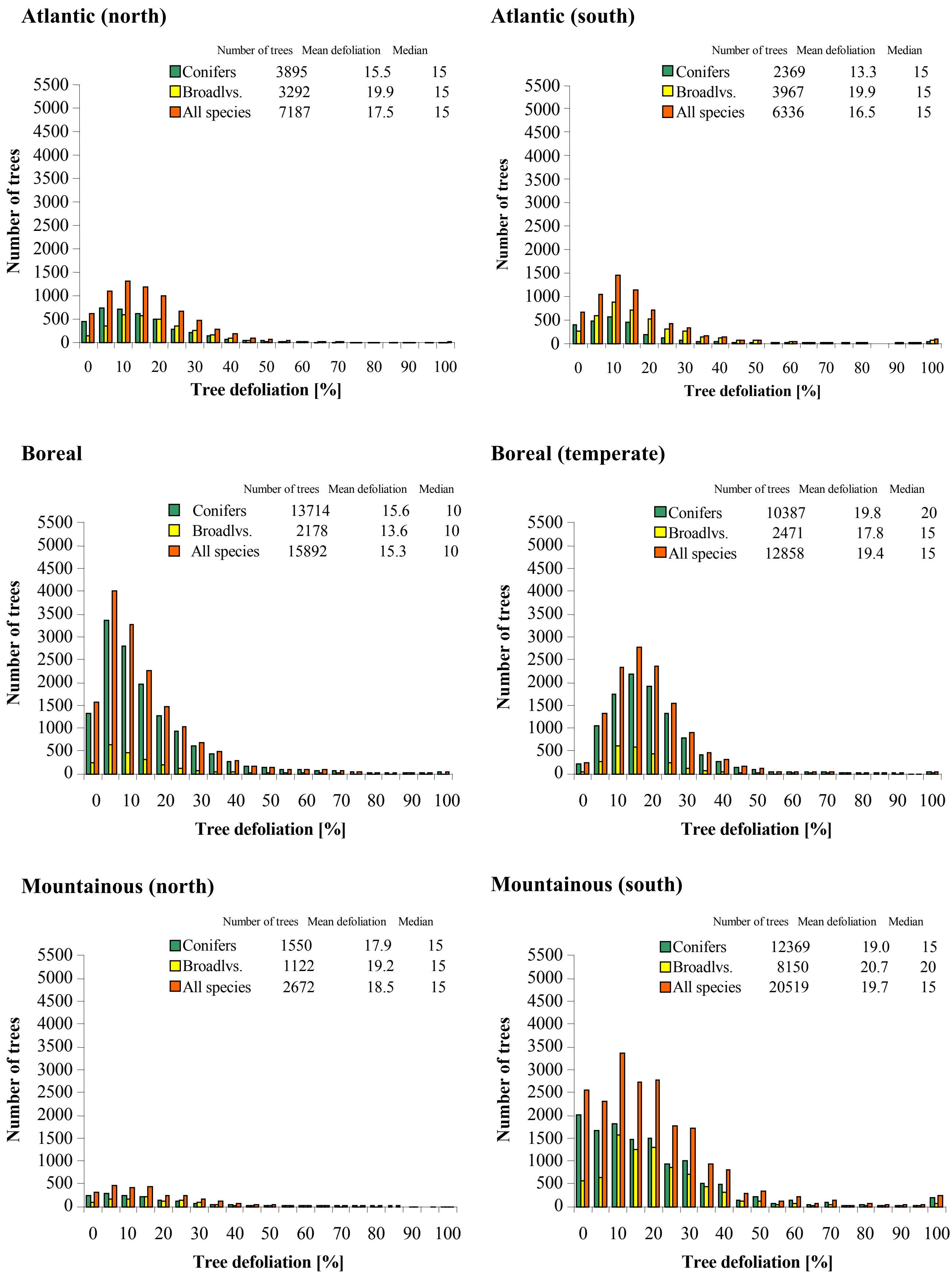


Figure 3.1.1-1a: Frequency distribution of trees in 5%-defoliation steps.

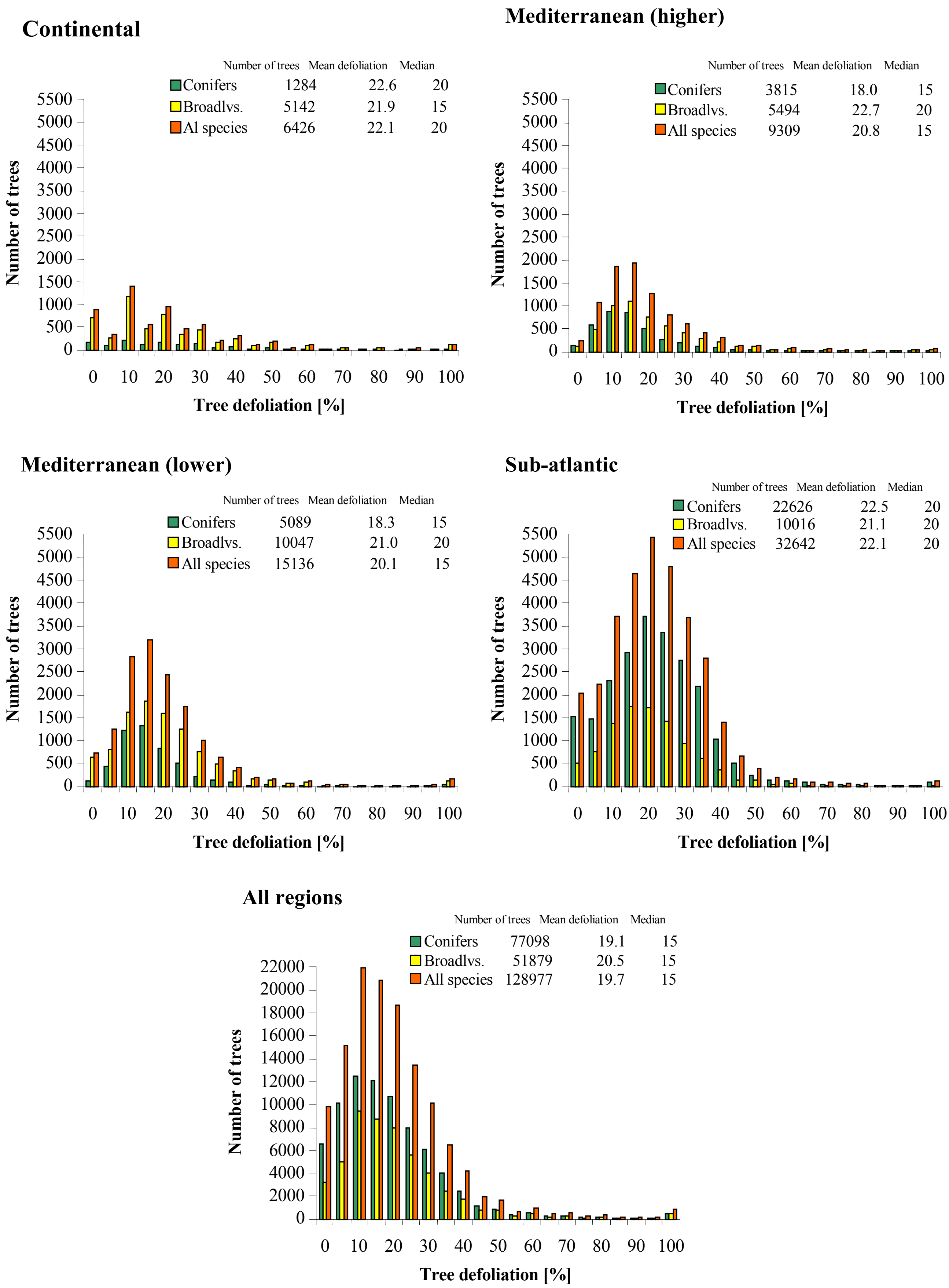


Figure 3.1.1-1b: Frequency distribution of trees in 5%-defoliation steps.

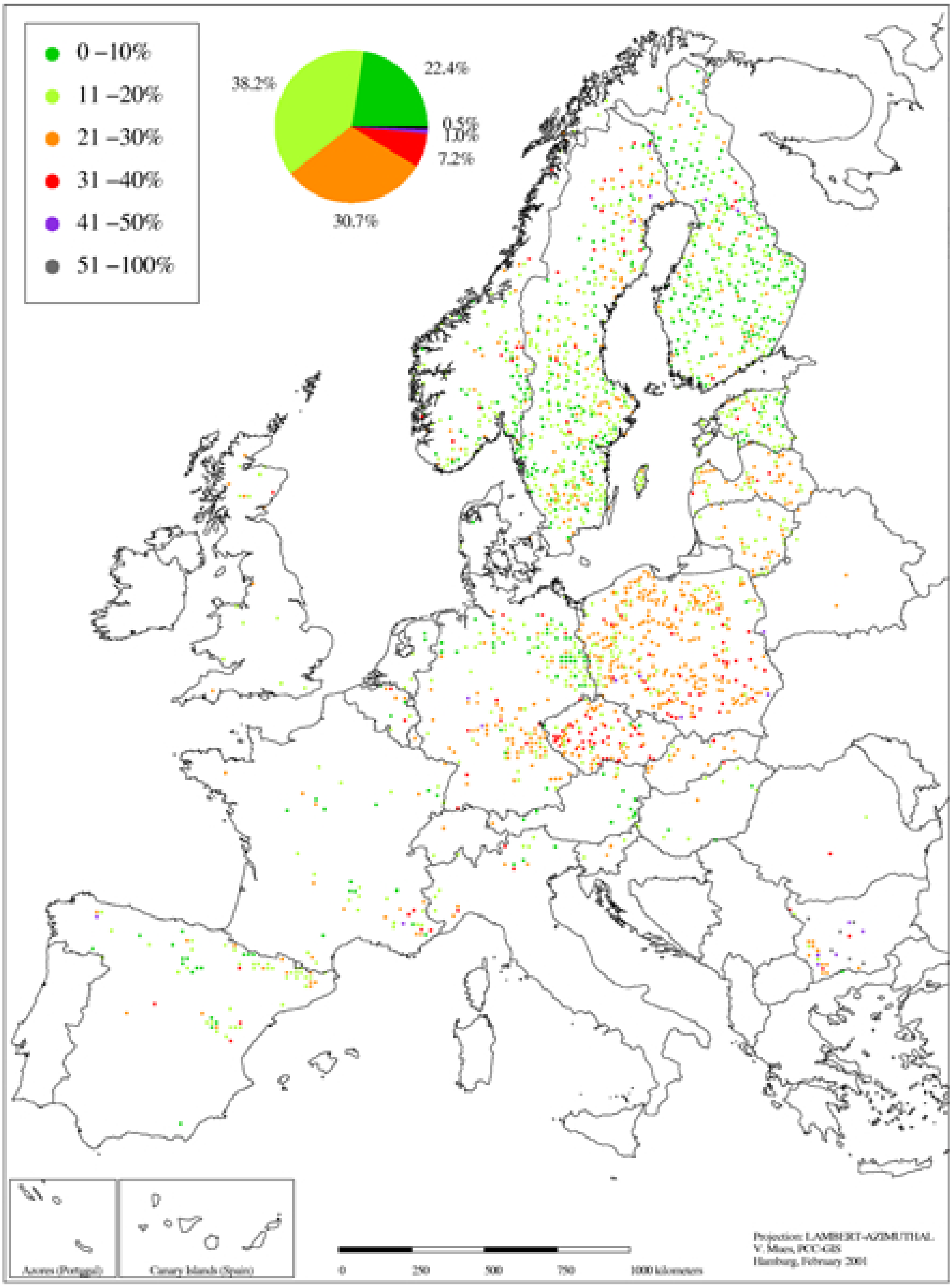


Figure 3.1.1-2: Mean plot defoliation of *Pinus sylvestris*.

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

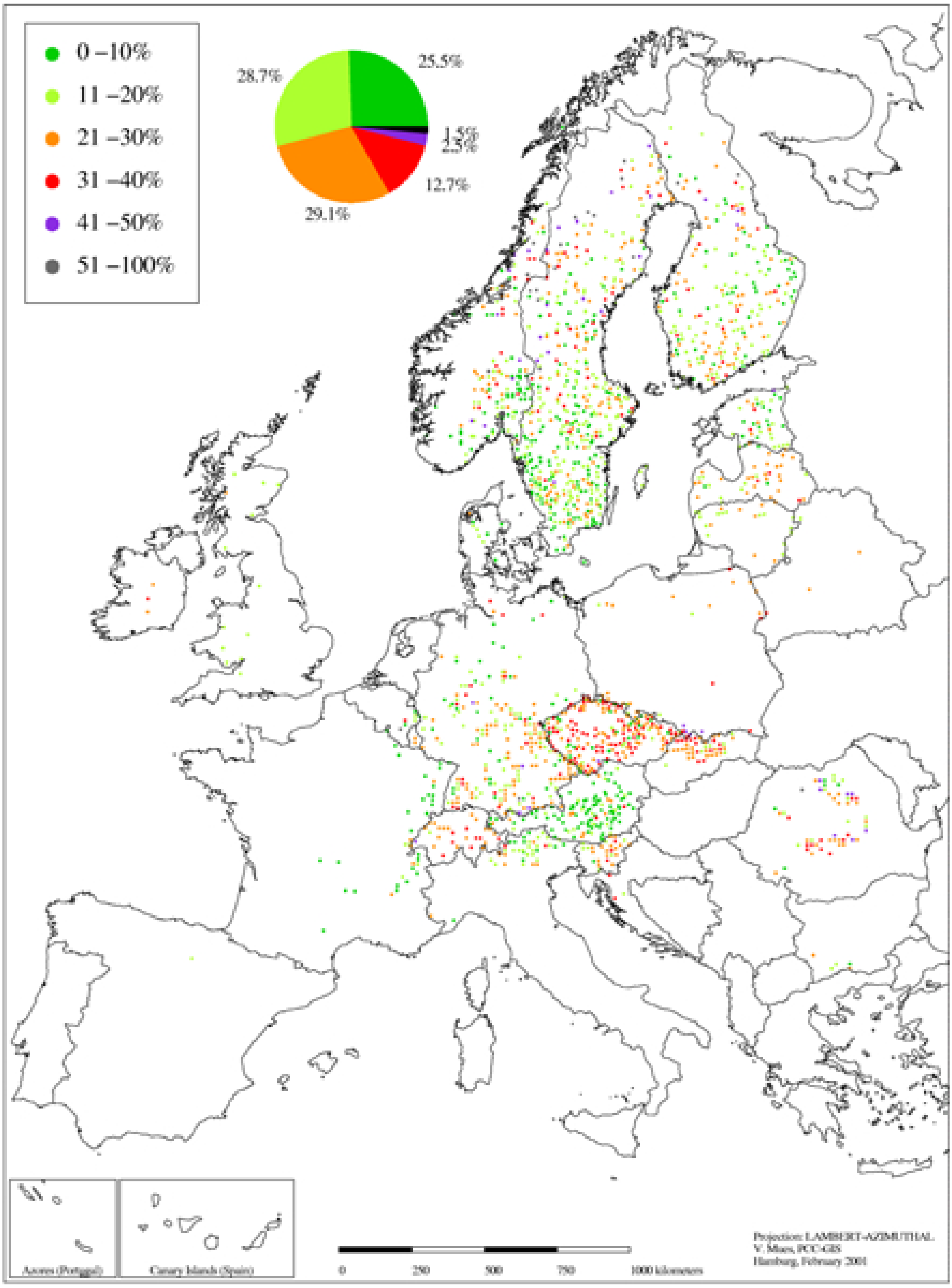


Figure 3.1.1-3: Mean plot defoliation of *Picea abies*.

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

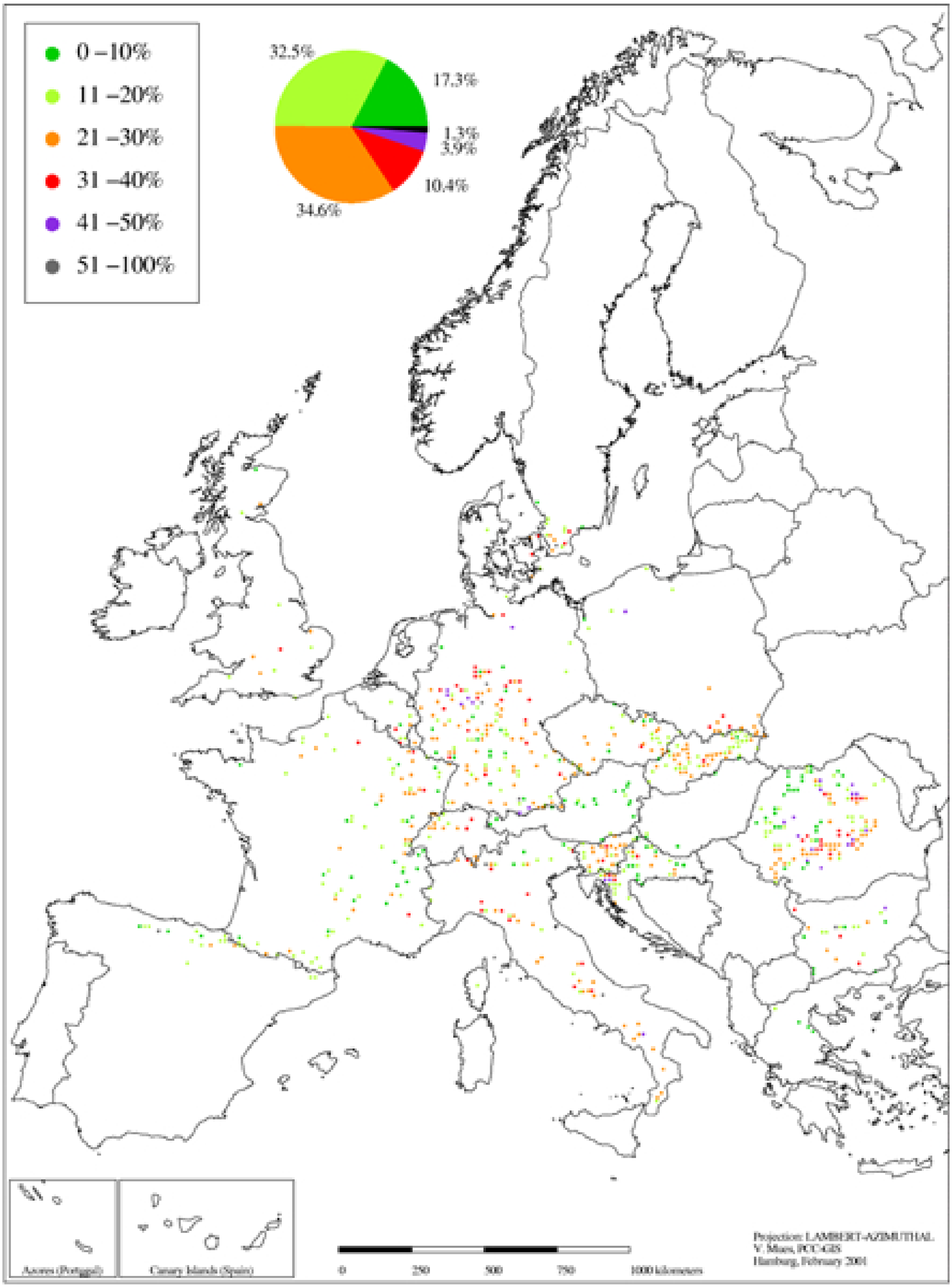


Figure 3.1.1-4: Mean plot defoliation of *Fagus sylvatica*.

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

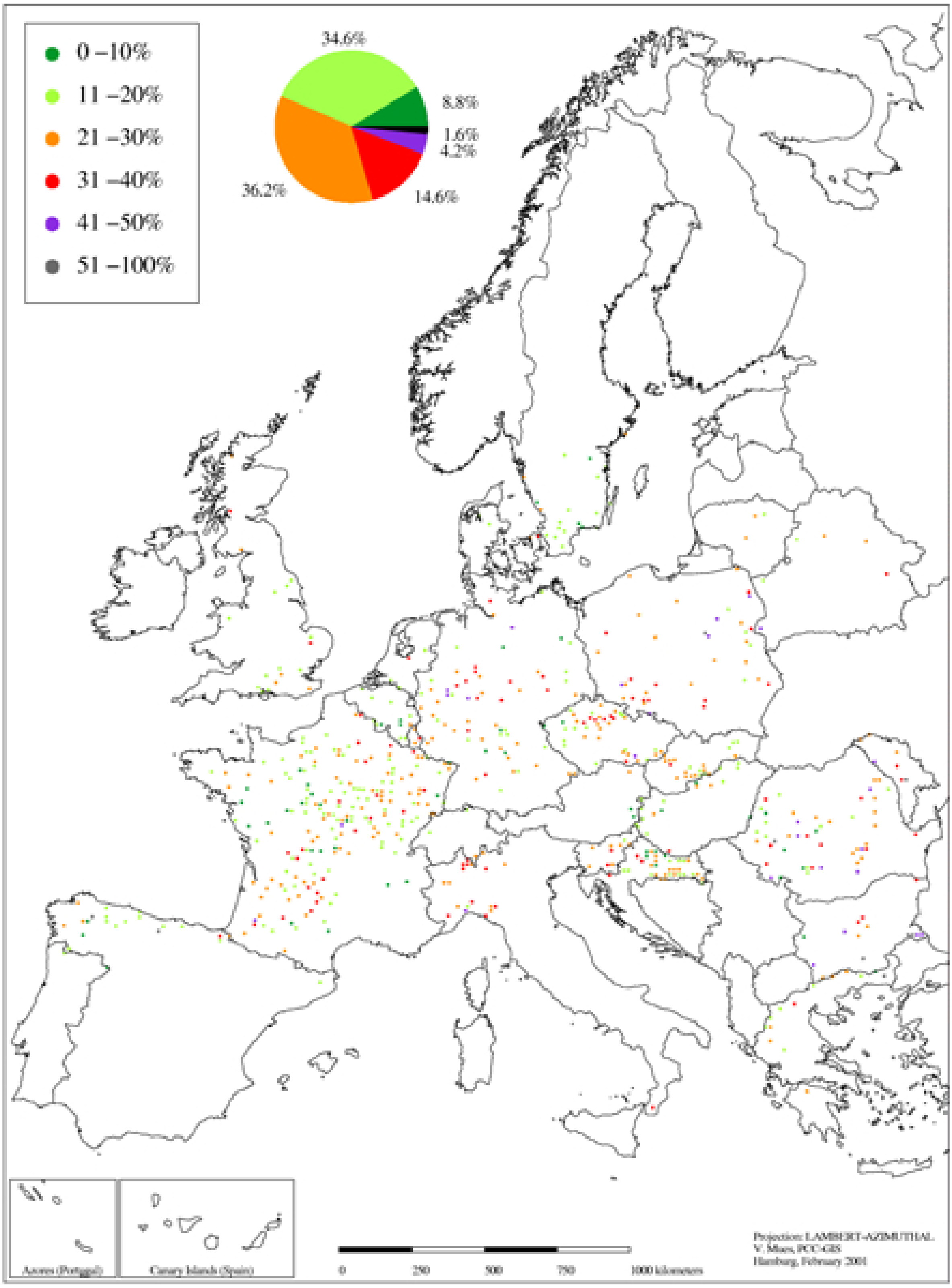


Figure 3.1.1-5: Mean plot defoliation of *Quercus robur*.

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

3.1.2 Defoliation and identified damage types

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

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

Table 3.1.2-1 provides the shares of trees for which each particular damage type was assessed and not assessed. The trees assessed are divided into those on which the respective damage type was present and those on which it was not present. The damage type most frequently recorded was insects, with 9.4% of the sample trees in total Europe being affected. Second largest was the share of trees showing abiotic agents (5.8%), followed by fungi attacks recorded on 5.0% of the total sample.

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

Damage type	Total Europe			EU		
	not assessed	assessed and not present	assessed and present	not assessed	assessed and not present	assessed and present
Game/grazing	57.9	41.2	0.9	52.7	46.1	1.2
Insects	54.3	36.3	9.4	48.5	39.3	12.2
Fungi	54.8	40.2	5.0	50.0	45.6	4.4
Abiotic agents	54.4	39.8	5.8	48.1	44.3	7.6
Action of man	55.0	41.2	3.8	49.2	46.9	3.9
Fire	58.9	40.8	0.3	51.7	47.9	0.4
Known air pollution	59.7	37.8	2.5	59.6	40.4	0.0
Other	53.0	39.7	7.3	48.6	44.7	6.7

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 2.5% of all sample trees air pollution was identified as a cause of damage. Of these trees, 41.8% had a defoliation greater 25%, i.e. were rated as damaged according to their defoliation.

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

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

	Defoliation (>25%)		Discolouration (>10%)	
Damage type	Total Europe	EU	Total Europe	EU
Game/grazing	19.6	17.5	7.9	8.3
Insects	33.4	31.0	12.5	11.8
Fungi	34.5	37.6	15.2	13.4
Abiotic agents	36.7	35.2	13.6	12.3
Action of man	32.7	26.8	16.4	16.9
Fire	41.8	43.7	18.0	21.0
Known air pollution	41.8	-	2.9	100.0 *
Other	28.9	26.6	7.3	10.0
Total tree sample	22.8	17.6	7.3	6.6

*) known pollution was attributed only to eight trees; these trees were discoloured to 10% and more.

3.2 Development of defoliation

3.2.1 The common samples

The temporal development of forest crown condition in Europe is presented on the basis of "Common Sample Trees" (CSTs). These have been monitored continuously over a certain interval. In this Forest Condition Report three intervals were evaluated: 1999-2000, 1994-2000 and 1988-2000.

For the $CSTs_{99}$ (1999-2000) differences in mean plot defoliation of 1999 and 2000 were calculated, checked for their statistical significance and mapped in Annex I-5. The sample size of 128444 trees corresponds to 94.6% of the total sample size.

As in the last report the $CSTs_{94}$ with the starting year 1994 and the $CSTs_{88}$ were basis for the main description of temporal development. Whereas the $CSTs_{94}$ cover all Climatic regions in Europe, the $CSTs_{88}$ with their longer time series are only delivered from a subgroup of countries, which have been participating the programme from the beginning on or have submitted data reaching back to 1988. The Boreal region, Boreal (temperate) region, Mountainous (North) region, and Continental region are not covered by the $CSTs_{88}$. The sample size of 24 345 trees (17.9% of the total sample size) in $CSTs_{88}$ could be extended to 68 379 (50.3%) by reducing the time series to the years 1994-2000 ($CSTs_{94}$). The tables 3.2.1-1 and 3.2.1-2 indicate the sample sizes of the six most frequent tree species and their distribution through the Climatic regions.

Chapter 3.2.2 presents the temporal development of defoliation for the total of all species. In Chapters 3.2.3-3.2.8 the development of defoliation is presented individually for the six most frequent tree species in Europe. The description is done by plotting the development of defoliation over time for all regions and for an additional one, which either represents the region with the highest abundance of CSTs or which shows an extraordinary temporal development. Differences between the mean plot defoliation in 1994 and 2000 were calculated, checked for their statistical significance and mapped. Because of their economic and ecological importance in some regions *Abies alba* and *Picea sitchensis* are included into Annex I-7 and Annex I-8, where the temporal development of defoliation of the most common tree species is presented for the $CSTs_{88}$ and the $CSTs_{94}$, respectively.

Table 3.2.1-1: Number of trees common to the surveys from 1988 to 2000 ($CSTs_{88}$) by species and climatic region. France is not included due to changes in the methodology.

Climatic region	*Picea abies*	*Pinus sylvestris*	*Pinus pinaster*	*Fagus sylvatica*	*Quercus ilex*	*Qu. robur et petraea*
Atlantic (North)	147	453	0	231	0	185
Atlantic (South)	0	74	245	29	24	76
Mediterranean (Higher)	0	411	242	221	504	264
Mediterranean (Lower)	52	96	941	250	1143	52
Mountainous (South)	1096	518	46	853	81	91
Sub-Atlantic	1992	1106	0	1481	0	724
All regions	3287	2658	1474	3065	1752	1392
Percent of all common trees 1988-2000	13.5	10.9	6.0	12.6	7.2	5.7

Table 3.2.1-2: Number of trees common to the surveys from 1994 to 2000 ($CSTs_{94}$) by species and climatic region. France is not included due to changes in the methodology.

