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Institute for World Forestry

Forest Condition in Europe

2006 Technical Report of ICP Forests

by

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PREFACE

Forest condition in Europe has been monitored since 1986 by the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) in close cooperation with the European Commission (EC). ICP Forests is working under the Convention on Long-range Transboundary Air Pollution (CLRTAP) under the United Nations Economic Commission for Europe (UNECE). With 40 countries including Canada and the United States of America participating, the programme has over the last 20 years grown up into one of the largest biomonitoring networks of the world. ICP Forests aims to provide CLRTAP with scientific information on the effects of air pollution on forests. For this purpose, it assesses the large-scale spatial and temporal variation of forest condition on a European-wide grid (Level I) as well as 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. Also on the transnational grid, soil condition and foliage chemistry were assessed once. At Level II, besides crown condition, soil condition and foliage chemistry, also increment, ground vegetation, air quality, deposition, soil solution meteorology and the phenology of tree crowns are assessed. This required the development and international harmonization of methods and standards for the implementation of data management and data quality control as well as for scientific evaluations of the monitoring data and for continuous reporting of results. The results obtained by ICP Forests reveal the extent and development of forest damage and contribute to the enlightenment of the complex causes and effects involved. They constitute a part of the scientific basis of the legally binding protocols on air pollution abatement policies of the countries of UNECE under CLRTAP.

Besides fulfilling its obligations under CLRTAP, ICP Forests will use its well developed monitoring system to also contribute to other processes of international environmental policies in close cooperation with EC. This will comprise the provision of information on several indicators for sustainable forest management laid down by the Ministerial Conference on the Protection of Forests in Europe (MCPFE). It may also include the contribution of urgently needed information on species diversity and carbon sequestration as requested by the United Nations Framework Conventions on Climate Change and on Biological Diversity. The recent summer heat and drought events across large parts of Europe and the reactions of forests to them underline the need for monitoring and evaluation of the impact of climate change on forests.

The monitoring results of each year are summarized in annual Executive Reports. The methodological background and detailed results of the individual surveys are described in Technical Reports. The present Technical Report on Forest Condition in Europe refers to the results of the large-scale transnational survey of the year 2005 and presents results of individual studies of the intensive monitoring data made available by the year 2003.

SUMMARY

The year 2005 marked the twentieth year in which the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) assessed forest condition in Europe in close cooperation with the European Commission (EC). 32 of the 40 countries assessed crown condition of 349 397 sample trees on 21 156 sample plots on their individual national grids. Results on the European scale were derived from a subsample of 133 840 trees on 6 093 plots in 30 countries. These plots are part of the 16 x 16 km transnational grid covering 34 countries. The transnational survey of 2005 revealed a mean defoliation of 20.6%. Of the main species, *Quercus robur* and *Q. petraea* had by far the highest mean defoliation (26.9%), followed by *Fagus sylvatica* (20.3%), *Picea abies* (20.2%) and *Pinus sylvestris* (18.3%).

For the calculation of the long-term development of defoliation, a group of those countries were selected which had been submitting data every year since 1990 without interruption. Several of the main species in these countries show an increase in defoliation from 1990 to 2005. This applies in particular to *Pinus pinaster* (increase from 13.2% to 18.9% mean defoliation), *Fagus sylvatica* (17.9%-22.2%), *Quercus ilex* and *Quercus rotundifolia* (13.8%-23.8%) as well as *Quercus robur* and *Quercus petraea* (21.0%-25.5%). Defoliation of *Picea abies* undulated around 23% without a clear trend. Of the main species, *Pinus sylvestris* is the only one experiencing a decrease in defoliation (24.3%-22.6%). Its recovery particularly in Poland and in parts of the Baltic States since the mid 1990s renders *Pinus sylvestris* in a slightly better condition than in 1990. Due to the severe heat and drought in summer 2003, crown condition of all main species except *Pinus sylvestris* and *Quercus ilex* and *Q. rotundifolia* deteriorated rapidly from 2003 to 2004 in southern Finland, southernmost Sweden, central and southern Germany, some parts of France and total Bulgaria. From 2004 to 2005 a recuperation was visible for *Fagus sylvatica*, *Picea abies*, as well as for *Quercus robur* and *Quercus petraea*.

The development of defoliation was also calculated for a shorter time series (1997-2005) involving a large number of countries. The underlying tree sample covers a number of countries in which the drought of 2003 did not occur. Hence, the drought impact on defoliation and the recovery from it were less pronounced.

For sulphate, nitrate, ammonium, calcium, sodium and chlorine, the spatial and temporal variation of bulk and throughfall deposition was evaluated. The spatial variation was mapped for the mean deposition over the year 2001-2003. The temporal variation was calculated for the period 1998-2003. Depending on data availability, between 197 and 260 intensive monitoring plots were involved in the study. Spatial patterns of deposition can be recognised and reflect partly the regional emission situation. High sulphate deposition in coastal areas is correlated with high sodium deposition, indicating sea salt as an origin. Throughfall deposition is confirmed to be higher than bulk deposition. In the period of observation, throughfall deposition of sulphate decreased from 8.8 kg ha^{-1} a^{-1} to 5.6 kg ha^{-1} a^{-1}, while bulk deposition decreased from 6.2 kg ha^{-1} a^{-1} to 4.2 kg ha^{-1} a^{-1}. Also bulk deposition of nitrogen compounds decreased, but at a lower rate than sulphate. No clear trend is obvious in throughfall deposition of the nitrogen compounds.

Nitrogen deposition at Level II was related to species composition of ground vegetation. Nitrogen indicating plants occurred more frequently on plots with high nitrogen deposition. The biogeographic region in which the plots are situated and the acid-base status of the soils are additional and predominant natural factors that determine the species composition. A five year monitoring period was too short to detect significant changes in species composition.

1. INTRODUCTION

The present report describes the results of the 20th European-wide survey of crown condition which was assessed by ICP Forests and EC in the year 2005. Besides that, the report presents results of analyses of the intensive monitoring of ICP Forests and EC. The report is outlined in the following way:

The sampling, assessment, evaluation, and the results of the large-scale (Level I) crown condition survey are laid down in Chapter 2. This includes a brief overview of the first results of the new assessment of symptoms, causes and extent of damage types. Also described are the results of the crown condition assessment of the year 2005. Emphasis is laid upon the current status and the development of crown condition with respect to species and regions.

Latest results of the intensive (Level II) monitoring are presented in Chapter 3. First of all, bulk deposition, throughfall deposition and their trends are described for ammonium, nitrate and sulphate. Depositions of these substances as measured by ICP Forests are in a second step compared with the respective depositions modelled by the Co-operative Programme for Monitoring and Evaluation of the Long-range transmission of Air Pollutants in Europe (EMEP). Moreover, effects of nitrogen depositions and acidity on the ground vegetation on ICP Forests plots are shown. Finally, the results of a dynamic modelling approach are presented which attempts to estimate the development of forest soils under the impact of air pollution to be expected in future years.

Chapter 4 consists of national reports by the participating countries, focussing on crown condition in 2005 as well as its development and its causes.

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

2. LARGE-SCALE CROWN CONDITION SURVEYS

2.1 Methods of the surveys in 2005

2.1.1 Background

Transnational forest condition monitoring under ICP Forests is carried out following harmonized methods. These are laid down in the "Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests" (LORENZ et al., 2004). In the following sections, the selection of sample plots, the assessment of stand and site characteristics, the assessment of crown condition and the assessment of damage types are described. The sections also refer to the evaluation and presentation of the survey results.

2.1.2 Selection of sample plots

2.1.2.1 The transnational survey

The transnational survey aims to provide a periodic overview on the spatial and temporal variation in forest condition in relation to natural as well as anthropogenic stress factors (in particular air pollution) at the European-wide and national scale. This aim 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 2.1.2.2). 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 their homogeneity.

The transnational survey in 2005 was carried out on 6 093 plots in 30 countries. The number of plots was slightly lower as compared to 2004. This is partly due to a reduced number of plots in Portugal were the forest fires have affected a number of Level I plots in 2005. The number of plots in each participating country is presented in Table 2.1.2.1-1 for the last 13 years. In addition, 13 plots were assessed on the Canary Islands, but excluded from the transnational evaluation as they are not located in those geoclimatic regions to which all other plots were assigned (Annex I-1). They are, however, shown in the respective maps. The figures in Table 2.1.2.1-1 are not necessarily identical to those published in previous reports. Rearward changes in the data base are in principle possible due to consistency checks and subsequent data corrections as well as new data submitted by countries. In 2005, only very minor rearward changes were carried out.

The spatial distribution of the plots assessed in 2005 is shown in Figure 2.1.2.1-1. The plot sample is stratified according to geoclimatic regions adapted from those by WALTER et al. (1975), and WALTER and LIETH (1967). For an explanation of these regions see Annex I–1. Percentages of plots in the 10 different regions are given in Table 2.1.2.1-2.

Table 2.1.2.1-1: Number of sample plots from 1993 to 2005 according to the current database.

Country	Number of sample plots												
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Austria	76	76	76	130	130	130	130	130	130	133	131	136	136
Belgium	29	29	29	29	29	29	30	29	29	29	29	29	29
Cyprus									15	15	15	15	15
Czech Republic	178	205	199	196	196	116	139	139	139	140	140	140	138
Denmark	25	25	24	23	22	23	23	21	21	20	20	20	22
Estonia	86	90	90	91	91	91	91	90	89	92	93	92	92
Finland	405	382	455	455	460	459	457	453	454	457	453	594	609
France	506	534	543	540	540	537	544	516	519	518	515	511	509
Germany	412	417	417	420	421	421	433	444	446	447	447	451	451
Greece	96	96	95	95	94	93	93	93	92	91	-	-	87
Hungary	65	62	63	60	58	59	62	63	63	62	62	73	73
Ireland	22	21	21	21	21	21	20	20	20	20	19	19	18
Italy	212	209	207	207	181	177	239	255	265	258	247	255	238
Latvia	101	94	94	99	96	97	98	94	97	97	95	95	92
Lithuania	74	73	73	67	67	67	67	67	66	66	64	63	62
Luxembourg	4	4	4	4	4	4	4	4	-	4	4	4	4
The Netherlands	13	13	13	12	11	11	11	11	11	11	11	11	11
Poland	476	441	432	431	431	431	431	431	431	433	433	433	433
Portugal	143	147	141	142	144	143	143	143	144	145	136	133	119
Slovak Republic	111	111	111	110	110	109	110	111	110	110	108	108	108
Slovenia	34	34	42	42	42	41	41	41	41	39	41	42	44
Spain	460	444	454	447	449	452	598	607	607	607	607	607	607
Sweden	59	340	726	766	758	764	764	769	770	769	776	775	784
United Kingdom	69	66	63	79	82	88	85	89	86	86	86	85	84
EU	3656	3913	4372	4466	4437	4363	4613	4620	4645	4649	4532	4691	4765
Andorra												3	-
Belarus					416	416	408	408	408	407	406	406	403
Bulgaria		109	120	120	120	135	115	108	109	99	106	103	103
Croatia	84	88	82	83	86	89	84	83	81	80	78	84	85
Moldova	12	12	11	10	10	10	10	10	10	-	-	-	-
Norway	390	384	386	387	386	386	381	382	408	414	411	442	460
Romania	167	199	241	224	237	235	238	235	232	231	231	226	229
Russian Fed.		7	134										-
Serbia and Montenegro											103	130	-
Switzerland	45	45	47	49	49	49	49	49	49	49	48	48	48
Total Europe	4354	4757	5393	5339	5741	5683	5898	5895	5942	5929	5915	6133	6093

Table 2.1.2.1-2: Distribution of the 2005 sample plots over the climatic regions.

Climatic region	Number of plots	Percentage of plots
Boreal	1167	19.2
Boreal (Temperate)	940	15.4
Atlantic (North)	342	5.6
Atlantic (South)	278	4.6
Sub-atlantic	1124	18.5
Continental	246	4.0
Mountainous (North)	303	5.0
Mountainous (South)	705	11.6
Mediterranean (Higher)	400	6.5
Mediterranean (Lower)	588	9.6
All regions	6093	100.0

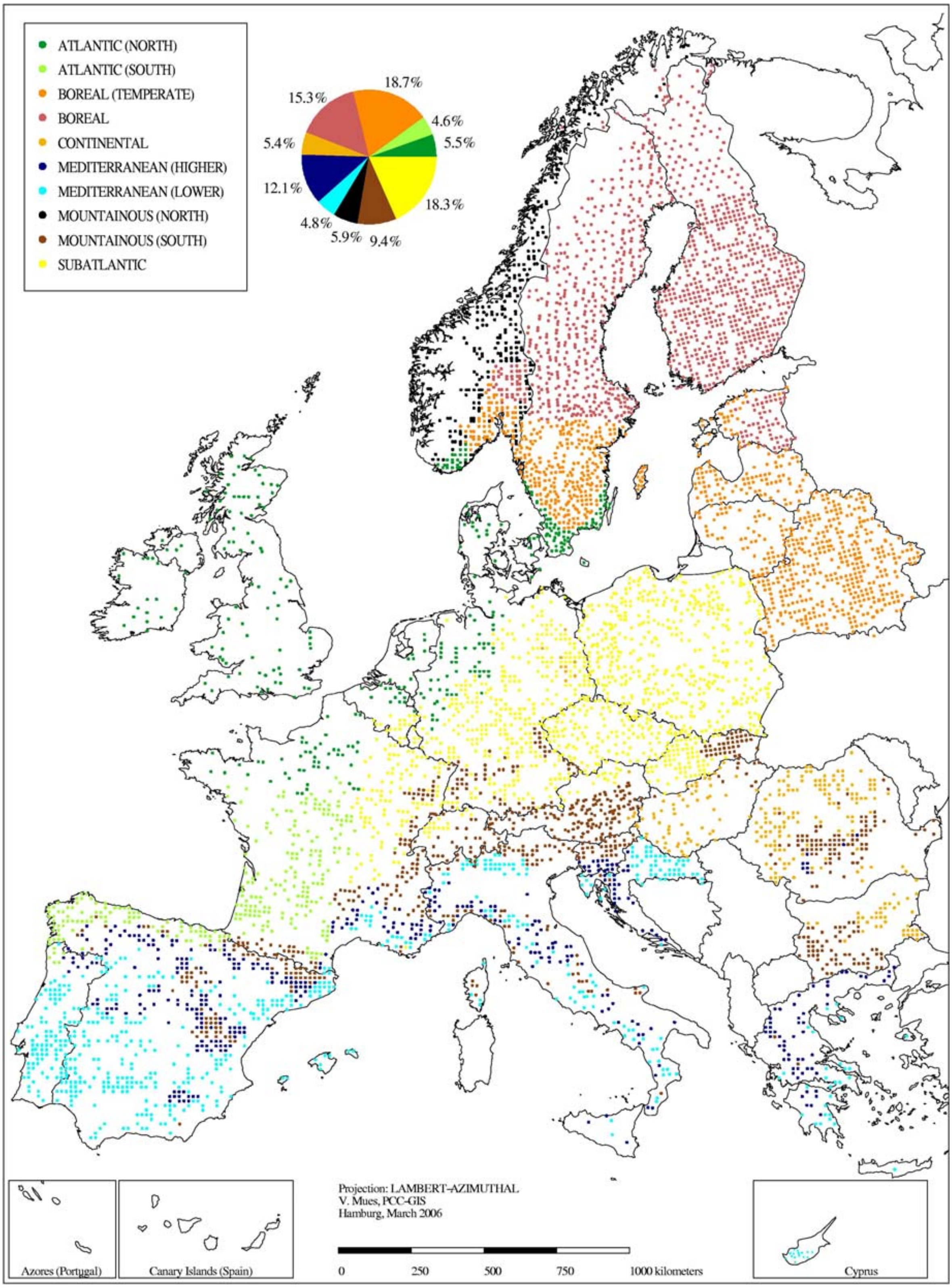

Figure 2.1.2.1-1: Plots according to climatic regions (2005).

2.1.2.2 National surveys

National surveys are conducted in many countries in addition to the transnational surveys. The national surveys in most cases rely on denser national grids and aim at the documentation of forest condition and its development in the respective country. Since 1986, densities of national grids with resolutions between 1 x 1 km and 32 x 32 km have been applied due to differences in the size of forest area, in the structure of forests and in forest policies. Results of crown condition assessments on the national grids are tabulated in Annexes II-1 to II-7 and are displayed graphically in Annex II-8. 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.

2.1.3 Assessment parameters

2.1.3.1 Stand and site characteristics

The following plot and tree parameters are reported on the transnational plots in addition to defoliation and discolouration:
Country, plot number, plot coordinates, altitude, aspect, water availability, humus type, soil type (optional), mean age of dominant storey, tree numbers, tree species, identified damage types and date of observation (Table 2.1.3.1-1).
Within a demonstration project at Level I (BioSoil) that includes the repetition of the soil survey using a more differentiated classification of soil types than the one reproduced in Table 2.1.3.1-1 will be carried out.

Table 2.1.3.1-1: Stand and site parameters given within the crown data base.

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

Nearly all countries submitted data on water availability, humus type, altitude, aspect, and mean age. The numbers of plots for which these site parameters were reported increased distinctively in recent years (Table 2.1.3.1-2). The data set is now almost complete for these parameters.

Table 2.1.3.1-2: 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	136	136	128	136	136	136	130
Belgium	29	29	29	29	29	29	28
Cyprus	15	15	15	15	15	15	0
Czech Republic	138	138	58	138	138	138	58
Denmark	22	22	22	22	22	22	22
Estonia	92	92	92	92	92	92	92
Finland	609	609	609	609	609	609	609
France	509	509	509	509	509	509	509
Germany	451	451	451	451	451	451	420
Hungary	73	61	40	61	61	73	61
Ireland	18	18	18	18	18	18	18
Greece	87	87	85	87	87	87	87
Italy	238	238	238	238	238	238	0
Latvia	92	92	92	92	92	92	92
Lithuania	62	62	62	62	62	62	62
Luxembourg	4	4	4	4	4	4	4
The Netherlands	11	11	11	11	11	11	11
Poland	433	433	424	433	433	433	38
Portugal	119	119	119	119	119	119	113
Slovak Republic	108	0	108	108	108	108	108
Slovenia	44	43	43	44	44	44	43
Spain	607	607	607	607	607	607	431
Sweden	784	784	771	784	784	784	589
United Kingdom	84	84	84	84	84	84	84
EU	4765	4644	4619	4753	4753	4765	3609
Percent of EU plot sample		97.5	96.9	99.8	99.8	100.0	75.7
Belarus	403	403	400	403	403	403	399
Bulgaria	103	103	103	103	103	103	103
Croatia	85	85	85	85	85	85	66
Norway	460	0	430	460	460	460	370
Romania	229	229	229	229	229	229	216
Switzerland	48	45	45	48	48	48	45
Total Europe	6093	5509	5911	6081	6081	6093	4808
Percent of total plot sample		90.4	97.0	99.8	99.8	100.0	78.9

2.1.3.2 Defoliation

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

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

Changes in defoliation and discolouration attributable to air pollution cannot be differentiated from those caused by other factors. Consequently, defoliation due to factors other than air pollution is included in the assessment results. Trees showing mechanical damage are not included in the sample. Should mechanical damage occur to a sample tree, any resulting loss of foliage is not counted as defoliation. In this way, mechanical damage is ruled out as a cause as far as possible (compare 2.1.3.3).

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 2.1.4). Discolouration is reported both in the transnational and in the national surveys using the traditional classification.

The total numbers of trees assessed from 1993 to 2005 in each country are shown in Table 2.1.3.2-1. The figures are not necessarily identical to those published in previous reports for the same reasons explained in Chapter 2.1.2.1.