Climatic region	*Picea abies*	*Pinus sylvestris*	*Pinus pinaster*	*Fagus sylvatica*	*Quercus ilex*	*Qu. robur et petraea*
Atlantic (North)	713	792	0	684	0	643
Atlantic (South)	0	75	373	47	24	173
Boreal	2115	3081	0	0	0	3
Boreal (temperate)	1801	3060	0	2	0	50
Continental	256	270	0	779	0	691
Mediterranean (Higher)	54	535	358	407	658	306
Mediterranean (Lower)	68	111	1262	409	1598	331
Mountainous (North)	641	777	0	0	0	0
Mountainous (South)	3035	1401	46	2100	86	316
Sub-Atlantic	4825	8598	0	2123	0	1548
All regions	13508	18700	2039	6551	2366	4061
Percent of all common trees 1994-2000	19.7	27.3	3.0	9.6	3.5	5.9

3.2.2 All species

The crown condition development of all species in **all regions** showed a considerable decrease in the share of undamaged trees (Figure 3.2.2-1). This decrease was especially pronounced from 1988 to 1995. Afterwards a stabilisation can be observed. The proportion of undamaged trees in the $CSTs_{94}$ was slightly higher as compared to the $CSTs_{88}$. However, also the share of trees defoliated by >25% was slightly higher in the $CSTs_{94}$. The shares of damaged trees in both the $CSTs_{88}$ and $CSTs_{94}$ showed a very slight decrease as well since 1995.

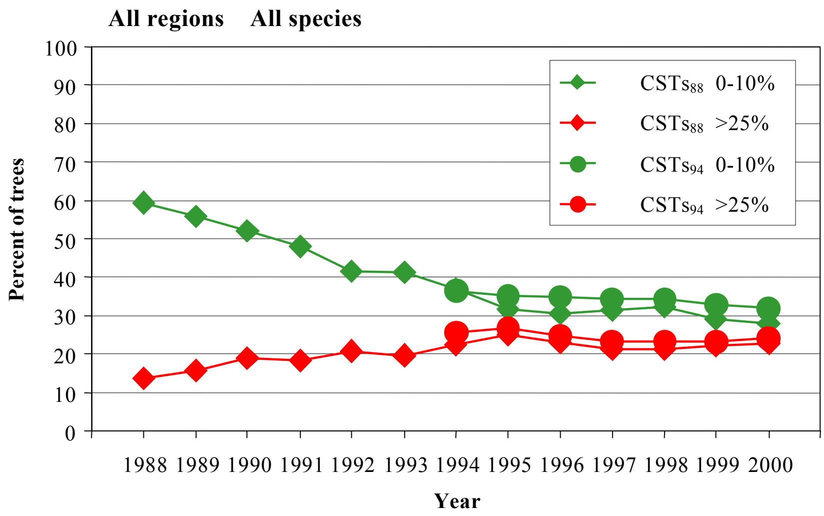


Figure 3.2.2-1: Sample sizes in all regions: $CSTs_{88}$ = 24 345; $CSTs_{94}$ = 68 379

The development of crown condition in the Climatic regions is represented in Annex I-7 for the $CSTs_{88}$ and in Annex I-8 for the $CSTs_{94}$. The **Mediterranean (Higher)** and the **Mediterranean (Lower)** regions show a clear deterioration, which is remarkable less strong since 1996. Only for 1993 and 1994 a recuperation is observed within the Mediterranean (Lower) region. The proportions of undamaged trees in these climatic regions, however, were larger as compared to the European scale. The same is observed even more distinctly for the **Atlantic (North)** and especially the **Atlantic (South)** region, where the share of undamaged trees is highest and that of damaged trees lowest of all climatic regions (< 10% for all years but 1990, 1991, and 2000). The development in 2000, however, shows a distinct deterioration for the Atlantic (South) region. The contrary observation, higher share of damaged and lower share of undamaged trees than calculated over all regions, can be made for the **Sub-Atlantic** region. There, the share of damaged trees takes values of about 30% and in 1994 even up to 39.0% ($CSTs_{88}$; 1995: 38.2%), whereas the share of undamaged trees has been smaller than that of damaged trees since 1989. Undamaged trees show a decrease from 32.9% in 1988 to 15.6% in 1994 ($CSTs_{88}$) and afterwards a slight increase to 22.4% in 1997, holding this share until 2000. The **Mountainous (South)** region shows similar development to that over all regions since 1991, with lower share of undamaged and higher share of damaged trees from 1988 to 1990. For the **Boreal**, **Boreal (Temperate)**, **Continental**, and the **Mountainous (North)** regions the time series for the $CSTs_{88}$ are not available. A clear temporal development of the $CSTs_{94}$ is found for none of them, but all show distinctly different levels of defoliation. The highest share of damaged trees and the lowest one of undamaged trees, which is still higher than that of the Sub-Atlantic region was found for the Continental region, whereas the Boreal region shows the highest share of undamaged trees of all climatic regions. The Mountainous (North) and the Boreal (Temperate) regions show no extraordinary values.

Figure 3.2.2-2 shows the geographic distribution of differences in defoliation between 1994 and 2000 in Europe. In 56.9% of the Level I monitoring plots no statistically significant differences were calculated. 20.2% of the plots showed a significant improvement. Such plots are distinctly clustered in Poland, adjacent parts of Germany and the Czech Republic, Slovak Republic and parts of the Baltic States. Also the crown condition in parts of Romania, Spain and Scandinavia is significantly better in 2000. In contrast 23.0% of the plots were identified with worse crown condition in 2000 compared to 1994. Such plots were especially frequent showing clustered patterns in wide areas in the Mediterranean regions but even spread over several other countries (e.g. Norway, Sweden, Germany, the United Kingdom).

The mean defoliation of the six most frequent tree species in the $CSTs_{88}$ showed deterioration and recuperation of different intensity (Figure 3.2.2-3). Only for the Mediterranean tree species the deterioration amounts to more than 10 percent points. Most impressing is the trend of deterioration for *Pinus pinaster*. The mean values for the $CSTs_{94}$ of *Pinus sylvestris* even show a recuperation from 1994 on.

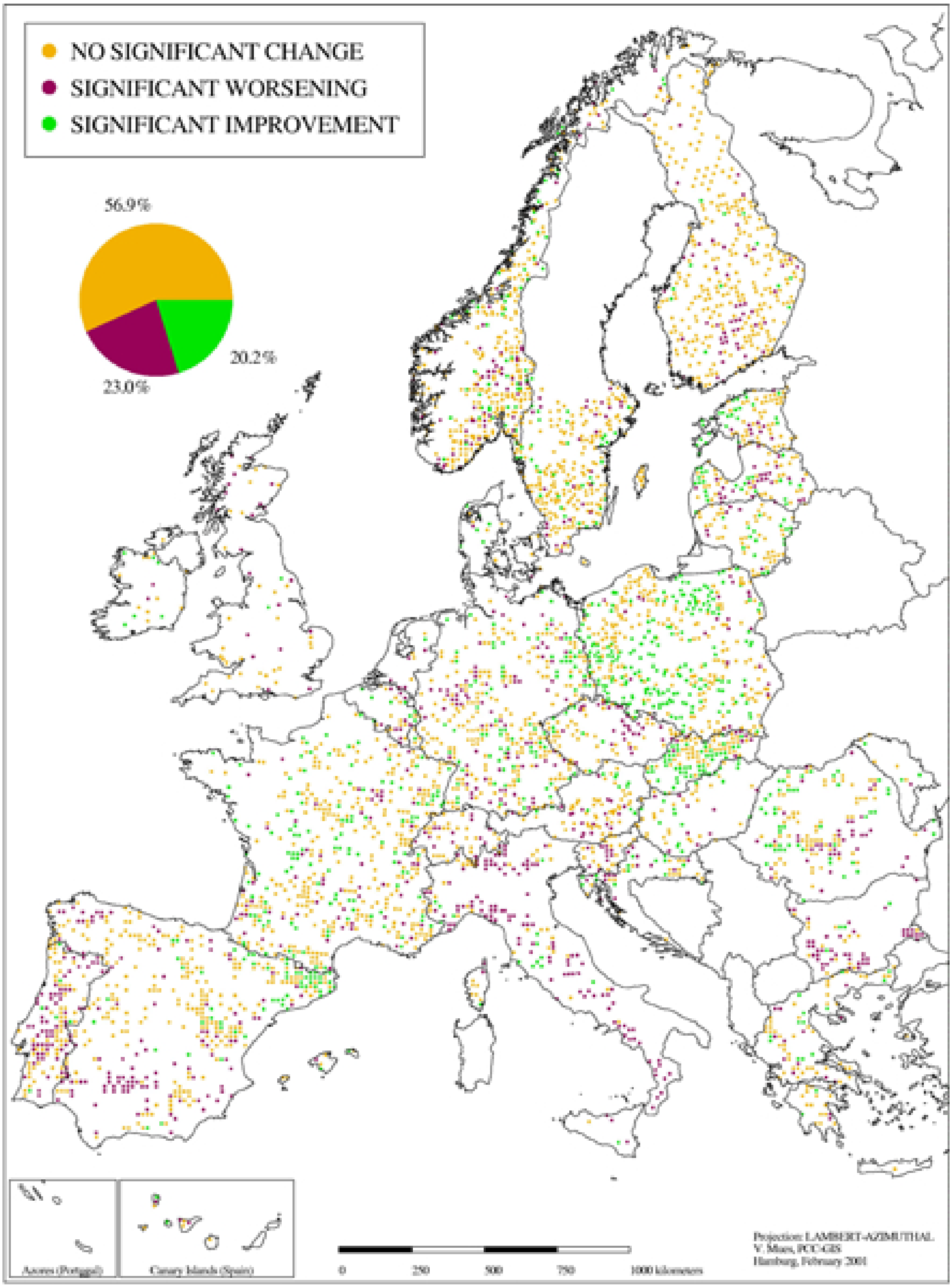


Figure 3.2.2-2: Mean plot defoliation of all species in the year 2000 compared with 1994 (with 1997 for France).

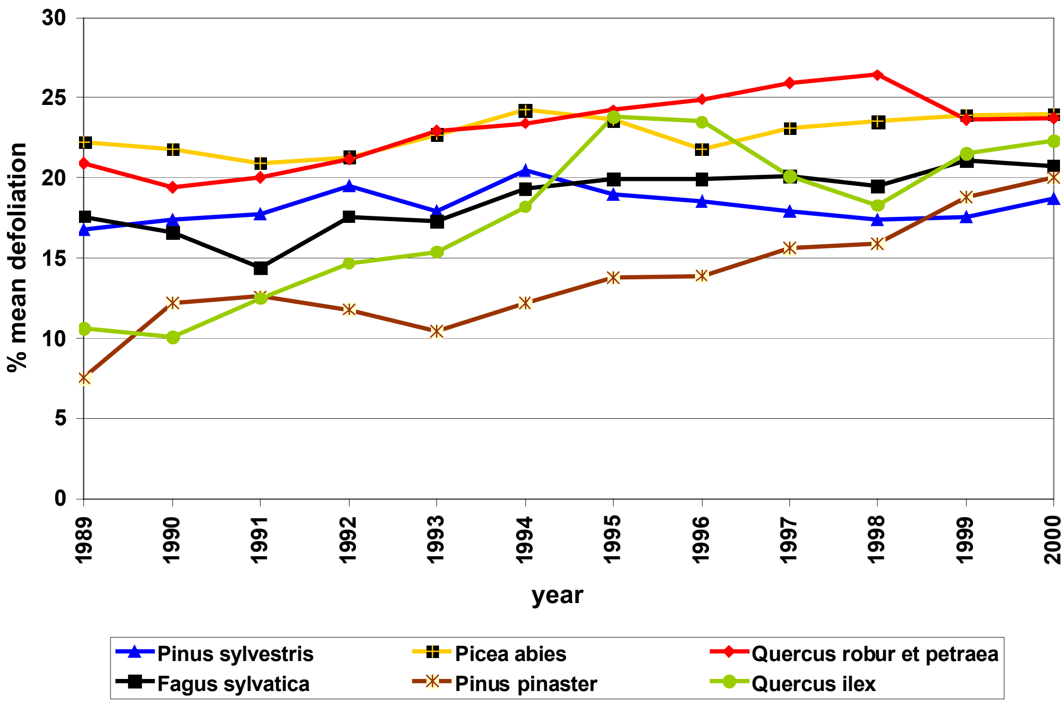


Figure 3.2.2-3: Development of mean defoliation of $CSTs_{88}$ of the 6 most frequent species. Mean defoliation could be calculated only from 1989 onwards, because in 1988 defoliation was assessed in the traditional defoliation classes instead of 5% steps.
Number of trees: *Pinus sylvestris*: 2 658; *Picea abies*: 3 287; *Qu. robur* et *petraea*: 1 392; *Fagus sylvatica*: 3 065; *Pinus pinaster*: 1 474; *Quercus ilex*: 1 752

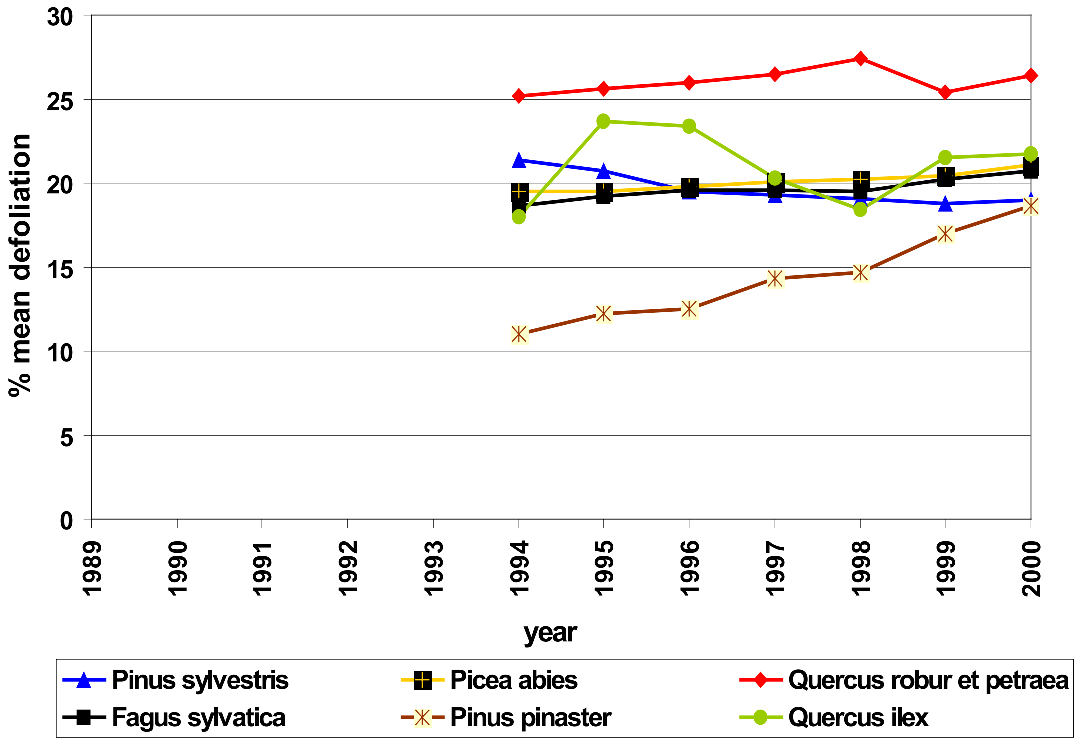


Figure 3.2.2-4: Development of mean defoliation of $CSTs_{94}$ of the 6 most frequent species.
Number of trees: *Pinus sylvestris*: 18 700; *Picea abies*: 13 508; *Quercus robur* et *petraea*: 4 061; *Fagus sylvatica*: 6 551; *Pinus pinaster*: 2 039; *Quercus ilex*: 2 366

3.2.3 Pinus sylvestris

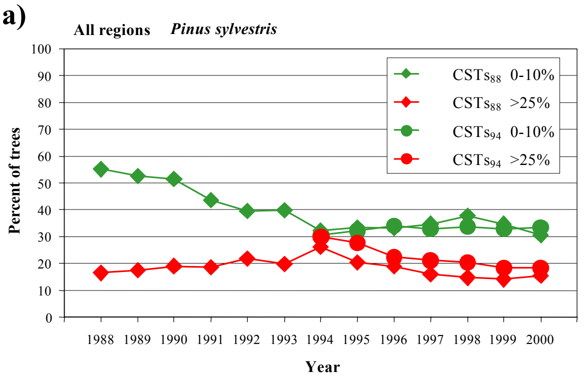
Due to an increasing number of countries participating in the programme, *Pinus sylvestris*, which is the most widespread tree species in Europe, has been the most frequent species assessed since 1994 (see Tables 3.2.1-1 and 3.2.1-2). It is the only species present in all climatic regions, although in some climatic regions it is present with few specimens only. 46.0% of the sample are located in the Sub-Atlantic region alone ($CSTs_{94}$, Table 3.2.1-2).

In the total of all regions, a continuous decrease in the share of undamaged trees (0-10% defoliation) was observed from the start of the surveys up to 1994 (Figure 3.2.3-1a). The $CSTs_{88}$ showed a slight recuperation between 1994 and 1998, but deteriorated again in 1999 and 2000. The share of damaged trees (>25% defoliation) slightly increased to reach a peak in 1994, showed a marked decrease afterwards, lasting until 1999. For 2000 a slight increase is observed. This development is well reflected by the $CSTs_{94}$, but with a slightly higher share of damaged trees as compared to the $CSTs_{88}$. The share of undamaged trees among the $CSTs_{94}$ did not change.

The temporal development in the Sub-Atlantic region remarkably differed from that in all regions (Figure 3.2.3-1b). In contrast to the latter, the share of undamaged trees in the Sub-Atlantic region was continuously lower than the share of damaged trees. Between 1988 and 1994 a distinct worsening in crown condition was observed with the proportion of undamaged trees decreasing, and the share of damaged trees slightly increasing during the same time.

Compared to 1994 crown condition of *Pinus sylvestris* in 2000 shows an obvious improvement especially in Poland and Lithuania (Figure 3.2.3-2). In Germany, Spain, Latvia and Estonia, and other countries several plots with improving crown condition were observed. This was observed in 26.1% of all plots. However, on another 11.4%, the crown condition in 2000 was significantly worse than in 1994. These plots were clustered notably in Bulgaria and Italy and in parts of Latvia and Estonia.

a)



b)

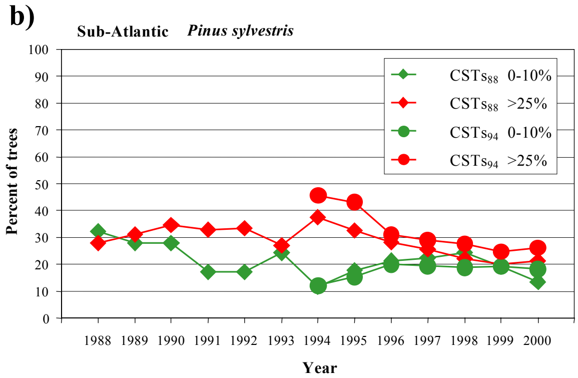


Figure 3.2.3-1: a) Sample sizes in all regions: $CSTs_{88}$ = 2 658; $CSTs_{94}$ = 18 700
b) Sample sizes in the Sub-Atlantic region: $CSTs_{88}$ = 1 106; $CSTs_{94}$ = 8 598

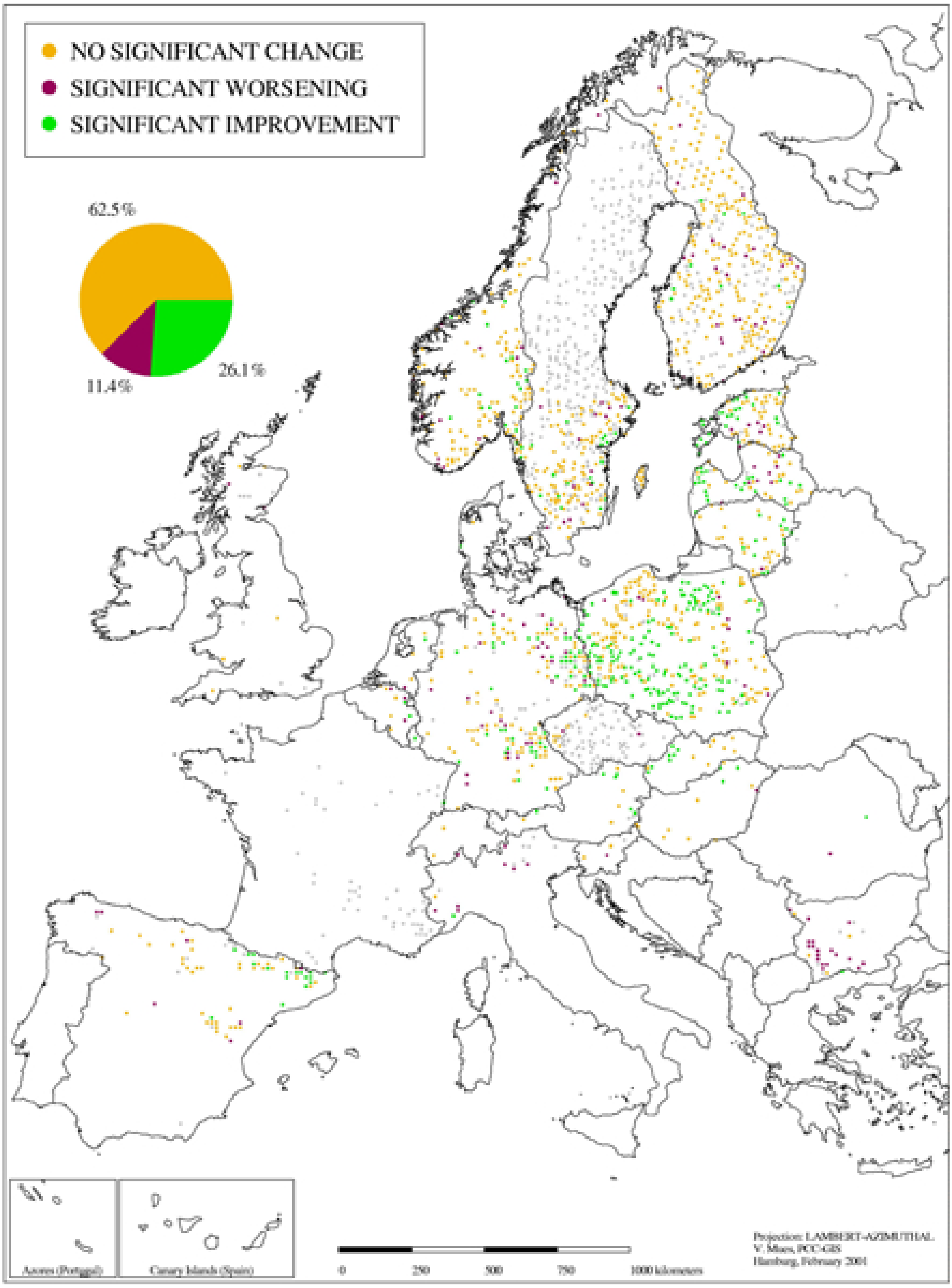


Figure 3.2.3-2: Mean plot defoliation of *Pinus sylvestris* in the year 2000 compared with 1994. (Grey plots contain *Pinus sylvestris* trees which could not be used as $CSTs_{94}$)

3.2.4 Picea abies

Picea abies was spread mainly in the Mountainous (South) and Sub-Atlantic regions. It was not present in the Atlantic (South) and Mediterranean (Higher) regions. The participation of several new countries after 1988 led to a remarkable increase in sample size. However, in the $CSTs_{94}$ *Picea abies* ranges only second after *Pinus sylvestris*, but with a lot more of a total of 13 508 trees in competition to the 3 287 $CSTs_{88}$.

No distinct temporal trend in the crown condition of *Picea abies* could be observed on the European scale (Figure 3.2.4-1a). Only minor fluctuations occurred in the samples of both the $CSTs_{88}$ and $CSTs_{94}$. In the Sub-Atlantic region a slight deterioration was observed with an intermediate recuperation taking place in 1996 after a phase of deterioration from 1993 to 1995 (Figure 3.2.4-1b). This temporary recuperation was more reflected among the $CSTs_{88}$ by both the shares of undamaged and damaged trees, than in the $CSTs_{94}$.

Plots with significantly worse crown condition compared to 1994 are obviously clustered in some regions (Figure 3.2.4-2). These plots account for 21.7% of all plots dominated by *Picea abies*. No significant difference occurred in 63.4% of the plots. Only in 14.9% a significant better crown condition was observed. Such plots were especially frequent along the boarders between Poland and the Czech Republic, the Czech Republic and Germany, and in the Slovak Republic.

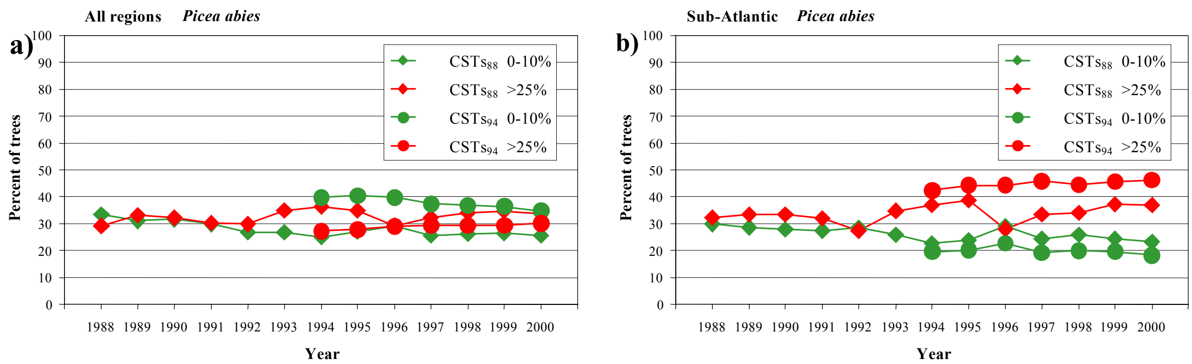


Figure 3.2.4-1: a) Sample sizes in all regions: $CSTs_{88}$ = 3 287; $CSTs_{94}$ = 13 508
b) Sample sizes in the Sub-Atlantic region: $CSTs_{88}$ = 1 992; $CSTs_{94}$ = 4 825

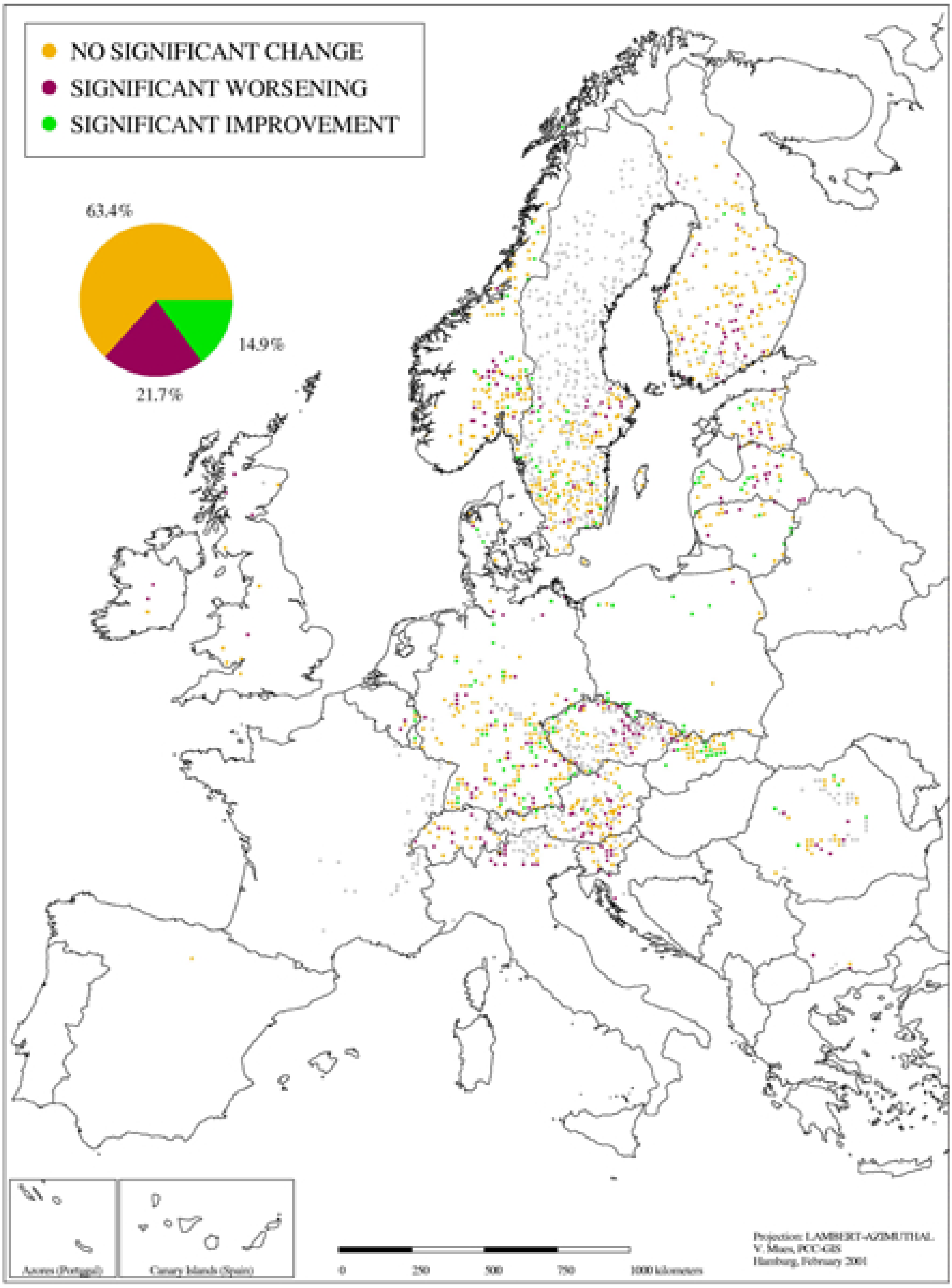


Figure 3.2.4-2: Mean plot defoliation of *Picea abies* in the year 2000 compared with 1994. (Grey plots contain *Picea abies* trees which could not be used as $CSTs_{94}$)

3.2.5 Fagus sylvatica

As can be seen in Table 3.2.1-1 and Table 3.2.1-2, *Fagus sylvatica* was the most frequently observed broadleaved tree species. It occurs especially in the Sub-Atlantic and Mountainous (South) regions with more than 50% of the CSTs for *Fagus sylvatica*. The species lacks in the Boreal region and in the Mountainous (North) region.

The crown condition of *Fagus sylvatica* showed a slight deterioration over all regions (Figure 3.2.5-1a). Only in 1991 there was a remarkable recuperation reflected in both the share of undamaged and damaged trees. The proportion of undamaged trees of the $CSTs_{94}$ was slightly larger as compared to the $CSTs_{88}$.

About one third of the sample is located in the Mountainous (South) region. The trends in crown condition in that region are characterised by strong fluctuations, especially during the early years of the surveys (Figure 3.2.5-1b). To a lesser extent, such fluctuations have also taken place in recent years. Besides of the early years' surveys, the proportion of damaged trees have generally remained at a level between 10 and 20%.

The crown condition of *Fagus sylvatica* in 2000 was in 48.6% of the $CSTs_{94}$ without significant difference compared to that in 1994 (Figure 3.2.5-2). The respective plots were distributed throughout Europe with a lower proportion in Italy, Bulgaria and Slovenia. Most of the 20.8% of the plots with better crown condition in 2000 were located in Croatia, Germany, Romania and in the west of the Slovak Republic. A significantly worse crown condition of *Fagus sylvatica* was observed on 31.1% of the plots. Such plots were distributed over several different areas ranging from Southern Sweden south to Italy, Slovenia, and Croatia, the east of the Slovak Republic and the south east of Romania.

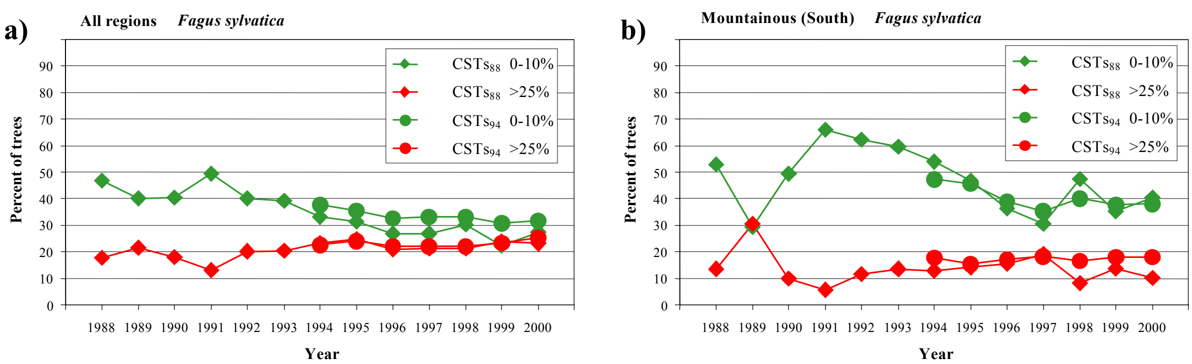


Figure 3.2.5-1: a) Sample sizes in all regions: $CSTs_{88}$ = 3 065; $CSTs_{94}$ = 6 551
b) Sample sizes in the Mountainous (South) region: $CSTs_{88}$ = 853; $CSTs_{94}$ = 2 100

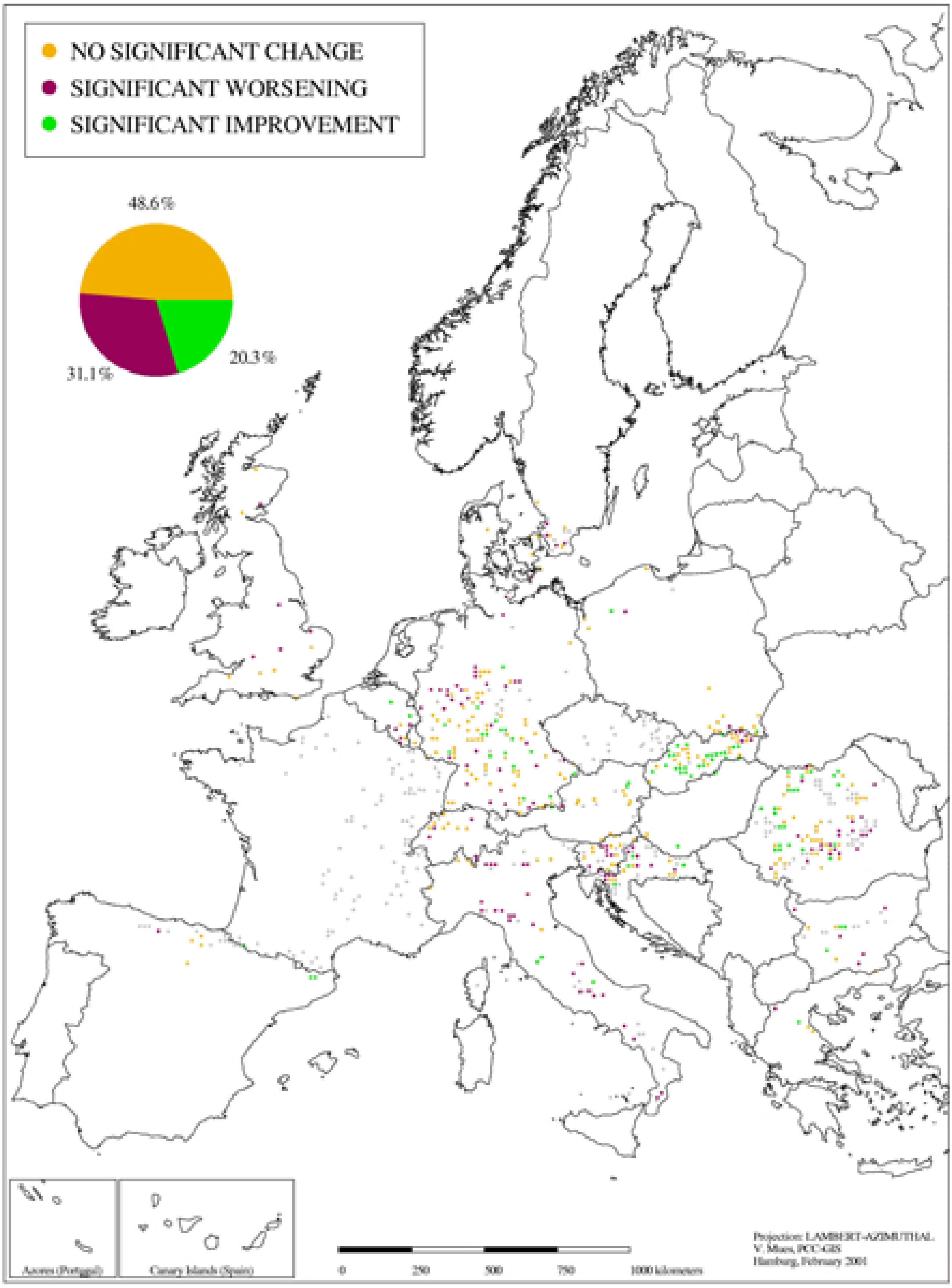


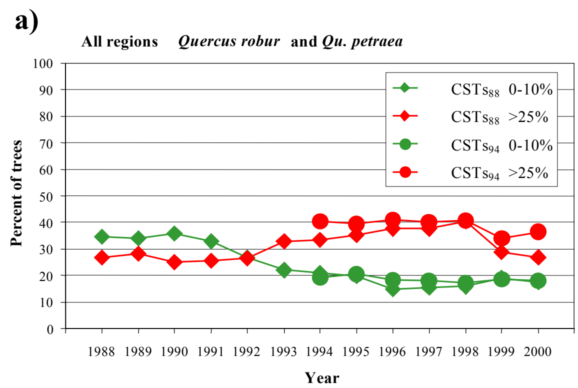
Figure 3.2.5-2: Mean plot defoliation of *Fagus sylvatica* in the year 2000 compared with 1994. (Grey plots contain *Fagus sylvatica* trees which could not be used as $CSTs_{94}$)

3.2.6 Quercus robur and Quercus petraea

Quercus robur et petraea are barely present in the Boreal region, and completely lacking in the Mountainous (North) region. Most of the trees are located in the Sub-Atlantic region. These are the second most frequent tree species of the $CSTs_{94}$.

The temporal development in all regions showed a steady, slight decrease in the share of undamaged trees (Figure 3.2.6-1a). The share of damaged trees increased from 1991 until 1998. In 1999 and 2000, however, a marked recuperation was observed for the $CSTs_{88}$, whereas the $CSTs_{94}$ in 2000 imply a deterioration. In the Sub-Atlantic region this trend was well reflected over the whole time sequence (Figure 3.2.6-1b). However, the crown condition in this climatic region was worse from 1994 to 1998 than the average of all regions. The share of undamaged trees notably decreased between 1988 and 1994 to remain constantly low afterwards.

As Figure 3.2.6-2 shows, 52.1% of the plots with *Quercus robur et petraea* did not show significant differences between 1994 and 2000. 23.6% of the plots had a significantly better crown condition in 2000, especially in plots located in the centre of Germany, in Poland, the Slovak Republic, Hungary, and Romania. The remaining 24.3% of the plots showed significantly worse crown condition compared to 1994. The deterioration, which is indicated for the south-east of Bulgaria, is the main reason for the increased share of dead oaks in comparison with that reported last year.



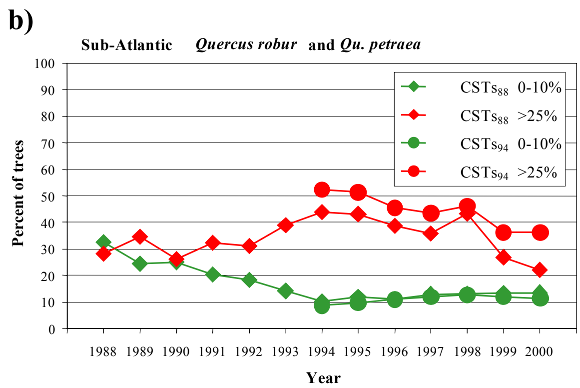


Figure 3.2.6-1: a) Sample sizes in all regions: $CSTs_{88}$ = 1 392; $CSTs_{94}$ = 4 061
b) Sample sizes in the Sub-Atlantic region: $CSTs_{88}$ = 724; $CSTs_{94}$ = 1 548

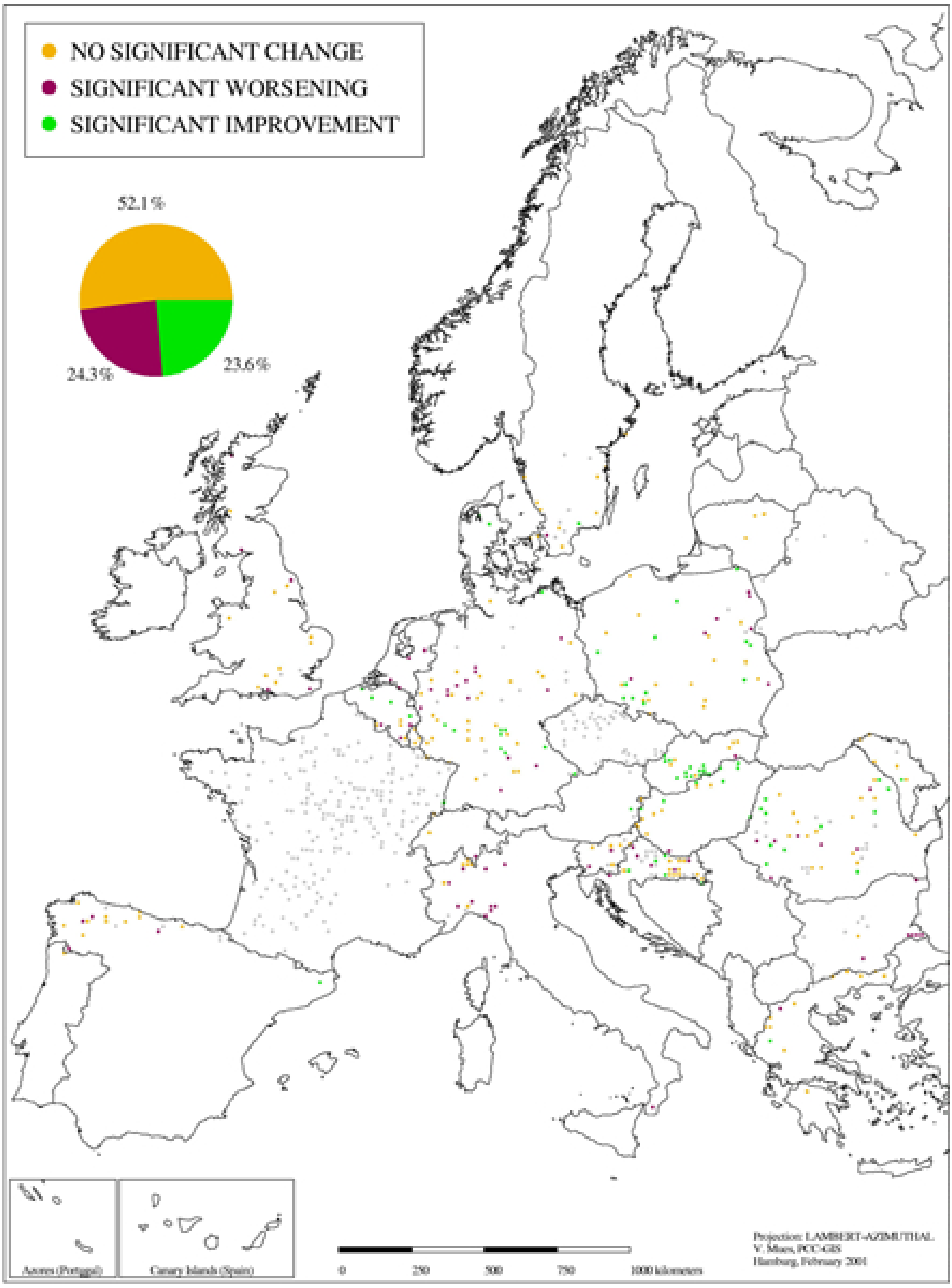


Figure 3.2.6-2: Mean plot defoliation of *Quercus robur et petraea* in the year 2000 compared with 1994. (Grey plots contain *Quercus robur et petraea* trees which could not be used as $CSTs_{94}$)

3.2.7 Quercus ilex

Two thirds of the *Quercus ilex* trees ($CSTs_{88}$ and $CSTs_{94}$) grow in the Mediterranean (Lower) region (Tables 3.2.1-1 and 3.2.1-2). Thus, the pronounced changes of *Quercus ilex* are dominated by the development in this region.

During the early years of the survey, the share of undamaged trees distinctly increased by 20 percent points to almost 80%, but from 1991 to 1995 it sharply decreased to about 15% (Figures 3.2.7-1a and 3.2.7-1b). Only minor changes in the share of damaged trees were observed up to 1994. Afterwards this share increased by approximately 15 percent points and in 1995 and 1996 it doubled that of undamaged trees. After a recuperation, however, from 1998 to 2000 the crown condition of *Quercus ilex* deteriorated again.

The map showing the crown condition of *Quercus ilex* in 2000 compared to 1994 implies that the 37.2% plots with significantly worse crown condition in 2000 are mostly located in the south of Spain. 11.6% of the plots showed a significantly better crown condition in 2000 compared to 1994, whereas no significant differences could be traced for the remaining 51.2%.

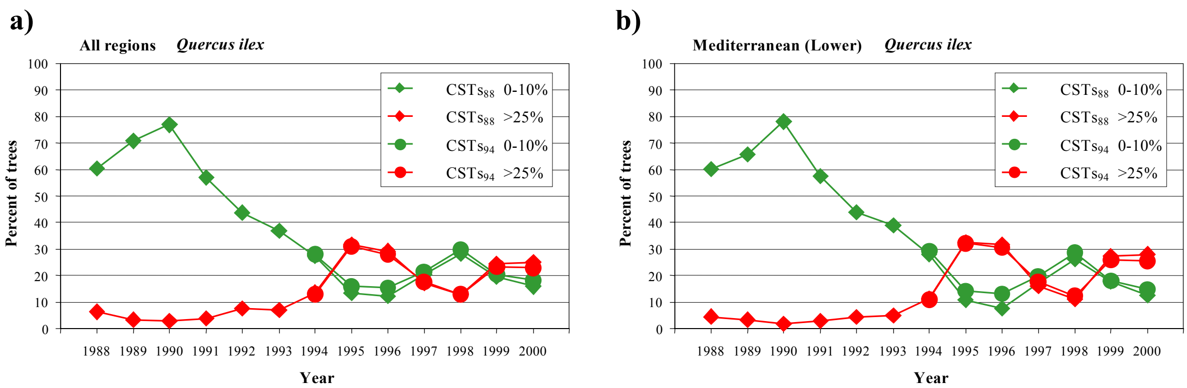


Figure 3.2.7-1: a) Sample sizes in all regions: $CSTs_{88}$ = 1 752; $CSTs_{94}$ = 2 366
b) Sample sizes in the Mediterranean (Lower) region: $CSTs_{88}$ = 1 143; $CSTs_{94}$ = 1 598

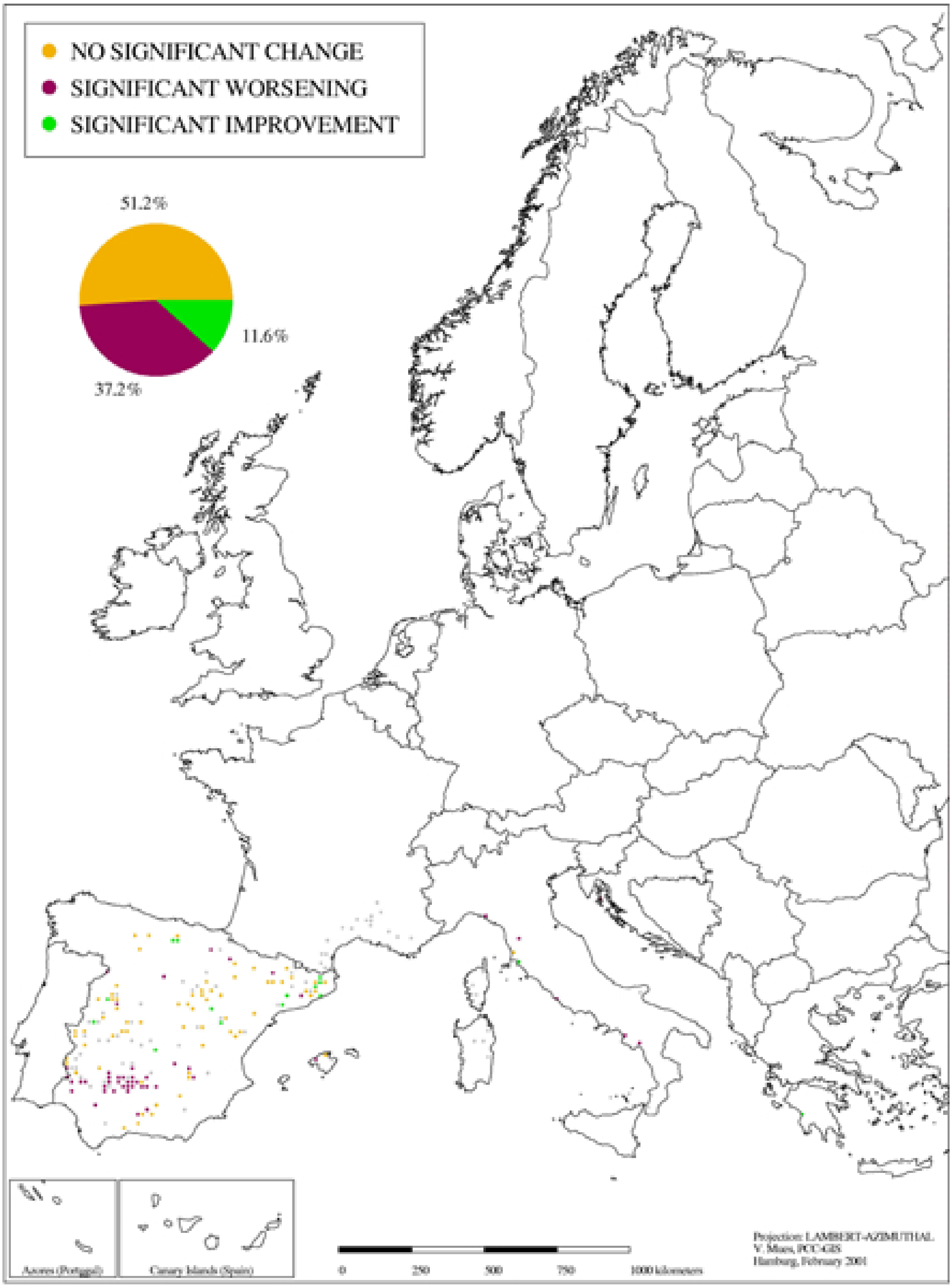


Figure 3.2.7-2: Mean plot defoliation of Quercus ilex in the year 2000 compared with 1994. (Grey plots contain *Quercus ilex* trees which could not be used as $CSTs_{94}$)

3.2.8 Pinus pinaster

Pinus pinaster is the second Mediterranean species evaluated separately. More than half of the $CSTs_{88}$ and the $CSTs_{94}$ are growing in the Mediterranean (Lower) region (Tables 3.2.1-1 and 3.2.1-2). The other CSTs of *Pinus pinaster* are located in the Atlantic (South), the Mediterranean (Higher), and less frequent in the Mountainous (South) region.

A continuous pronounced deterioration in the crown condition of *Pinus pinaster* was observed (Figure 3.2.8-1a). However, the share of undamaged trees has constantly remained larger than the share of damaged trees. An above average deterioration was observed between 1989 and 1991.

For the Mediterranean (Higher) region a recuperation from 1995 to 1997/1998 was found, which is contradicting to the overall trend of slight deterioration. But this trend is not consolidated by the years 1999 and 2000.

Only 6.0% of the plots dominated by *Pinus pinaster* showed a significantly improved crown condition in 2000 compared to 1994 (Figure 3.2.8-2), most of them located in Portugal. However, also the majority of the 36.0% of plots with significantly worse crown condition is located in this country. For the remaining 58.0% of the plots no significant differences are observed.

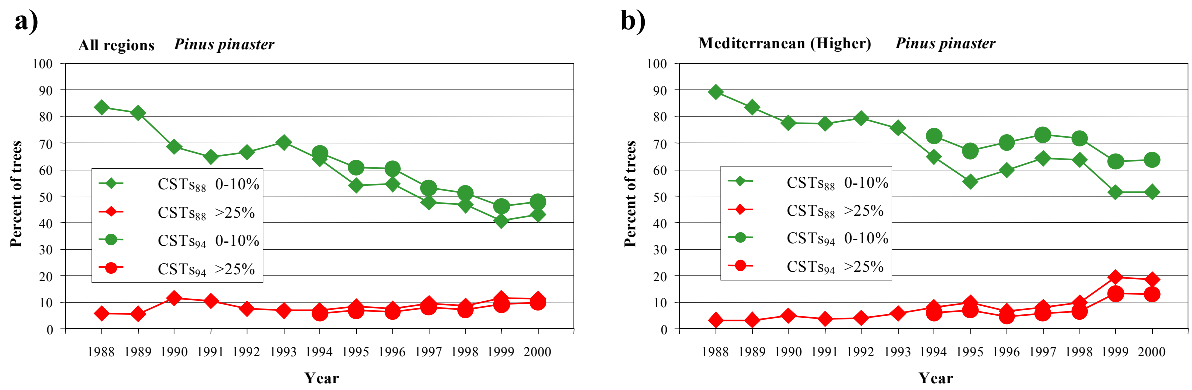


Figure 3.2.8-1: a) Sample sizes in all regions: $CSTs_{88}$ = 1 474; $CSTs_{94}$ = 2 039
b) Sample sizes in the Mediterranean (Higher) region: $CSTs_{88}$ = 242; $CSTs_{94}$ = 358

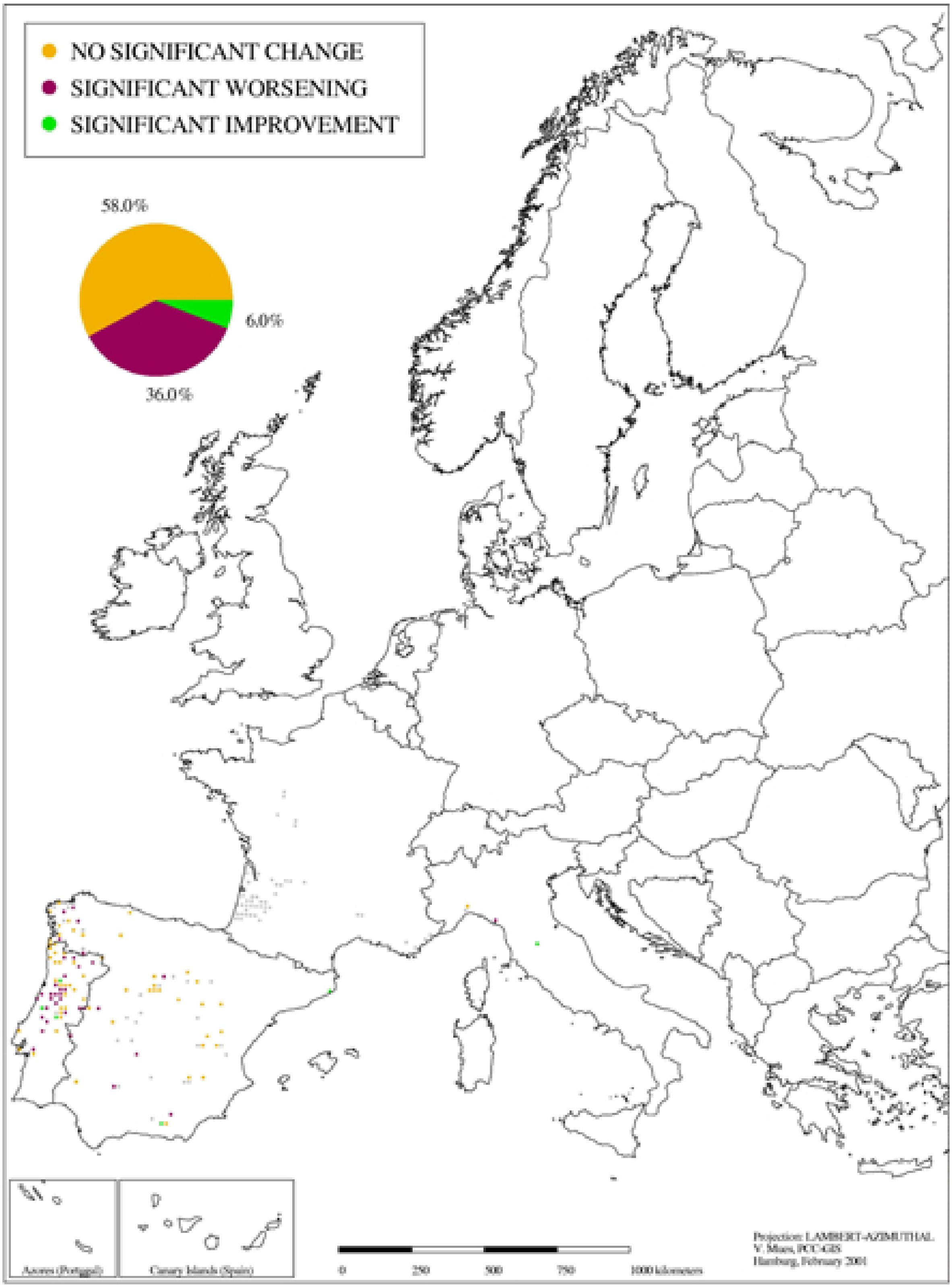


Figure 3.2.8-2: Mean plot defoliation of *Pinus pinaster* in the year 2000 compared with 1994. (Grey plots contain *Pinus pinaster* trees which could not be used as $CSTs_{94}$)

4 RESULTS OF INTEGRATIVE STUDIES

4.1 Generalised Linear Models for the main tree species in Europe

Results from generalised linear models (GLM) with defoliation and discolouration of tree crowns as target variables and country, age as well as influences of biotic factors (insect, fungi) as predictors are summarised in Table 4.1-1. For Scots pine (*Pinus sylvestris*) the largest number of plots was available, closely followed by Norway spruce (*Picea abies*). Both, common beech (*Fagus sylvatica*) respective pedunculate and sessile oak together (*Quercus robur et petraea*), are represented with approximately 500 plots, whereas for each of the Mediterranean species holm oak (*Quercus ilex*) and maritime pine (*Pinus pinaster*) only about 150 plots could be evaluated.