Of the tree sample of the year 2005, 114 species (-groups) were reported. 64.3% of the plots were dominated by conifers, 35.7% by broadleaves (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 27.8% followed by *Picea abies* with 19.9%, *Fagus sylvatica* with 8.9%, and *Quercus robur* with 3.7% of the total tree sample (Annex I-3).

Table 2.1.3.2-1: Number of sample trees from 1993 to 2005 according to the current database.

Country	Number of sample trees												
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Austria	2121	2107	2101	3670	3604	3577	3535	3506	3451	3503	3470	3586	3528
Belgium	685	684	678	684	683	692	696	686	682	684	684	681	676
Cyprus									360	360	360	360	361
Czech Rep	4423	5087	4933	4853	4844	2899	3475	3475	3475	3500	3500	3500	3450
Denmark	600	600	576	552	528	552	552	504	504	480	480	480	528
Estonia	2064	2159	2160	2184	2184	2184	2184	2160	2136	2169	2228	2201	2167
Finland	4427	4261	8754	8732	8788	8758	8662	8576	8579	8593	8482	11210	11535
France	10118	10672	10851	10800	10800	10740	10883	10317	10373	10355	10298	10219	10129
Germany	10729	10866	10907	10980	10990	13178	13466	13722	13478	13534	13572	13741	13630
Greece	2272	2272	2248	2248	2224	2204	2192	2192	2168	2144	-	-	2054
Hungary	1361	1322	1342	1298	1257	1383	1470	1488	1469	1446	1446	1710	1662
Ireland	462	441	441	441	441	441	417	420	420	424	403	400	382
Italy	5884	5791	5703	5836	4873	4939	6710	7128	7350	7165	6866	7109	6548
Latvia	2420	2257	2262	2368	2297	2326	2348	2256	2325	2340	2293	2290	2263
Lithuania	1843	1760	1776	1643	1634	1616	1613	1609	1597	1583	1560	1487	1512
Luxembourg	95	93	96	96	96	96	96	96	-	96	96	96	97
The Netherlands	260	260	257	237	220	220	225	218	231	232	231	232	232
Poland	9520	8820	8640	8620	8620	8620	8620	8620	8620	8660	8660	8660	8660
Portugal	4308	4414	4230	4260	4319	4290	4290	4290	4320	4350	4080	3990	3569
Slovak Rep.	5144	5115	5091	5018	5033	5094	5063	5157	5054	5076	5116	5058	5033
Slovenia	816	816	1008	1008	1008	984	984	984	984	936	983	1006	1055
Spain	11040	10656	10896	10728	10776	10848	14352	14568	14568	14568	14568	14568	14568
Sweden	311	3989	10310	10925	10910	11044	11135	11361	11283	11278	11321	11255	11422
United Kingdom	1656	1584	1512	1896	1968	2112	2039	2136	2064	2064	2064	2040	2016
EU	82559	86026	96772	99077	98097	98797	105007	105469	105491	105540	102761	105879	107077
Andorra												72	
Belarus					9974	9896	9745	9763	9761	9723	9716	9682	9484
Bulgaria		4370	4812	4789	4788	5389	4379	4197	4209	3753	3870	3629	3611
Croatia	2016	2150	1970	1974	2030	2066	2015	1991	1941	1910	1869	2009	2046
Moldova	288	288	263	236	253	234	259	234	234	-	-	-	
Norway	4016	3942	3905	3948	4028	4069	4052	4051	4304	4444	4547	5014	5319
Romania	4004	4776	5688	5375	5687	5637	5712	5640	5568	5544	5544	5424	5496
Russian Fed.		183	3180										
Serbia and Mont.											2274	2915	
Switzerland	500	509	824	854	880	868	857	855	834	827	806	748	807
Total Europe	93383	102244	117414	116253	125737	126956	132026	132200	132342	131741	131387	135372	133840

2.1.4 Evaluation and presentation of the survey results

2.1.4.1 Scientific background

The interpretation of the results of the crown condition assessments has to take into account the following limitations:

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

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

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

2.1.4.2 Classification of defoliation data

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 results of the evaluations of the crown condition data 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 2.1.4.2-1) is a practical convention, as real physiological thresholds cannot be defined.

Table 2.1.4.2-1: Defoliation and discolouration classes according to UNECE and EU classification

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

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

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

Attention must be paid to the fact that *Quercus robur* and *Quercus petraea* are evaluated together and referred to as "*Quercus robur* and *Q. petraea*". Similarly, *Quercus ilex* and *Quercus rotundifolia* are evaluated together and noted as "*Quercus ilex* and *Q. rotundifolia*".

The most important results have been tabulated separately for all countries having participated (called "total Europe") and for the 24 EU-Member States.

2.1.4.3 Mean defoliation and temporal development

For all evaluations related to the tree species a criterion had to be set up to be able to decide if a given plot represents this species or not. The number of trees with species being evaluated had to be three or more per plot ($N \geq 3$). The plot wise species specific mean defoliation was calculated as the mean of defoliation values of the trees of the selected species on the respective plot.

The temporal development of defoliation is expressed on maps as the slope, or regression coefficient, of a linear regression of mean defoliation against the year of observation. It can be interpreted as the mean annual change in defoliation. A value of e.g. 3% means an increase by 3% defoliation per year on average. These slopes are called "significant" only if there was less than 5% probability that they are different from zero by random variation.

Besides the temporal development, also the change in the results from 2003 to 2004 was calculated (Annex I-7). In this case, changes in mean defoliation per plot are called "significant" only if both,

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

For detailed information on the respective calculation method for the change from 2004 to 2005 see Annex IV.

2.2 Results of the transnational survey in 2005

2.2.1 Crown condition in 2005

The crown condition assessment of the year 2005 comprised 133 840 sample trees on 6 093 sample plots. Of these trees a share of 23.2% was scored as damaged, i.e. had a defoliation of more than 25% (Table 2.2.1-1). The share of damaged broad-leaves exceeded with 26.0% the share of damaged conifers with 21.1%. The percentages of damaged trees are mapped for each plot in Annex I-4. Table 2.2.1-1 shows also the mean and the median of defoliation. Mean defoliation in total Europe was 20.6%. A map of mean plot defoliation of all species is given in Annex I-5.

Table 2.2.1-1: Percentages of trees in defoliation classes and mean defoliation for broad-leaves, conifers and all species.

	Species	Percentage of trees in defoliation class							Defoliation		No. of
	type	0-10%	>10-25%	0-25%	>25-60%	>60%	dead	>25%	Mean	Median	trees
EU	Broad-leaves	25.9	46.1	72.0	24.4	2.7	0.8	28.0	23.0	20	41070
	Conifers	35.7	42.5	78.2	19.3	1.5	1.0	21.8	19.7	15	66007
	All species	32.0	43.9	75.9	21.3	1.9	0.9	24.1	21.0	20	107077
Total Europe	*Fagus sylv.*	33.3	43.7	77.0	20.8	1.6	0.6	23.0	20.3	15	11898
	Quercus robur + Q. petraea	15.2	43.8	59.0	37.7	2.4	0.9	41.0	26.9	25	8447
	Broad-leaves	29.0	45.0	74.0	22.7	2.4	0.9	26.0	22.2	20	53696
	Picea abies	38.5	35.2	73.7	23.0	2.0	1.3	26.3	20.2	15	26582
	Pinus sylv.	37.2	46.4	83.6	14.6	1.0	0.8	16.4	18.3	15	37180
	Conifers	36.1	42.8	78.9	18.6	1.5	1.0	21.1	19.5	15	80144
	All species	33.3	43.5	76.8	20.3	1.9	1.0	23.2	20.6	15	133840

Defoliation classes have uneven widths. For this reason, the frequency distributions for the 5% classes in which defoliation data are submitted were calculated. These frequency distributions are shown for the broadleaved trees, for the coniferous trees and for the total of all trees in Figures 2.2.1-1a and 2.2.1-1b for each climatic region as well as for the total of all regions. Also given are the number of trees, the mean defoliation and the median. Mean defoliation is lowest with 15.0% in the Boreal region and it is highest with 24.0% in the Mediterranean (lower) region.

Figures 2.2.1-2 to 2.2.1-5 show maps of mean plot defoliation for *Pinus sylvestris*, *Picea abies*, *Fagus sylvatica*, and *Quercus robur* and *Q. petraea*. The maps reflect partly the differences in crown condition between species and regions seen in Table 2.2.1-1 and in Figures 2.2.1-1a and 2.2.1-1b: Defoliation is highest for *Quercus robur* and *Quercus petraea* and it is lowest for *Pinus sylvestris*. For *Pinus sylvestris* the map shows large and partly well defined regions of both high and low defoliation. Particularly many plots with hardly defoliated *Pinus sylvestris* trees are situated in Finland and in northern and central Sweden, i.e. in the Boreal region. In contrast, *Picea abies* and especially the main broad-leaved species, *Fagus sylvatica* as well as *Quercus robur* and *Quercus petraea*, show highly defoliated plots throughout their habitat.

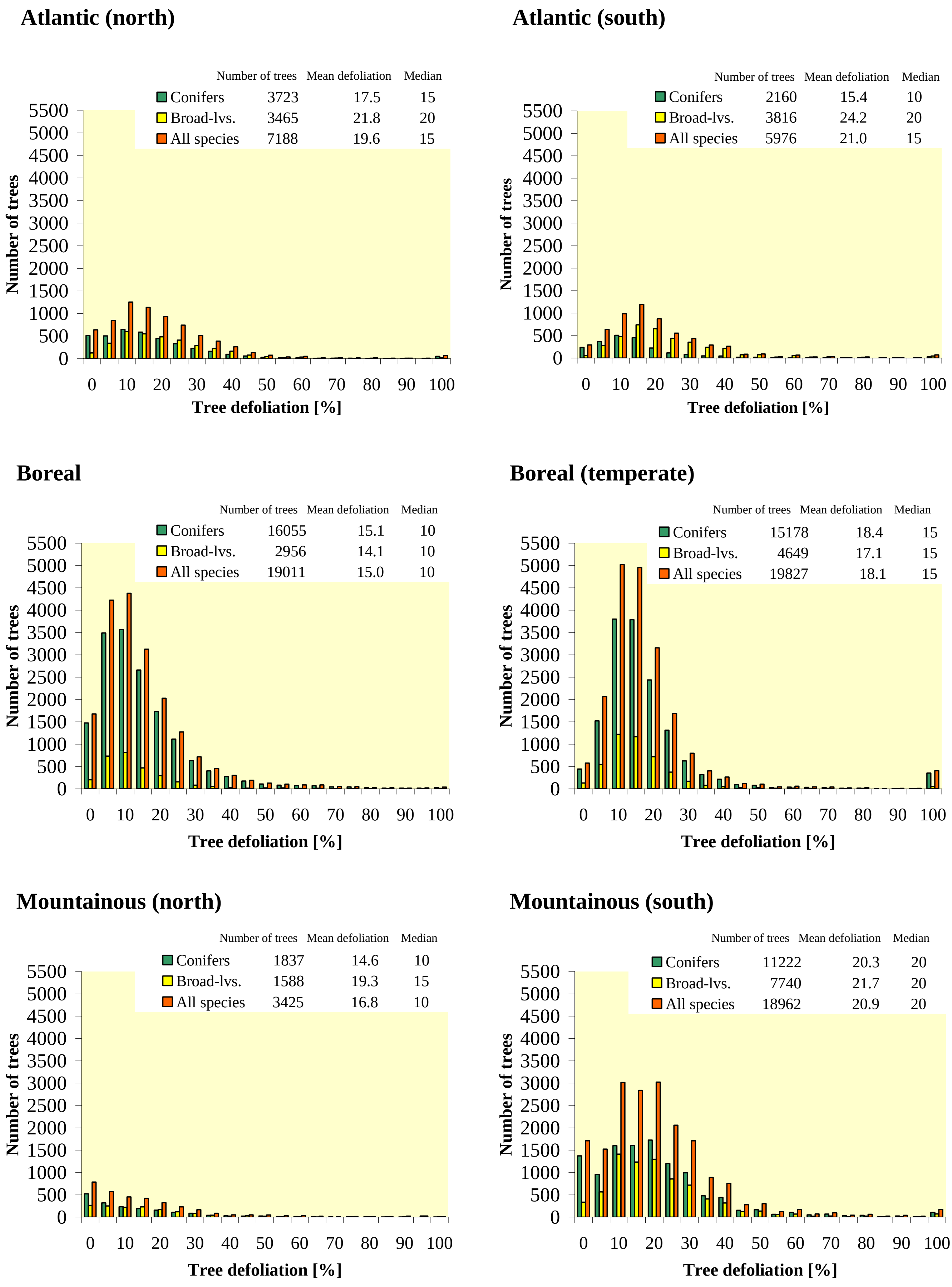

Figure 2.2.1-1a: Frequency distribution of trees in 5%-defoliation steps.

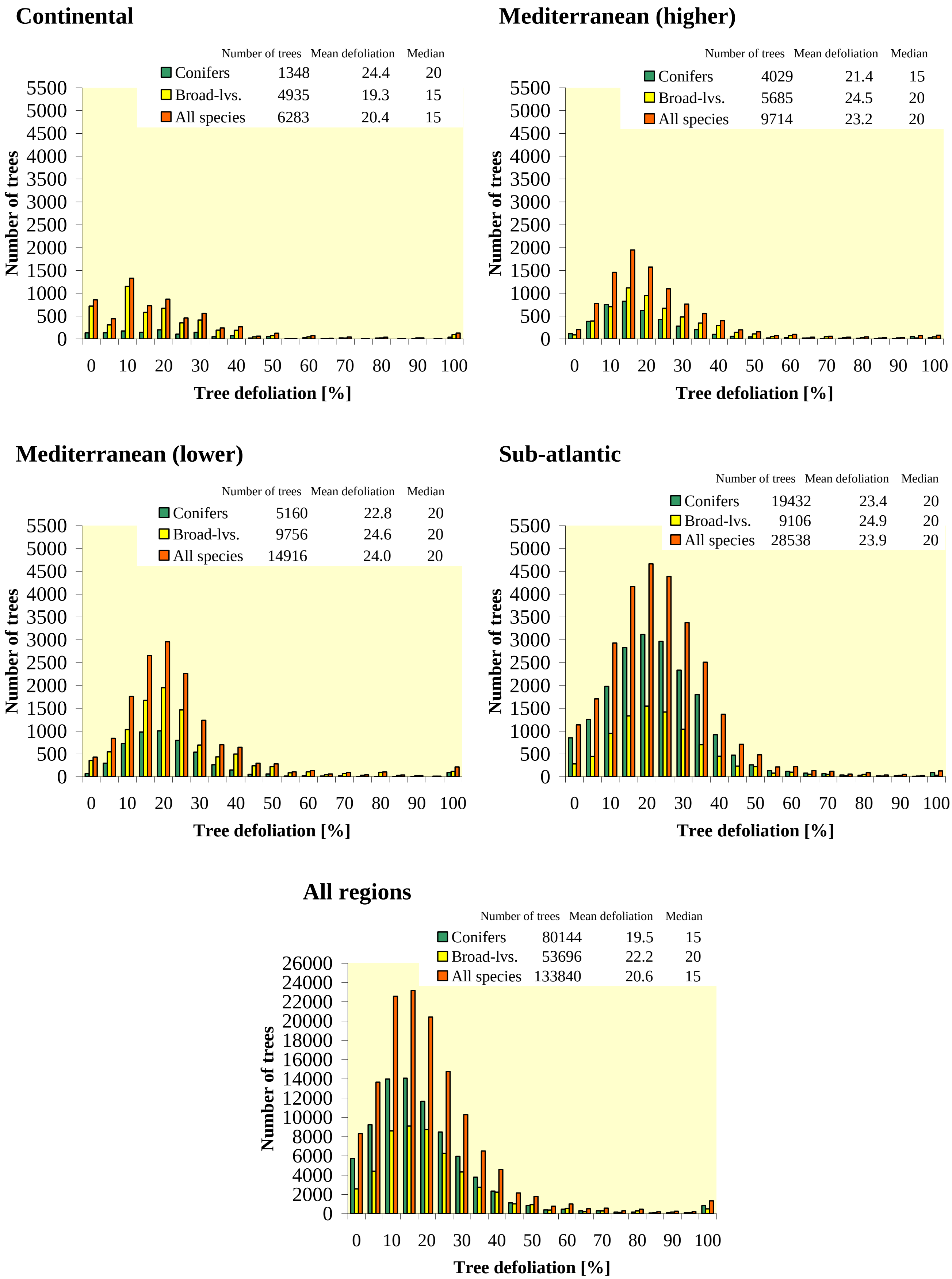

Figure 2.2.1-1b: Frequency distribution of trees in 5%-defoliation steps.

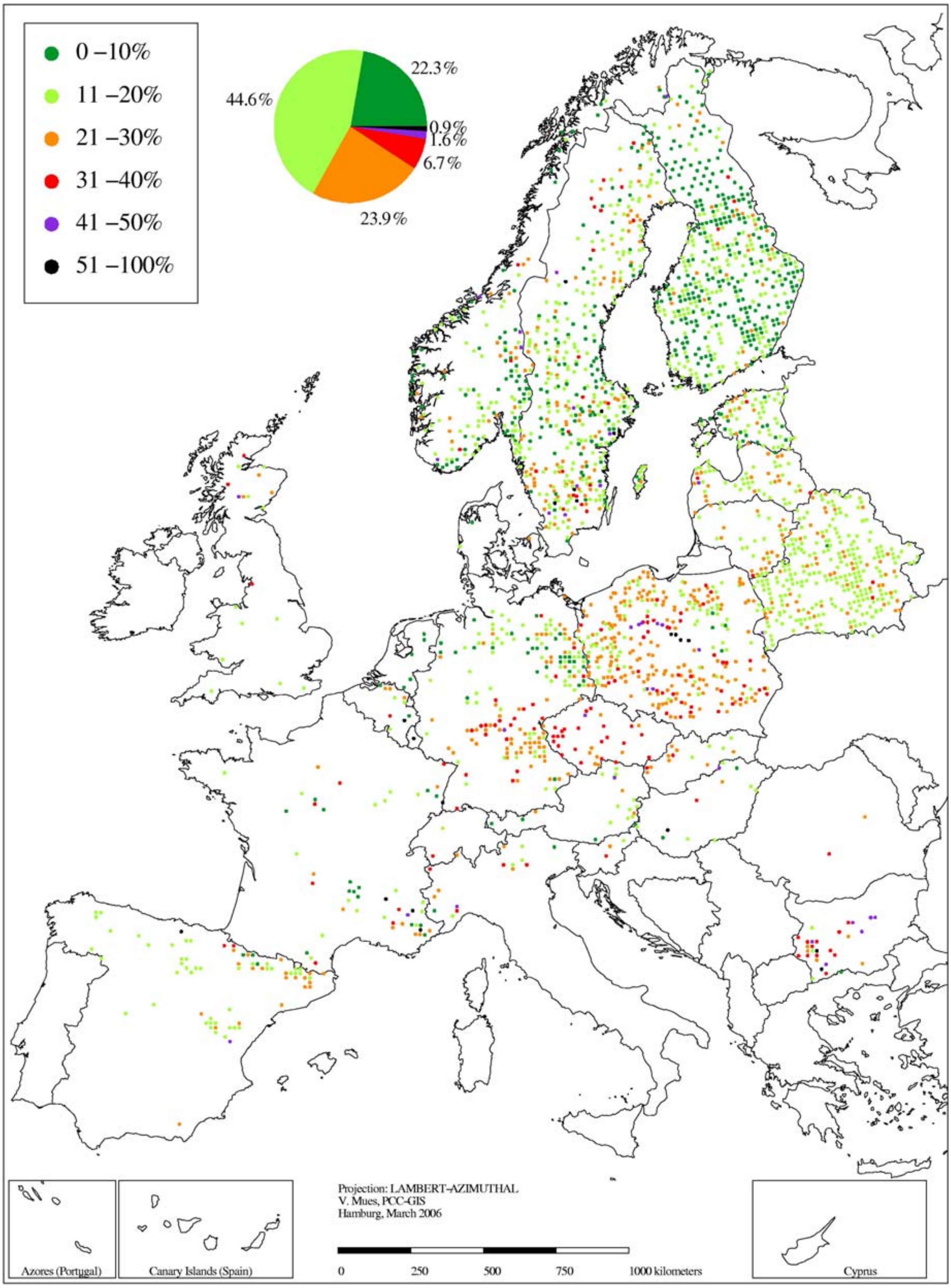

Figure 2.2.1-2: Mean plot defoliation of *Pinus sylvestris.*

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

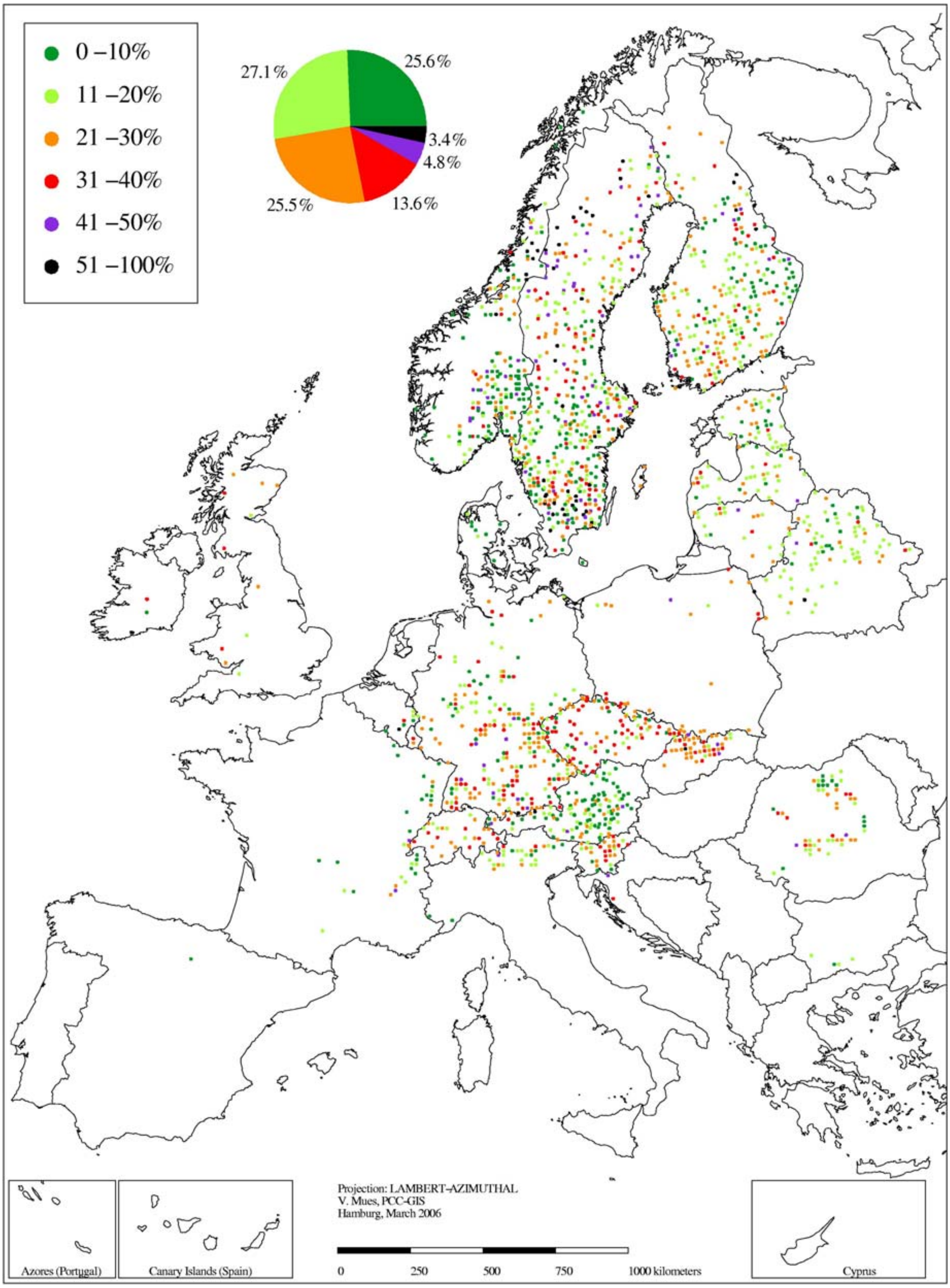

Figure 2.2.1-3: Mean plot defoliation of *Picea abies.*

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

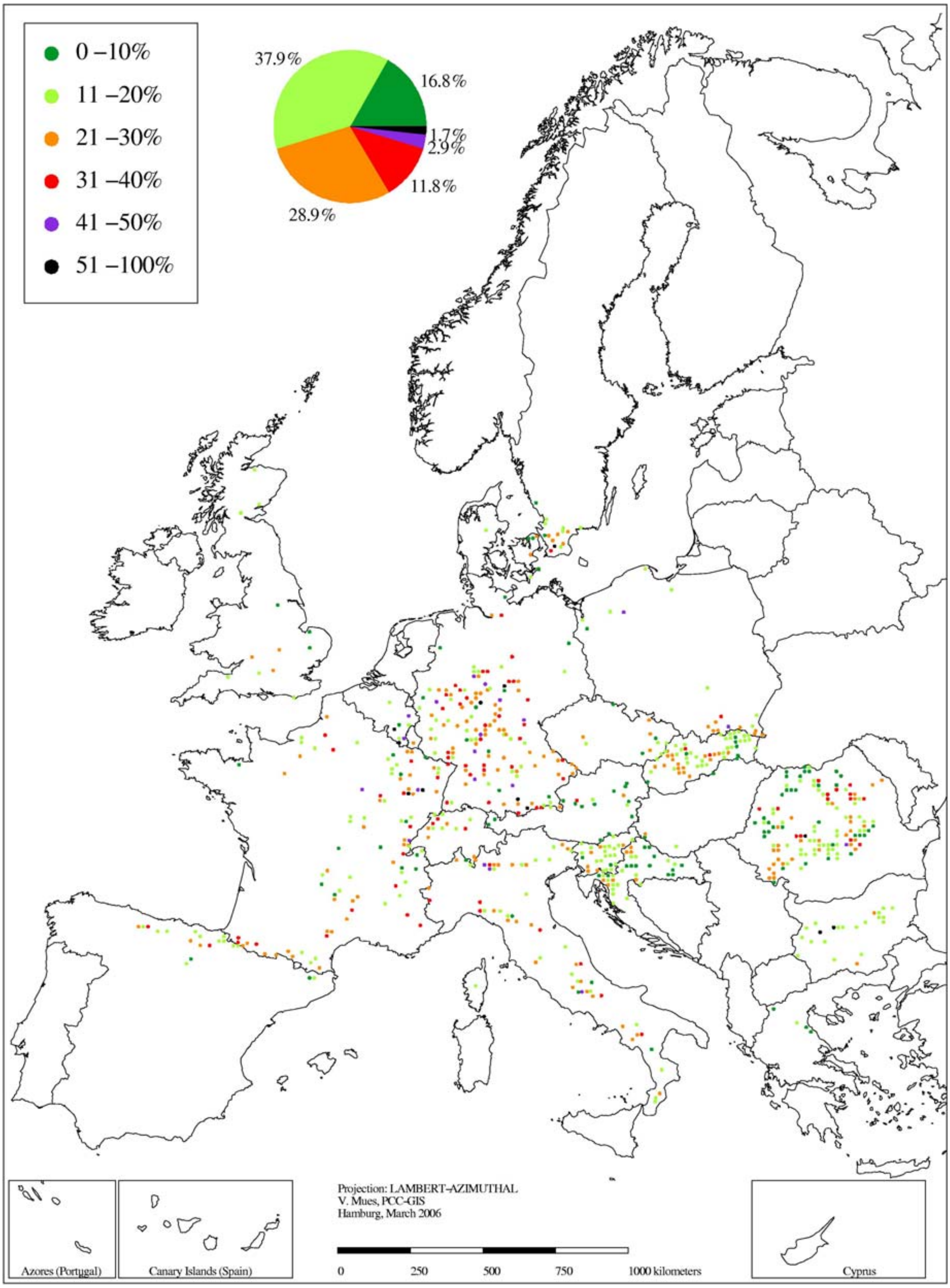

Figure 2.2.1-4: Mean plot defoliation of *Fagus sylvatica.*

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

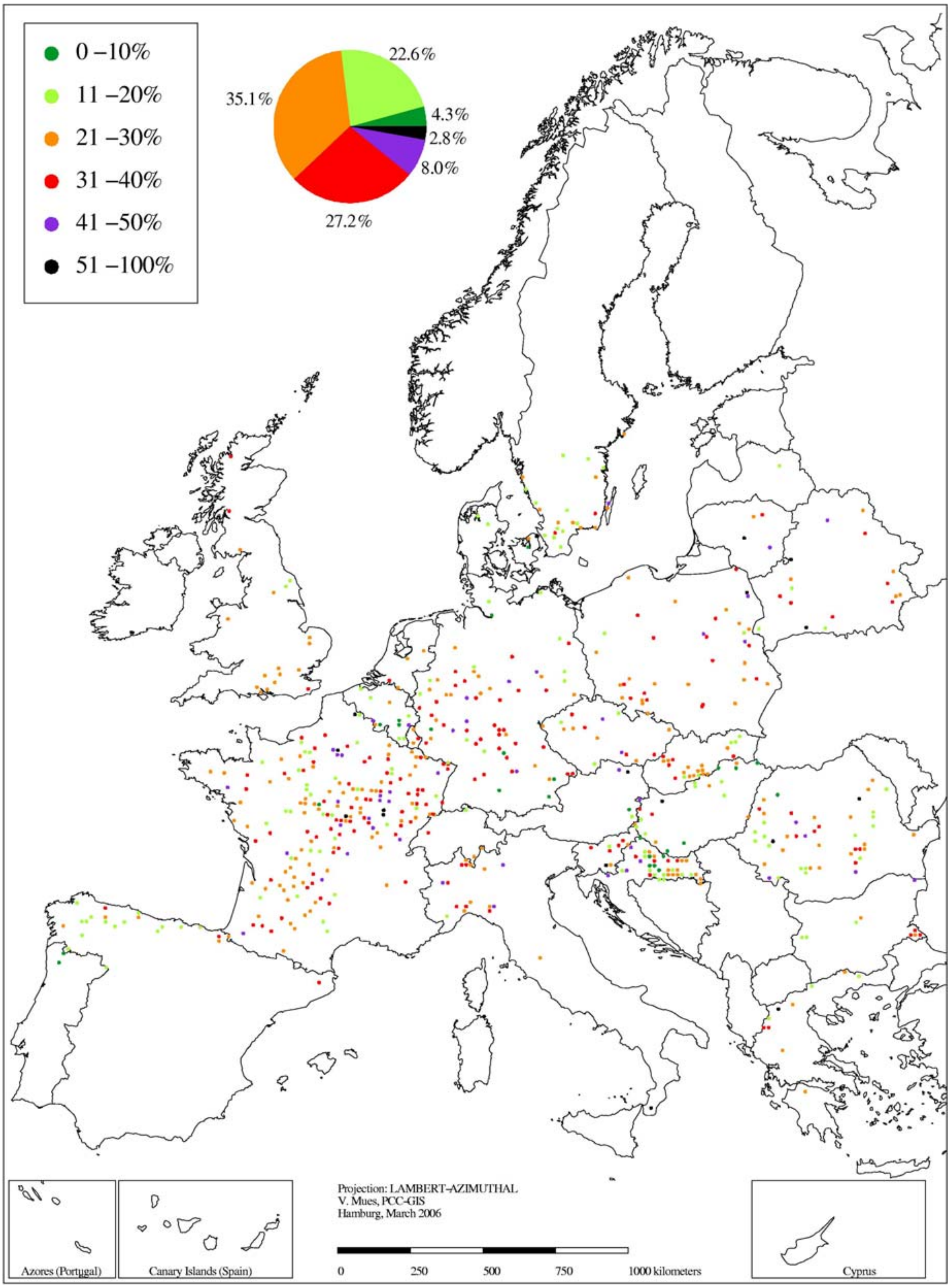

Figure 2.2.1-5: Mean plot defoliation of *Quercus robur* and *Quercus petraea.*

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

Table 2.2.1-2 shows the discolouration of the 133 840 trees of the crown condition survey. Of these trees, a share of 6.2% is discoloured, i.e. has a discolouration of more than 10%. Annex I-6 shows a map of mean plot discolouration.

Table 2.2.1-2: Percentages of trees in discolouration classes and mean defoliation for broad-leaves, conifers and all species.

	Species type	Discolouration						No. of trees
		0-10%	>10-25%	>25-60%	>60%	dead	>10%	
EU	Broad-leaves	94.8	2.8	1.1	0.5	0.8	5.2	41070
	Conifers	94.6	3.5	0.8	0.2	0.9	5.4	66007
	All species	94.6	3.3	1.0	0.2	0.9	5.4	107077
Total Europe	Broad-leaves	94.0	3.6	1.0	0.6	0.8	6.0	53696
	Conifers	93.6	4.4	0.9	0.3	0.8	6.4	80144
	All species	93.8	4.1	0.9	0.4	0.8	6.2	133840

2.2.2 Development of defoliation

2.2.2.1 Approach

The development of defoliation is calculated assuming that the tree sample of each survey year represents forest condition. The experience and special studies of previous years shows that the fluctuation of trees in this sample due to the exclusion of dead and felled trees as well as due to inclusion of replacement trees does not cause distortions of the results over the years. However, fluctuations due to the inclusion of newly participating countries must be excluded, because forest condition among countries can deviate greatly. For this reason, the development of defoliation can only be calculated for defined sets of countries. Different lengths of time series require different sets of countries, because at the beginning of the surveys the number of participating countries was much smaller than it is today. For the present evaluation the following two time series and respectively, the following countries were selected for tracing the development of defoliation:

- Period 1990-2005:
  Belgium, Denmark, Germany (west), Hungary, Ireland, Latvia, Poland, Portugal, Slovak Republic, Spain, Switzerland, and The Netherlands.
- Period 1997-2005:
  Austria, Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, The Netherlands, and United Kingdom.

Several countries could not be included in one or both time series because of changes in their tree sample sizes, changes in their assessment methods or missing assessments in certain years. Development of defoliation is presented either as graphs or in maps. Graphs show the fluctuations of either mean defoliation or shares of trees in defoliation classes over time. Maps indicate trends in mean defoliation calculated as described in Chapter 2.1.5.3.

In addition to the development of defoliation in the above mentioned periods, also the change in mean defoliation from 2004 to 2005 was mapped (Annex I-7). This biannual comparison shows a significant increase in defoliation on 16.5% of the plots, whereas only 10.3% of the plots show a significant decrease. Although the plots with increased defoliation are scattered all across Europe, they are particularly frequent on the Iberian Peninsula due to the fact that dry years increase the risk of forest fires and the susceptibility of trees to be attacked by bark beetles. Increased defoliation due to drought and biotic agents was also observed in parts of France and Bulgaria. The deterioration of crown condition in southernmost Sweden is partly explained by severe storm in January 2005.

Chapter 2.2.2.2 presents trends in defoliation for the six most frequent tree species. For each of these species, Chapters 2.2.2.3 to 2.2.2.8 describe the trends in different climatic regions. In each of these chapters the development of defoliation of the respective species is visualised for the total tree sample of all climatic regions in one graph. Additional graphs reflect particular developments in selected climatic regions. Each chapter contains also a map indicating trends of mean plot defoliation. Annexes I-8 and I-9 provide for each of the two time series and each of the six species the number of sample trees and their distribution over the defoliation classes for each year. This information is given for the total of all climatic regions and for each region separately. In addition, the same information is provided for three more species, namely *Abies alba*, *Picea sitchensis* and *Quercus suber* because of their ecological and economical importance in some regions.

2.2.2.2 Main tree species

From 1990 to 2005, *Pinus pinaster*, *Fagus sylvatica*, *Quercus ilex* and *Quercus rotundifolia* as well as *Quercus robur* and *Quercus petraea* show an obvious increase in defoliation (Figure 2.2.2.2-1). Defoliation of *Picea abies* undulates without a clear trend. *Pinus sylvestris* is the only species with slightly decreasing defoliation since 1990. Its recovery particularly in Poland, Belarus and in parts of the Baltic States since the mid 1990s renders this species in 2005 in a slightly better condition than at the beginning of the time series. Being less susceptible to drought, *Pinus sylvestris* shows no rise in defoliation even after the dry summer of the year 2003. In contrast, *Picea abies*, *Fagus sylvatica* as well as *Quercus robur* and *Quercus petraea* reacted upon the drought with a marked increase in defoliation from 2003 to 2004. In 2005, their crown condition recovered obviously. A different development over the last two years is shown by the Mediterranean species *Pinus pinaster* as well as by *Quercus ilex* and *Quercus rotundifolia*.

The impact by and the recovery from the drought in 2003 is less pronounced in the time series from 1997 to 2005 (Figure 2.2.2.2-2). The reason is that the underlying tree sample covers a large number of countries, in many of which no drought occurred in 2003. Trends in mean plot defoliation for the period 1997-2005 are mapped in Figure 2.2.2.2-3. The share of plots with distinctly increasing defoliation (20.6%) surmounts the share of plots with decreasing defoliation (12.9%). The latter improving plots are largely *Pinus sylvestris* plots in Belarus and Poland.

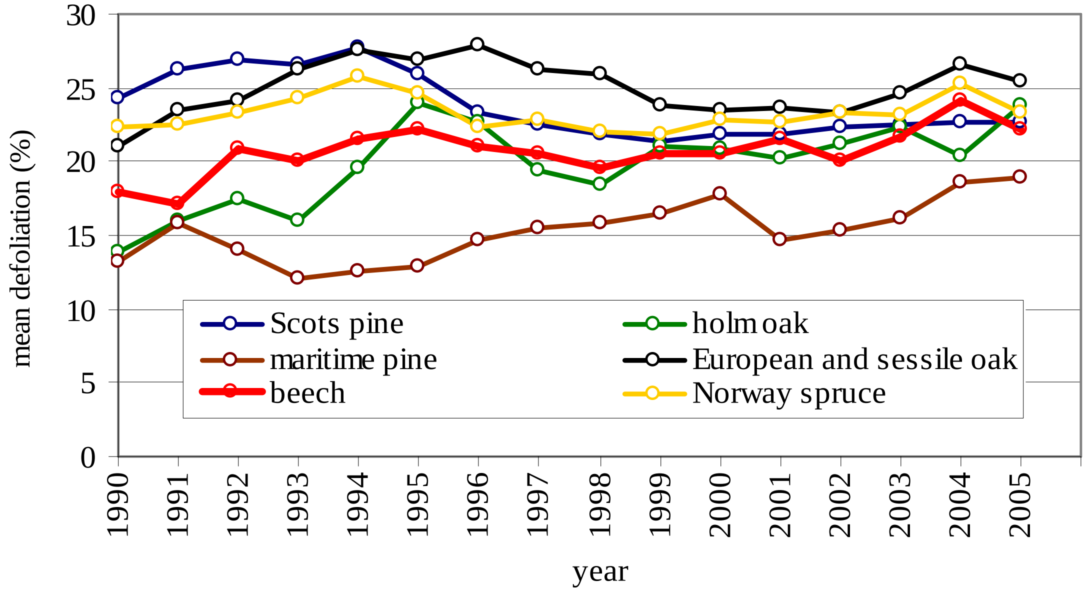

Figure 2.2.2.2-1: Mean defoliation of main species 1990 – 2005.