The medium-term mean defoliation of the investigated tree species is influenced to a different extent by effects related to country. With 47% of the explained variance *Pinus sylvestris* shows by far the highest influence of country, whereas for *Quercus ilex* no country effect at all was detected.

Table 4.1-1: Matrix of basic statistical relationships in terms of explained variance (R^2 in %) evaluated by generalised linear models (GLM) for crown condition parameters of the main tree species.

	Predicting variables	*Picea abies*	*Pinus sylvestris*	*Pinus pinaster*	*Fagus sylvatica*	*Qu. robur et petraea*	*Quercus ilex*
n of plots		**1099**	**1376**	**148**	**518**	**487**	**156**
mean defoliation 1994-2000	Country	26.42	46.77	33.85	23.39	29.44	0.74
	Country, age*)	59.11	58.41	39.72	35.13	39.25	5.31
	Country, age*), insect*)	60.54	59.61	46.65	40.68	45.24	6.35
	Country, age*), fungi*)	59.89	60.99	47.95	39.82	44.22	5.67
	Country, age*), insect*), fungi*)	61.10	62.23	50.08	44.39	49.46	6.52
mean discoloration 1994-2000	Country	21.95	38.39	30.71	40.91	33.04	1.46
	Country, age*)	30.03	41.20	32.69	44.94	36.79	2.67
	Country, age*), insect*)	31.69	44.10	35.81	56.72	44.27	4.06
	Country, age*), fungi*)	31.08	48.03	36.88	50.57	47.78	2.91
	Country, age*), insect*), fungi*)	32.70	48.80	42.58	59.72	54.78	4.19

age: stand age class transformed into class mean stand age [y]
country: class variable describing all peculiarities related to single countries
fungi: medium-term mean share of trees infested by fungi [%]
insect: medium-term mean share of trees infested by insects [%].
*) additionally interaction with country included.

It has already been shown that defoliation is positively correlated with age. For the four species shown in Fig. 4.1-1 the relationships between country-corrected defoliation and age respective age class are visualised by box-and-whisker plots. The country-corrected defoliation is calculated according to the analysis-of-variance model (cf. equation (1) in Chapt. 2.5.2.1). According to this model age explains additional amounts of the total variance between 6% in *Quercus robur et petraea*, 8% in *Pinus sylvestris*, 8% in *Fagus sylvatica* and as much as 27% in *Picea abies*. In both Mediterranean species less than 1% of the total variance is explained by age; their presentation has therefore been omitted in this context. If interaction effects between country and age are additionally considered, an even higher amount of variance could be explained by both variables (see Tab. 4.1-1).

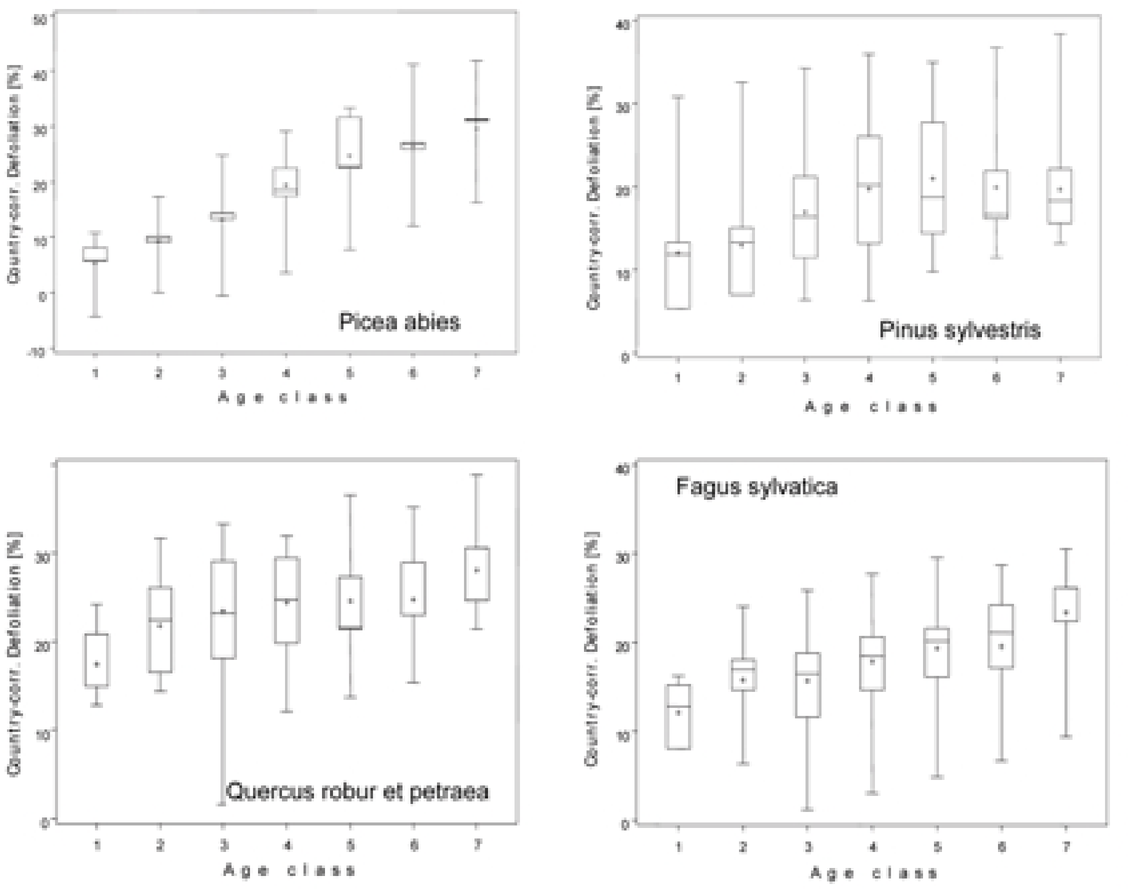


Fig. 4.1-1: Species-specific country-corrected defoliation values (according to GLM, without consideration of the interaction term age*country) over age class. Boxes embrace the 25th to 75th percentile with the median in the middle, denoted by the horizontal bar. The end of the wiskers mark the extremes, the crosses the mean values.

Each species reveals its own type of relationship between defoliation and age. In *Picea abies* linear to slightly sigmoide increase in defoliation over the whole life span can be observed. A similar increase can be observed in *Fagus sylvatica*. *Pinus sylvestris* reveals a typical logistic relationship between defoliation and age with a distinct increase in defoliation values up to age class 4 (60 to 80 years). In the higher age classes no further increase in defoliation values can be observed. The two oak species *Quercus robur* and *Q. petraea* reveal the least distinct age effects among the four temperate tree species given here. From age class 1 to age class 2 the country-corrected mean defoliation rises from about 17.5% to about 22%. After that only an additional degressive increase to about 25% within the 6th age class occurs, however the oldest age class shows again a stronger increase.

Especially the non-linear correlation within Scots pine challenges more sophisticated statistical models in future integrated approaches. The defoliation-age relationship requires its consideration also within statistical models with more predictors as well as in mapping defoliation. Without regard of age, variation due to the different ages of the assessed stands would limit the comparability of defoliation values.

The models, which in addition include age and its interaction with country, denote *Picea abies* as the species for which defoliation is explained best, closely followed by *Pinus* *sylvestris*. For *Picea abies* the enclosure of age and its interaction with country has more than doubled the amount of explained variance. For the deciduous tree species the increase in the explained variance due to the inclusion of age amounts to approximately 10%, whereas for *Pinus pinaster* the increase is comparatively poor. In *Quercus ilex* also a small age effect was found, but the model with country and age explains only 5.3% of the total variance.

If the medium-term mean occurrence of insects and fungi is added to the model, for some of the tree species a further increase of the amount of explained variance can be detected. This is most obvious for *Pinus pinaster* and for the two deciduous tree species. For *Pinus sylvestris* and *Picea abies* the influence of insects and fungi including their interactions with country improves the statistical model only to minor degrees. For *Quercus ilex* there is almost no effect. Both *Pinus* species show a stronger correlation between mean defoliation and fungi, while the other tree species reveal a stronger correlation between defoliation and insects.

In general, the models show distinct influences of country, age, insects, and fungi as these factors explain 44% to 62% of the variance of defoliation. Only in *Quercus ilex* the model remains quite poor with respect to the explained variance.

Like for defoliation, distinct country effects show up for discolouration (Fig. 4.1-1). Expressed as R^2 values, they range between 22% (*Picea abies*) and 41% (*Fagus sylvatica*). Again, *Quercus ilex* shows no country specific peculiarities at all. The inclusion of age and its interaction with country reveals a considerable increase in the explained variance for *Picea abies*. For all other tree species it only reveals an increase of maximally 4%.

After inclusion of the mean influence of insects and fungi and their interactions with country into the generalised linear model, a remarkable increase in the explained variance is achieved for *Fagus sylvatica* and for *Quercus robur et petraea*, reflecting especially for the oaks their high receptivity to a large number of biotic agents.

For the deciduous species the models concerning discolouration reveal higher degrees of explained variance than the models focusing at defoliation. For both *Pinus* species as well as for *Picea abies* the model on discolouration is distinctively worse than the model for defoliation. Like in defoliation, discolouration of the wintergreen holm oak (*Quercus ilex*) is not influenced significantly by any of the introduced variables.

4.2 Species specific results

4.2.1 Picea abies

According to the selection criteria (2.2.5.1) 1099 *Picea abies* plots are available for statistical evaluations. They are located in 24 countries (Tab. 4.2.1.1-1). The general distribution pattern (Fig. 4.2.1.2-2) is roughly congruent with the phytogeographic features of Norway spruce.

4.2.1.1 Generalised Linear Models

For *Picea abies* the class variable country explains 26% of the variance of medium-term mean defoliation (Tab. 4.2-1) which is the smallest amount among the coniferous species. The intercepts of the GLM found for the different countries vary between -5.61% (Norway) and 29.06% (Czech Republic). 115.06% for Luxembourg or 35.47% for Croatia must be considered as statistical artefacts due to very low numbers of plots within these countries. Countries with sufficiently large numbers of plots reveal positive coefficients for the influence of age onto defoliation. Norway and Finland, for example, show an average increase in defoliation per age class (20 years) of 6.4% and 5.8% respectively. Negative coefficients may largely depend on random effects due to low plot numbers or effects not regarded yet (e.g. Luxembourg with two plots and a negative slope for age of -0.89%). Another explanation might be the fact that some countries include the natural age trend into their reference tree system (UN/ECE 1998), whereas other countries use similar reference trees for all age classes. Further, in countries with limited variation of age, only very low amounts of variance can potentially be explained by this variable.

The resulting model values for defoliation referred to an age of 90 years shows strong differences in the evaluated areas of Europe (Tab. 4.2.1.1-1). The model values for Poland, the Czech Republic, the Slovak Republic, and Luxembourg are between 30 and 40%. Croatia, which takes value above 40%, and Luxembourg show very low plot numbers and should not be over-emphasised. The other three countries in the class below 40% form a centre of high defoliation values in central Europe. In contrast to them the neighbouring country Austria shows a model value of only 7.7%.

Table 4.2.1.1-1: Number of observations, mean, and model for medium-term mean defoliation [%] for *Picea abies* in Europe, listed according to the country specific mean defoliation; values for countries with less than 50 plots shaded.

	medium-term mean defoliation		GLM		
	n	mean [%]	intercept [%]	age trend [%/a]	model value for age = 90 ; [%]
France	37	5.4	-2.74	0.1462	10
Spain	1	5.5	5.01	0.0526	10
Austria	66	7.6	2.41	0.0588	8
Denmark	8	12.5	11.49	0.0299	14
Bulgaria	3	12.5	16.12	-0.0373	13
Estonia	31	13.5	2.29	0.2051	21
Italy	15	15.7	14.97	0.0089	16
United Kingdom	11	16.4	10.81	0.0865	19
Sweden	162	18.5	5.09	0.1794	21
Ireland	3	18.8	22.80	-0.1097	13
Latvia	38	19.1	15.88	0.0526	21
Finland	148	20.0	-2.28	0.2911	24
Germany	180	20.3	2.13	0.2302	23
Belgium	7	21.3	23.85	-0.0355	21
Lithuania	24	21.5	11.39	0.1683	27
Norway	130	22.0	-5.61	0.3202	23
Romania	33	22.4	13.15	0.1332	25
Switzerland	25	22.6	13.08	0.0816	20
Slovenia	21	22.8	18.44	0.0516	23
Luxembourg	2	26.4	115.06	-0.8869	35
Slovak Republic	44	31.7	25.27	0.0785	32
Poland	26	31.8	27.09	0.0550	32
Czech Republic	83	32.0	29.06	0.0320	32
Croatia	1	41.3	35.47	0.0526	40

4.2.1.2 Spatial Variation of Preliminarily Adjusted Defoliation (PAD)

The residuals of the model above (Chapt. 4.2.1.1) with the explanatory variables country and age and their interaction named as preliminarily adjusted defoliation (PAD), were object of a geostatistical analysis. The resulting variogram for *Picea abies* shows a very high nugget effect of 47.0 and a low sill of 8.0 (Fig. 4.2.1.2-1).

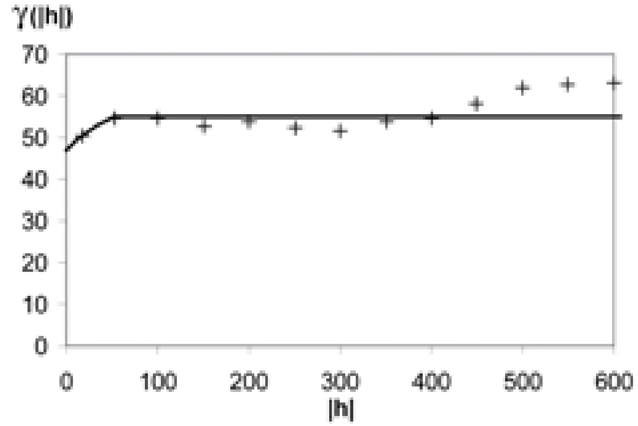


Figure 4.2.1.2-1: Empirical variogram (dots) and modelled spherical variogram (line) for the residuals of the mean defoliation model of *Picea abies*, including age, country and their interaction as explanatory variables; |h| = distance in km; nugget: 47.0, sill: 8.0, range: 60 km.

The comparatively high semivariance, especially those for pairs with distances > 400 km, results mainly from high dissimilarities related to a certain plot in Germany and to several plots in Norway (north of Trondheim) with very high defoliation values. Whereas the German plot reveals very high indices of infestations by insect and fungi, there are no similar indications for the high defoliation of the plots in Norway. However, according to SOLBERG (1999) needle (*Chrysomyxa abietis*) and root (*Heterobasidion annosum*) affecting fungi are quite common in the respective Trøndelag region.

Although the high variance of defoliation in Norway covers the largest part of the variance found within other countries, Fig. 4.2.1.2-2 shows regions of elevated PAD in other countries too. Some of them can be explained by the coincidence of insects of fungi, but the discussion of the country specific pattern with the particular National Focal Centres should be a promising task for the detection of new explanatory variables.

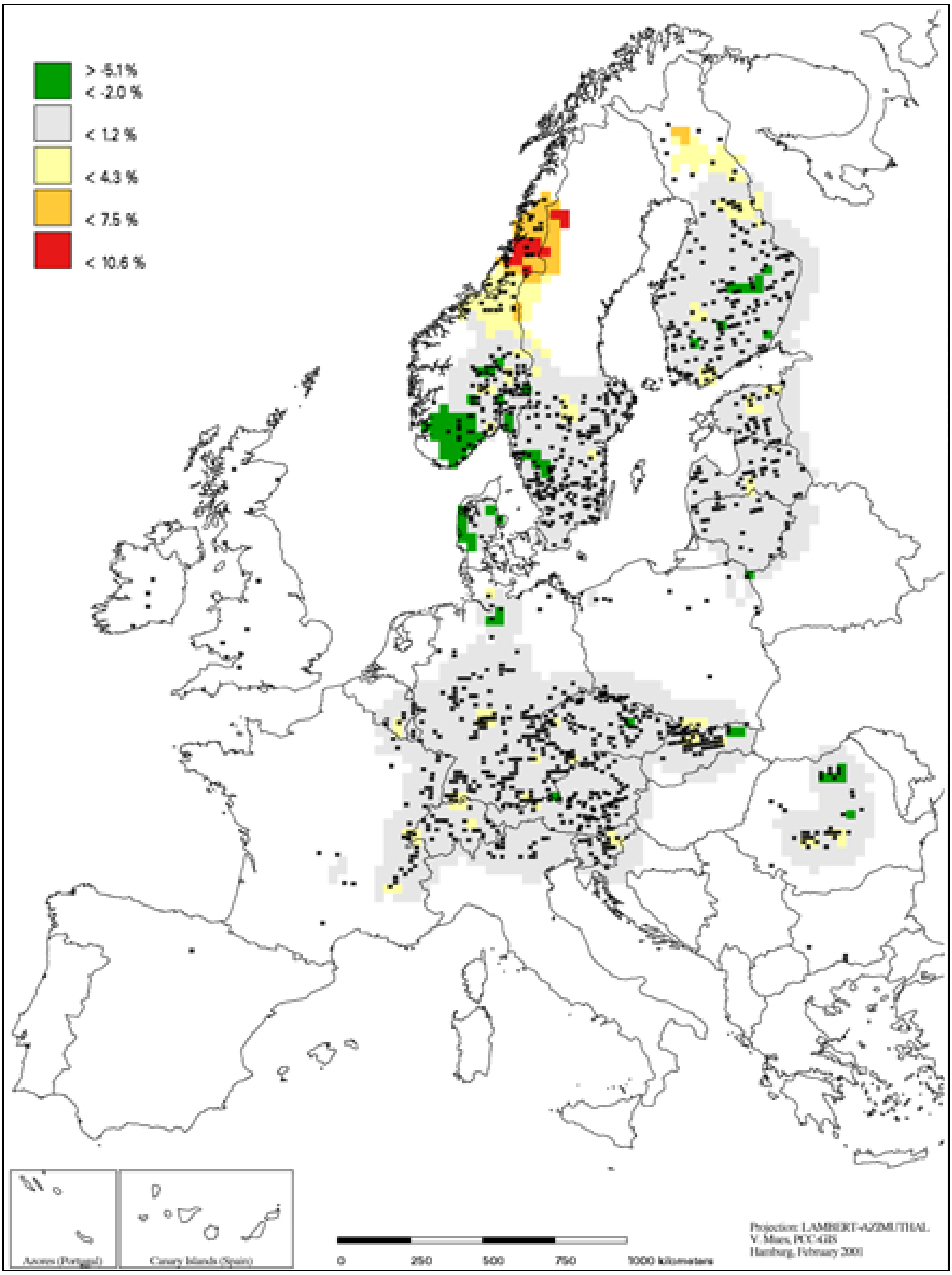


Figure 4.2.1.2-2: Map of deviations from the defoliation expected from country and age for *Picea abies* (kriged PAD).

4.2.2 Pinus sylvestris

Pinus sylvestris plots are distributed over large parts of Europe ranging from northern Spain and Portugal to northern Finland (Fig. 4.2.2.2-2). Data from 1376 Level I plots located in 26 countries are available (Tab. 4.2.2.1-1).

4.2.2.1 Generalised Linear Models

From the total variance of medium-term mean defoliation of *Pinus sylvestris*, 47% can be explained by the class variable country. The inclusion of age and its interaction with country results in a model, which explains 58% of the variance (Tab. 4.1-1). This model is described in more detail in table 4.2.2.1-1. The smallest intercept of -0.42% is found for Norway indicating that in theory very young trees are considered to have the full amount of needles within this country. For many countries the high intercept statistically shows that trees of age = 0 are already estimated as defoliated. For a series of countries the number of pine plots is, however, too small to substantiate country-specific systematic deviations.

Table 4.2.2.1-1: Number of observations, mean, and model for medium-term mean defoliation [%] of *Pinus sylvestris* in Europe, listed according to country specific mean defoliation; values for countries with less than 50 plots shaded.

	medium-term mean defoliation		GLM		
	n	mean [%]	intercept [%]	age trend [%/a]	model value for age = 90 ; [%]
The Netherlands	6	6.3	4.85	0.0202	7
Austria	11	9.9	10.45	-0.0058	10
Finland	234	10.2	1.64	0.1280	13
Portugal	1	11.9	11.67	0.0202	13
Greece	1	12.9	11.53	0.0202	13
Sweden	151	13.6	8.59	0.0626	14
Norway	142	15.7	-0.42	0.1626	14
Denmark	3	15.8	15.28	0.0079	16
France	52	16.0	7.94	0.1307	20
Hungary	14	16.8	20.44	-0.0747	14
United Kingdom	8	17.0	17.44	-0.0084	17
Spain	62	17.1	15.87	0.0229	18
Germany	161	17.2	9.31	0.1085	19
Estonia	68	17.7	15.94	0.0269	18
Switzerland	2	18.3	25.13	-0.0623	20
Belgium	9	20.8	23.00	-0.0290	20
Lithuania	38	21.0	21.57	-0.0093	21
Italy	10	21.2	31.93	-0.1781	16
Latvia	52	22.7	21.31	0.0202	23
Slovenia	4	25.8	55.59	-0.3307	26
Poland	298	26.6	25.03	0.0206	27
Romania	2	28.0	48.34	-0.5097	2
Slovak Republic	16	28.8	36.58	-0.1036	27
Bulgaria	21	32.5	32.82	-0.0114	32
Luxembourg	1	33.9	32.12	0.0202	34
Czech Republic	9	35.7	35.49	0.0024	36

Most countries show positive age trends (Tab. 4.2.2.1-1). However, like in *Picea abies*, for a considerable number of countries the model results in negative coefficients for age. The most negative value is observed for Romania with only two pine plots. But also some countries with a remarkable number of plots show negative coefficients, which might be based on adjustments of the reference tree to age-effects. The modelled defoliation values for *Pinus sylvestris* adjusted for an age of 90 years show generally higher defoliation values in central Europe. The outstanding high values of Luxembourg, Belgium, Bulgaria, and the Czech Republic and the outstanding low values for Austria and Romania should however not be over-interpreted due to their low numbers of plots.

4.2.2.2 Spatial Variation of Preliminarily Adjusted Defoliation (PAD)

A spherical model was fitted to the empirical variogram of *Pinus sylvestris* residuals (Fig. 4.2.2.2-1). In comparison to the results for *Picea abies* the nugget of 16.8 is distinctively lower (Picea abies: 47) and the sill is higher 10.9 (8.0). However, for *Pinus sylvestris* the sill is still lower than the nugget value which also indicates a high amount of unexplained random variance. A distinct spatial autocorrelation can be traced up to a range of 55 km.

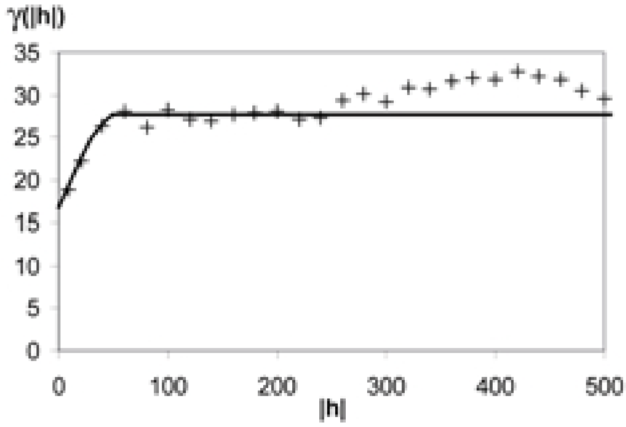


Figure 4.2.2.2-1: Empirical variogram (dots) and modelled spherical variogram (line) for the residuals of the mean defoliation model of *Pinus sylvestris*, including age, country and their interaction as explanatory variables; |h| = distance in km; nugget: 16.8, sill: 10.9, range 55 km.

For some areas distinct spatial patterns of the kriged PAD are observed (Fig. 4.2.2.2-2). The spatial patterns in Poland are quite obvious. Whereas the low residuals in the northern and especially the north-western regions are an indication for better crown condition, the PAD is high in the south. Similar observations can be made for the north west of Estonia, France – in the south east – and in the east of Spain. Germany, Norway and Finland show also spots of higher residuals.

Some of the "red spots" are directly related to the high variogram values of the empirical variogram. Namely one plot in Finland shows very high dissimilarities compared with plots in all distances. Even single plots in France, Spain and Germany show elevated defoliation values.

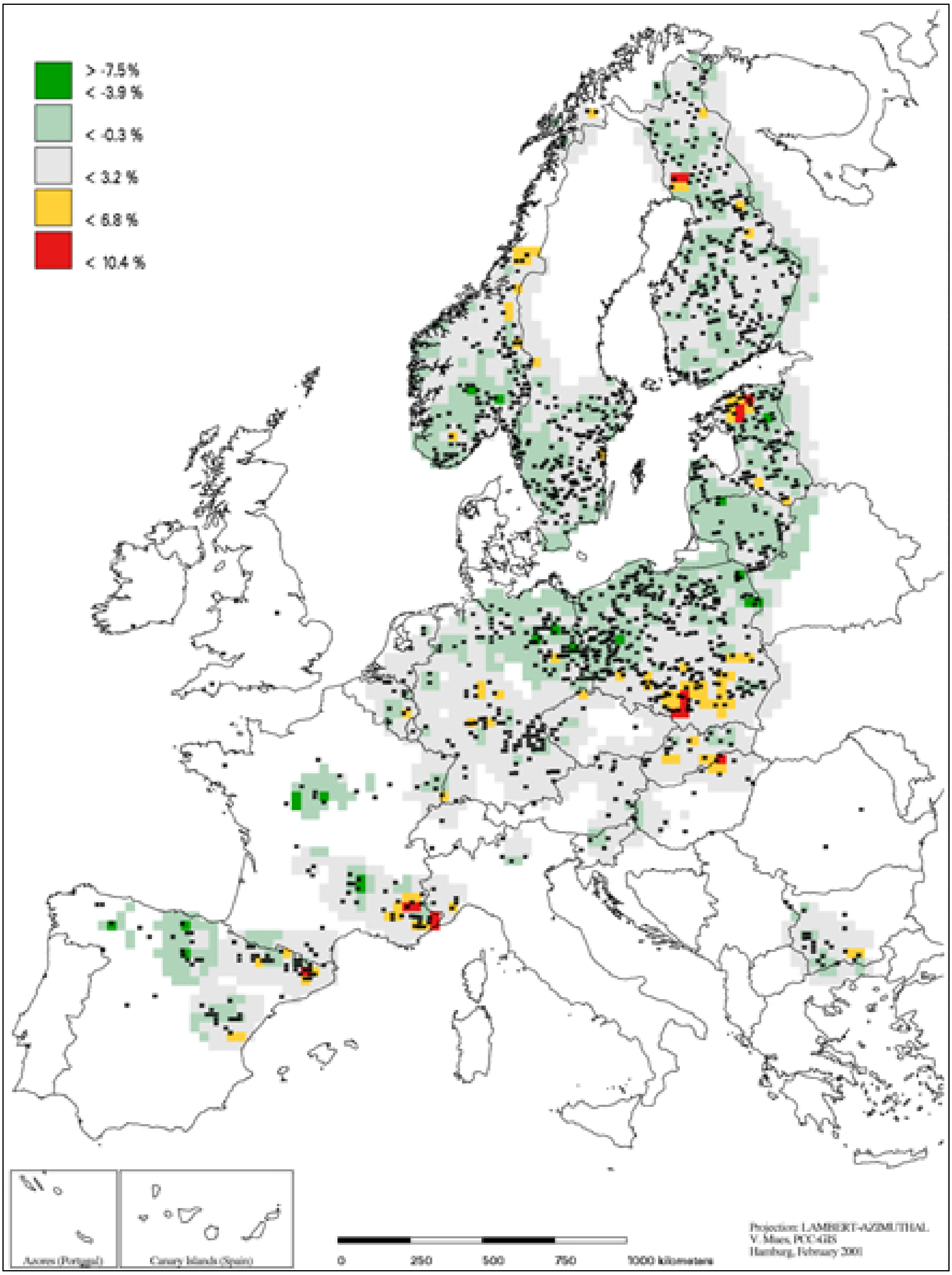


Figure 4.2.2.2-2: Map of deviations from the defoliation expected from country and age for *Pinus sylvestris* (kriged PAD).