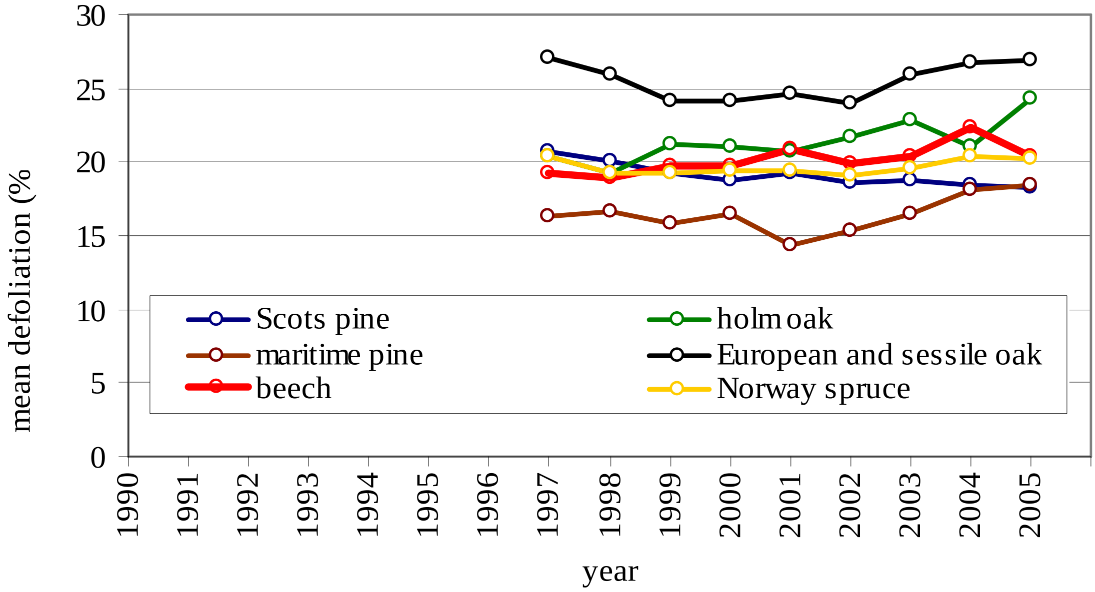

Figure 2.2.2.2-2: Mean defoliation of main species 1997 – 2005.

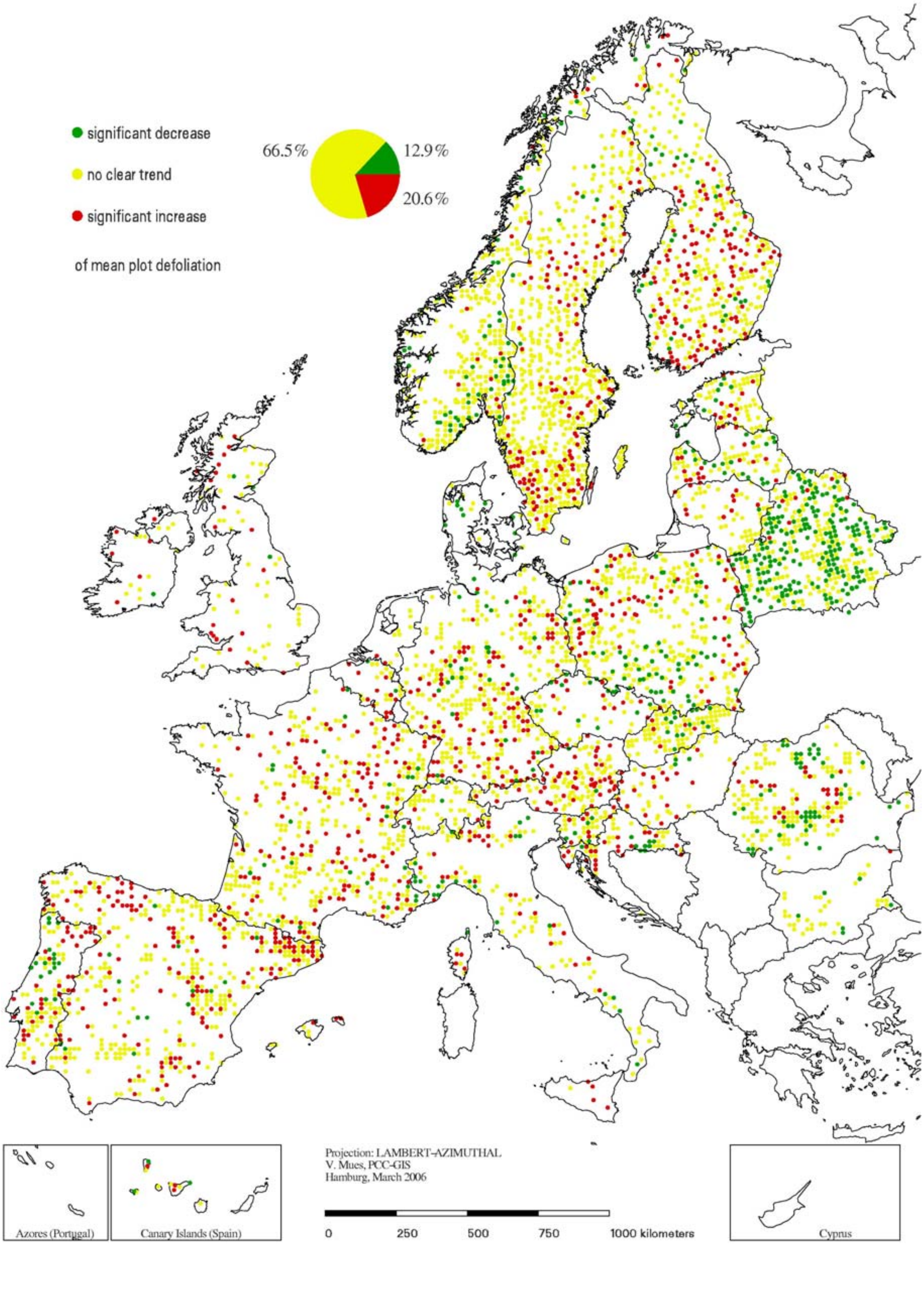

Figure 2.2.2.2-3: Trends of mean plot defoliation of all main species over the years 1997 to 2005.

2.2.2.3 Pinus sylvestris

Pinus sylvestris constitutes the largest share of sample trees in both periods of investigation, 1990-2005 and 1997-2005. It is the only species which is present in all climatic regions. In the total of all regions, the portion of damaged trees shows a pronounced decrease from a peak at 46.2% in 1994 to 25.0% in 2005. This reflects mainly the recuperation in the Sub-Atlantic region - which represents by far the largest share of trees – and to a lower extent an extreme decrease in the share of damaged trees after 1992 in Latvia, i.e. in the Boreal (temperate) region (Figure 2.2.2.3-1). In the Boreal (temperate) region defoliation decreased also in the period from 1997-2005. As a result, the share of damaged trees of this period has with 9.4% its so far lowest value. The recuperation in the Sub-Atlantic and Boreal (temperate) regions is also reflected in Figure 2.2.2.3-2. The map shows the high number of recuperating plots after 1997 in Belarus. Many recuperating plots are also seen in Poland, Latvia and Estonia, as well as in parts of Finland and Germany. Especially Poland and Lithuania have attributed the recuperation largely to reduced air pollution. The pie diagram shows that the share of recuperating plots (17.3%) is larger than that of the plots showing a deterioration (15.4%), which is largely due to the results reported from Belarus.

The recuperation of *Pinus sylvestris* is absent or less pronounced in other climatic regions. An example is the Mediterranean (higher) region. It represents only a small portion of the total *Pinus sylvestris* sample trees, but here the share of not defoliated trees decreased from 85.9% in 1990 to 36.9% in 2005 (Figure 2.2.2.3-1).

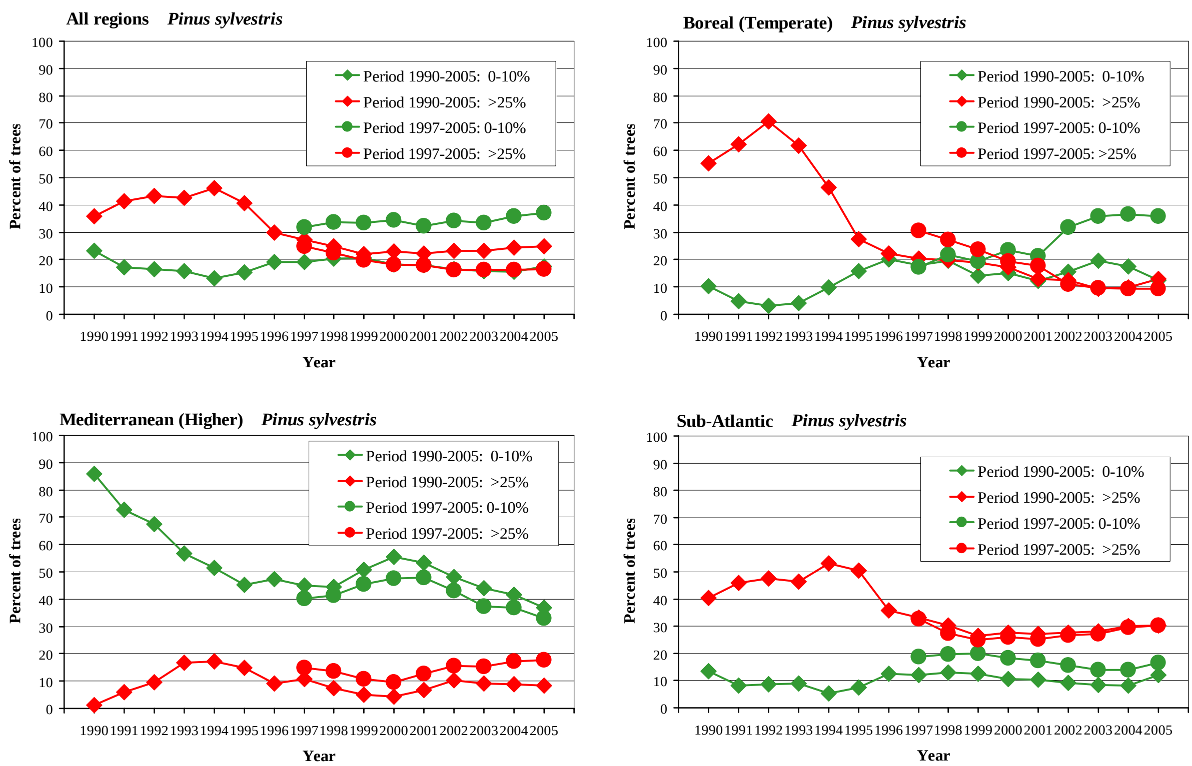

Figure 2.2.2.3-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2005 and 1997-2005).

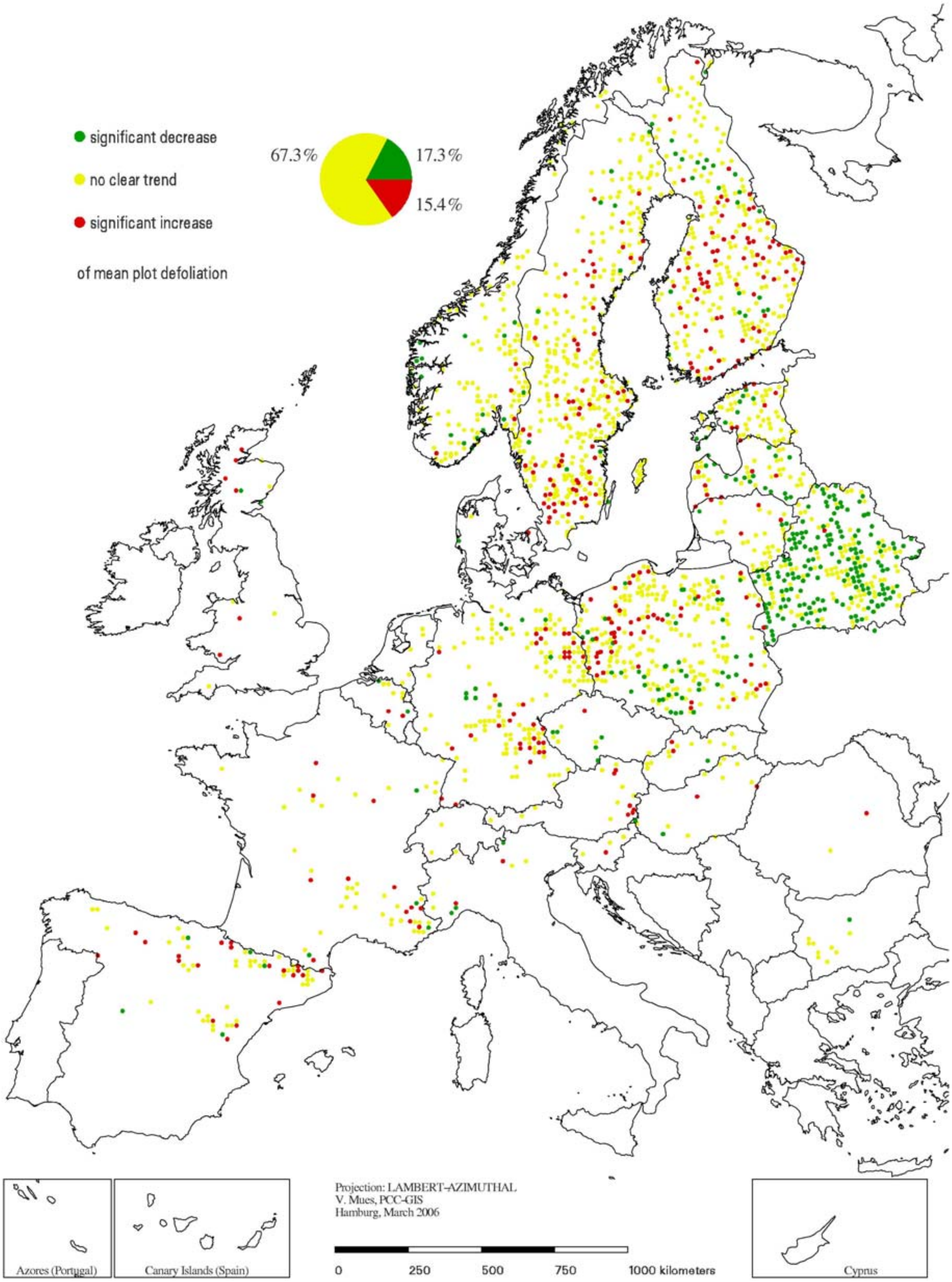

Figure 2.2.2.3-2: Trend of mean plot defoliation (slope of linear regression) of *Pinus sylvestris* over the years 1997 to 2005.

2.2.2.4 Picea abies

In both periods of observation, *Picea abies* constitutes the second largest share of trees behind *Pinus sylvestris*. In the period 1990-2005, the share of damaged trees in the total of all regions decreased from its peak of 38.2% in 1994 to 32.6% in 2005 (Figure 2.2.2.4-1). This development reflects largely the one in the Sub-Atlantic and Mountainous (south) regions, which comprise the largest and second largest share of *Picea abies* trees, respectively. These two regions – especially the Mountainous (south) region – show a sudden increase in defoliation from 2003 to 2004 with a subsequent decrease to nearly its old level in 2005. This pattern is interpretable as an effect of the dry and hot summer of 2003 and a recuperation from it in 2005. It is absent in the Boreal (temperate) region, where no unusual summer drought occurred.

In the 1997-2005 sample of *Picea abies* in the Sub-Atlantic and Mountainous (south) regions crown condition deteriorated. This is hardly reflected in the share of damaged trees, but is obvious from the decrease in not defoliated trees. Figure 2.2.2.4-2 shows the spatial distribution and the shares of plots with decreasing and increasing defoliation. Of all plots in the map, 18.9% showed a distinct increase in defoliation, whereas only 11.1% of them showed a distinct decrease.

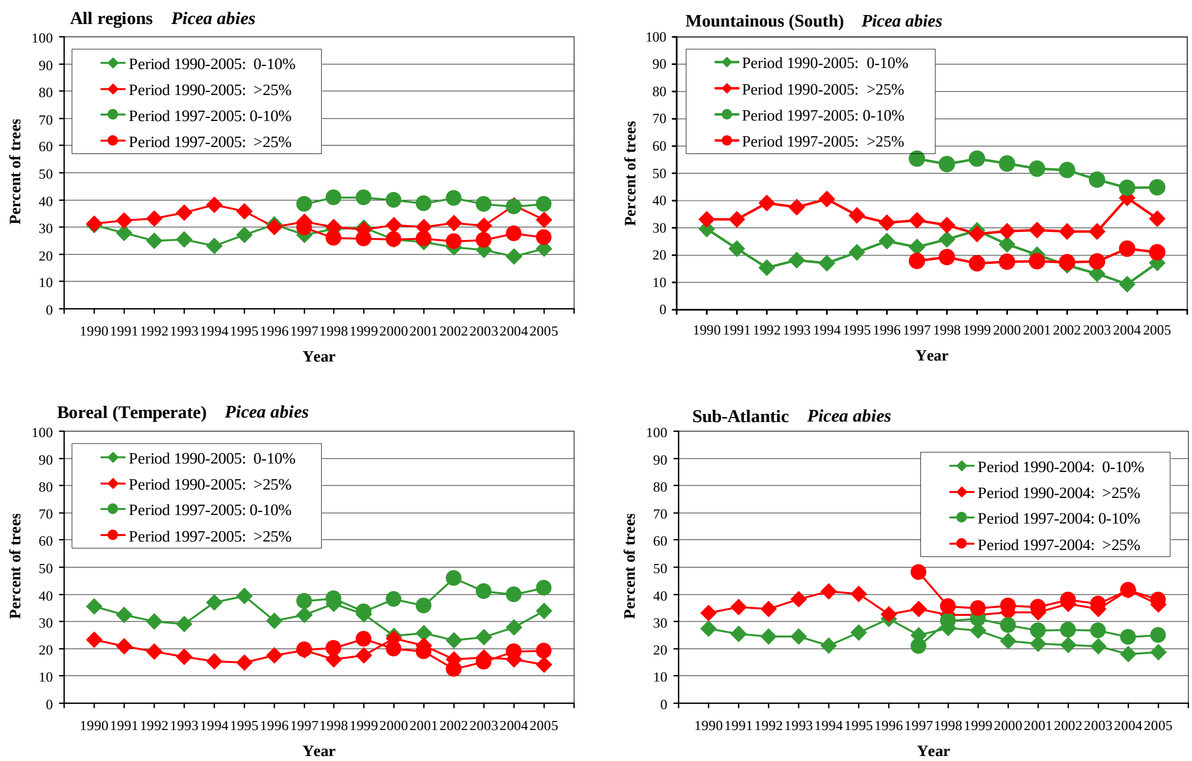

Figure 2.2.2.4-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2005 and 1997-2005).

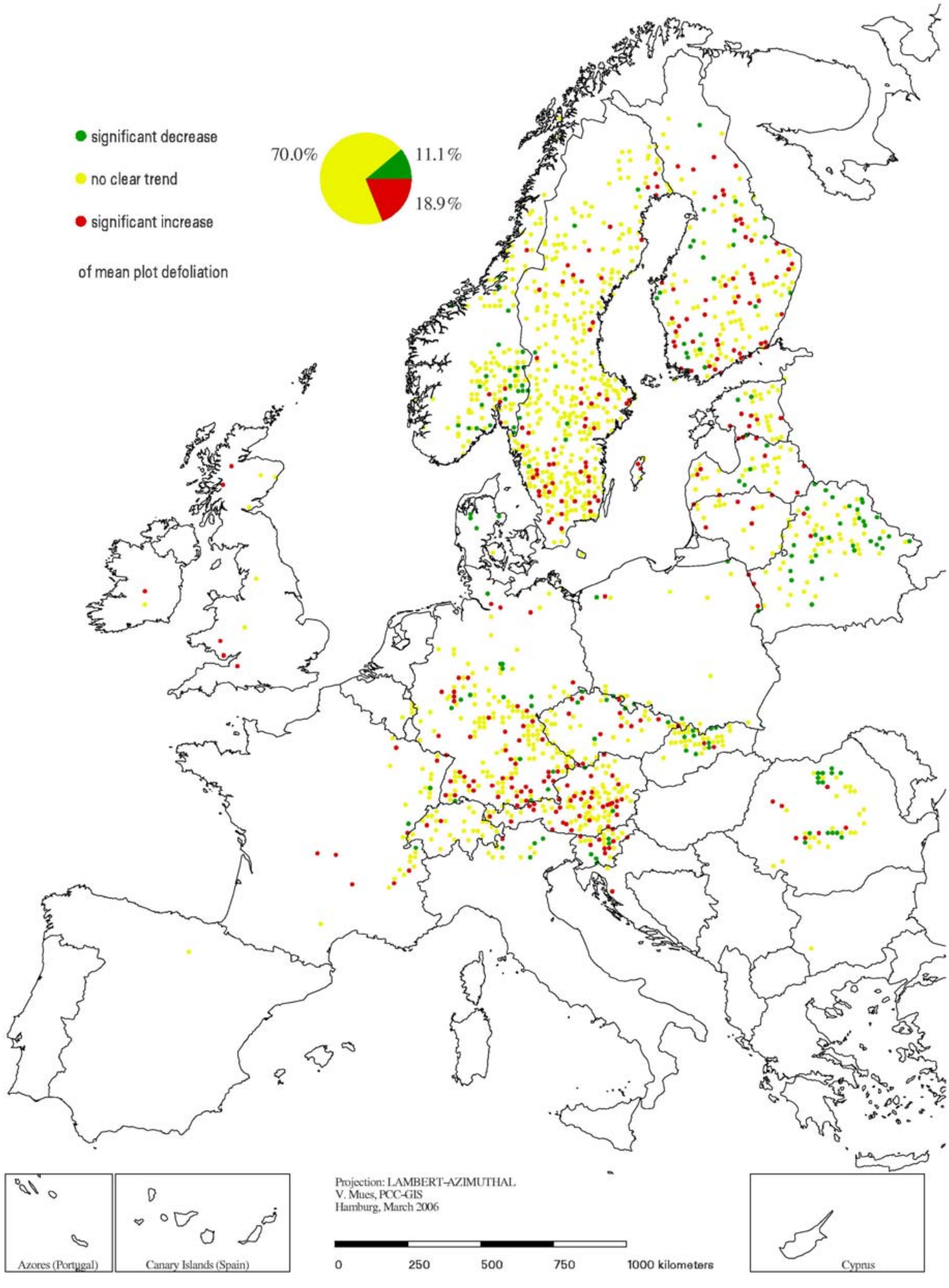

Figure 2.2.2.4-2: Trend of mean plot defoliation (slope of linear regression) of *Picea abies* over the years 1997 to 2005.

2.2.2.5 Fagus sylvatica

Fagus sylvatica constitutes the largest portion of the broadleaved species. In both periods of observation (1990-2005 and 1997-2005) crown condition across all regions deteriorates slightly. This becomes particularly obvious in the decrease of the share of not defoliated trees between 1990 and 2005 (Figure 2.2.2.5-1). The dry and hot summer of 2003 caused an increase in the defoliation in 2004. The subsequent decrease in defoliation indicates a recuperation of the trees in 2005. This reflects in particular the development of crown condition in the Sub-Atlantic and Mountainous (south) regions which comprise together more than half of the *Fagus sylvatica* trees. Both the drought damage and the recuperation from it are especially pronounced in the Atlantic (North) region, where the share of damaged trees increased by 16.6 percent points from 29.2% in 2003 to 45.8% in 2004, and decreased again to 32.0 % in 2005. Another obvious increase in defoliation occurred in the 1990-2005 sample in the Mountainous (south) region. There, the share of damaged trees tripled approximately from 11.8% in 2002 to 32.5% in 2003 which reflects largely the high fructification in the eastern Slovak Republic.

The overall deterioration of crown condition of *Fagus sylvatica* over the whole period of 1997-2005 observed particularly in the Atlantic (north), in the Sub-Atlantic and in the Mountainous (south) region is discernable in Figure 2.2.2.5-2. The map shows the spatial distribution of the trends since 1997 across Europe. The share of plots with increasing defoliation is 20.4% against a share of 9.7% of plots showing decreasing defoliation.

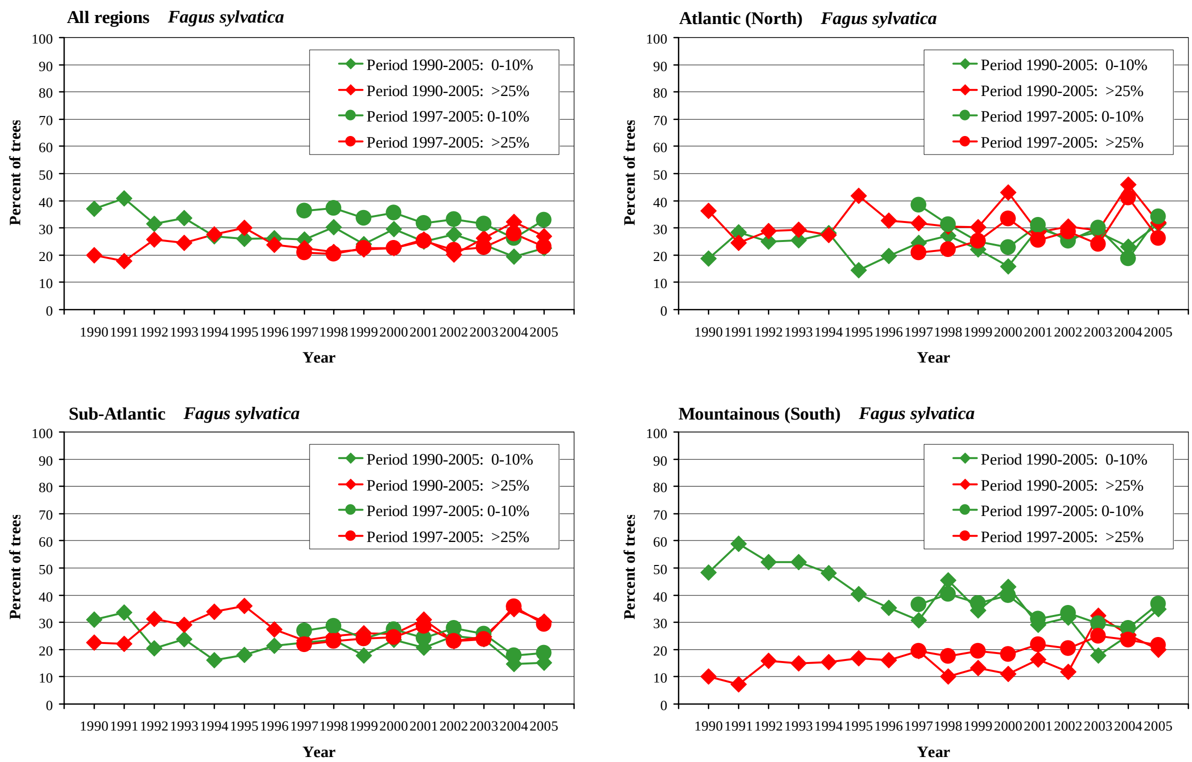

Figure 2.2.2.5-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2004 and 1997-2005).

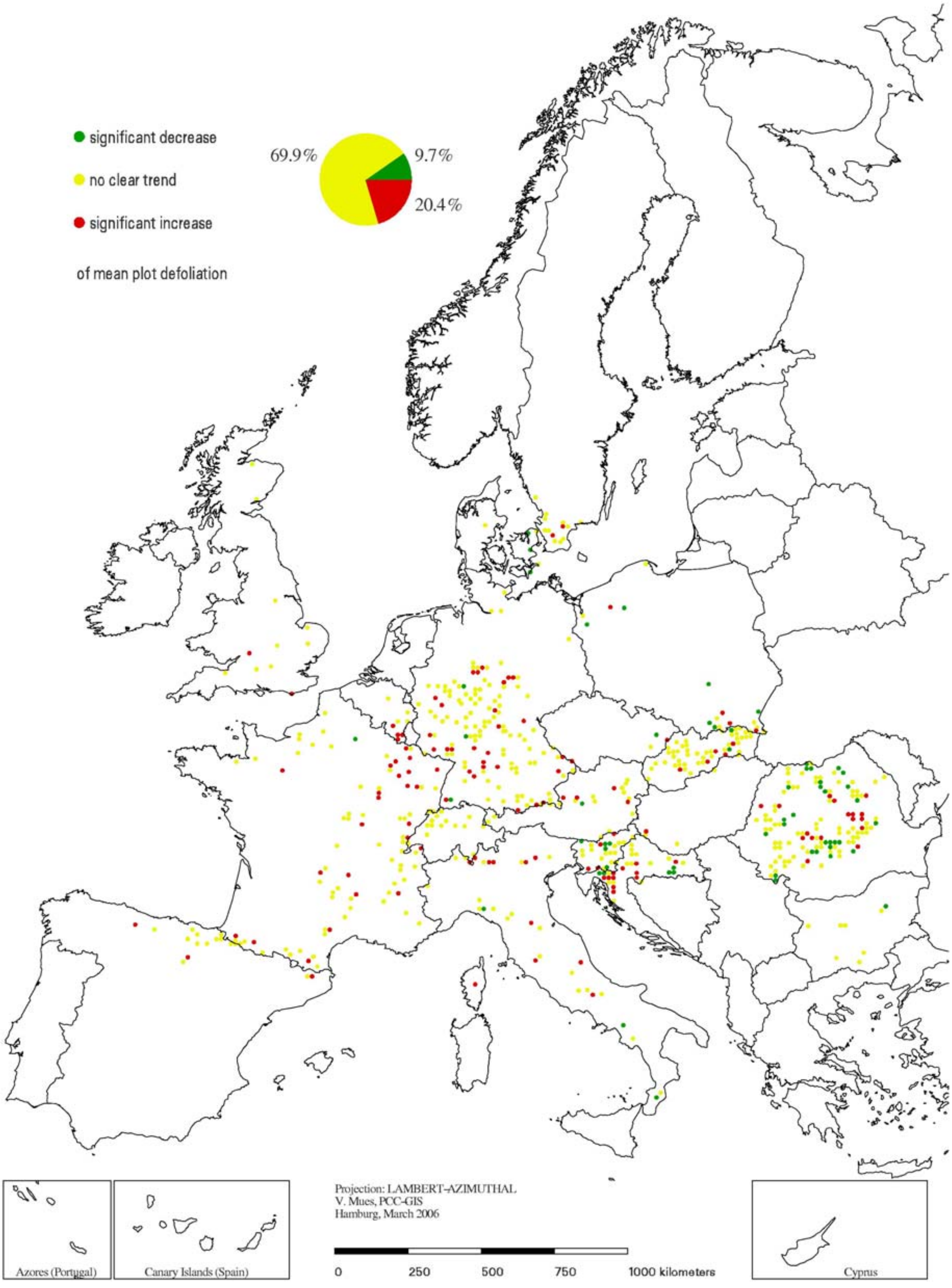

Figure 2.2.2.5-2: Trend of mean plot defoliation (slope of linear regression) of *Fagus sylvatica* over the years 1997 to 2005.

2.2.2.6 Quercus robur and Q. petraea

In the species group *Quercus robur* and *Quercus petraea*, the share of damaged trees across all regions recovered from its peak at 46.5% in 1994. After a steady state from 1999 onwards, it increased markedly in 2003 because of the summer heat and drought. This reflects mainly the development of crown condition in the Sub-Atlantic region which comprises the largest share of the sample trees of this species group. There, the share of damaged trees of the time series 1990-2005 increased by 10.1 percent points from 32.6% in 2002 to 42.7% in 2005, so far without any recuperation (Figure 2.2.2.6-1). A deterioration of crown condition in 2003 and 2004 is also visible in the Atlantic (North) region. The subsequent decrease in defoliation in 2005 reflects partly a recuperation of the trees in Denmark and northern Germany. In the Continental region, defoliation has been highly variable without a clear trend.

Of the 1997-2005 sample, nearly half of the trees with increasing defoliation is situated in France (Figure 2.2.2.6-2). Of all plots in the map, 20.1% show increasing and 9.4% of all plots show decreasing defoliation.

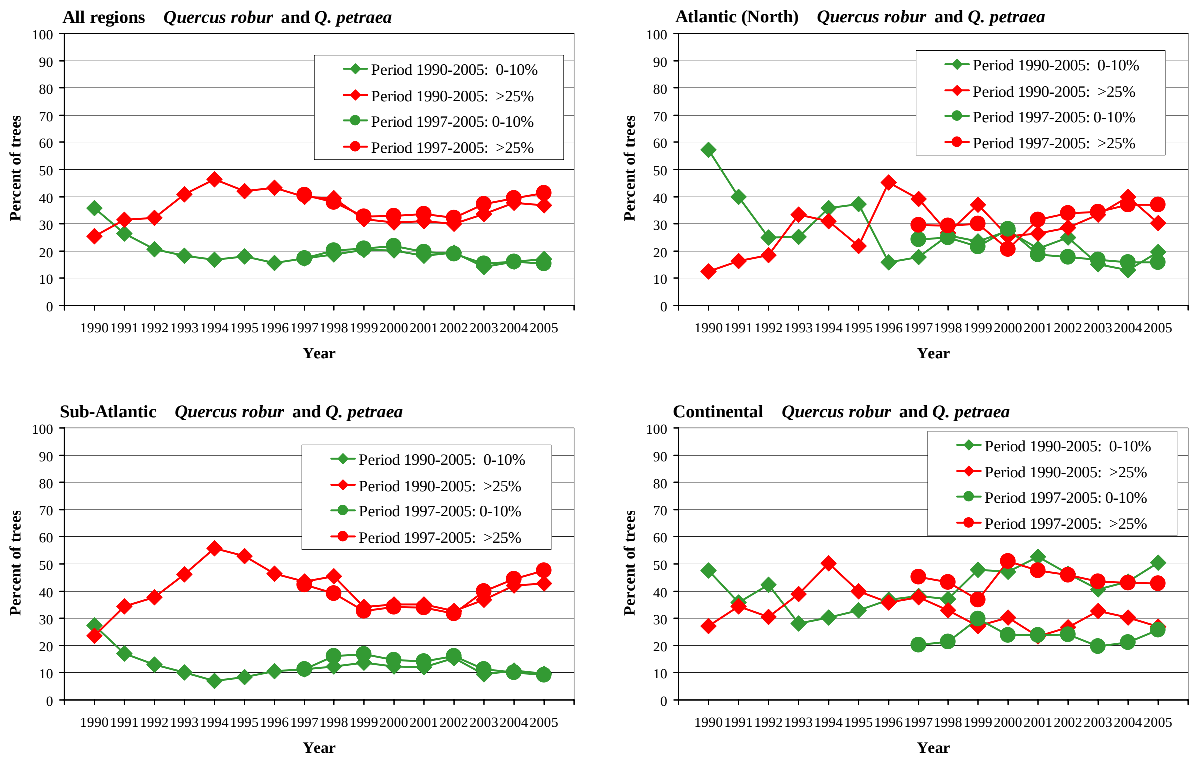

Figure 2.2.2.6-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2005 and 1997-2005).

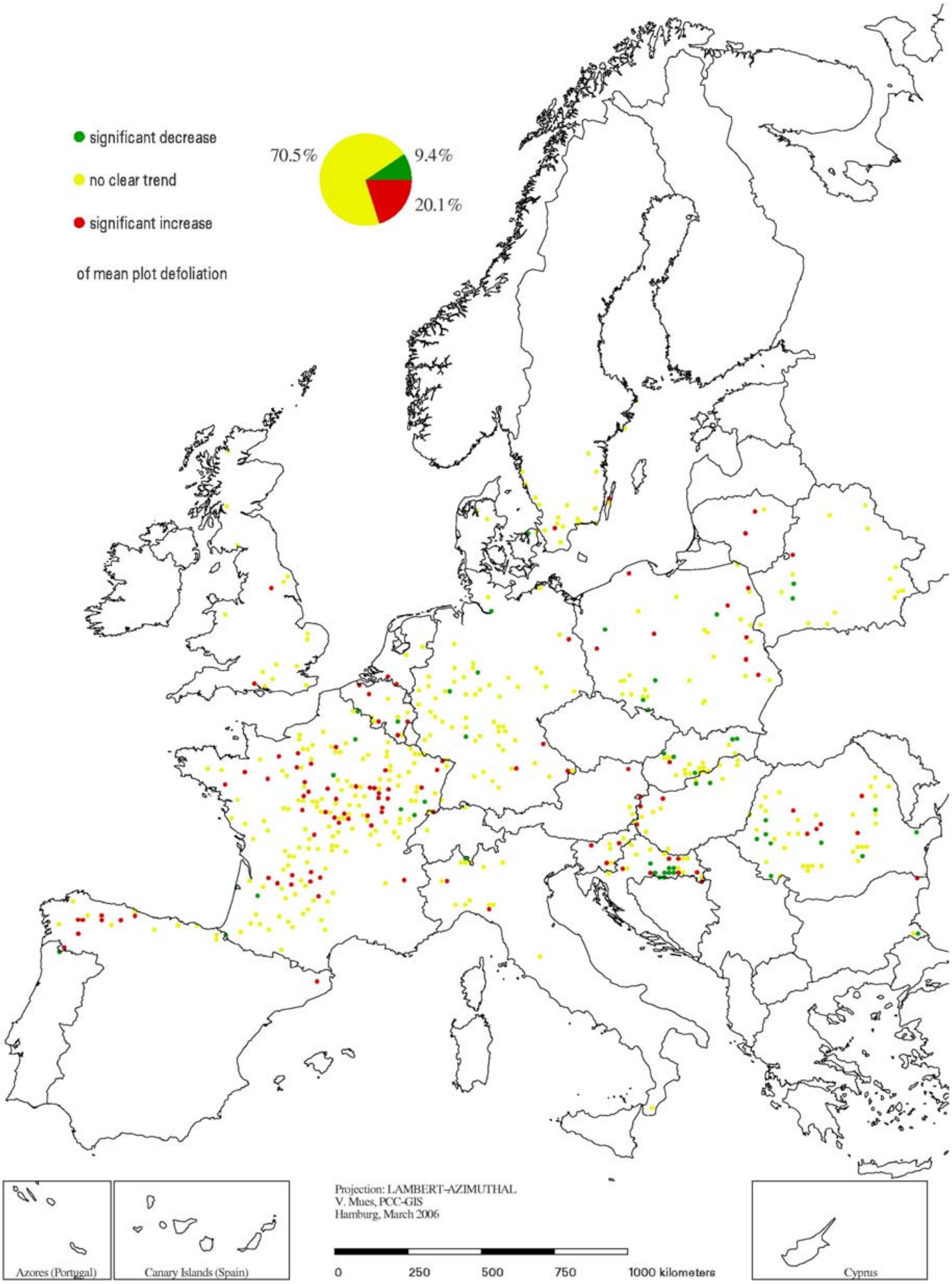

Figure 2.2.2.6-2: Trend of mean plot defoliation (slope of linear regression) of *Quercus robur* and *Quercus petraea* over the years 1997 to 2005.