4.2.3 Pinus pinaster

Pinus pinaster mainly occurs in the southern Atlantic and the western Mediterranean region (Fig. 4.2.3.2-2). Four countries share a total of 148 plots, most of them belonging to Portugal, France, and Spain (Table 4.2.3.1-1).

4.2.3.1 Generalised Linear Models

Country alone explains 34% of the total variance (Tab. 4.1-1). Age explains an additional amount of 6% of the total variance. The main reason is, that only France shows a distinct positive age effect with an increase of 3.6% per age class (20 years). In the other countries maritime pine shows almost no age trend (Tab. 4.2.3.1-1). The four plots in Italy are characterised by distinctively higher defoliation values. Modelled mean defoliation at the age of 90 years is lowest in Spain and Portugal.

Table 4.2.3.1-1: Number of observations, mean, and model for medium-term mean defoliation [%] of Pinus pinaster in Europe, listed according to country specific mean defoliation; values for countries with less than 50 plots shaded.

	medium-term mean defoliation		GLM		
	n	mean [%]	intercept [%]	age trend [%/a]	model value for age = 90 ; [%]
France	45	13.3	6.64	0.180	23
Portugal	51	13.4	13.45	-0.003	13
Spain	48	19.3	21.10	-0.044	17
Italy	4	48.1	49.43	-0.044	45

4.2.3.2 Spatial Variation of Preliminarily Adjusted Defoliation (PAD)

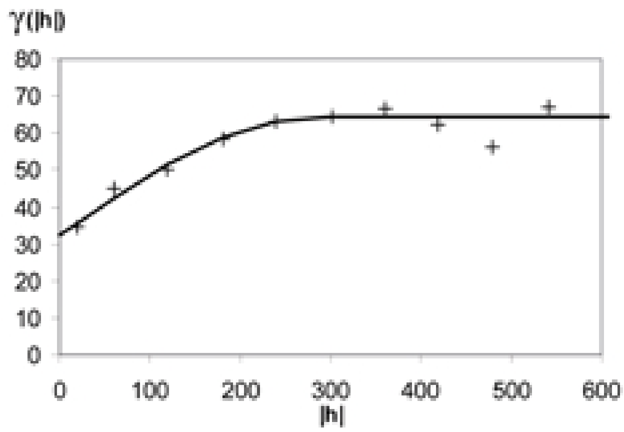


Figure 4.2.3.2-1: Empirical variogram (dots) and modelled spherical variogram (line) for the residuals of the mean defoliation model of *Pinus pinaster*, including age, country and their interaction as explanatory variables; |h| = distance in km; nugget: 32.4, sill: 32.0, range: 286 km.

The empirical semivariogram for the *Pinus pinaster* residuals is the most typical one found in the geostatistical analyses of the Level I data (Fig. 4.2.3.2-1). The parameters of the fitted theoretical variogram show a relatively high sill (32.0) in relation to the nugget (32.4). Especially in comparison with the respective graphs of the other coniferous tree species, this relation is very high and indicates a high spatial autocorrelation among the

PAD. Regarding the discontinuous locations of the plots (Fig. 4.2.3.2-2), the results must be interpreted with care.

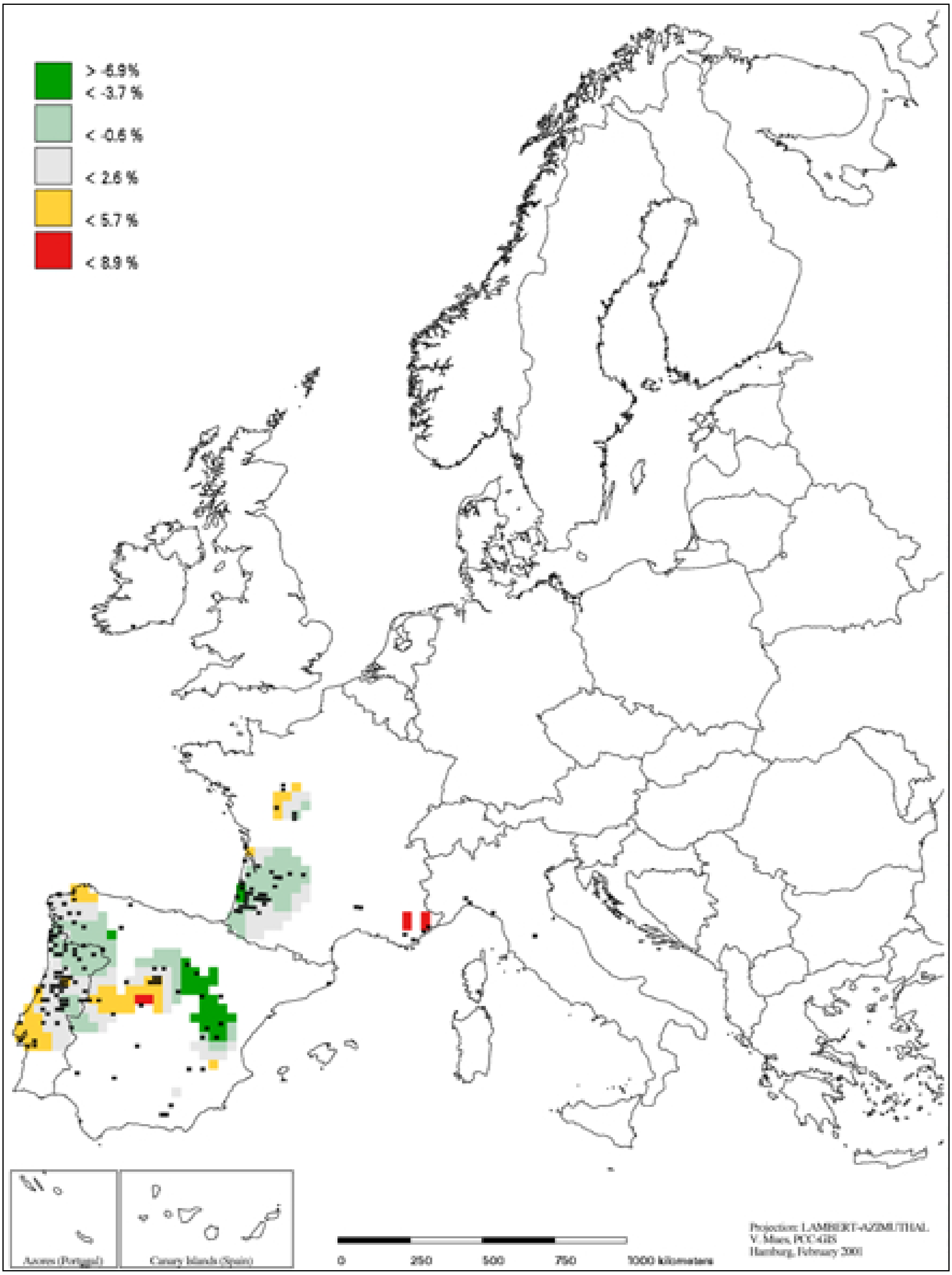


Figure 4.2.3.2-2: Map of deviations from the defoliation expected from country and age for *Pinus pinaster* (kriged PAD).

The spatial variation of the preliminarily adjusted defoliation (PAD) shows high residuals in south eastern France (Fig. 4.2.3.2-2). Residuals are lowest in north eastern parts of the sample area in Spain and Portugal.

4.2.4 Fagus sylvatica

Plots stocked with *Fagus sylvatica* are mainly located in central Europe as well as in mountainous regions of the northern Mediterranean zone and south-eastern Europe (Fig. 4.2.4.2-2). 518 plots from 19 countries are included in the evaluations (Tab. 4.2.4.1-1).

4.2.4.1 Generalised Linear Models

The model explaining medium-term mean defoliation is given in Table 4.2.4.1-1. Negative intercepts, as observed for Austria and Belgium, are due to random effects mainly based on small numbers of plots per country.

For most countries the model results in positive relationships between age and defoliation. For Germany, the country with the most *Fagus* plots, an increase in defoliation of 3.38% per age class (20 years) is calculated. France with the second most plots shows a little lower increase in defoliation with 1.58% per age class.

Table 4.2.4.1-1: Number of observations, mean, and model for medium-term mean defoliation of *Fagus sylvatica* in Europe, listed according to country specific mean defoliation; values for countries with less than 50 plots shaded.

	medium-term mean defoliation		GLM		
	n	mean [%]	intercept [%]	age trend [%/a]	model value for age = 90 ; [%]
Hungary	5	4.5	6.14	-0.020	4
Austria	12	6.2	-1.64	0.085	6
Greece	5	6.8	7.36	-0.005	7
Croatia	22	10.3	4.28	0.083	12
France	83	14.3	8.04	0.079	15
Belgium	8	16.2	-49.75	0.573	2
United Kingdom	12	16.4	13.99	0.026	16
Slovenia	18	16.4	11.02	0.060	16
Romania	88	18.7	14.98	0.050	19
Spain	8	18.8	16.12	0.045	20
Slovak Republic	51	19.4	19.69	-0.003	19
Italy	36	20.0	18.30	0.033	21
Sweden	7	20.5	2.01	0.168	17
Switzerland	13	20.5	14.36	0.060	20
Germany	115	22.3	7.41	0.169	23
Denmark	6	24.8	7.89	0.145	21
Bulgaria	11	26.0	26.81	-0.015	25
Poland	17	26.6	20.22	0.073	27
Luxembourg	1	27.1	28.84	-0.015	27

The model values for defoliation of *Fagus sylvatica* adjusted for the age of 90 years are below 30% in all countries. In Austria, Belgium, Greece, and Hungary the lowest defoliation values (< 10%) can be found, however the number of observations is also low.

4.2.4.2 Spatial Variation of Preliminarily Adjusted Defoliation (PAD)

Figure 4.2.4.2-1 shows the empirical variogram for the residuals of the age-country model for defoliation of *Fagus sylvatica*. It was fitted by a theoretical variogram of the spherical type with the following parameters: nugget = 25.5, sill = 31.0, and range = 136 km. The high variogram values at distances (h) of c. 350 km can mainly be explained by four plots with high defoliation, and particular high residual values located in Germany, Romania and France. For these plots the mean defoliation values are underestimated by the age-country model with residuals between 30 and 34%. With the exception of a single German plot these extreme values can be explained by the conspicuous appearance of insects in the observed period, reported within the Level I data. An analysis of the plots in the neighbourhood of these conspicuous plots shows that they are no isolated extraordinary observations but extreme values in regions with relatively high defoliation values.

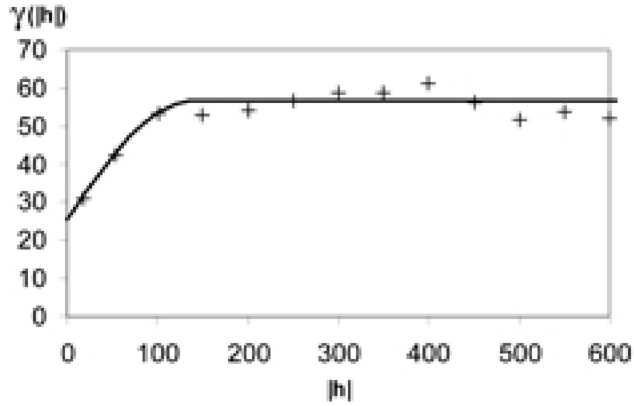


Figure 4.2.4.2-1: Empirical variogram (dots) and modelled spherical variogram (line) for the residuals of the mean defoliation model of *Fagus sylvatica*, including age, country and their interaction as explanatory variables; h = distance in km; nugget: 25.5, sill: 31.0, range: 136 km.

The map of the PAD shows a strong variation of relative crown condition throughout Europe (Fig. 4.2.4.2-2). Areas in central and southern Germany and southern Romania show high positive residuals respective defoliation values for *Fagus sylvatica*. For the particular plots in Romania a high occurrence of insects and fungi is observed. Also for the plots in southern Germany, influences of fungi on crown condition among other influences are described by EWALD et al. (2000).

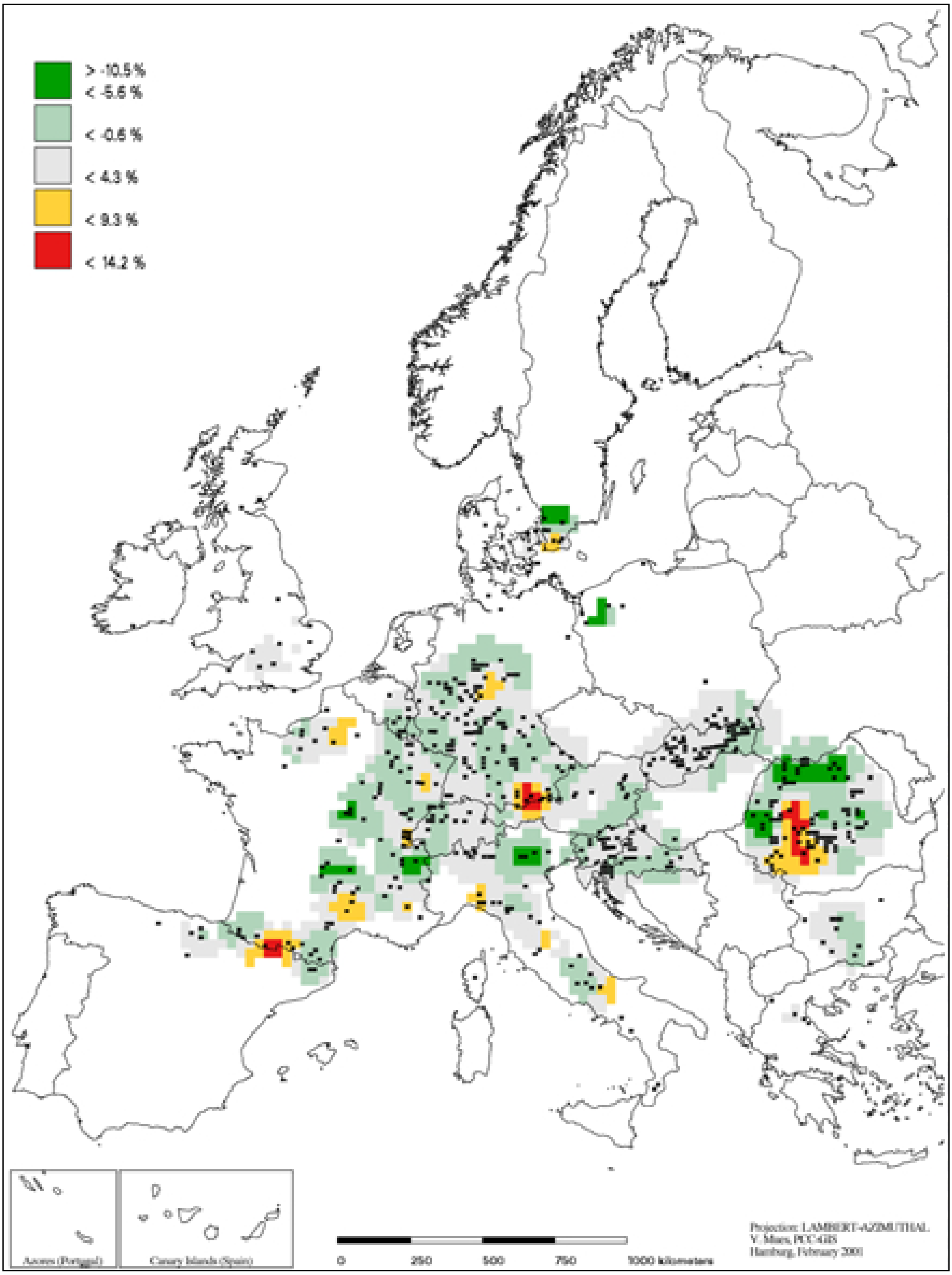


Figure 4.2.4.2-2: Map of deviations from the defoliation expected from country and age for *Fagus sylvatica* (kriged PAD).

4.2.5 Quercus robur et petraea

The two oak species (*Quercus robur, Q. petraea*) are processed together, because a separate treatment would lead to a marked reduction of cases, even for the more frequent species (*Q. robur*). One or both species can be found on 487 plots spread over large parts of Europe reaching from the belt of nemoral woodlands in north-western Spain to eastern Bulgaria and Moldova (Fig. 4.2.5.2-2). The total sample contains plots from 23 countries, however by far the most of the oak plots are located in France (Table 4.2.5.1-1).

4.2.5.1 Generalised Linear Models

Apart from Austria with an outstandingly low mean defoliation of 1.6%, based however on one plot only, most of the countries do have high defoliation values with averages above 20% or even above 30%, what is also expressed by most of the model due to high intercepts (Tab. 4.2.5.1-1).

The age trends vary considerably. France with its 180 *Quercus* plots reveals an average increase of 1.94% per age class (20 years). Similar coefficients are found for many countries, especially for those with higher numbers of plots. In countries with only a few plots, often negative coefficients are found, probably due to random effects.

Table 4.2.5.1-1: Number of observations, mean, and model for medium-term mean defoliation of Quercus robur et petraea in Europe, listed according to country specific mean defoliation; values for countries with less than 50 plots shaded.

	medium-term mean defoliation		GLM		
	n	mean [%]	intercept [%]	age trend [%/a]	model value for age = 90 ; [%]
Austria	1	1.6	13.26	-0.234	-8
Portugal	1	13.7	34.77	-0.234	14
Belgium	11	14.9	6.13	0.084	14
The Netherlands	4	15.2	26.01	-0.154	12
Spain	15	16.9	21.28	-0.072	15
France	180	20.2	12.91	0.097	22
United Kingdom	15	20.4	19.03	0.012	20
Lithuania	3	21.1	6.99	0.169	22
Hungary	18	21.8	1.66	0.312	30
Slovenia	7	22.0	38.28	-0.170	23
Sweden	11	22.1	28.29	-0.070	22
Croatia	22	25.3	16.60	0.114	27
Switzerland	2	26.9	56.34	-0.246	34
Germany	56	27.4	17.40	0.110	27
Italy	16	27.4	22.87	0.092	31
Greece	13	27.6	29.72	-0.044	26
Slovak Republic	21	29.7	17.97	0.159	32
Romania	36	31.1	32.11	-0.016	31
Poland	35	31.5	24.12	0.092	32
Luxembourg	3	31.9	45.04	-0.172	30
Moldova	6	32.9	31.27	0.029	34
Bulgaria	7	33.5	45.89	-0.234	25
Denmark	4	33.9	27.07	0.065	33

Country-wise modelled defoliation values for an age of 90 years are between 20% and 40% (Tab. 4.2.5.1-1). Exceptions are the results for Belgium, the Netherlands, and Spain with model values below 20%. The result for Austria and Portugal may not be representative due to the observation of a single plot in both countries.

4.2.5.2 Spatial Variation of Preliminarily Adjusted Defoliation (PAD)

The empirical variogram for the residuals of the age-country model for the oak species *Quercus robur* and *Quercus petraea* shows a typical shape and thus can be modelled easily with a theoretical semivariogram of the spherical type (Fig. 4.2.5.2-1). Most characteristic is the low sill (15.6) in relation to the high nugget value (39.3). Spatial autocorrelation is thus low compared with the random component of spatial variability.

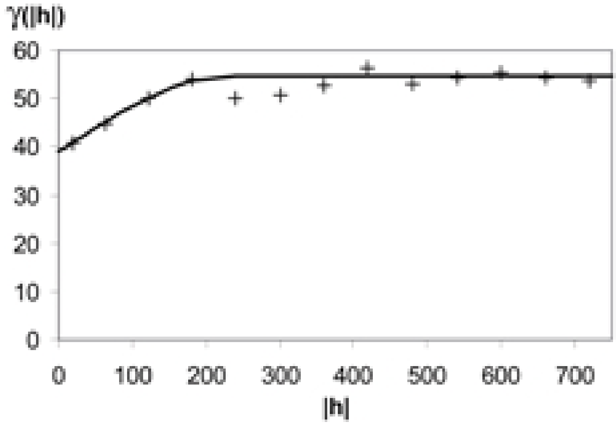


Figure 4.2.5.2-1: Empirical variogram (dots) and modelled spherical variogram (line) for the residuals of the mean defoliation model of *Quercus robur et petraea*, including age, country and their interaction as explanatory variables; |h| = distance in km; nugget: 39.3, sill: 15.6, range: 230 km.

The mapping of PAD of the two *Quercus* species (Fig. 4.2.5.2-2) shows a rich structured pattern, which reminds partly on those of *Fagus sylvatica*. An in-depth explanation of the spatial pattern is not possible without further integrated evaluations and consultation through the National Focal Centres. So, e.g. the spatial pattern for Poland could be explained by industrial pollution and "disturbance in ground water level. In the upper part of Odra river watershed, hydrological constructions were founded to prevent flooding. Changes of ground water level for oak stands could influence the health condition of trees " (WAWRZONIAK 2001, personal communication).

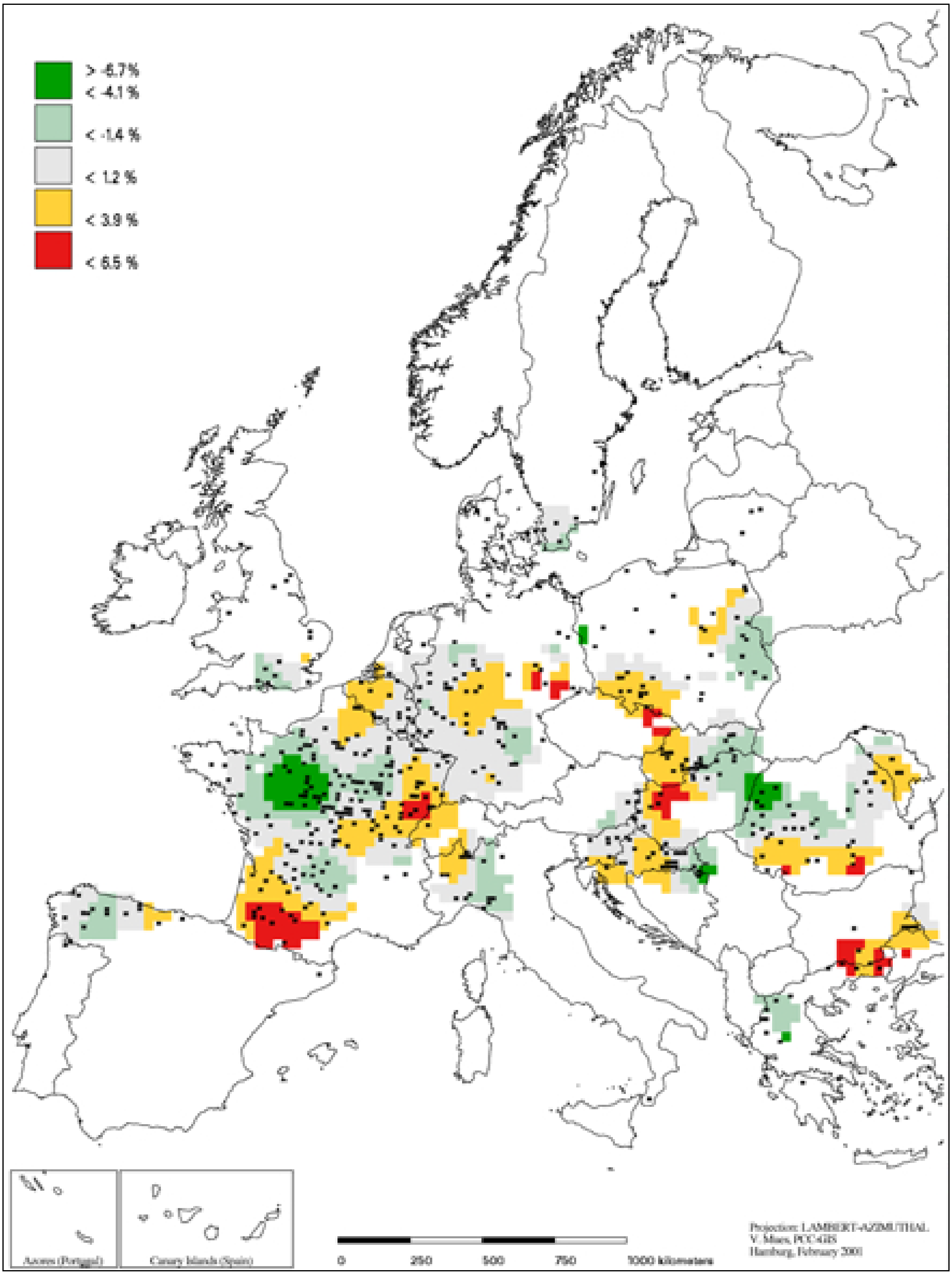


Figure 4.2.5.2-2: Map of deviations from the defoliation expected from country and age for *Quercus robur et petraea* (kriged PAD).

4.2.6 Quercus ilex

Quercus ilex has – similar to *Pinus pinaster* - its main distribution in the western parts of the Mediterranean zone. The overwhelming majority of the 156 plots is situated in Spain (Tab. 4.2.6.1-1, Fig. 4.2.6.2-2). The mean defoliation values differ only slightly between the countries. Therefore it is not surprising that country does not explain any substantial amount of the total variance (Tab. 4.1-1).

4.2.6.1 Generalised Linear Models

A positive age trend is found for France with an increase of approximately 3% per age class (Tab. 4.2.6.1-1). For Spain, where most of the plots are situated, a slightly negative age trend is calculated.
As has been shown, insects do not contribute much to the explanation of crown condition within this species (Tab. 4.1-1). Thus it is assumed that the variation of crown condition of holm oak is caused by effects other then country, age, insects or fungi. The modelled defoliation values for age = 90 are <30% for Spain and France and <20% for the other countries.

Table 4.2.6.1-1: Number of observations, mean, and model for medium-term mean defoliation [%] of *Quercus ilex* in Europe, listed according to country specific mean defoliation; values for countries with less than 50 plots shaded.

	medium-term mean defoliation		GLM		
	n	mean [%]	intercept [%]	age trend [%/a]	model value for age = 90 ; [%]
France	22	20.4	12.07	0.152	26
Italy	7	21.0	26.92	-0.097	18
Greece	1	16.9	17.37	-0.014	16
Spain	125	21.6	22.46	-0.014	21
Croatia	1	18.1	18.48	-0.014	17

4.2.6.2 Spatial Variation of Preliminarily Adjusted Defoliation (PAD)

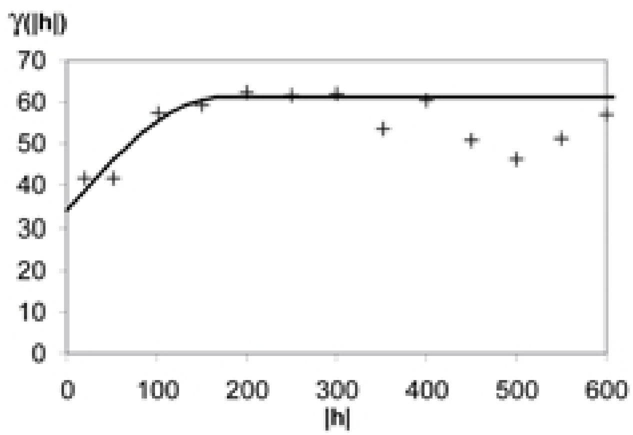


Figure 4.2.6.2-1: Empirical variogram (dots) and modelled spherical variogram (line) for the residuals of the mean defoliation model of *Quercus ilex*, including age, country and their interaction as explanatory variables; |h| = distance in km; nugget: 34.2, sill: 27.0, range: 170 km.

The empirical variogram for *Quercus ilex* was adapted with a theoretical one of spherical shape (Fig. 4.2.6.2-1). The values (nugget: 34.2, sill: 27.0, range: 170km) indicate that an remarkable part of the spatial variability of PAD must not be traced back to spatial autocorrelation but to random effects. However, the share of spatial autocorrelation is relatively high compared to the results of the other *Quercus* species or of *Picea abies*.