2.2.2.7 Quercus ilex and Q. rotundifolia

Across all regions, *Quercus ilex* and *Quercus rotundifolia* shows an increase in the share of damaged trees to a peak of 28.1% in 1995. This deterioration was followed by a clear recuperation to 13.4% in 1998 (Figure 2.2.2.7-1). Since then the share of damaged trees of both samples (1990-2004 and 1997-2004) undulated around 20% until the year 2004. The subsequent sharp increase in 2005 is explained by exceptional summer drought. It is particularly obvious in the Mediterranean (Higher) region, where the share of damaged trees of the 1997-2005 sample reached 34.0%. In Portugal, after dry summers already in 2003 and 2004, the summer of 2005 was the driest for the last 50 years. Defoliation was caused by water deficit followed by insects and fungi outbreaks in trees weakened by insufficient water supply. Forest fires occurred also more frequently. Furthermore, Spain and France report unusual summer drought in recent years as the main cause of increasing defoliation.

A comparison of the maps in Figures 2.2.2.7-2 and 2.1.2.1-1 confirms that many of the plots with increasing defoliation are situated at higher altitudes. Of all plots on the map, 32.1% show increasing defoliation against only 6.5% with decreasing defoliation.

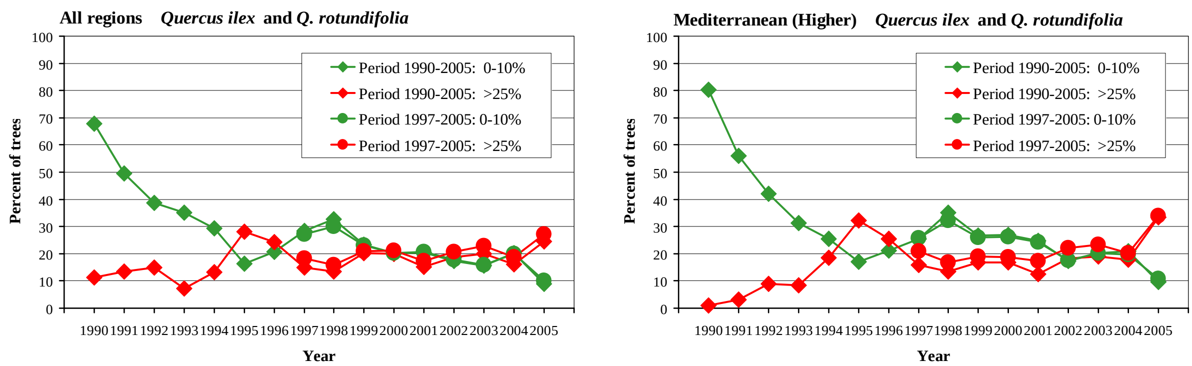

Figure 2.2.2.7-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2005 and 1997-2005).

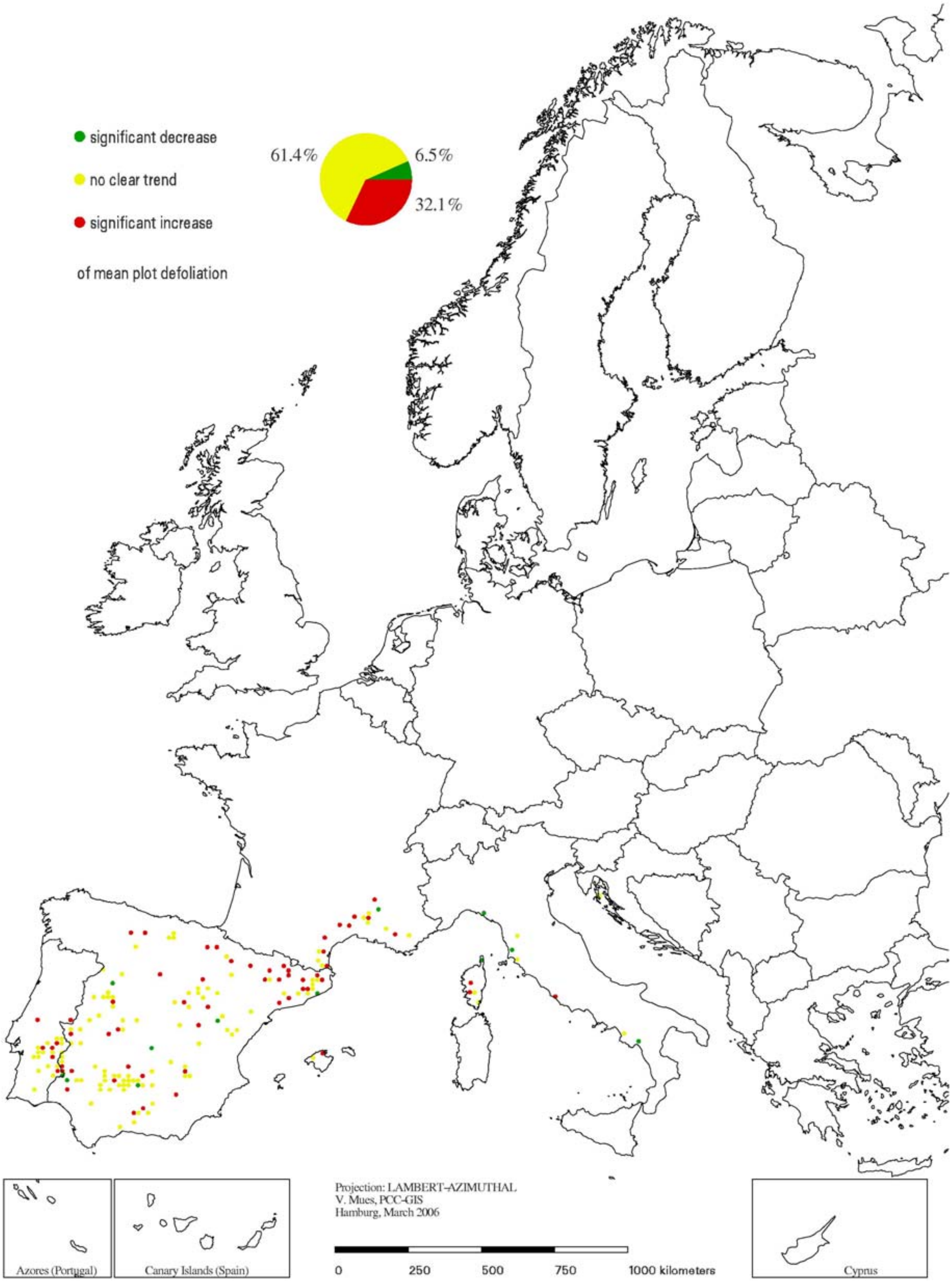

Figure 2.2.2.7-2: Trend of mean plot defoliation (slope of linear regression) of *Quercus ilex* and *Quercus rotundifolia* over the years 1997 to 2005.

2.2.2.8 Pinus pinaster

Over the entire period of observation, the share of damaged trees of *Pinus pinaster* across all regions changed only slightly (Figure 2.2.2.8-1). Despite this, defoliation of this species increased due to a continuous decrease in the share of not defoliated trees. This share fell from 68.1% in 1990 to 38.4% in 2004. This development reflects largely the one in the Mediterranean (Lower) and Mediterranean (Higher) regions, in which more than half of the sample trees are situated. In the Mediterranean (Higher) region, the share of damaged trees was nearly halved from 77.5% in 1990 to 42.6% in 2005.

The map in Figure 2.2.2.8-2 shows that the plots with increasing mean defoliation are scattered across the whole habitat, while a number of recuperating plots is concentrated in Portugal. The share of deteriorating plots is with 28.2% clearly larger than the share of improving plots with 13.0%.

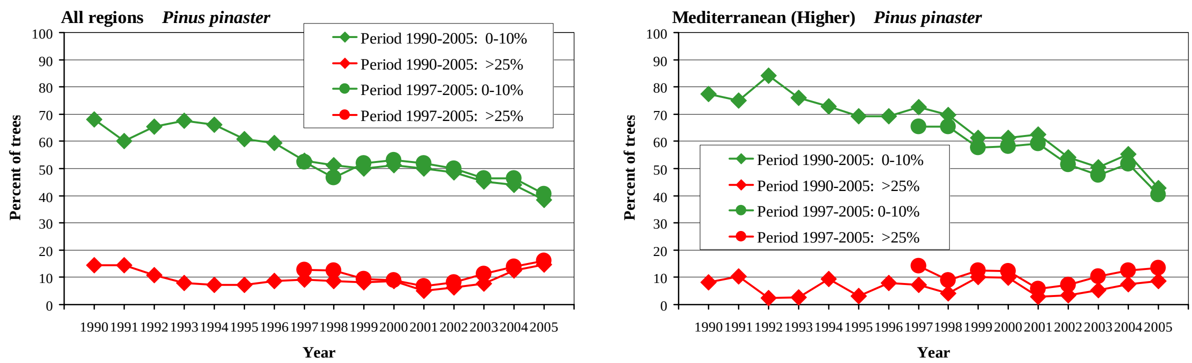

Figure 2.2.2.8-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2005 and 1997-2005).

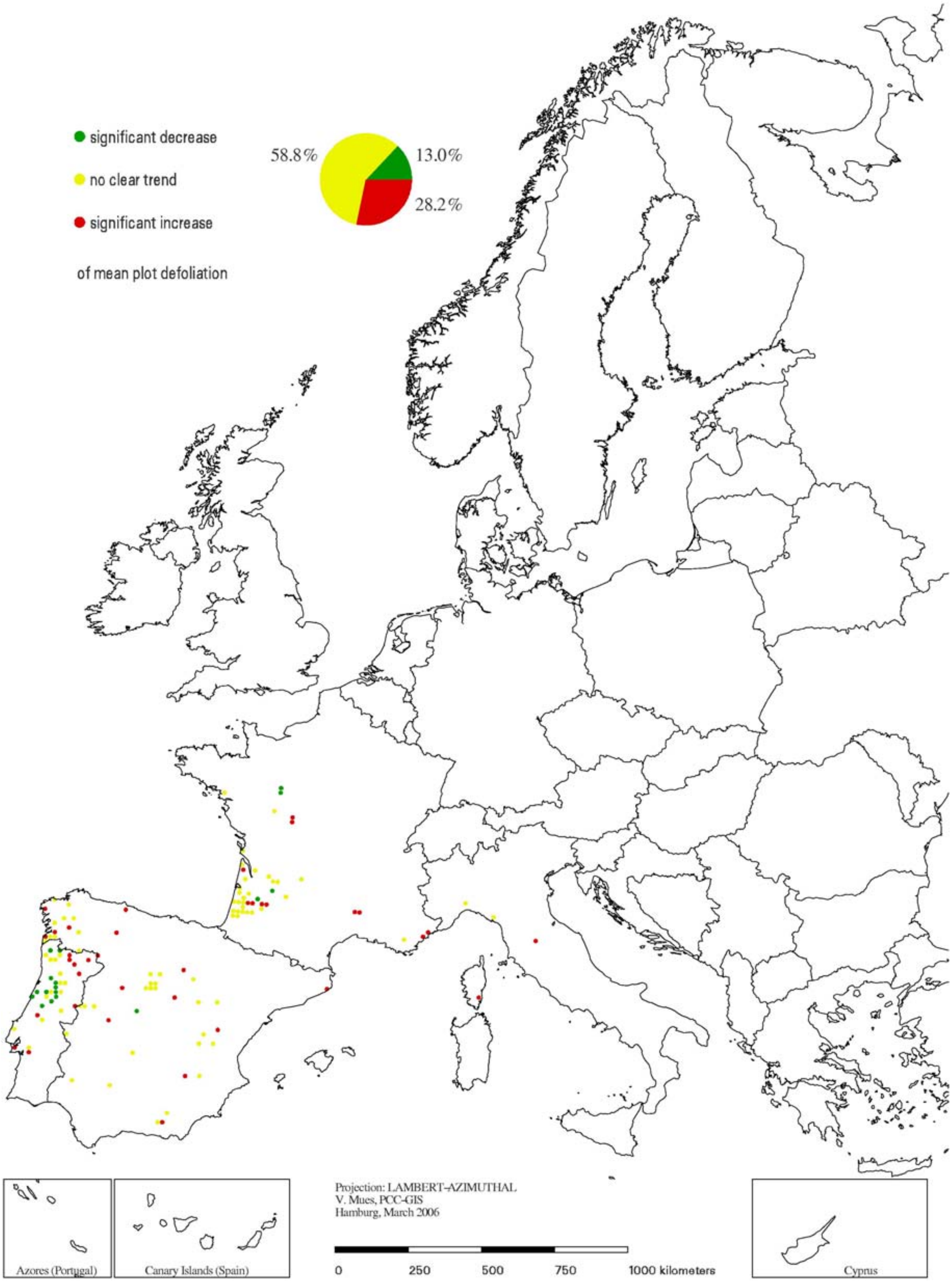

Figure 2.2.2.8-2: Trend of mean plot defoliation (slope of linear regression) of *Pinus pinaster* over the years 1997 to 2005.

2.2.3 Mortality

One of the problems in evaluation of mortality arises from the different ways of treating dead trees i.e. trees completely defoliated. In some countries trees with defoliation scores of 100% are removed, in other countries dead trees are kept in the database and are repeatedly reported as dead.

To avoid trees to be counted and qualified more than once as being dead, only trees that in a given year showed defoliation of 100% and in the subsequent year disappeared were considered as dead and included into the calculation of the mortality. As a sample suitable to reflect spatial and temporal changes in tree mortality, the time span from 2000 to 2005 was considered. By subdividing this sample into the time periods 2000 to 2002 and 2003 to 2005 the question was pursued if after extreme drought in 2003 a significant increase in the mortality of trees could be observed. The annual mortality as defined above and expressed in number of the dead trees and their share related to all trees sampled lies in all years below 0.5%. The increase in the year after the drought (2004) is negligible (Table 2.2.3-1 and Figure 2.2.3-1). The increase is larger in 2005, but given the small share of dead trees this must not necessarily be related to the drought.

Table 2.2.3-1: Annual mortality in 2000 to 2005.

Year	No. of sample trees	No. of dead trees	Mortality (%)
2000	13 2200	351	0.27
2001	13 2342	365	0.28
2002	13 1741	402	0.31
2003	13 1387	381	0.29
2004	13 5372	444	0.33
2005	13 3840	530	0.40

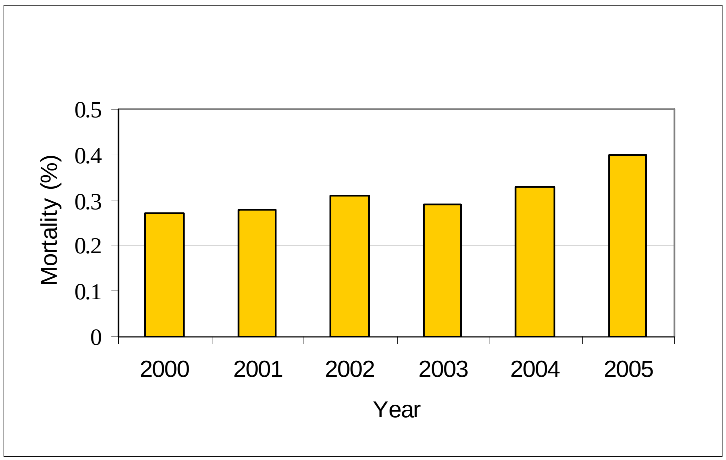

Figure 2.2.3-1: Development of the annual mortality between 2000 and 2005

In order to check if mortality increased in regions from which summer drought in 2003 was reported, it was mapped for the two periods 2000-2002 and 2003-2005 (not figured). Table 2.2.3-1 and Figure 2.2.3-1 comprise trees from all plots whose mortality dynamics range from only one tree scored as completely defoliated and disappeared up to all or almost all trees dying from one to the next assessment year. The different number of dead trees on plots was accounted for in the legend categories of the maps.

The overwhelming majority of plots experienced in both time periods only a slight mortality rate ranging from 1 to 5 trees per plot. The share of these plots is hardly different before (91.1%) and after the drought in 2003 (90.9%). The share of plots with more than 20 dead trees decreased in the time period 2003 to 2005 as compared to 2000-2002 from 3.5 to 1.8%. The spatial distribution of the plots (more or less affected by mortality) is similar in both maps. However, southern France shows an increase in the number of plots with 1 to 5 dead trees. Regions showing an increase in the number of dead trees per plot are southern Sweden as well as Spain and Bulgaria. Mortality in southern Sweden was caused by wind throw and an outbreak of *Gremmeniella abietina* (fungi affecting buds). Due to extended periods of drought mortality of trees (mainly with *Quercus* species and *Pinus halepensis*) increased in Spain in 2004 and 2005.

2.2.4 Further damage symptoms and their causes

Until 2004, the presence of the following damage types was reported (Chapter 2.1.3.1):

Game and grazing, insects, fungi, abiotic agents, direct action of man, fire, known regional air pollution, and other factors (T1-T8).

In 2005, a new system for the assessment of damage causes on Level I and Level II plots was implemented. The following 17 countries reported data according to the new method:

Austria, Belarus, Belgium (Flanders), Cyprus, Czech Republic, Finland, France, Italy, Latvia, Lithuania, Luxemburg, Norway, Poland, Slovak Republic, Spain, Sweden, United Kingdom.

The new method aims at providing information on the impact of damage factors on crown condition. It gives more detailed information on symptoms, causes and extent of the damage as follows:

- <u>Symptom description</u>
  Symptoms are divided into broad categories, e.g. wounds, necroses and deformations. Each symptom can be described more in detail. For instance, wounds are divided into cracks, debarking, and others. In addition, symptoms observed in the crown can be allocated to different parts of the crown (lower crown, upper crown, patches).

- <u>Determination of the cause</u>
  The damage causes are described in a hierarchical system. In the first step the previous categories (T1-T8) are maintained. However, in each category, a more detailed determination is possible. The most detailed level of the hierarchical system comprises the scientific names of the organisms involved.

- <u>Extent of damage</u>
  The extent of the damage is given as the percentage of the affected part of the tree (e.g. % of leaves eaten by defoliators).

In the following evaluation all trees submitted in tables prescribed for the detailed assessment of damage types are included into calculations. Of the 133 840 trees assessed for defoliation in 2005, about 66% (88 334 trees) were examined using the new damage type system. As different i.e. multiple damage types could be specified for a single tree the number of observations in tables presented below is much larger than 88 334.

Table 2.2.4-1 lists the most frequently assessed symptoms for each of the three parts of the trees. For each symptom the number of observations is given, i.e. the frequency with which the particular symptom was reported. Of the total number of observations, nearly one third were made on needles and leaves. Over 23% of the observations were made on branches, shoots and buds. Only 0.4% of observations refer to the stem and collar.