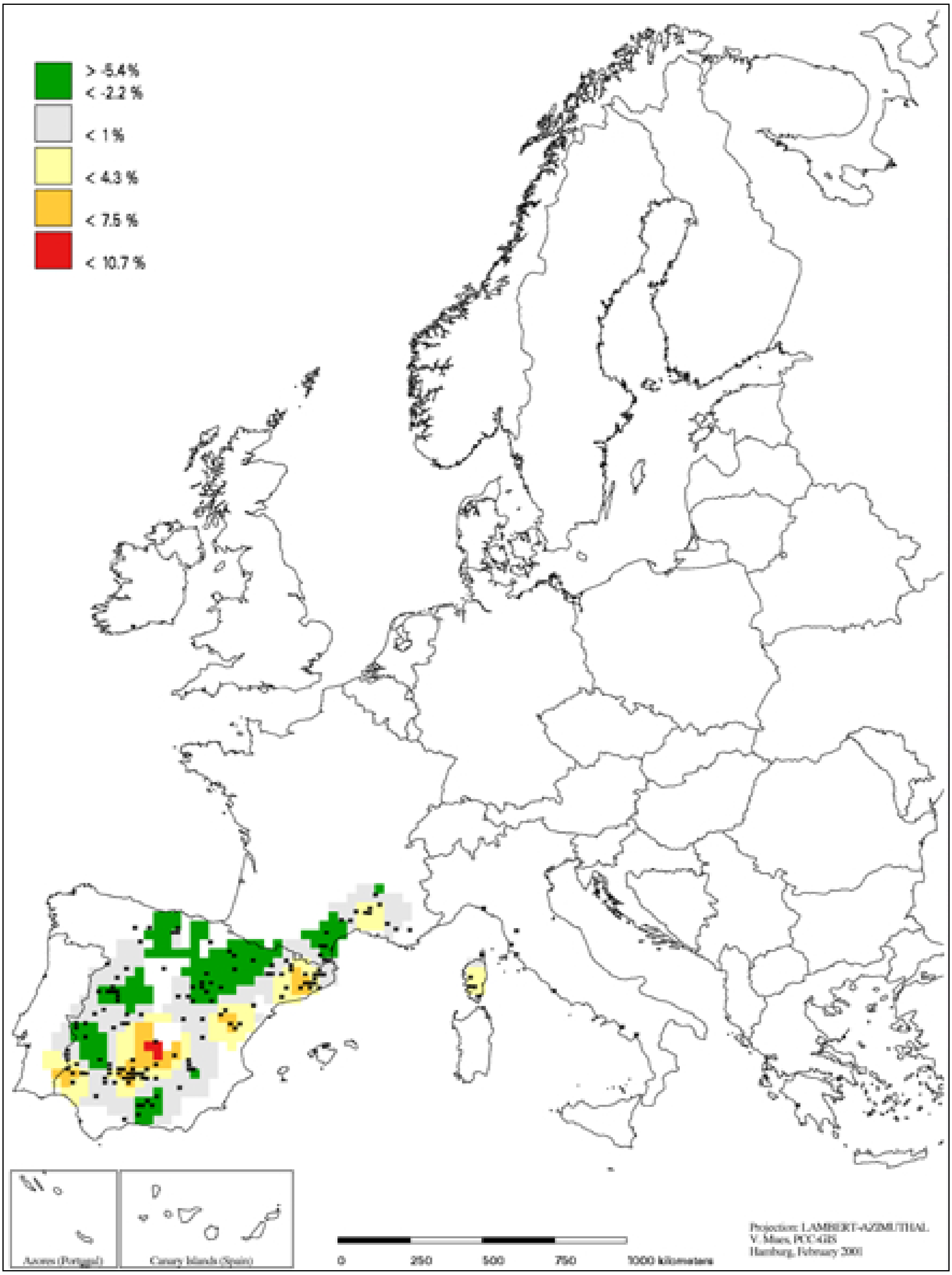


Figure 4.2.6.2-2: Map of deviations from the defoliation expected from country and age for *Quercus ilex* (kriged PAD).

The map of the kriged residuals (PAD) of the age-country-model for *Quercus ilex* shows sharp contrasts between several regions (Fig. 4.2.6.2-2). Especially for one region in Spain very high values were interpolated, caused by the high defoliation of a single plot.

5 NATIONAL SURVEY REPORTS IN 2000

In 2000, 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 32 countries. These tabulated results are presented in Annex II. In Annex II-1 basic information on the forest area and survey design of the participatory countries is given. The distribution of the trees over the defoliation classes for all species is given in Annex II-2. Annexes II-3 and II-4 contain the data for conifers and for broadleaved 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 broadleaved trees in Annex II-7. Graphical presentations of the results are given in Annex II-8. It has to be noted, however, that it is not possible to directly compare the national survey results of individual countries. The sample sizes and survey designs may differ substantially and therefore conflict with comparisons. Gaps in the Annexes, both tabulated and plotted, may indicate that data for certain years are missing. Gaps also may occur if large differences in the samples were given e.g. due to changes in the grid, or the participation of a new country.

5.1 Northern Europe

5.1.1 Estonia

The forest condition survey in 2000 was conducted on 91 permanent sample points.

A remarkable improvement has been observed in the crown condition of Scots pine *(Pinus sylvestris)* during the last 9 years and particularly since 1999. The share of undamaged pine trees was 22.3% in 1991 compared to 51.1% in 2000.

In contrast, a serious increase in defoliation was observed in Norway spruce (*Picea abies*). In the latest survey 28.4% of the spruce trees were classified as slightly, 9.5% as moderately and 0.6% as severely defoliated. With 1.8% the share of dead trees was highest since the beginning of the assessments 12 years ago. Bark beetle attacks following drought stress of a warm and dry summer are one of the reasons for the described worsening. The heavy wind damages that occurred in autumn 1999 might be another reason for the increased damage.

In total the health state of the broadleaved trees was markedly better than that of the conifers, however the share of damaged broadleaves was higher than in 1999.

Crown condition revealed considerable regional differences. The most severe defoliation in spruce stands occurred in the western and north-western part of Estonia. The most severe defoliation in pine stands occurred in the north-western part of Estonia. As in previous years some highly defoliated spruce plots are situated close to local sources of air pollution.

In addition to atmospheric pollution, biotic stress due to *Ascocalyx abietina* and *Lophodermium seditiosum* had serious influence on the crown condition, especially in the south-eastern part of Estonia.

5.1.2 Finland

The forest condition survey 2000 was conducted on 453 sample points arranged in 24 x 32 and 16 x 16 km grids. No marked changes were observed in the average defoliation level of any tree species between the years 1999 and 2000. In 2000 the average defoliation was 9% (9% in 1999) in Scots pine (*Pinus sylvestris*), 19% (18%) in Norway spruce (*Picea abies*), and 12% (11%) in broadleaves. Tree mortality was at the same level as in the previous years (0.2 %).

The proportion of discoloured Scots pine decreased from 2.5% in 1999 to 0.4% in 2000, and that of Norway spruce increased from 6% to 8%. The most frequent discolouration symptoms were needle tip yellowing and needle yellowing. Discolouration symptoms were mainly concentrated on needles older than two years. Discolouration was rare in broadleaves (0.4% of trees) in 2000.

Needle damage caused by sawflies, mainly pine sawfly (*Diprion pini*), was at a lower level than during the previous year. The decrease in the sawflies population density was attributable to natural factors, and it appears that the peak in the mass outbreak, which started in 1998, has now passed. There were no extensive fungal disease epidemics during 2000. However, due to the wet summer, some rust fungi were rather common in 2000, especially *Chrysomyxa ledi* on Norway spruce and *Melampsoridium betulinum* on birch (*Betula* spp.). The most common biotic agents on Scots pine were insects (*Diprionidae and Tomicus* spp.) and scleroderris pine canker (*Gremmeniella abietina*).

No correlation was found between the defoliation pattern of conifers or broadleaves and the modelled sulphur or nitrogen deposition (1993) at the national level in 2000.

5.1.3 Latvia

The forest condition survey 2000 in Latvia was conducted on 316 permanent monitoring points.

Scots pine *(Pinus sylvestris)* is the most common tree species in Latvia and on the monitoring plots. Highest defoliation for this species was observed in the early 1990s. The main causes were extreme weather conditions followed by pest attacks. From 1993 on, crown condition has improved. The mean defoliation in 2000 was 21.8% (22.9% in 1999). The improvement is explained by more favourable climatic conditions and by a decrease of forest pests and fungi.

For Norway spruce *(Picea abies)* a slight deterioration has been observed since 1996 reaching a mean value of 21.5% in 2000. Compared to previous years, the proportion of undamaged trees decreased (23.5% in 2000) and the share of damaged trees increased (53.6% in defoliation class 1; 21.3% in class 2). The damage by bark beetle (*Ips typographus)* and root rot *(Heterobasidion annosum)* has significantly affected the health of spruce stands.

The latest assessment also shows an increase in defoliation for birch (*Betula* spp.) since 1996 (mean value in 2000 was 22.0%). This is related to attacks by *Phyllobius argentatus* and other stress factors as well as to unfavourable weather conditions.

5.1.4 Lithuania

The 2000 crown condition survey in Lithuania was carried out on a systematic network of 287 permanent sample plots in a combined 16 x 16 and 8 x 8 km grid. The total number of sample trees was 6646.

In 2000 the mean defoliation of all species was 20.8%. The mean defoliation of broadleaves was higher (21.5%) than the mean defoliation of conifers (20.4%). There was only minor crown discolouration in 2000. No significant changes have been observed in the mean defoliation of the main tree species in Lithuania (Scots pine – *Pinus sylvestris*, Norway spruce – *Picea abies* and birch – *Betula* spp.) during the past four years, except for European ash (*Fraxinus excelsior*). The deterioration of crown condition of European ash has been observed since 1996. The average defoliation of this species in 2000 was 32.4%.

Visually identifiable damage symptoms were observed on 8.6% of all trees. The most frequent damage was caused by fungi and diseases (2.9% of all trees observed), insects (2.4%), and abiotic agents (2.1%).

Annual changes in crown condition were caused mainly by climatic conditions (drought) and biotic factors rather than by air pollution. A dry summer, late frosts and defoliating insects (especially mass outbreak of *Panolis flammea* in the southern part of Lithuania) caused local damage in 2000.

5.1.5 Norway

With respect to all investigated species, 35.8% of all sampled trees showed no symptoms of defoliation. The mortality rate for trees was 0.2% which is regarded as the normal mortality rate at the national level. Average crown density was 81.3% (80.7% in 1999) for Norway spruce (*Picea abies*), 83.7% (82.4% in 1999) for Scots pine (*Pinus sylvestris*) and 76.4% (74.0% in 1999) for birch (*Betula pendula*). There were 41.3% (40.2% in 1999) fully leaved conifers and 14.7% (14.4% in 1999) fully leaved birch trees. Of the spruce trees, 22.4% (19.0% in 1999) were discoloured. Only minor changes were detected for pine and birch since last year. The average crown densities for Norway spruce, Scots pine and birch have had an increasing trend since 1997.

Identified damage symptoms occurred on 34% of Norway spruce, on 59% of Scots pine and on 64% of the assessed birch trees. Damage from insects and fungi was mainly limited to birch with symptoms shown by 33% and 19% of the trees, respectively. The outbreak of *Oporinia autumnata* has continued in higher elevation birch forests in southern Norway.

In general, the observed crown condition results from an interaction between adverse climate, pests, pathogens and general stress; interaction with air pollution may be a predisposing factor in some areas.

The results of this year's assessment confirm the positive change in forest vitality recorded over the last few years. This improvement in crown condition may be attributed to favourable weather conditions for growth with relatively cool and wet summers in large parts of Norway in the same period.

5.1.6 Sweden

Small changes in defoliation of the main tree species Norway spruce (*Picea abies*) and Scots pine (*Pinus silvestris*) have been observed during the past five years. An increased defoliation of Norway spruce in Northern Sweden indicates an ending of the improvement noticed during recent years. In Southern Sweden, however, a general improvement is noticed with small fluctuations during recent years. In Scots pine no clear trends are noticed.

The share of dead trees, 0.4%, has doubled compared to previous years. The increased amount of dead trees results from an increased number of wind fallen trees after the stormy weather in late 1999. Of all dead trees 50% are windthrown.

The share of discoloured Norway spruce has decreased during the last three years. Discolouration on Scots pine is still rare although is has increased to 3% of all pine trees.

Known damage symptoms were observed on 22% of the conifers. Insects and fungi attacks, not including root rot, were identified in 2% of the damages. Most common on pine is pine blister rust and on spruce bark beetle (*Ips typographus*), although it has decreased, and rust fungi as *Chrysomyxa ledii*. Regional outbreak of *Melampsoridium betulinum* on birch (*Betula sp*.) was observed in the middle of Sweden.

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

5.2 Central Europe

5.2.1 Austria

The 2000 crown condition survey showed a remarkable deterioration of crown condition of Norway spruce *(Picea abies)*. The proportion of tree classified as "damaged" i.e. defoliation classes 2-4 increased by 2.8 percent points, the proportion of class 0 decreased by 5.3 percent points. On the other hand crown condition of silver fir *(Abies alba)*, the coniferous species with the highest defoliation, recuperated. The proportion of the classes 2-4 decreased by 3.2 percent points and the proportion of class 0 increased by 5.2 percent points. Crown condition of Scots pine (*Pinus sylvestris)* and European larch *(Larix decidua)* as well as crown condition of the main deciduous species beech *(Fagus sylvatica)* and oak *(Quercus* spp.*)* did not show considerable changes.

For the total of all sample trees crown condition deteriorated. This is due to the high proportion of Norway spruce (*Picea abies)* which accounts for 67% of all sample trees. The deterioration is considered to be caused by some periods of drought during spring and summer, the storms during last winter and by local hail-events and regional infections with needle fungus in 1999.

The assessment of easily identifiable damage revealed at about 13% of the sample trees damage caused by direct action of man, about 5% of the sample trees showed damage caused by game and about 28% of the sample trees showed damage caused by abiotic factors like snow and storm. About 25% of the sample trees were affected by multiple damage types. Discolouration was only found on about 1.5% of the sample trees.

5.2.2 Croatia

Monitoring results in the Republic of Croatia for the year 2000 have not shown major differences in the percentages of trees within defoliation classes 2-4 (all species), compared to 1999. For broadleaves the share of trees in classes 2-4 decreased by 1.9 percent points to 18.3%. For conifers, the percentage of trees in classes 2-4 shows an equally slight decrease by 1.3 percent points, to 53.3%. Although the percentage of moderately to severely damaged conifers is high, it does not have a stronger impact on the overall percentage of trees for the same damage class, due to their low representation of 14.5% in the sample (289 conifers vs. 1702 broadleaves).

Silver fir (*Abies alba*) is among the most damaged species. The lowest value, 36.6% of moderately to severely damaged trees was recorded in 1988, whereas in 1993 the share was already 70.8%, remaining relatively stable until the year 2000 when it reached a maximum with 77.1%. Similarly, among broadleaves, the state of health of European oak (*Quercus robur*) is of major interest, not only because of its ecological importance, but also because it is used in large quantities by the industry. The minimum damage was recorded in 1988 (8.1%), the maximum in 1994 (42.5%), while it has been fairly constant in the past few years at around 25-30% (24.9% in 2000). The health status of common beech (*Fagus sylvatica*) has not significantly changed in the past ten years. It remains the healthiest species with only 5.7% trees in the classes 2-4. Overall, despite a relatively high degree of damage, forest condition in Croatia has remained stable in the course of the last few years.

5.2.3 Czech Republic

The proportion of trees in defoliation class 2 has increased from 62.6% in 1999 to 64.1% in 2000. Compared to last year's results a moderate worsening of the crown condition has especially been observed for most conifers in stands of 60 years and older. For the broadleaves the most significant increase in defoliation was found for oak (*Quercus)* species.

The weather was very warm and dry in the first half of the spring season. This distinct irregularity was undoubtedly one of the decisive factors influencing the partial increase in defoliation. The warm and dry weather in the early vegetation period also caused an early first swarming of bark beetles. The second half of the year was comparatively cool and was characterised by high precipitation. The second swarming was therefore not so serious. The greatest occurrence of cambiophagous insects was observed in the National Park Šumava.

The forest stands (broadleaves, pine) in the Polabí lowland were mechanically damaged by hailstorm and destructive wind at the end of the summer season which caused an increase in defoliation in this area. A massive attack of the spruce stands by fungus *Ascocalyx abietina* was observed in the higher mountainous altitudes (Orlické hory, Hrubý Jeseník). Blight of white pine (*Pinus strobus)* caused by *Meloderma desmazieressii* is still the reason of the calamity in the Labské Sandstones.

In 2000 the decrease of the total emission of sulphur oxides and solid particulates has continued just as in the previous years. The emission of other pollutants (NO_x, C_xH_y) has remained approximately at the same level since 1995. The exposure index for ozone AOT40 in forests exceeded the critical value of 10 ppm/h on the greater part (98.6 %) of the Czech Republic territory; nevertheless, this value was in total distinctly lower than in

1998 when the weather was warm and sunny and thus relatively favourable for ozone formation.

5.2.4 Germany

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

After a peak in 1992 mean defoliation of all species had in 1995 again reached the level of the mid-eighties. During the last three years there has again been a slight but statistically nonsignificant increase in mean defoliation values. The percentages of all species in defoliation classes 2-4 were 21% in 1998, 22% in 1999 and 23% in 2000.

For Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) the shares of trees in classes 2-4 were 25% and 13% in 2000. The figures have hardly changed since 1995 and remain clearly below the levels calculated at the beginning of the survey in 1984. The situation is different as regards beech (*Fagus sylvatica*) and oak (*Quercus petrea, Quercus robur*). In the 17-year monitoring period the share of beech trees showing severe damage increased to 29% in 1998 and further on to 40% in 2000. Thus, beech is presently the most damaged tree species in the assessments. Between 1984 and 1997 the share of severely damaged oak trees increased more or less continuously but decreased since then to 35 % in 2000. The survey results still do not allow for an interpretation as to whether the negative development of oak crown condition has now come to an end and whether a reverse trend has started.

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

The deposition levels in Germany are among the highest in Europe. Based on results of the intensive monitoring plots, long-term, nitrogen-related changes, including changes in the composition of the ground vegetation are expected to take place in large forest areas in the future.

5.2.5 Poland

The forest condition survey 2000 was carried out on 1180 permanent observation plots, consisting each of 20 marked dominant trees and arranged in a 16 x 16 km grid.

Forest condition was almost at the same level as in the previous year. 10.4% of all sample trees were without any symptoms of defoliation, indicating a decrease only by 0.6 percent points as compared to 1999. The proportion of damaged trees (defoliation classes 2-4) increased by 1.4 percent points to an actual level of 32.1% of all trees. The share of trees defoliated more than 25% increased by 1.6 percent points for conifers and by 0.8 percent points for broadleaves. The slight worsening is considered as a response to the lower precipitation during the vegetation period of the year 2000.

For 32.1% of the conifers a defoliation of more than 25% (classes 2-4) was observed. Silver fir *(Abies alba)* remained the species with the highest defoliation (55.8% trees in classes 2-4).

For broadleaves the proportion of trees with more than 25% defoliation (classes 2-4) amounted to 32.0%. As in the previous survey, the highest defoliation amongst broadleaved trees was observed in oak stands *(Quercus* spp*.)*. In 2000, a share of 46.8% of all oak trees was in damage classes 2-4.

In 2000, discolouration (classes 1-4) was observed on 1.0% of the conifers and 2.5% of the broadleaves.

5.2.6 Slovak Republic

The 2000 national crown condition survey was carried out on 111 Level I plots on the 16 x 16 km grid net. Of the assessed trees, 23.5% were damaged (defoliation classes 2-4). The respective figures were 37.9% for conifers and 13.9% for broadleaves. Compared to 1999, the share of trees defoliated more than 25% decreased by 4.2 percent points.

From 1987 till now, crown condition surveys have shown lowest damage in common beech (*Fagus sylvatica*) and hornbeam (*Carpinus betulus*), whereas the most severe damaged was observed in silver fir (*Abies alba*), Norway spruce (*Picea abies*), and locust tree (*Robinia pseudoacacia*). Compared to the 1999 survey, a pronounced improvement in average defoliation was observed in oak (*Quercus* spp.), pine (*Pinus* spp.), maple (*Acer* spp.) and common larch (*Larix decidua*). Changes in mean defoliation in other species were not significant.

A pronounced improvement of crown condition has been observed since 1996 and has led to the best crown condition since the beginning of the monitoring in 1987.

16.2% of all sample trees had some kind of damage symptoms. The most frequent damage was caused by logging activities (5.5%) and fungi (5.2%) as a consequence of tree stem damage. The next more important cause of damage were abiotic agents (1.9%) and insects (1.9%). Abiotic agents, game and damage by epiphytes had an important influence on defoliation. 62% of trees with epiphytes had a defoliation higher than 25%.

5.2.7 Slovenia

In the 2000 national forest survey a total of 984 trees on 41 sample plots were assessed. The sampling and the assessment methods were the same as in 1999.

The average defoliation of all trees in the sample (all species) was 22.0% in 2000 (24.4% in 1999) while the proportion of trees with more than 25% unexplained defoliation attained 24.8% (29.1% in 1999). For the first time since 1996 both values have slightly decreased. However, the shift was statistically not significant.

The health status of all main tree species has generally improved. The average defoliation and the share of the damaged (defoliated more than 25%) Norway spruce trees (*Picea abies*) decreased by 1.0 percent points and 2.8 percent points, respectively. Mean defoliation of beech (*Fagus sylvatica*) decreased by 1.7 percent points and so has the share of damaged trees which was lower by 3.4 percent points compared to the previous year.

The improvement can partly be explained by the well distributed rainfalls during the vegetation period in 1999. For the first time since 1994 precipitation in the vegetation period has reached the 30 year's average. Known damage types were identified on 19.7 % of all trees. About 18% of all trees were affected by insects or diseases which explains about 1.8% of the overall defoliation.

5.2.8 Switzerland

As in the previous two years, in 2000 the Swiss Forest Health Inventory was carried out on the 16 x 16 km grid. For the first time since 1995 a substantial increase in assessed crown defoliation was observed. This increase (10.4 percent points in the share of trees with above 25% defoliation and 4.6 percent points in mean defoliation) was the largest observed until now resulting in the highest share of trees with above 25% defoliation ever observed. The increases were mostly due to an increase in defoliation of the conifers, mainly Norway spruce (*Picea abies*) and silver fir (*Abies alba*). Defoliation of European beech (*Fagus sylvatica*) only showed a slight increase. Possible causes for this increase include the effect of the severe winter storm in December 1999, drought in spring 2000 and observer variation.

The winter storm of 26 December, 1999 can only partially explain the observed increase in defoliation. Wind damage as a cause of defoliation was recorded on 5.7% of all trees, a share more than twice as high as in the previous two years on the same grid. However, plots in the most affected area showed only a slightly higher increase in defoliation than plots outside that area. On plots with visible storm damage the increase was lower as wind damage was subtracted from the total defoliation, while plots in the affected area, but without visible damage had the highest increase in defoliation. This indicates that defoliation due to wind was not always recognised and that the proportion of trees with wind induced defoliation is actually higher than the reported 5.7%.

Water availability was reduced on most of the plots during the months of May and June and increased sharply with the rain period in July. However, at present it can not be verified whether the lack of available soil water also led to an increased shedding of leaves and needles.

5.3 Southern Europe

5.3.1 Albania

The 2000 forest condition survey in Albania was carried out on 291 permanent monitoring plots, comprising 8730 sample trees.

10.1% of all assessed trees were in defoliation classes 2-4. 12.3% of the conifers were moderately or severely damaged. The respective share of broadleaved trees was remarkably lower with 8.5%.

The occurrence of biotic stress factors was estimated by so-called damage incidence values. Severe damage, indicated by a damage incidence of 35% was caused by *Thaumetopea pityocampa* in Austrian black pine (*Pinus nigra*). Chestnut (*Castanea sativa*) was strongly damaged by *Cryptonectria parasitica* (25 % damage incidence). Common cypress (*Cupressus sempervirens*) was strongly damaged by *Seridium cardinale* (52 % damage incidence). In addition, a variety of further insect and fungi species were recorded with lower damage incidence values. As abiotic agents winter and spring frosts, drought, as well as snow and windbreak were reported.

Complex diseases caused by a multitude of interacting stress factors occurred in oak (*Quercus* spp.), silver fir (*Abies alba*), common beech (*Fagus sylvatica*) and pine *(Pinus* spp.).

Air pollution is assumed to impair crown condition of forest trees in general.

5.3.2 Greece

During the year 2000 crown assessments were carried out on 77 plots of high forests. When all species are taken together, 81.8% of the total sample trees were not or slightly, 14.9% were moderately and 1.8% were severely defoliated. 1.5% were dead.

A comparison of the 2000 survey results with those of the previous year shows a slight deterioration in the condition of both coniferous and broadleaved species. In all species, an increase by 2.4 percent points in the slightly and by 1.1 percent points in the moderately defoliated trees was observed. In the conifers a remarkable decrease by 6.6 percent points in the not defoliated class was observed.

Oak trees (*Quercus* spp.) showed signs of a recuperation. The number of oak trees in the not and slightly defoliated classes increased by 2.8 percent points and 0.9 percent points with a decrease by 2.8 percent points in the moderately defoliated class. From the total number of trees inspected about 24.9% showed signs of insect attack and 13.7%, 1.7%, and 17.3%, showed signs of adverse effects by abiotic, human or “other agents”, respectively. No damage was attributed to any of the known pollutants.

The year 2000 was very dry, resulting in the desiccation of a large number of bushy and forest tree species, especially in the south of the country. Extensive areas of forests (even productive forests at higher elevations) were destroyed by fire.

5.3.3 Italy

The 2000 crown condition assessment was carried out on 7128 sample trees on 255 Level I plots on the 16 x 16 km transnational grid. Considering all species, 34.4% of the trees were in defoliation classes 2-4. The respective value in 1999 was 35.3%, indicating only slight changes since the previous year. In general, conifers showed less defoliation than broadleaves.

With regard to age classes and tree species, 31.5% of Scots pine (*Pinus sylvestris*) younger than 60 years were in defoliation classes 2-4, whereas in this age class Norway spruce (*Picea abies*) showed a good health status with only 3.3% in the same defoliation classes.

For conifers older than 60 years, Arolla pine (*Pinus cembra*) and European larch (*Larix decidua*) showed worst crown condition with 32.2% and 30.1% in defoliation classes 2-4 respectively. For broadleaves in the age class <60 years, 60.2% of the assessed pubescent oak (*Quercus pubescens*) and 53.7% of chestnut (*Castanea sativa*) were in defoliation classes 2-4. In age class ≥60 years, 100% of the assessed sessile oak (*Quercus petraea*) were in classes 2-4, whereas the respective shares for beech and chestnut were 40.0% and 57%, respectively.

Analysing the presence of biotic and abiotic factors as possible causes for defoliation and discolouration, 65.8% of the sample trees revealed one or more damage types. The respective values were 31.6% for conifers and 79.7% for broadleaves. Insects, fungi and climatic stress were the most frequently observed damaging factors.

5.3.4 Portugal

In 2000 a number of 4290 trees was assessed on 143 forest plots.

The assessment results since 1990 show that forest condition has improved. The improvement is mainly due to a considerable decrease in the share of damaged trees from 30.8% in 1990 to 5.7% in 1994. The bad crown condition of several tree species in the years 1990 and 1991 has to be interpreted in connection with attacks by fungi and insects as well as by forest fires, triggered by a sequence of dry years (1989-1991). The obvious recuperation after that time stopped in 1995 mainly due to a new drought period in connection with forest fires. The improvement of crown condition observed in 1996 can be interpreted as an effect of more favourable weather conditions. The share of damaged trees in 2000 was 10.3%. This recent slight worsening observed from 1997 to 2000, can be interpreted as an effect of not so favourable weather conditions and is mainly caused by an increase in the share of damaged broadleaves (mainly holm oak - *Quercus ilex*, cork oak - *Quercus suber* and Eucalyptus – mainly *Eucalyptus globulus*).

5.3.5 Spain

86.1% of all sample trees were classified as not or slightly defoliated in the assessments of 2000 (defoliation classes 0 or 1). 10.7% of the trees were grouped into classes 2 and 3 (defoliation higher than 25%). For conifers a slight worsening was observed compared to 1999. It is expressed in a decrease in the share of trees in class 0 and in an increase in classes 1 and 2. Broadleaved tree species on the other hand showed a slight improvement after some years of deterioration (e.g. *Quercus pyrenaica*).

From the regional results the improvement of the *Quercus* forests in the Extremadura region is worth mentioning, mainly attributed to good water supply in the vegetation period. In the Baleares crown condition on the assessed plots mainly deteriorated due to dry weather conditions in combination with different biotic stress factors. The decline of *Quercus ilex* and *Quercus suber* that had mainly taken place between 1993 and 1996 in the Mediterranean was still relevant in 2000. Effects of the winter storm in 1999 were most pronounced in the Basque country. Of particular concern was the dying of conifers in the Sierra Morena.