In 2005 nearly 15% of the observations refers to missing or devoured leaves and needles, followed by dead or dying branches and shoots. Discolouration constitutes the third largest share of observations (7.8%). That “missing or devoured leaves and needles” is a frequently observed symptom is not surprising: it reflects that defoliators are a quite common and widespread group of organisms in European forests. Moreover this symptom is easy to detect by the observers during crown condition assessment and may therefore be reported more frequently than other symptoms.
The shares of observations of all other symptoms are smaller. Deformations of needles and leaves comprise 4.5%, wounds on branches account for 4.2% of all observations. It is worth mentioning that the dozen of symptoms specified in Table 2.2.4-1 covers nearly all observations reported. Those symptoms on needles and leaves summarised as “other symptoms” account for only 1.2 % of the observations.

Table 2.2.4-1: Numbers and percentages of observations of symptoms in each part of the trees.

Affected part	Symptom	Number of observations	Percent
Needles and leaves	Partly or totally devoured/missing	18772	15.4
	Deformations	5428	4.5
	Light green to yellow discolouration	5526	4.5
	Red to brown discolouration (necrosis)	4061	3.3
	Signs of insects	2367	2.0
	Other signs	1512	1.3
	Signs of fungi	1126	0.9
	Microfilia	2050	1.7
	Other symptoms	1516	1.2
	Subtotal	42358	34.8
Branches, shoots and buds	Dead/dying	16372	13.5
	Wounds (debarking, cracks etc.)	5074	4.2
	Decay/rot	1948	1.6
	Resin flow (conifers)	1652	1.3
	Broken	1657	1.4
	Necrosis/necrotic parts	1213	1.0
	Other symptoms	447	0.4
	Subtotal	28363	23.4
Stem and collar	Various symptoms	591	0.4
Missing		50107	41.4
	Total	121419	100.0

Table 2.2.4-2 describes the affected part of the tree more in detail. The subtotals of the observations, however, are not the same as in Table 2.2.4-1 as the number of missing values vary among the evaluated parameters.

Table 2.2.4-2: Numbers and percentages of observations of tree parts affected.

Affected part		Number of observations	Percent
Needles and leaves	Broadleaves	19223	15.8
	Older needles	6005	4.9
	Needles of all ages	3864	3.2
	Current needle year	2763	2.3
	Subtotal	31855	26.2
Branches, shoots and buds	Current year shoots	879	0.7
	Twigs diameter < 2 cm	11506	9.5
	Branches diameter 2 <10 cm	5180	4.3
	Branches diameter => 10 cm	737	0.6
	Varying size	2428	2.0
	Top leader shoot	517	0.4
	Buds	91	0.1
	Subtotal	21338	17.6
Stem and collar	Main trunk or bole within the crown	1571	1.3
	Trunk between the collar and the crown	9475	7.8
	Whole trunk	939	0.8
	Roots (exposed) and collar (=< 25 cm)	3509	2.9
	Subtotal	**15494**	12.8
	Subtotal all three parts	68687	56.6
Dead tree		2677	2.2
No assessment		921	0.8
No symptoms on any part of trees		40856	33.6
Missing		8278	6.8
	Total	121419	100.0

The parameter “affected part” could be evaluated for 121419 observations (Table 2.2.4-2). Needles and leaves are reported most frequently as part of trees affected by damage agents (26.2%) followed by damage on branches, shoots and buds (17.6%). Stem and collar as damaged tree parts were found on 12.8% of all observations. The proportion of dead trees is surprisingly high (2.2%). No assessment was explicitly coded only in one country with 921 observations (0.8%) whereas other countries left out the specification completely when affected part could not be assessed resulting in 8278 missing values (6.8% of all observations).

The information specifying the location of the damage in the crown (mandatory only on Level II) was reported for 1 095 trees (Table 2.2.4-3).

Table 2.2.4-3: Numbers and percentages of observations for parameter “location in crown”

	Location in crown	Number of observations	Percent
Lower crown		681	62.2
Patches		357	32.6
Upper crown		57	5.2
	Total	1095	100.0

In the table below the most frequent causes of damage are compiled with information on number and percentages found. Only factors with a frequency 0.9% and more are presented separately.

Table 2.2.4-4: Numbers and percentages of observations of causes.

Cause	Number of observations	Percent
Defoliators	8273	6.8
Drought	5741	4.7
Dieback and canker fungi	3994	3.3
Stem, branch and twig borers	3532	2.9
Decay and root rot fungi	1300	1.1
Competition	1271	1.1
Needle cast and needle rust fungi	1132	0.9
Subtotal	25243	20.8
Investigated but unidentified	18768	15.4
Other causes	16004	13.2
Missing	61404	50.6
Total	121419	100.0

The largest share (6.8%) refers to defoliators. This is in line with the national reports on forest condition, where insects are often quoted as important damage causes. In 4.7% of all observations drought was found as a factor impairing the health of the trees. Different fungi groups occurring on leaves, needles and roots are also identified as causes of tree damage. In very few cases the individual damage agents were specified by their scientific names.

In this chapter some preliminary results of the new method for the assessment of damage causes are presented. These results indicate that this new method was implemented successfully and has proven to be operational in various forest types and on a large number of plots. Compared to the old method it provides more detailed information on the causes of the observed damage and allows to link these damage symptoms to certain damage factors. A major improvement is the availability of data on the severity of the stress factors and not only on their occurrence, increasing the potentials for cause – effect relationships. Keeping record of causal factors over the years will provide an interesting tool for quantifying their impact on tree health as well as their role in stand dynamics. It provides also new potentials for the assessment of combinations of stress factors and cumulative stresses.

3. INTENSIVE MONITORING

3.1 Introduction

The intensive monitoring aims to assess causal relationships on the forest ecosystem scale. For this purpose, more than 860 intensive monitoring (Level II) plots were selected in the most important forest ecosystems of 30 participating countries. Mandatory and hence to be carried out on all plots are annual assessments of crown condition, assessments of soil condition every ten years, bi-annual foliage chemistry surveys and forest growth studies every five years. Under the programme BioSoil a new soil survey is planned to be carried out on a limited number of Level II plots. Ground vegetation is assessed every five years on 715 plots. On 513 plots, atmospheric deposition is assessed continuously. Also continuously assessed are ambient air quality on 170 plots, soil solution chemistry on 242 plots and meteorology on 206 plots. Phenology is assessed several times per year on 64 plots. The complete methods of the intensive monitoring are laid down in the "Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests" (ANONYMOUS, 2004).

Results of the intensive monitoring have been presented in annual Technical Reports since 1997 (e.g. DE VRIES et al., 2003). Chapter 3.2 of the present report describes bulk and throughfall deposition as measured by the countries on their Level II plots until the year 2003. In Chapter 3.3, the measured depositions are compared with those depositions calculated with models by the Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe. Chapter 3.4 describes the effects of depositions on ground vegetation as assessed on Level II plots. Chapter 3.5 presents the approach and results of the application of dynamic models on Level II data aimed to estimate the future effects of depositions on forest soils.

3.2 Deposition and its trends

3.2.1 Introduction

Following the approach already described by LORENZ et al. (2005) for the calculation of deposition data from 1996 to 2001, deposition and its trends during the years 1998 to 2003 are presented in this section. Depositions, critical loads of depositions and exceedances of critical loads were presented by DE VRIES et al. (2002). ULRICH (2003) found linear trends in nitrogen, sulphur, calcium and magnesium concentration between 1992 and 2002 for the French intensive monitoring network "Renecofor". Mean concentrations of nitrogen and sulphur bulk depositions and their trends were presented by LORENZ et al. (2004).

A study of the temporal development and spatial variability of nitrate (N- NO_3^-), ammonium (N- NH_4^+) and sulphate (S- SO_4^{2-}) deposition on Level II plots from 1998 to 2003 is presented in this section. In addition, depositions of calcium (Ca), sodium (Na), and chlorine (Cl) as well as the amount of precipitation are taken into account whenever needed for a sound interpretation of the results.

3.2.2 Methods

The Level II data used were collected and analysed according to the ICP Forests Manual (ANONYMOUS 2004). The data employed for statistical analyses were checked and validated by the Forest Intensive Monitoring Coordinating Institute (FIMCI). Open field (bulk) deposition is measured in order to reflect the local air pollution situation. For assessments of air pollution effects on forests deposition under canopy throughfall and in some cases stemflow are measured. Deposition under canopy is mostly larger than in the open field as wet deposition is additionally polluted by dry deposition washed off the foliage. With respect to element fluxes in the forest canopy, two major processes can be observed during the passage of the deposition through the canopy:

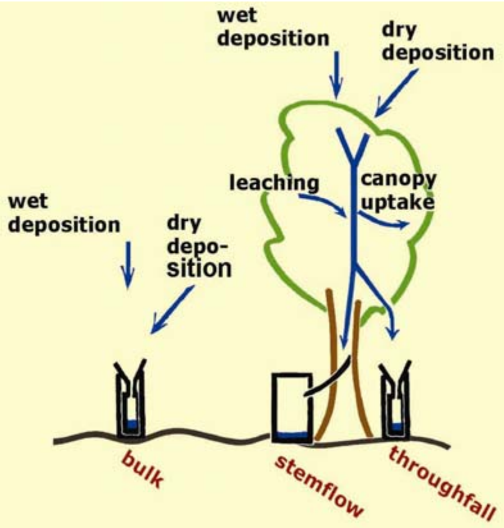

Figure 3.2.2-1: Deposition measurement in forests.

1. Leaching: The solution of an element, mostly of nutrient cations, from the tree crown into the precipitation water, which leads to an enrichment of the particular element in the throughfall deposition compared to bulk deposition.
2. Canopy uptake: The absorption of an element, mostly nitrogen compounds, from the precipitation water by the leaves which leads to decreased deposition of the particular element in the throughfall deposition compared to bulk deposition.

Both effects have to be taken into account when interpreting the results of this study related to throughfall deposition.

The study is based on the Level II data on bulk deposition measured in the open field and on throughfall deposition in order to describe the deposition under canopy. Due to the fact that stemflow data were available only for 17 plots continuously from 1998 to 2001 those measurements could not be taken into consideration which leads most probably to an underestimation of the throughfall deposition on these sites. A correction for sea salt impact was not calculated.

The variables subjected to the statistical analyses are bulk and throughfall deposition data expressed in terms of annual deposition in kg ha^{-1} a^{-1}. The time span for trend analyses was 1998 to 2003. This is a trade-off between the needs for high numbers of plots in order to cover a wide range of deposition situations and for the length of the time span. In fact, real trend analysis begins to make sense only for periods of at least 10 years and, thus, the present study must be understood as a case of descriptive analyses.

From the approximately 500 sites on which deposition is measured within ICP Forests, only those sites were selected which have been operational for the whole period 1998-2003, with a maximum of 1 month of missing data per year (s. Table 3.2.2-1). Deposition in missing periods was replaced by the respective average daily deposition of the remaining year.

For mapping and quantifying temporal developments, the slope of plot specific linear regression over the years of observation was used. Thus, with the years of assessment as predictor and annual deposition as target variable for each plot, linear relationships were obtained. The slopes of the linear equations were statistically tested and depicted in maps according to the following classification:

- Significant decrease: negative slope, error probability lower or equal 5% (green)
- Decrease: negative slope, error probability greater than 5% (light green)
- Significant increase: positive slope, error probability lower or equal 5% (red)
- Increase: positive slope, error probability greater than 5% (orange)
- no slope, same deposition in each year (grey)

In order to get information if trends for a particular ion are due to trends in precipitation the trends of deposition water amount were mapped as well. It must be stressed that conclusions about temporal changes in ion deposition based on such short time series can only be made with great reservations and do not have final character or validity.

In order to describe the high variability of deposition, the plot-wise mean deposition for a three years period (2001 to 2003) was mapped instead of deposition of a single year. The period 2001 to 2003 gives the most recent picture of the deposition situation. By selecting measurements from only 3 years a higher number of plots could be taken into account than in case of a longer time span (Table 3.2.2-1). For the mapping of mean deposition, percentile classes were chosen comprising the whole range of values found. The percentiles were calculated for the combination of bulk and throughfall values in order to permit a comparison between bulk and throughfall maps due to uniform threshold values.

Table 3.2.2-1: Number of plots which fulfilled the selection criteria.

No. of observations		Na^+	Cl^-	Ca^{2+}	N- NH_4^+	N- NO_3^-	S- SO_4^{2-}
Trend 1998 – 2003	Bulk	208	209	208	208	209	202
	Throughfall	239	240	239	239	240	233
Mean 2001 – 2003	Bulk	233	233	233	232	233	225
	Throughfall	265	265	265	264	265	267

3.2.3 Results

It must be clearly stated here that the throughfall deposition evaluated in this study does not reflect the total deposition. Neither the stemflow deposition nor the interactions between the canopy and the wet deposition are taken into account. The results are to be interpreted as a descriptive study in order to present the field measurements. All statements about the deposition quantities are intended to give a relative view of the deposition situation on the evaluated plots. No interpretations on absolute level are made.

3.2.3.1 Mean Annual Deposition 2001 to 2003

For ammonium, nitrate and sulphur as the most important anions in the acidification process the mean annual deposition in the period 2001 to 2003 was calculated in bulk as well as in throughfall deposition. To enable a sound interpretation of the results, in addition, calculations for sodium, chloride and calcium were done. Thus, Figure 3.2.3-1 shows the mean annual sodium (Na^+) bulk deposition in order to get an impression on which plots probably sea spray is an important source of sodium and sulphate deposition. Many of those plots which are in the class with highest sodium depositions are located close to the coast and seem to be influenced by sea spray effects.

Some of the plots on which relatively high sulphur bulk depositions were measured (Figure 3.2.3-2) also relatively high depositions of sodium are observed (Figure 3.2.3-1), e.g. at the west coast of the UK, in the south west of Norway or in Italy and Greece. On the other hand there are also plots with relatively high sulphur deposition in the Czech Republic, Slovakia, the west of Germany, and the North of Italy on which the relatively high sulphur deposition can not be linked to sea spray due to large distances to the coast and surrounding plots with lower sulphur deposition. Thus, the combined interpretation of sodium and sulphur depositions permits an identification of plots with relatively high sulphur depositions which are most probably of anthropogenic origin.

For the mean annual throughfall deposition of sulphate (Figure 3.2.3-3) a higher number of plots with relatively high deposition values were observed. These are located in Central Europe, the United Kingdom and the south of Sweden and Norway. The classification of the values used for the mapping of sulphur bulk and throughfall deposition is uniform. The share of plots in the classes with relatively high sulphur deposition is higher for throughfall than for bulk deposition.

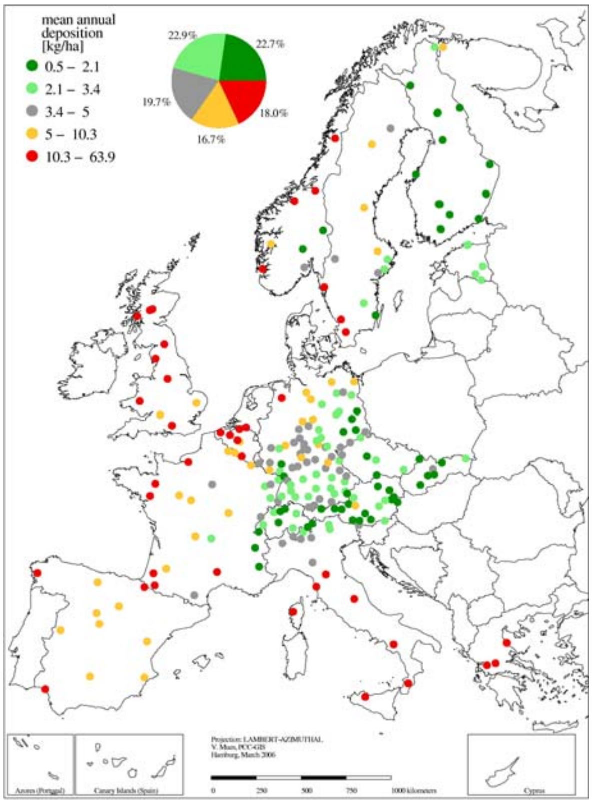

Figure 3.2.3-1: Mean annual sodium (Na^{+}) bulk deposition 2001 to 2003.

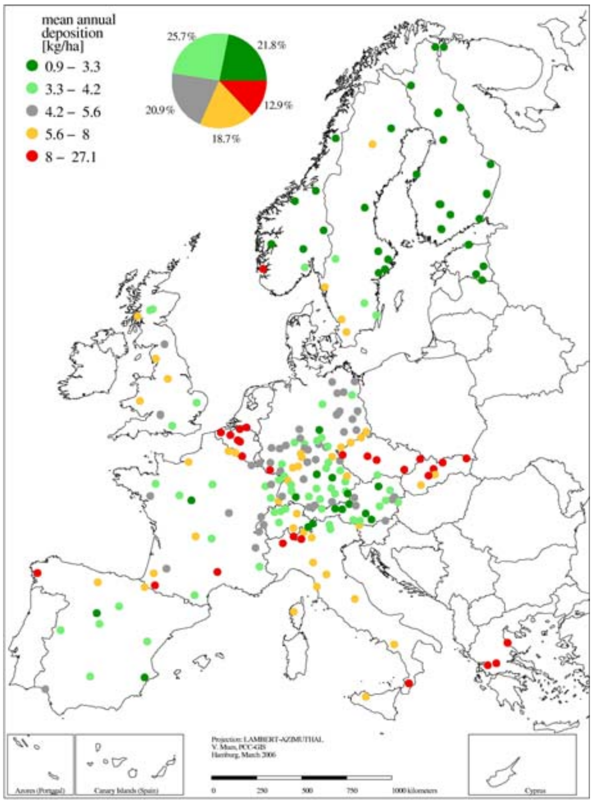

Figure 3.2.3-2: Mean annual sulphate (S- SO_4^{2-}) bulk deposition 2001 to 2003.

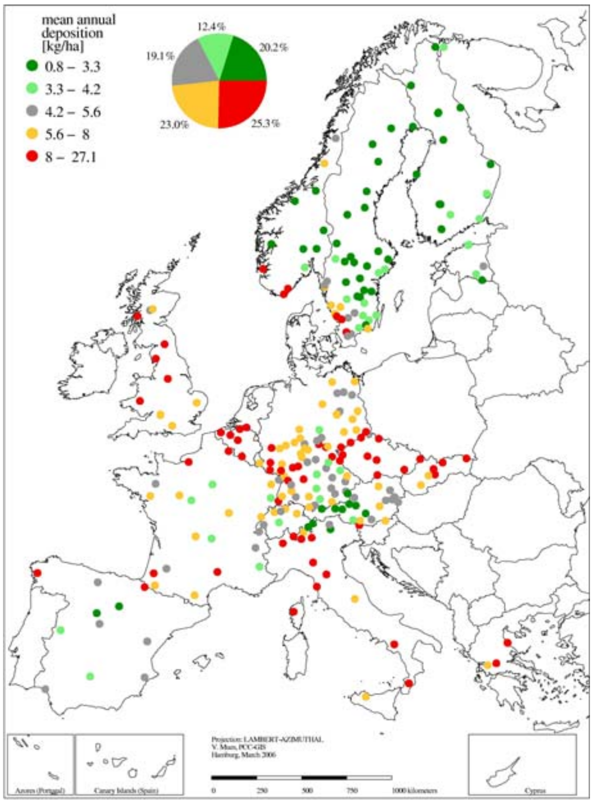

Figure 3.2.3-3: Mean annual sulphate (S- SO_4^{2-}) throughfall deposition 2001 to 2003.