Among the easily identifiable damage types abiotic agents (mainly hydric shortage) were identified at 35 % of the observations. Insects, fungi, and parasitic plants were recognised at 32% of the trees. Defoliating insects such as *Thaumetopoea pytiocampa,* sucking insects in pine forests, as well as *Gonipterus scutellatus* in *Eucalyptus* spp forests as well as *Lymantria dispar* and *Altica quercetorum* in broadleaved tree species were of particular importance in 2000. Locally a strong presence of parasitic phanerogams (*Viscum album and Arceuthobium oxycedri*) and a constant presence of bark beetles and other wood – boring insects were recognized. Damage caused by *Coroebus florentinus* in *Quercus* spp. and the presence of *Micosphaera alphitoides* in wet areas are constant (decaying process "seca").

The influence of atmospheric pollution for the observed state of the forests can not be quantified directly as it is disguised by more apparent processes. However, predisposing effects are assumed.

5.3.6 Yugoslavia

The 2000 crown condition assessment covered 2 837 sample trees on 120 plots of the 16 x 16 km transnational grid. The assessment included 348 conifers and 2 489 deciduous trees.

For the total tree sample, 72.3% of the trees belonged to class 0 (not defoliated), 19.3% to class 1 (slightly defoliated), 8.4% to classes 2-3 (moderately to severely defoliated) and 2% to class 4 (dead trees).

Compared to last year's situation, there was an increase in the share of damaged trees in all coniferous species, except for Austrian pine (*Pinus nigra*). Among the deciduous trees, an increase was registered in oak (*Quercus cerris*, *Quercus petraea*), while in beech (*Fagus sylvatica*) an increased share of undamaged trees was recorded, but also an increase in completely defoliated trees.

The analysis of weather conditions in spring and summer 2000 indicates a possible danger of a further increase in defoliation, especially after months of drought and high summer temperatures at the end of the growing season in late August. This will adversely affect the physiological activity of plants and their viability.

5.4 Western Europe

5.4.1 Belgium

Wallonia

In 2000, 12.4% of the assessed broadleaved tree species and 12.3% of the conifers were classified as damaged. The average defoliation since 1993 seems stable for European and Sessile oak (*Quercus robur* and *Quercus petraea)* and has decreased for Norway spruce (*Picea abies)*. For beech (*Fagus sylvatica)* it has increased continuously since 1996. Among the four main tree species the two oak species show the worst condition.

No significant change was observed in discolouration: old beech trees were the most discoloured ones (16.7% of the trees moderately or severely discoloured). 14.4% of the conifers were moderately or severely discoloured.

Identifiable damage types were observed at only 7.9% of the trees. Nevertheless, insects, sometimes fungi and abiotic agents could partly explain the high defoliation, as they are linked with higher defoliation rates. For example, mean defoliation was 11% in 2000, but for trees with insect damage it was 20.8%.

A special problem occurred for beech in the Ardennes, with high damage of scolytidae (mainly *Trypodendron signatum* and *T. domesticum*) and fungi (mainly *Fomes fomentarius*). This calamity can be attributed to late frost and snow in April 1999, associated with wind, resulting in bark necrosis. Insect damage due to diverse caterpillar species was in addition observed at oak, birch (*Betula pendula)* and cherry (*Prunus avium*).

Compared to 1999, water supply was good in 2000, with rainfall lower than the average only in June and August, and particularly high in August; this could partly explain the slightly improved condition of European oak.

Condition of oak and beech remains a major concern in Wallonia. In general there are no single identifiable causes for their poor condition. Nevertheless, poor soils, especially with respect to Mg, Ca and sometimes P, partly explain the problem. Nitrogen deposition is regarded as a cause of the aggravation.

Flanders

The 2000 forest condition survey in the Flemish Region was carried out in 72 plots in a 4 x 4 km grid. Compared to 1999 the results indicated a deterioration for beech (*Fagus sylvatica*), red oak (*Quercus rubra*) and the main coniferous species. In European oak (*Quercus robur*) a slight improvement was observed. For all species, the share of damaged trees (defoliation classes 2-4) increased from 21.9% to 25.2%. The proportion of trees showing discolouration increased from 6.0% to 9.8%.

The crown condition of conifers deteriorated compared to 1999. In contrast to previous years, defoliation was higher than in broadleaves. The share of moderately to severely damaged Scots pine (*Pinus sylvestris*) increased to 24.5%, in Corsican black pine (*Pinus nigra subsp. laricio*) an increase to 40.8% occurred. This deterioration was partly due to biotic factors: in the north-eastern part of Flanders, both in Scots pine and in Corsican black pine stands, important needle loss caused by the red-black pine bug *(Haematoloma dorsatum*) was observed. Severe damage by this insect had already been observed in the first half of the nineties. Especially in Corsican black pine, infection by the fungus *Sphaeropsis sapinea* caused shoot and crown dieback.

The share of broadleaves with more than 25% leaf loss increased slightly to 23.9%. The crown condition of European oak improved slightly but the change in defoliation was not significant. Compared to previous year, defoliation of poplar (*Populus* spp.) remained at the same high level (43% damaged). The share of damaged beech and red oak increased to 15.7% and 15.2% respectively. In beech the increase in defoliation was partly due to intense fructification. In a few beech and European oak plots mortality of trees was observed. Consecutive years of drought stress and insect attack by winter moth (*Erannis defoliaria* and *Operophtera brumata*) were among the factors involved in the decline of oak. Also two spotted oak borer (*Agrilus biguttatus*) were found in declining oaks.

5.4.2 Denmark

In December 3-4, 1999 a storm stroke the forests in the south western part of Denmark and caused important damages. Apart from regional severe damages of the storm the Danish survey of forest condition in 2000 showed a satisfying condition for most tree species. The crown condition survey and the general evaluation of forest condition carried out by the 25 State Forest Districts, only showed small changes for most tree species compared to 1999. However, oak improved remarkably in 2000.

The results of the crown condition survey in 2000 showed that 63% of all coniferous trees and 42% of all deciduous trees were undamaged. 28% of all coniferous and 44% of all deciduous trees were in the warning stage. 9% of all coniferous trees and 14% of all deciduous trees were damaged.

There was no significant change in the health condition of Norway spruce (*Picea abies*) from 1999 to 2000. The mean defoliation improved from 13 % to 12%. Even though the Norway spruce stands were subject to major wind throws in December 1999, all the 25 State Forest Districts evaluated the health condition as satisfying. There were only few reports of attacks by *Ips typographus*.

The health condition of beech (*Fagus sylvatica*) did not change significantly compared to 1999. The mean defoliation was the same as in 1999 (16%) which is the lowest ever recorded since the survey started. The share of damaged trees decreased slightly from 16% to 14% in 2000.

The condition of oak in Denmark is highly influenced by attacks of *Operophtera brumata*, *Tortrix viridana* and *Microsphaera alphitoides*. The level of defoliation has been high compared to the other tree species during all years since the crown condition survey started. Mean defoliation was particularly high in 1996 and 1997 (34% in both years). In 1998 and 1999 the defoliation decreased to 28% and 29 %. In 2000, mean defoliation remarkably decreased to 22%.

The damages on the forest ecosystems of the areas affected by the storm are presumed to cause the forest condition in the next years.

5.4.3 France

Two severe winter storms (Lothar and Martin) in December 1999 were the most important events affecting a large part of the national forest inventory grid. The damage was substantial: 23 plots were totally destroyed, 41 plots which is 7.5% of the total were damaged more than 50%, and 29% of the plots lost at least one tree. Thus, 387 plots (71% of all plots) were damaged. In the 2000 survey, 1158 sample trees, i.e. 10.6% of the assessed trees of the previous year, were replaced, 1051 of them due to storm damage. 29 plots (5.3%) in the affected area will be excluded from assessment until the trees will have the minimum height for assessment as laid down in the regulations.

Nevertheless, 10317 sample trees on 516 plots (95% of the total of 1999) were assessed. For most broadleaved and coniferous species a decrease in defoliation has been observed for the last two years. Broadleaves still show a distinctly higher defoliation than conifers. For all species, discolouration was stable or decreased. With 0.1% the morality rate remains at a low level.

As in 1999 climatic events were rarely recorded in 2000. The number of defoliating insects was also very low. In the Mediterranean region, an increase in damage due to branch cancer (*Crumenulopsis sororia*) was observed at Aleppo pine (*Pinus halepensis*).

5.4.4 Ireland

The annual assessment of crown condition was conducted on the Level I plots in Ireland between July and August 2000. Overall mean defoliation and discolouration was 14.4% and 4.7% respectively. This represents a deterioration in crown condition of Irish forests between the 1999 and 2000 survey of 2.1 percent points for defoliation but an improvement of 0.1 percent points for discolouration. Both defoliation and discolouration levels remained below the 11-year average of 15.4% and 8.7% respectively. In terms of species, defoliation decreased in the order of Norway spruce (*Picea abies*) (27.4%) > lodgepole pine (*Pinus contorta*) (14.2%) > Sitka spruce (*Picea sitchensis*) (10.6%), while the trend in discolouration was in the order of lodgepole pine (6.8%) > Sitka spruce (3.6%) > Norway spruce (3.3%). The number of trees with absolutely no damage (i.e. 0% defoliation and 0% discolouration) decreased in 2000 by over 6 percent points, to 14% of trees in the survey. An additional 44% of trees had such low levels of defoliation and discolouration that the causes of damage were indiscernible, a value similar to the 1999 survey. Of the remaining trees where causes of damage could be identified, approximately 13% of trees had greater than 25% defoliation and less than 2% of trees had greater than 25% discolouration.

Exposure continued to be the greatest single cause of damage to the sample trees in 2000. The instances of observed aphid damage were similar to 1999 with less than 3% of trees affected in 2000. (Over 14% of trees were affected by aphids in the 1998 survey.) Other damage types e.g. shoot die-back, top-dying, nutritional problems, and sawfly damage occurred in only a small percentage of trees. The issue of "top dying" in Norway spruce is discussed in the national report. No instances of damage directly attributable to atmospheric deposition were recorded in the 2000 Irish survey.

5.4.5 The Netherlands

The annual survey of the national gridnet of 187 sample plots was stopped in 1998; some parameters (e.g. vegetation and soil) will be further monitored, but only on a 5 year interval basis. Since 1999 crown condition is assessed only at the 11 plots of the systematic gridnet and on the 14 intensive monitoring plots.

From the limited number of level I plots it seems that the crown condition has deteriorated, despite the fact that the weather conditions during the growing season were relatively favorable and that important insect attacks and diseases did not occur.

5.4.6 United Kingdom

Following a mild winter, rainfall was well distributed throughout the growing season and tree growth was generally good. Unseasonal high winds in June resulted in damage to both Norway spruce *(Picea abies)* and Sitka spruce *(Picea sitchensis)* in the north of the UK, although their overall impact on the condition of these species was minimal. Considering all species together there was little change in crown condition with respect to 1999, but the gradual trend of deterioration since 1995 continued.

A marked deterioration of common beech *(Fagus sylvatica)* was largely attributable, as in previous cases of decline in 1990 and 1995, to heavy mast production. Levels of damage from insects (particularly *Rhynchaenus fagi)* and fungi on beech were similar to those recorded in 1999. Changes in the condition of both Norway spruce and Sitka spruce were minor, the latter having yet to recover fully from severe defoliation by the green spruce aphid *(Elatobium abietinum)* in 1997. A slight improvement in Scots pine *(Pinus sylvestris)* reflected the low incidence of attacks by both the pine shoot beetle *(Tomicus piniperda)* and the defoliating fungus *Lophodermium seditiosum* in 2000. The condition of European oak *(Quercus robur)* also improved, with damage by insects such as *Operophtera brunnata* and *Erranis defoliaria* being frequent but less severe than in recent years.

5.5 South-eastern Europe

5.5.1 Bulgaria

In 2000, the forest condition survey was carried out on 120 plots. A total of 4418 sample trees was assessed, 2565 of them conifers and 1853 broadleaves.

For all species, after the improvement observed in 1999, the share of slightly to severely damaged trees (defoliation classes 1-4) increased. The share of trees without visible defoliation decreased from 24.9% in 1999 to 20.3% in 2000.

The condition of all assessed conifers was nearly the same as in the previous year. However, a different development was recognised between the tree species. For trees older than 60 years the shares in class 0 decreased significantly by 18.2 percent points for Scots pine (*Pinus sylvestris*) and by 51 percent points for Austrian pine (*Pinus nigra*). Also for silver fir (*Abies alba*) a deterioration in crown condition was registered: the share of trees without defoliation decreased in both age groups. More than 90% of Norway spruce (*Picea abies*) trees belong to defoliation classes 0-1.

The condition of the broadleaves was worse compared to the 1999 results. The share of trees without any defoliation symptoms decreased by 11.6 percent points while an increase in the slightly and moderately defoliated trees was observed. Beech (*Fagus sylvatica*) trees were in a better condition than oak (*Quercus* spp.) trees. The share of moderately defoliated oak trees increased significantly by 20.5 percent points and 35 percent points in the two age groups respectively.

Forest condition is influenced by a number of natural and anthropogenic stress factors. Their importance depends on the region, tree species and site characteristics. Regionally the attacks by *Leucaspis loewi, Microsphaera alphitoides, Rhynchaenus fagi, Discula quercina* and *Lithocolletis quercifoliella* played an important role.

In 2000 large areas were affected by forest fires. However, no damage was observed in the monitoring plots.

5.5.2 Hungary

Defoliation as well as discolouration of all tree species increased slightly in 2000 changing the fairly stable situation of defoliation observed since 1993 and the decreasing tendency of the number of discoloured trees since 1994. While European oak (*Quercus robur*) improved, a deterioration of the crown of black locust (*Robinia pseudoaccacia*), hornbeam (*Carpinus betulus*), poplar (*Populus* spp.) and conifers – especially Austrian pine (*Pinus nigra*) – was observed. Black locust was the only tree species with continuous (3 years) worsening of crown condition. The proportion of defoliated trees (defoliation > 10%) increased by 25 percent points within this period. It was the second time since the start of observations in 1988, that a strikingly high increase (48% in 2000) of defoliated Austrian pines was observed.

Weather conditions were less favourable than in 1999. Highest ever floods in the eastern region – following a water stress of a smaller extent in the previous year – caused serious damage especially in young stands. Lack of precipitation in late spring and summer accompanied by high temperature occurred throughout the country. High defoliation of Austrian pine – frequently planted on poor, shallow soils – is likely to be related to the lack of soil moisture. Drought stress is well reflected by the increased discolouration. Hornbeam and black locust were the most affected species, but even the number of discoloured beech trees (*Fagus sylvatica*) (the "healthiest" species) tripled in 2000.

Biotic damage on leaves due to leaf defoliators or fungi was less frequent in this year, except leaf miners of black locust (*Parectopa robiniella* and *Phillonoricter robiniella*), which are present in the whole country and attack not only the lower, but also the upper part of the crown. Despite the new hunting law – enacted in 1996 – game damages are still important factors limiting the success of reforestation and afforestation.

5.5.3 Romania

The national survey on the 4 x 4 km grid revealed a percentage of 14.3% for all tree species in the defoliation classes 2-4 (9.8% conifers, 15.8% broadleaves). The species with lowest defoliation were spruce (*Picea abies*; 8.7%), beech *(Fagus sylvatica;* 12.2%) and silver fir (*Abies alba*; 13.1%). Black locust (*Robinia pseudoaccacia*; 29.9%) and Hungarian oak *(Quercus pubescens;* 40.3%) showed the highest defoliation.

Compared to 1999 all these species revealed an increasing percentage of trees in classes 2-4. This deterioration of crown condition from 12.7% in 1999 to 14.3% of trees in clases 2-4 in 2000 is explained as a result of excessive drought in summer and autumn of 1999 and in spring of 2000.

Evaluations stratified according to altitude revealed that the increase of defoliation was consistent for all altitude classes up to 1000m.

5.6 Eastern Europe

5.6.1 Belarus

In 2000, 1437 plots were observed on a 4 × 4 km, 8 × 8 km and 16 × 16 km grid. In total 34388 trees were assessed.

Of all trees observed, the shares in defoliation classes 0 and 1 were 73.1% for conifers and 82.5% for broadleaves. Regarding the individual species, 12.8% of Scots pine (*Pinus sylvestris*), 6.6% of spruce (*Picea abies*), 7.5% of oak (*Quercus* spp.), 38.6% of ash (*Fraxinus* spp.), 25.7% of birch (*Betula* spp.), 27.2% of black alder (*Alnus glutinosa*), 18.5% of aspen (*Populus tremula*) and 43.9% of grey alder (*Alnus incana*) trees were not defoliated.

The mean defoliation of all species was 22.6%, in comparison to 22.4% in 1999. Of all trees observed in 2000, 98.7% showed no discolouration.

3.5% of all trees had some kind of identifiable damage symptoms. The most frequent damage types were fungi (0.7%), insects (0.7%) and abiotic factors (2.1%).

5.6.2 Republic of Moldova

In 2000 forest condition monitoring was carried out in Moldova on a 2 x 2 km grid. 70.9% of all trees were classified as not or slightly damaged. Defoliation strongly varied in the different forest vegetation zones: In the steppe zone mean defoliation was 54.5%, in the forest steppe zone it amounted to 14.0% and in the forest zone it was assessed with 26.8%.

The most damaged species were black locust (*Robinia pseudoacacia),* poplar (*Populus* spp.), and oak (*Quercus* spp.) with a mean defoliation of 45.1%, 38.7% and 33.1% respectively. Significant defoliation differences were registered in black locust plantations growing at different altitudes. Whereas the overall defoliation was 29.1%, plantations located on altitudes up to 250 m above sea level showed a mean defoliation of 29.8%. Plantations located on altitudes above 250 m, had only 27.1% defoliation. As for the identified damage types, insects (mostly *Tortrix viridana* L., *Stereonychus fraxini* Ded.) were the most frequent ones, occurring at 17.5% of the assessed trees.

The observed increase in damage in Moldavian forests is explained by (i) a considerable part of oak stands of vegetative origin and in high generations, (ii) global climate change effects and processes (especially in southern Moldova), (iii) large areas covered by mature black locust stands on unsuitable site types and by (iv) a general deterioration of the ecological situation.

5.6.3 Ukraine

In 2000, 1853 sample trees were assessed on 76 forest monitoring plots in 5 administrative regions of Ukraine (about 20% of the total area of the country). These monitoring plots are located in the eastern and southern parts of Ukraine, where natural conditions are very unfavourable for forest growth and where the atmospheric pollution level is the highest in the country.

Mean defoliation was 26.4% for conifers and 34.8% for broadleaved trees. For the 1694 common sample trees (CSTs, see Chapter 3.3) only minor changes were observed compared to 1999. Mean defoliation of all species in 2000 (34.6%) was nearly the same as in 1999 (34.0%). Changes are characterised by decreasing shares in defoliation classes 0, 1, 3 and by an increase in class 2. Obvious deterioration of crown condition was registered for CSTs of European oak (*Quercus robur*) and common ash (*Fraxinus excelsior*). For European oak statistically significant changes were observed in class 2 (decrease by 11.2 percent points) and in class 3 (increase by 8.9 percent points). At the same time, an improvement was observed among the CSTs of Scots pine (*Pinus sylvestris*) and Crimea pine (*Pinus pallasiana*). Changes in defoliation class 1 (increase by 9.9 percent points) and in defoliation class 2 (decrease by 8.7 percent points) were statistically significant for Scots pine. Some minor improvement was observed for common beech (*Fagus sylvatica*) and sessile oak (*Quercus petraea*).

Spring frost, continuous summer drought and high temperatures are considered as main factors causing the unfavourable forest condition in eastern and southern Ukraine in 2000.

5.7 Northern America

5.7.1 Canada

In 1996, the national Acid Rain Early Warning System (ARNEWS) ceased to exist. Instead, the Canadian Forest Service forest health plot network will be integrated with the new National Forest Inventory (NFI) program. Forest health monitoring and research, at the national scale, now involves a three-tiered approach that links Long-term Ecological Research and Monitoring (Level III), Case Studies (Level II) and National/Regional Assessments (Level I). More detail on Canada's new NFI can be found at the following website: http://www.pfc.cfs.nrcan.gc.ca/landscape/inventory/index.html.

The first national Forest Health Assessment was released in late 1999. The highlights are:

- The forests of three ecozones, Boreal Cordillera, Taiga Plains and Taiga Shield, are considered healthy.
- Two ecozones, Mixedwood Plains and Atlantic Maritime, have much of their forest ecosystems under stress largely from land-use practices, including forest management and air pollution.
- The remaining forested ecozones have major forest ecosystems under varying degrees of stress. Some are relatively pristine while others are under considerable stress.
- Air pollution, particularly acid rain and ground-level ozone, impacts certain forest ecosystems that are close to large, urban centers or along major pathways of pollution from distant industrial sources. These ecosystems occur largely within the ecozones of southeastern Canada.
- Forest management practices, such as harvesting and fire suppression, are changing the basic ecological structure of some forest ecosystems. Long-term changes to historical plant succession and tree species composition are occurring.
- Exotic (non-native) insects and diseases pose an increasing threat to the health of native species.
- Historically, Canada's forests are viewed to have been sizeable sinks for atmospheric carbon dioxide.
- Modelled results suggest that the current boreal forest may be a net contributor of carbon to the atmosphere. Apparent increases in the past 30 years in area burned by wildfire or devastated by insects and diseases are possible causes for this change.

In 2000, exotic insects have been of primary interest. The discovery of brown spruce longhorn beetle (*Tetropium fuscum* Fabr.) in Halifax has led to an eradication program within and adjacent to the city of infected spruce and other conifers. The European gypsy moth (*Lymantria dispar L.*) which is established in eastern Canada, has been introduced to British Columbia in western Canada numerous times since 1975 with the movement of people and vehicles. Ongoing monitoring programs have identified these introductions and subsequent eradication programs have prevented permanent establishment of the insect. The most recent establishments on southern Vancouver Island (1999) and the city of Burnaby (2000) were treated with aerial applications of BtK. The Asian Long-horned beetle (*Anoplophora glabripennis* Motchulsky) has been intercepted at several entry points in Canada. As yet, no evidence exists that it has established in Canadian forests.

6 DISCUSSION

6.1 Development of crown condition

The large-scale surveys of crown condition have revealed increasing defoliation over many years. Of 24 345 trees observed continuously since 1988, the share of damaged trees increased from 13.8% in 1988 to 22.7% in 2000. However, the development of defoliation over time shows a high variation according to species and regions. In recent years, the overall increase in defoliation has slowed down and in some species and regions a recuperation has been observed.

Of the six most abundant species, *Picea abies* and *Quercus robur et Quercus petraea* had high defoliation from the beginning of the surveys on. The continuously high defoliation of *Picea abies* partly reflects the poor condition of this species in the main damage areas of central and eastern Europe for which it is known that the detrimental development started well before the first survey (Ardö et al. 1997). For this region, the Czech Republic, Poland and Germany have been stressing the role of air pollution for many years in their industrialized regions. Because of the high levels of air pollution and the results of forest damage research (e.g. Schulze 1989, Gobold and Hüttermann 1994, Freer-Smith 1998) the high defoliation has been largely attributed to depositions. Also in this area, the survey results for *Pinus sylvestris* indicate an increase in defoliation until 1994 which is then followed by a clear recuperation. This recuperation has been attributed to favourable weather conditions as well as to an improvement of air quality. Scientific evidence for this, however, is still lacking.

Quercus robur et Quercus petraea after years of increasing defoliation was the most damaged species in Europe in the second half of the 1990s. This decline was attributed to a complex of several stressors, including largely insects (e.g. FISCHER 1999) and weather extremes (e.g. Landmann et al. 1993, Mather et al. 1995). A predisposing effect of air pollutants such as continuing nitrogen depositions was presumed. After a first decrease in defoliation in the Atlantic (south) region (UN/ECE, EC 1999), the results of the survey in 2001 reveal a pronounced recuperation of *Quercus robur et Quercus petraea* also in the Sub-atlantic region. Crown condition of *Fagus sylvatica* has been deteriorating in several parts of Europe. It is assumed that the ability of Fagus sylvatica to respond to environmental stress has been reduced (Eichhorn 1995). The severest deterioration of crown condition was found for *Quercus ilex* and *Pinus pinaster*. The defoliation of these two species rose from a low level in 1988 to a level comparable to that of *Pinus sylvestris* and *Quercus robur et Quercus petraea* in 2000.

The primary factors influencing the large-scale spatial and temporal variation of crown condition in Europe are insects, fungi and weather extremes. Most obvious is the importance insect and fungi infestations reported by the participating countries especially in Northern, Western and Southern Europe. A wide variety of different insects or fungi are observed within all three climatic regions, however only the needle affecting fungus *Crysomyxa ledii* (Finland and Sweden) and the leaf-eating *Operophtera brumata* (Belgium and Denmark) are mentioned twice. In central as well as in south-eastern and eastern Europe biotic cases for defoliation seem to play a minor role.

High temperature and climatic drought are reported by half of the countries as reasons for leaf or needle loss. Only in western Europe with its higher precipitation rates climatic drought plays a minor role for tree crown conditions. However, three of the six countries in western Europe have experienced crown damage due to storms. Fire is a specific problem in Mediterranean countries and less pronounced in states in south-eastern Europe.

Low nutrition and other disfavours of sites was designated by only four countries as a cause for leaf and needle loss. Different findings suggest disorder and imbalances of nutrients due to long-term inputs of acidifying air pollutants (e.g. ULRICH et al. 1979). In this respect the findings may partly reflect anthropogneous changes of site conditions. The result of DE VRIES et al. (2000a), who found an increasing concentration of Al in the soil solution along with increasing concentrations of SO_4 and NO_3 also indicates a dependency of soil qualities from atmospheric inputs. However, natural differentiation of sites according to their nutrient levels is also mirrored be crown condition (ELLENBERG 1996).

Air pollution is at least made partly responsible for poor crown condition by six countries. Three countries in less polluted regions of Europe assume that it has no influence. Future integrated studies may provide more precise information on the role of air pollutants within forest ecosystems.

6.2 Integrated Evaluations

6.2.1 Generalized Linear Models (GLM)

Generalised Linear Models (GLM, SAS 1990) offer the possibility of a combined analysis of class (like country) and numerical variables (like age). Therefore GLMs are used to explain the spatial variance of species-specific medium-term mean defoliation and medium-term mean discoloration at the European level. Both target variables are field estimates and are therefore generally prone to comparatively high sampling errors (e.g. INNES 1988, DOBBERTIN et al. 1997), which should however be random. In the present study, for the sake of robustness, linearity of the underlying processes has been assumed, which seemed at the moment to be sufficient and lead to remarkable results, but will be refined in further approaches, especially for those species, which reveal non-linear regressions between defoliation and stand age (see Fig. 4.1-1). The use of medium-term averages (1994 to 2000) of crown condition parameters should not only level off fluctuations due to annual meteorological extremes, but also short-term insect gradations, strong fruiting or other short-term influences. They should respond preferably to medium-term and long-term stresses from adverse soil related processes like acidification, nutrient imbalances, or continuous direct impacts of air pollutants. The criteria for a plot to be taken into consideration were largely in accordance with former Technical Reports (e.g. UN/ECE, EC 2000), however, all plots with on average more than two specimen of a particular tree species were included and plots with negative lower limits of the confidence interval were not excluded.

The results of this study confirm earlier findings (INNES et al. 1993, KLAP et al. 1997, 2000, SEIDLING 2001) that the crown condition data are not directly comparable between countries. Apart from *Quercus ilex*, which shows no country effect, the variance of the medium-term mean defoliation is explained with 23% (*Fagus sylvatica*) to 47% (*Pinus sylvestris*) by country. KLAP et al. (2000) could explain up to 40 % of the variance of the response variable by 'country' in an European wide approach and according to SEIDLING (2001) up to 37% of the defoliation can be explained by country dummies within limited pilot areas. For integrated transboundary evaluations the consideration of this class variable is therefore indispensable.

Discoloration reveals, like defoliation, a considerable influence of country. For *Fagus sylvatica* and the *Quercus species* the effect of country onto discoloration is even more pronounced than onto defoliation. SEIDLING (2001) also found a considerable amount of the variation of discoloration explained by country specific peculiarities. Since up to now discoloration has seldom been introduced into empirical statistical studies, much less comparisons with results from other studies are possible and the potential value of this crown condition parameter is rather unknown. The results above, contribute at least for some of the main tree species to a better general understanding of crown related processes.

Since there are no simple statistical means to differentiate between methodological and 'real' differences of the crown condition between countries, parts of the variance might thus be explained by different natural or anthropogenic stress factors. Up to now, no sufficient data sets are available that allow for a quantification of the methodological part of the differences. For a more objective consideration of country-specific differences, independent correction factors should be worked out, according to proposals made by INNES et al. (1993) or FERRETTI (1998). Independently gained correction factors, should improve the comparability of defoliation and discoloration values throughout the sampling areas in Europe. Combined statistical and geostatistical approaches (KLAP, in prep.) promise further improvements, especially in the context of retrospective evaluations of crown condition data in Europe, since regression analyses have shown that trends of defoliation have been affected by country bias (KLAP et al. 1997, SEIDLING 2001).

As many studies show (e.g. SEIDLING 2000) stand age is one of the most important predictors of defoliation. Independently from those empirical studies, it could be shown by needle-trace method (e.g. POUTTU and DOBBERTIN 2000) that older trees show lower needle retention than younger ones. Models with age and country and their interaction reveal a considerable amount of explained variance with a maximum of almost 60% for *Picea abies* and *Pinus sylvestris*. Again, *Quercus ilex* is an exception as it shows only a weak correlation between age and crown condition. The general results confirm earlier findings from international (KLAP et al. 1997, 2000), national or even regional studies (e.g. INNES & BOSWELL 1988, HENDRIKS et al. 1994, RIEK & WOLFF 1999 and others, see SEIDLING 2000 for an overview). Further the homogeneity of slopes was tested by the additional inclusion of the interaction term country*age. Differences of the age-defoliation relationship among the countries were detected for all tree species, again except for *Quercus ilex*. The detected country-specific differences of the age-defoliation relationship may be caused by (i) high random influences in countries with small numbers of plots, (ii) a limited variation of age in some countries and (iii) a different treatment of tree age at the level of local or regional reference tree systems. In order to minimize methodological differences between countries with respect to their consideration of age, the relationship between crown condition and age should also be parameterised with respect to the participating countries at future intercalibration courses, what could make possible a more exact description of methodological differences in comparison with this simple approach.

A negative concomitant of the performed adjustment of differences between the defoliation (and discoloration) levels of the participating countries by statistical means, is the lacking possibility to distinguish between methodological differences and those caused by real factors. This severe handicap was already described by others (e.g. DE VRIES et al. 2000b), but could up to now not been solved satisfactorily. Due to this limitation, the resulting maps of preliminarily adjusted defoliation (PAD) should not be interpreted without consideration of the country-wise means predicted by the GLMs. Nevertheless, the PAD is an expression of the deviation from the country-wise mean defoliation level and can directly be interpreted in physical terms.

Additionally to country, age and their interaction term in further approaches two biotic variables were included into the GLMs. The factors insects and fungi can be interpreted as immediate or indirect predictors for crown condition even if both estimates for the actual leaf or needle loss due to insects and fungi have to be considered rather critically. Sources of inaccuracies are: missing estimates in some countries, different threshold levels to denote infestations, different time-lags between field survey and the activity of biotic agents. Nevertheless, due to plot-wise and temporal averaging a rough estimate might be gained, which reflects at least some of the mean activities of these biotic agents at many monitoring plots. Up to now, only SEIDLING (2001) found an influence of insects onto defoliation in Scots pine within Level I data, however, due to insufficient data availability or quality, biotic factors have rarely been analysed in this respect. In the course of the statistical analysis for both estimates also country-specific differences became obvious, most probably due to methodological differences.

6.2.2 Regionalized preliminarily adjusted defoliation (PAD)

Models which explain medium-term mean defoliation by country, age and their interaction term country*age were applied for all major tree species exept *Quercus ilex* in order to achieve a measure of defoliation adjusted for methodological and age-dependent differences. The residuals of the above GLMs fulfil this precondition and were termed 'preliminarily adjusted defoliation' (PAD, compare KLAP et al. 2000: Fig. 1a). As shown above, not only methodological influences but also true country specific differences are eliminated, inter-country comparisons have still to be interpreted cautiously.

The maps of PAD for the evaluated tree species show very clear 'hot spots' (red) of high defoliation. These spots and the green counterparts of regions with very low defoliation have to be interpreted as deviations from the country-specific mean value. Thus, e.g. the very high variance of PAD for *Picea abies* in Norway and less pronounced in Finland must not be interpreted as the highest and lowest defoliation within the total of Europe, but in the respective countries. If there were not such high variances in both countries, the intra-country variation of other countries became more visible on the map.

Several observations can be made for more than one tree species. Thus, in the centre of the German low-mountain region a hot spot is observed for all investigated tree species with exception of *Pinus pinaster* and *Quercus ilex*, which do not occur in this region. For *Quercus robur et petraea* as well as for *Fagus sylvatica* and – with reduced clarity – for *Picea abies* the data from Romania show high PAD values in the south and low values in the north. For *Quercus robur et petraea* and for *Pinus sylvestris* distinct hot spots are situated in Poland. For oak, according to WAWRZONIAK (2001, pers. comm.), this is supposed to be a reactions to groundwater level disturbances and for Scots pine to high levels of industrial immissions. A study by EWALD et al. (2000) confirms a concentration of high defoliation values of *Fagus sylvatica* in a region at the northern fringe of the Alps, referring to dry soils as main cause.

The coincidence of some hot spots in the PAD maps with high values for insect and fungi indices could in some cases be confirmed and is thus emphasising the usefulness of the preliminarily adjusted defoliation. Many countries corroborate the importance of biotic agents for crown condition (Tab. 5.1-1). Distinct hot spots have to be analysed and discussed with the experts from the National Focal Centres. This should in many cases confirm that hot spots are not only due to an unique observation, but may represent a region with elevated defoliation values. Through the consultation process, explanations might be found that could improve the statistical models by new explanatory variables.

The maps of the primarily adjusted defoliation for *Fagus sylvatica*, *Quercus robur et petraea* and *Quercus ilex* is generally patchy at a medium scale of c. 150 to 250 km, well corresponding to the comparatively high ranges of the respective geostatistical models (comp. Fig. 4.2.4.2-1, Fig. 4.2.5.2-1). A substantial interpretation of these patterns is up to now not possible, but might be related to different causes at the regional scale. It has to be emphasised that the ranges of the present geostatistical models do not describe the influence of any distinct factor for the observed realisation of defoliation. However, the semivariograms are still influenced by all those factors, which are not regarded by the present general linear model. In contrast of the broad-leaved tree species the PAD maps for *Picea abies* and *Pinus sylvestris*, show for large regions within the middle of Europe more equable spatial properties and more isolated hot spots in certain regions like in the middle of Norway in *Picea abies*. In both coniferous species a comparatively small range of the geostatistical models was found and especially in *Picea abies* the nugget effect is quit large. The high variogram values at spatial lags greater than 500 km (Fig. 4.2.1.2-1) can be explained by isolated outliers, random effects and greater differences of PAD over large-scale distances. The PAD map of *Pinus pinaster* embraces a comparatively scattered regions with distinct within patterns, however due to the patchy distribution of the tree species, large scale patterns cannot be consistently interpreted.

Variogramm analyses with defoliation data have been done only sporadically. INNES and BOSWELL (1989) got empirical variograms, which show strong deviations to the spherical model. Mostly pure nugget effects and overall trends were found. GOSH et al. (1997) performed a spatial analysis with yearly plot averages and trends on the European level. They found spatial autocorrelation over distances of c. 50 km and adjusted an exponential kriging function. Because they did not adjust for country-specific differences, the resulting map over all species shows distinct border effects, however some major hot spots like the Trøndelag region in Norway, Upper Silesia in Poland or a region in southern Romania are also identifiable. These regions can also be traced on some of the species-specific maps shown above, however, the species-specific approaches achieve a higher selectivity, needed for sound interpretations.

REFERENCES

EUROPEAN UNION

COUNCIL REGULATION (EEC) No. 3528/86 on the protection of forests in the Community against atmospheric pollution. Brussels: 1986. Official Journal of the European Communities, No. L362/2 of 21 Nov. 1986, 3p.

COUNCIL REGULATION (EEC) No. 1613/89 amending Regulation (EEC) No. 3528/86. Brussels: 1989. Official Journal of the European Communities, No. L165/8 of 15 June 1989, 2p.

COUNCIL REGULATION (EEC) No. 2157/92, amending Regulation (EEC) No. 3528/86. Brussels: 1992. Official Journal of the European Communities, No. L217/1 of 31 July 1992, 2p.

COUNCIL REGULATION (EEC) No. 307/97 amending Regulation (EEC) No. 3528/86. Brussels: 1997. Official Journal of the European Communities, No. L51 of 21 February 1997.

COMMISSION REGULATION (EEC) No. 1696/87 laying down certain detailed rules for the implementation of Council Regulation (EEC) No. 3528/86 (inventories, network, reports), Brussels: 1987. Official Journal of the European Communities, No. L161/1 of 22 June 1987, 22p.

COMMISSION REGULATION (EEC) No. 926/93 amending Regulation (EEC) No. 1696/87 (soil condition survey, inventories). Brussels: 1993. Official Journal of the European Communities No. L100/1 of 26 April 1993, 35p.

COMMISSION REGULATION (EC) No. 836/94 amending Regulation (EEC) No.1696/87 (Survey on the chemical content of needles and leaves). Brussels: 1994, No. L97/4 of 15 April 1994, 15p.

COMMISSION REGULATION (EC) No.1091/94 laying down certain detailed rules for the implementation of Council Regulation (EEC) No. 3528/86 (intensive monitoring). Brussels: 1994, Official Journal of the European Communities No. L125/1 of 18 May 1994, 44p.

COMMISSION REGULATION (EC) No.690/95 amending Regulation (EC) No.1091/94. Brussels: 1995, Official Journal of the European Communities No. L71/25 of 31 March 1995, 46p.

COMMISSION REGULATION (EC) No.1398/95 amending Regulation (EEC) No.1696/87 (inventories, network, reports). Brussels: 1995, Official Journal of the European Communities No. L139/4 of 22 June 1995, 2p.

EUROPEAN COMMISSION, Directorate-General for Agriculture: European Community Forest health report 1987-1988. Brussels: CEC 1989.

EUROPEAN COMMISSION, Directorate-General for Agriculture: European Community Forest health report 1989. Brussels: CEC 1990.

EUROPEAN COMMISSION, Directorate-General for Agriculture: European Community Forest health report 1991 Brussels: CEC 1991.

EUROPEAN COMMISSION, Directorate-General for Agriculture: Observation des dommages sur les essences forestières méditerranéennes. Brussels: CEC 1991, 97p. (also in English, Greece, Italian, Portuguese, Spanish).

EUROPEAN COMMISSION, Directorate-General for Agriculture, and Mediterranean Expert Working Group: Mediterranean Forest Trees, A guide for crown assessment. Brussels, Geneva: EC-UN/ECE 1994, 156p. (also in German, French, Greece, Italian, Portuguese, Spanish).

EUROPEAN COMMISSION, Directorate-General for Agriculture: Basic documents for the implementation of the intensive monitoring programme of forest ecosystems in Europe . Brussels: EC 1995, 97p.

EUROPEAN COMMISSION, Directorate-General for Agriculture: General information on the permanent observation plots in Europe (Level II). Brussels: EC 1996, 107 p (also in French and German).

EUROPEAN COMMISSION, Directorate-General Information, Communication, Culture and Audiovisual Protection of forests against atmospheric pollution 1987-1996. Brussels: EC 1996, 25p (Green Europe No. 2/1996).

Diagnosis and classification of new types of damage affecting forests, Brussels: CEC 1986, 20p. special EEC edition, Allgemeine Forst-Zeitschrift (Munich, Federal Republic of Germany), also in Danish, Dutch, French, German, Greek and Italian.

UNITED NATIONS

INTERNATIONAL CO-OPERATIVE PROGRAMME ON ASSESSMENT AND MONITORING OF AIR POLLUTION EFFECTS ON FORESTS

Manual on methodologies and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests, Hamburg/Geneva: Programme Co-ordinating Center, UN/ECE 1986, (revised 1989), 97p.

Manual on methodologies and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests, Hamburg/Geneva: Programme Co-ordinating Center, UN/ECE 1994, 177p.

Manual on methodologies and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests, Hamburg/Geneva: Programme Co-ordinating Center, UN/ECE 1998.

Ten Years ICP Forests 1985-1995. Hamburg/Geneva: Programme Co-ordinating Centres, UN/ECE 1995, 16p.

TASK FORCE ON MAPPING OF CRITICAL LEVELS/LOADS

Mapping critical loads for Europe. Bilthoven, UN/ECE 1991, 86p.

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE/UNITED NATIONS ENVIRONMENT PROGRAMME

Forest damage and air pollution. Report of the 1986 forest damage survey in Europe. Geneva: UN/ECE/UNEP 1987, 47p.

Forest damage and air pollution. Report of the 1987 forest damage survey in Europe. Geneva: UN/ECE/UNEP 1988, 55p.

Forest damage and air pollution. Report of the 1988 forest damage survey in Europe. Geneva: UN/ECE/UNEP 1989, 71p.

Forest damage and air pollution. Report of the 1989 forest damage survey in Europe. Geneva: UN/ECE/UNEP 1990, 125p.

Forest damage and air pollution. Report of the 1990 forest damage survey in Europe. Geneva: UN/ECE/UNEP 1991, 128p.

Interim report on cause-effect relationships in forest decline. Geneva: UN/ECE/UNEP 1991, 240p.

UNITED NATIONS / EUROPEAN COMMISSION

Forest Condition in Europe. Report on the 1991 Survey. Geneva, Brussels: UN/ECE, CEC 1992, 117p.

Forest Condition in Europe. Report on the 1992 Survey. Geneva, Brussels: UN/ECE, CEC 1993, 156p.

Forest Condition in Europe. Report on the 1993 Survey. Geneva, Brussels: UN/ECE, CEC 1994, 173p.

Forest Condition in Europe. Report on the 1994 Survey. Geneva, Brussels: UN/ECE, CEC 1995, 191p., ISSN 1020-3729

Forest Condition in Europe. Report on the 1995 Survey. Geneva, Brussels: UN/ECE, CEC 1996, 212p., ISSN 1020-3729

Forest Condition in Europe. Report on the 1996 Survey. Geneva, Brussels: UN/ECE, CEC 1997, 160p., ISSN 1020-3729

Forest Condition in Europe. Report on the 1997 Survey. Geneva, Brussels: UN/ECE, CEC 1998, 180p., ISSN 1020-3729

Forest Condition in Europe. Report on the 1998 Survey. Geneva, Brussels: UN/ECE, CEC 1999, 84p. + Annexes, ISSN 1020-3729

Forest Condition in Europe. Report on the 1999 Survey. Geneva, Brussels: UN/ECE, CEC 2000, 86p. + Annexes, ISSN 1020-3729

Forest Condition in Europe. Executive Report. Geneva, Brussels: UN/ECE, EC 2000, 33 p.+ Annexes, ISSN 1020-587X.

EC and UN/ECE. 1997a. VANMECHELEN, L., R. GROENEMANS & E. VAN RANST. Forest Soil Condition in Europe. Technical Report. Ministry of the Flemish Community, EC and UN/ECE, Brussels, Geneva. 257 p.

EC and UN/ECE. 1997b. STEFAN, K., A. FÜRST & R. HACKER, U. BARTELS (chapter 2.3). Forest Foliar Condition in Europe. Technical Report. EC, UN/ECE and Austrian Federal Forest Research Centre, Brussels, Geneva, Vienna. 184 p.

EC and UN/ECE. 1997c. MÜLLER-EDZARDS, J.W. ERISMAN & W. DE VRIES. 1997. 10 Years Forest Condition Monitoring in Europe: Studies on Temporal Development, Spatial Distribution and Impacts of Natural and Anthropogenic Stress Factors. Technical Background Report. EC and UN/ECE, Brussels, Geneva. 350 p.

EC and UN/ECE. 1997d. DE VRIES, W., G. J. REINDS, E. M. VEL AND H. D. DEELSTRA. Intensive Monitoring of Forest Ecosystems in Europe. Technical Report 1997. EC and UN/ECE, Brussels, Geneva. 94p.

EC and UN/ECE. 1998. DE VRIES, W., G.J. REINDS, H.D. DEELSTRA, J. M. KLAP, E. M. VEL. Intensive Monitoring of Forest Ecosystems in Europe, Technical Report 1998. EC and UN/ECE, Brussels, Geneva 1998, 193 p.

EC and UN/ECE. 1999. DE VRIES, W., G. J. REINDS, H.D. DEELSTRA, J. M. KLAP, E. M. VEL. Intensive Monitoring of Forest Ecosystems in Europe, Technical Report 1999. EC and UN/ECE, Brussels, Geneva 1999, 173 p.

EC and UN/ECE. 2000. DE VRIES, W.; G. J. REINDS; M. KERKVOORDE, C. M. A. HENDRIKS; E. E. J. M. LEETERS; C. P. GROS; J. C. H. VOOGD; E. M. VEL. Intensive Monitoring of Forest Ecosystems in Europe, Technical Report 2000. EC and UN/ECE, Brussels, Geneva 2000, 173 p.189 p.

MINISTERIAL CONFERENCE ON THE PROTECTION OF FORESTS IN EUROPE

Report on the follow-up of the Strasbourg Resolutions. Ministry of Agriculture and Forestry, Conference Secretariat June 1993, 200p., ISBN 951-47-7632-1

Ministerial conference on the protection of the forests in Europe, 16-17 June 1993 in Helsinki, ISBN 951-47-8561-4

Interim report on the follow-up of the Second Ministerial Conference, Ministry of Agriculture and Forestry, Helsinki, March 1995, 255p., ISBN 951-53-0189-0

FAO

FAO (Food and Agriculture Organization of the United Nations), 1990: Guidelines for soil profile description, 3rd ed., Management and Conservation Service. Land and Water Development Division, Rome, 70 p.

OTHERS

Ardö, J., Lambert, N., Henzlik, V., Rock, B. N., 1997: Satellite-based estimations of coniferous forest cover changes: Krusné Hory, Czech Republic 1972-1989. Ambio 26: 158-166.

Bartels U. 2000, ICP-Forests 4th Needle/Leaf Interlaboratory Test 1999/2000 – Results, S. 11, not published.

Chappelka, A.H., Freer-Smith, P.H., 1995: Predeposition of trees by air pollutants to low temperatures and moisture stress. Environmental Pollution 87: 105-117.

Cline, S.P., Burkman, W.G., 1989: The role of quality assurance in ecological programs. In: Bucher, J.B., Bucher-Wallin, I. (eds.): Air pollution and forest decline. Proc. 14th Int. Meeting f. Specialists in Air Pollution Effects on Forest Ecosystems, IUFRO P2-05, Interlaken, Oct. 2-8 1988, Birmensdorf, 361-365.

Cozzi, A., Ferretti, M., Lorenz, M., 2001: Quality assurance in crown condition assessment in Europe. Results of the questionnaire. Report prepared for the Task Force of ICP-Forests, 2 p., not published.

Cressie, N., 1991: Statistiscs for Spatial Data; Wiley, New York.

Cronan, C.S., Grigal, D.F., 1995: Use of calcium/aluminium ratios as indicators of stress in forest ecosystems. Journal of Environmental Quality 24: 209-226.

De Vries, W., Reinds, G.J., Kerkvoorde, M., Hendriks, C.M.A., Leeters, E.E.J.M., Gros, C.P., Voogd, J.C.H., Vel, E.M., 2000a: Intensive Monitoring of Forest Ecosystems in Europe, Technical Report 2000. EC and UN/ECE, Brussels, Geneva 2000, 173 p.189 p.

De Vries, W., Klap, J.M., Erisman, J.W., 2000b: Effects of environmental stress on forest crown condition in Europe: Part I: hypotheses and approach to the study. Water, Air, and Soil Pollution 119: 317-333.

Dobbertin, M., Landmann, G., Pierrat, J.C., Müller-Edzards, C., 1997: Quality of crown condition data. In: Müller-Edzards, C., de Vries, W., Erisman, J.W., (eds.): Ten years of monitoring forest condition in Europe. United Nations Economic Commission for Europe, European Commission, Brussels, Geneva, 7-22.

Durrant, D., Ferretti, M., Solberg, S., 1999: Quality assurance. Report prepared for Expert Panel on Crown Condition Assessment of ICP Forests, not published.

Eichhorn, J., 1995: Stickstoffsättigung und ihre Auswirkungen auf das Buchenwaldökosystem der Fallstudie Zierenberg. Habilitationsschrift. In: Berichte des Forschungszentrums Waldökosysteme, Reihe A, Bd. 124, 175 p.

Eichhorn, J., 1998: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Part II: Visual Assessment of crown condition and submanual on visual assessment of crown condition on intensive monitoring plots. Programme Coordinating Centre/Federal Research Centre for Forestry and Forestry Products (ed.), Hamburg.

Eichhorn, J., Ackerbauer, E., 1987: Nadelkoeffizient und Kronentraufe als Vitalitätsweiser zur Beurteilung des Gesundheitszustandes von Fichten (Picea abies KARST.). Forschungsber. Hess. Forstl. Versuchsanstalt 4.

Ellenberg, H., 1996: Botanical aspects of landscape ecology with outlooks on forest dieback. Progress in Botany 57: 1-16.

Ewald, J., Reuther, M., Nechwatal, J., Lang, K., 2000: Monitoring von Schäden in Waldökosystemen des bayerischen Alpenraumes. Bayerisches Staatsministerium für Landesentwicklung und Umweltfragen, Materialien 155, 235 p.

Ferretti, M., 1998: Potential and limitation of visual indices of tree condition. Chemosphere 36: 1031-1036.

Freer-Smith, P.H., 1998: Do pollutant-related forest declines threaten the sustainability of forests. Ambio 27: 123-131.

Fischer, R., 1999: Folgen von Insektenfraß für den Gesundheitszustand der Eichen. Allgemeine Forstzeitschrift 7/99, 355-356.

Ghosh, S., Landmann, G., Pierrat, J. C., Müller-Edzards, C., 1997: Spatio-temporal variation in defoliation. In: Müller-Edzards, C., de Vries, W., Erisman, J. W., (eds.): Ten years of monitoring forest condition in Europe. United Nations Economic Commission for Europe, European Commission, Brussels, Geneva, 35-50.

Godbold, D.L., Hüttermann, A., 1994 (eds): Effects of acid rain on forest processes. Wiley-Liss, New York, Chichester, Brisbane, Toronto Singapore.

Hendriks, C.M.A., de Vries, W., van den Burg, J., 1994: Effects of acid deposition on 150 forest stands in the Netherlands. DLO Winand Staring Centre for integrated Land, Soil and Water Research, Wageningen, Report 69.2, 55 p.

Innes, J.L., 1988: Forest health surveys: problems in assessing observer objectivity. Can. J. For. Res. 18: 560-565.

Innes, J.L., Boswell, R.C., 1988: Forest health surveys 1987. Part 2: analysis and interpretation. Forestry Commission Bulletin (HMSO, London) 79, 52 p.

Innes, J.L., Boswell, R.C., 1989: Monitoring of forest condition in the United Kingdom 1988. Forestry Commission Bulletin (HMSO, London) 88, 73 p.

Innes, J.L., Landmann, G., Mettendorf, B., 1993: Consistency of Observations of Forest Tree Defoliation in Three European Countries. Environmental Monitoring and Assessment 25: 29-40.

Klap, J., Voshaar, J.O., de Vries, W., Erisman, J.W., 1997: Relationships between crown condition and stress factors. In: Müller-Edzards, C., de Vries, W., Erisman, J.W., (eds.): Ten years of monitoring forest condition in Europe. United Nations Economic Commission for Europe, European Commission, Brussels, Geneva, 277-302.

Klap, J. M., Voshaar, J. H. O., de Vries, W., Erisman, J.W., 2000: Effects of environmental stress on forest crown condition in Europe. Part IV: statistical analysis of relationships. Water, Air, and Soil Pollution 119: 387-420.

Köhl, M., 1991: Waldschadensinventuren: mögliche Ursachen der Variation der Nadel/Blattverlustschätzung zwischen Beobachtern und Folgerungen für Kontrollaufnahmen. Allg. Forst- Jagdztg. 162: 210-221.

Köhl, M., 1992: Quantifizierung der Beobachterfehler bei Nadel/Blattverlustschätzungen. Allg. Forst-Jagdztg. 163: 83-92.

Landmann, G., Becker, M., Delatour, C., Dreiyer, E., Dupouey, J.-L. 1993: Oak dieback in France: historical and recent records, possible causes, current investigations. In: Bayerische Akademie der Wissenschaften (ed.): Zustand und Gefährdung der Laubwälder. Rundgespräche der Kommission für Ökologie 5, 97-113.

Mather, R.A., Freer-Smith, P.H., Savill, P.S., 1995: Analysis of the changes in forest condition in Britain 1989 to 1992. Forestry Commission Bulletin No. 116. HMSO Publications Centre, London.

MÜLLER-EDZARDS, C., ERISMAN, J.W., DE VRIES, W., 1997: 10 Years Forest Condition Monitoring in Europe: Studies on Temporal Development, Spatial Distribution and Impacts of Natural and Anthropogenic Stress Factors. Technical Background Report. EC and UN/ECE, Brussels, Geneva. 350 p.

Pouttu, A., Dobbertin, M., 2000: Needle-retention and density patterns in Pinus sylvestris in the Rhone Valley of Switzerland: comparing results of the needle-trace method with visual defolation assessments. Can. J. For. Res. 30: 1973-1982.

Riek, W., Wolff, B., 1999: Integrierende Auswertung bundesweiter Waldzustandsdaten. Abschlußbericht. Institut für Forstökologie und Walderfassung Eberswalde. 137 p. + annex, not publ.

Ripley, B. D., 1981: Spatial Statistics. Wiley & Sons, New York.

Sanasilva, 1986: Kronenbilder, couronnes d'arbres, le chiome degli alberi. Eidgenössische Anstalt für das forstliche Versuchswesen, Birmensdorf, 98 p.

SAS Institute Inc., 1990: SAS/STAT User's Guide, Version 6, 4th Ed., SAS Institute Inc., Cary (USA), 1668 p.

Schadauer, K., 1991: Die Ermittlung von Genauigkeitsmaßen terrestrischer Kronenzustandsinventuren im Rahmen der Österreichischen "Waldzustandsinventur". Centralbl. f. d. ges. Forstwesen 108: 253-282.

Schall, P., 1999: Proposal for extrapolation of relationships identified for Level II plots with available data at Level I plots. Internal paper, unpubl.

Schulze, E.-D., 1989: Air pollution and forest decline in a spruce (Picea abies) forest. Science 244: 776-783.

Seidling, W., 2000: Multivariate statistics within integrated studies on tree crown condition in Europe - an overview. United Nations Economic Commission for Europe, European Commission, Geneva, Brussels, 56 p + annexes.

Seidling, W., 2001: Integrative studies on forest ecosystem conditions: Multivariate evaluations on tree crown condition for two area with distinct deposition gradients. United Nations Economic Commission for Europe, European Commission, Flemish Community, Geneva, Brussels, Gent, 88 p.

Solberg, S., 1999: Spruce crown condition and drought in Norway 1988-97. Paper 9 in: Forest health monitoring: Evaluation of methods, trends and causes based on a Norwegian nationwide set of monitoring plots. Dr. thesis, Agric. Univ. of Norway, 16 p.

Stefan, K., Fürst, A., Hacker, R., Bartels, U., 1997: Forest Foliar Condition in Europe. Technical Report. EC, UN/ECE and Austrian Federal Forest Research Centre, Brussels, Geneva, Vienna. 184 p.

Stefan K., Raitio H., Bartels U., Fürst A., 2000: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Part IV: Sampling and analysis of needles and leaves. Programme Coordinating Centre/Federal Research Centre for Forestry and Forestry Products (ed.), Hamburg, 37 p.

Ulrich, B., Mayer, R., Khanna, P.K., 1979: Deposition von Luftverunreinigungen und ihre Auswirkungen in Waldökosystemen des Solling. Sauerländer's Verlag, Frankfurt, 291 p.

VANMECHELEN, L., GROENEMANS, R., VAN RANST, E., 1997: Forest Soil Condition in Europe. Technical Report. Ministry of the Flemish Community, EC and UN/ECE, Brussels, Geneva. 257 p.

Walter, H. and H. Lieth. 1960-1967. Klimadiagramm-Weltatlas. 9000 Klimadiagramme, 33 Hauptkarten, 22 Nebenkarten. G. Fischer. Jena.

Walter, H., E. Harnickel, D. Müller-Dombois, D., 1975. Klimadiagramm-Karten der einzelnen Kontinente und die ökologische Klimagliederung der Erde. G. Fischer, Stuttgart, p. 36 + 9 maps.

Wolff, B. and W. Rieck. 1998. Chemischer Waldbodenzustand in Deutschland. AFZ/Der Wald, 10, 503.