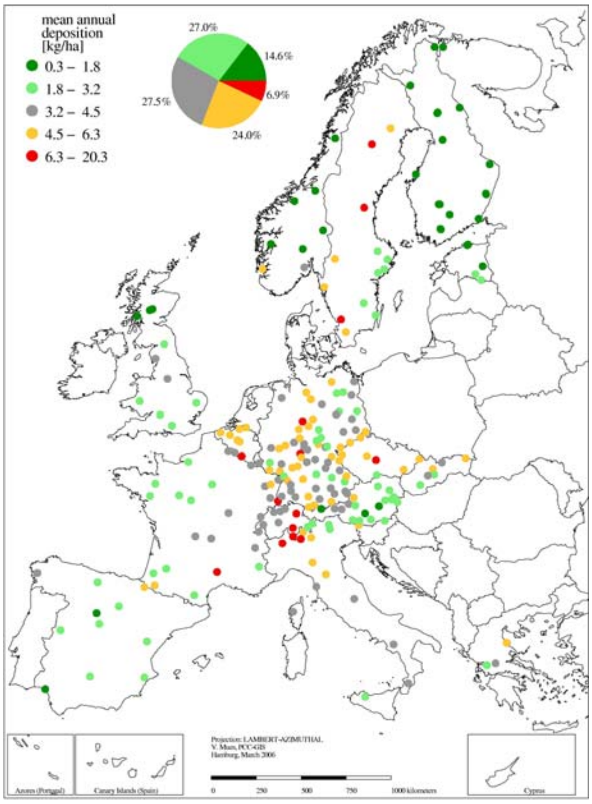

Figure 3.2.3-4: Mean annual nitrate (N- NO_3^-) bulk deposition 2001 to 2003.

As traffic is a major source of nitrate depositions relatively high values for the mean annual nitrate bulk deposition (Figure 3.2.3-4) are measured in Central Europe. But also in Sweden and in northern Italy relatively high values are found.

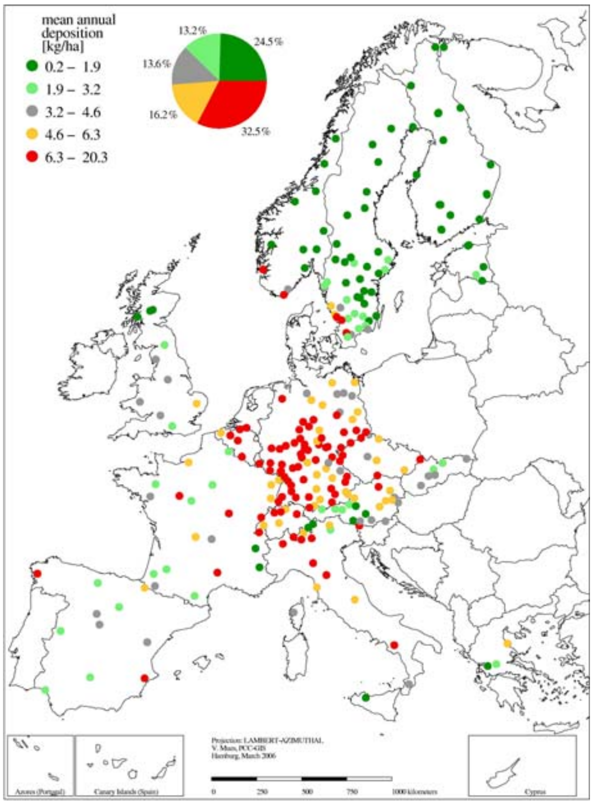

Figure 3.2.3-5: Mean annual nitrate (N- NO_3^-) throughfall deposition 2001 to 2003.

As already described for sulphur the amount of nitrate is relatively higher in throughfall (Figure 3.2.3-5) than in bulk deposition on the evaluated plots. Whereas for bulk deposition only 6.9% were found in the highest deposition class, for throughfall deposition the share of plots in the highest nitrate deposition class (6.3 to 20.3 kg ha^{-1} a^{-1}) is 32.5%. On most plots for which high bulk deposition values were calculated also high throughfall deposition values were found but there are also some exceptions. E.g. in northern Sweden high nitrate bulk deposition and relatively low nitrate throughfall deposition are observed for the same plots. This could be an indication for N-uptake during the rain passage through the canopy (Chapter 3.2.2).

Similar to the findings for nitrate the mean annual depositions of ammonium are high on plots in Central Europe and in case of bulk deposition also in Sweden (Figure 3.2.3-6). For nitrate two observations can be made which are described above also for ammonium: Throughfall deposition is higher than bulk deposition on most plots and there are also plots with the opposite relation (Sweden and northern England).

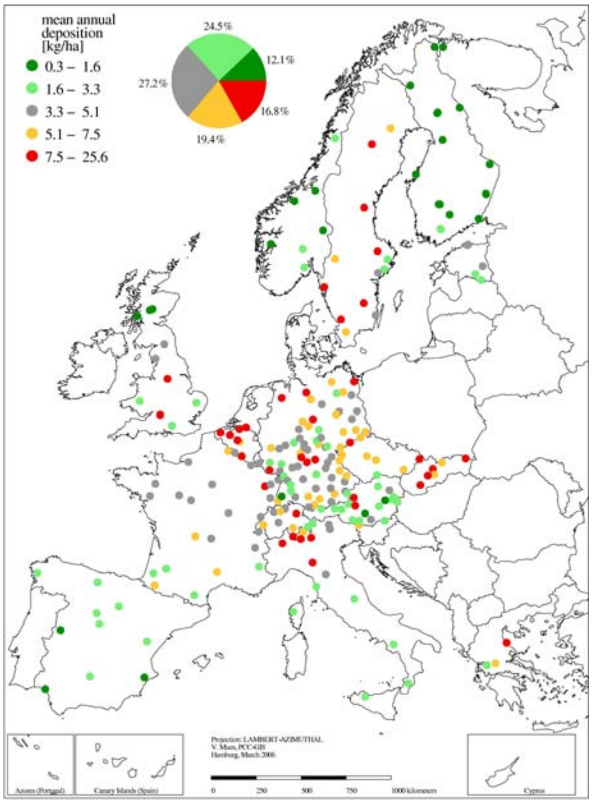

Figure 3.2.3-6: Mean annual ammonium (N- NH_4^+) bulk deposition 2001 to 2003.

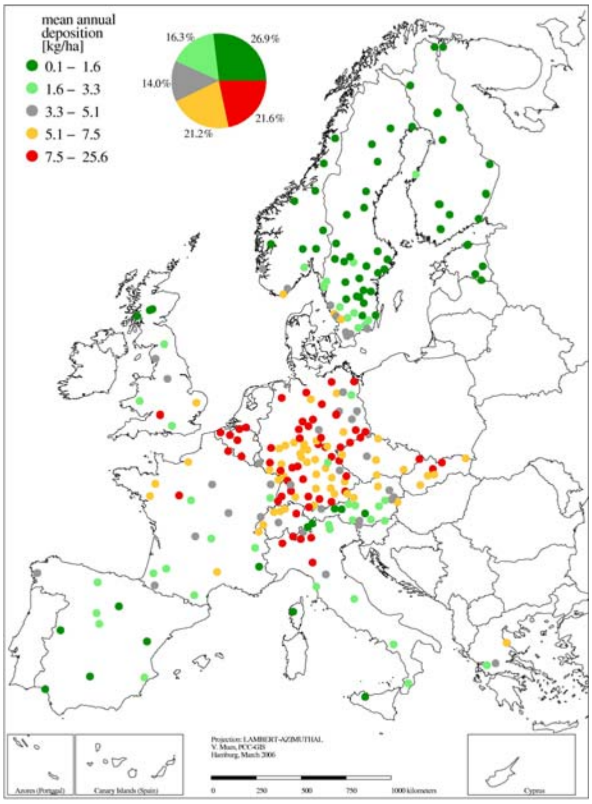

Figure 3.2.3-7: Mean annual ammonium (N- NH_4^+) throughfall deposition 2001 to 2003.

3.2.3.2 Trends

Mean annual deposition shows a reduction for sulphate and a less clear development for ammonium and nitrate deposition from 1998 to 2003 (Figure 3.2.3-8). Sulphur throughfall deposition decreases from almost 9.3 kg ha^{-1} a^{-1} in 1998 to 5.8 kg ha^{-1} a^{-1} in 2003. The reduction of bulk deposition from 6.5 to 4.3 kg ha^{-1} a^{-1} is at a relatively lower level but consistent with the reduction in throughfall deposition. As further results show the deposition situation is of high variation on the examined Level II plots and the results of this study cannot be ex-

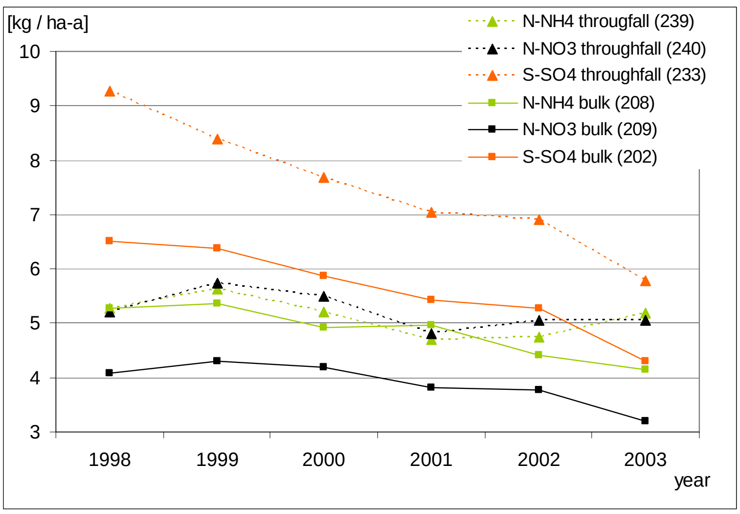

Figure 3.2.3-8: Mean annual deposition of sulphate, nitrate and ammonium in bulk and throughfall deposition.

trapolated to entire Europe. This is also true due to the fact that the Level II plots are not representative for Europe but a selection of typical forest types all over Europe.

The mean depositions of nitrogen compounds are of low variability at relatively low level. Nevertheless, especially in Central Europe there are some plots with relatively high nitrogen deposition. Especially in bulk deposition a decrease is observed. Two very interesting observations can be made for the year 2003 which was characterised by a very hot and dry summer in Central Europe. Whereas throughfall deposition for nitrate and especially for ammonium increased from 2002 to 2003 a decrease for the other deposition compounds can be observed. A possible explanation for this could be the main source for ammonium, namely intensive agriculture and cattle breeding. Gaseous emissions due to intensive cattle breeding can be expected to be higher with higher temperatures.

In order to permit a sound interpretation of the development of deposition and due to the fact that the amounts of bulk deposition and throughfall deposition depend on the amount of wet deposition it is a basic need to know the trend of precipitation. The plot specific trends of the amount of water in bulk deposition are not figured. Mean annual precipitation decreased on more than 80% of the evaluated plots in opposite to the period 1996 to 2001 (on less than 30% of the plots). This reflects most probably the very dry summer 2003 in Central Europe.

Following the described positive correlation between the amount of precipitation and deposition one should expect decreasing deposition on most plots during the evaluation period. This expectation is fulfilled e.g. in northern Finland where statistically significant decrease of precipitation coincides with statistically significant decrease in nitrate bulk deposition (Figure 3.2.3-9). The opposite relation can be observed for a plot in eastern Austria where a significant increase in nitrate bulk deposition coincides with a (not significant) decrease in precipitation.

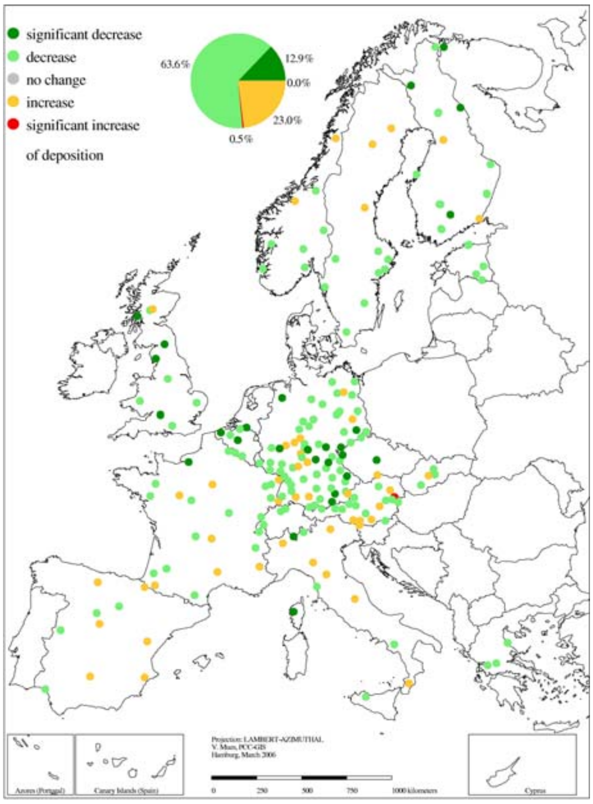

Figure 3.2.3-9: Trends of nitrate (N- NO_3^-) in bulk deposition 1998 to 2003.

Most probably due to the dry summer in 2003 on most plots in Central Europe the amount of water in bulk deposition, the precipitation, decreased during the observed period. This decrease was statistically significant only on some plots in Scandinavia, the UK, the north of France and on Sicily. The trends in bulk deposition of nitrate (Figure 3.2.3-9) and of ammonium (Figure 3.2.3-12), in general, reflect this decrease by a respective decrease in deposition. The opposite can be observed for nitrate and ammonium throughfall deposition on a number of plots in Central Europe: throughfall deposition increased from 1998 to 2003 (Figure 3.2.3-10 and Figure 3.2.3-11). The contrary observations for bulk and throughfall deposition are most probably caused by the relatively high amount of dry deposition in throughfall deposition. The filtering effect of trees seems to be even more important and effective in dry years.

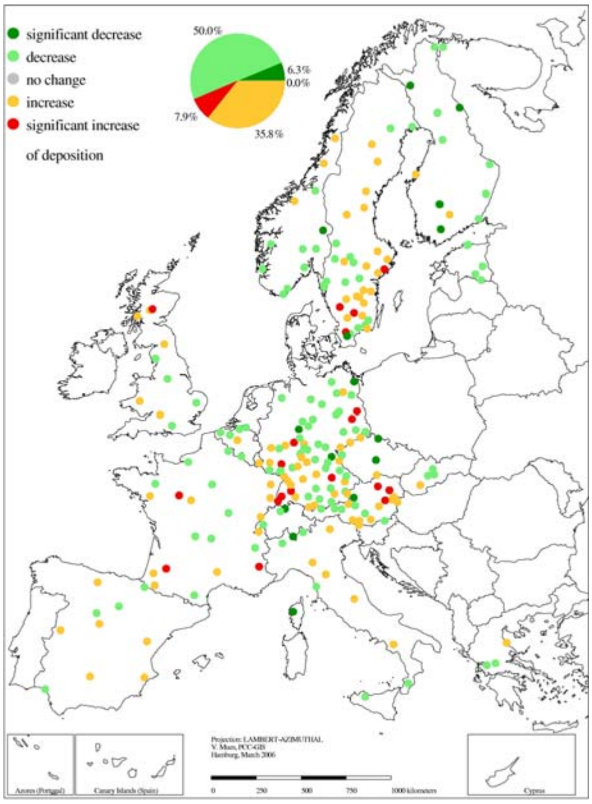

Figure 3.2.3-10: Trends of nitrate (N- NO_3^-) in throughfall deposition 1998 to 2003.

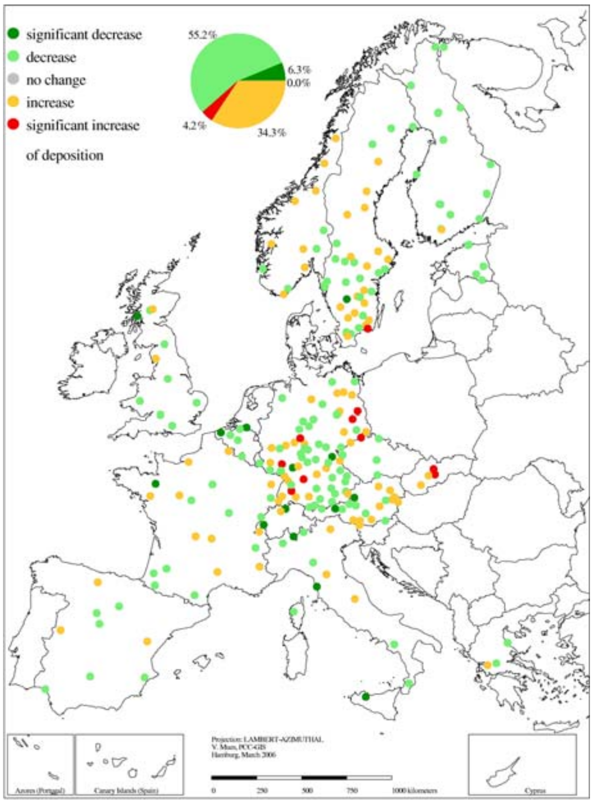

Figure 3.2.3-11: Trends of ammonium (N- NH_4^+) in throughfall deposition 1998 to 2003.

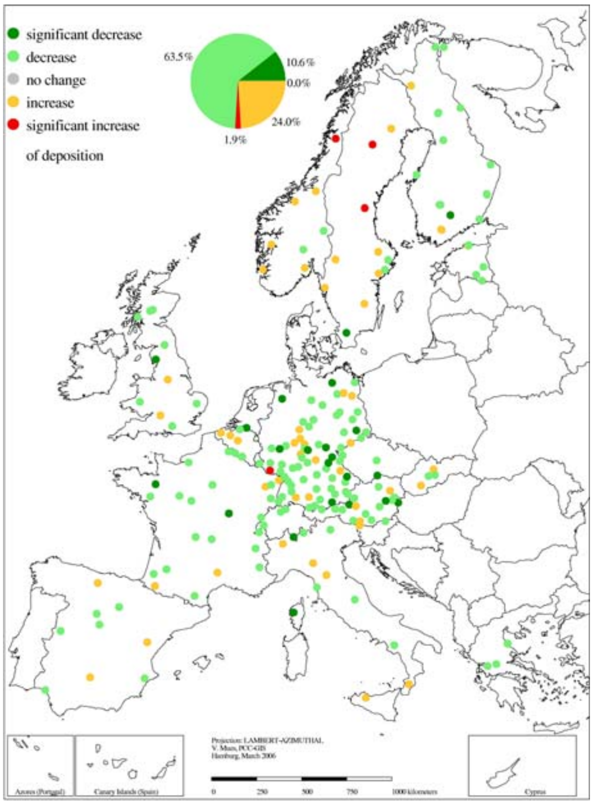

Figure 3.2.3-12: Trends of ammonium (N-NH_4^+) in bulk deposition 1998 to 2003.

The only exceptions from the positive correlation between precipitation and deposition in bulk deposition were found for ammonium in northern Sweden and Norway and on one plot in western Germany (Figure 3.2.3-12) where a significant increase in deposition was observed although precipitation decreased during the evaluation period (not figured). Interestingly, this increase in bulk deposition did not coincide with a respective increase in the throughfall deposition which might be explained by N-uptake.

The same observation - increase in bulk but decrease in throughfall deposition – is made for sulphur in the north of Sweden (Figure 3.2.3-13 and Figure 3.2.3-14). Most plots show a decrease in bulk deposition as well as in throughfall deposition which may reflect the decrease in wet deposition / precipitation.

The highest frequency of plots with statistically significant decrease in deposition was found for sulphur throughfall deposition with 30.9% (Figure 3.2.3-13), on 59.7% of the plots a decrease was found but not significantly.

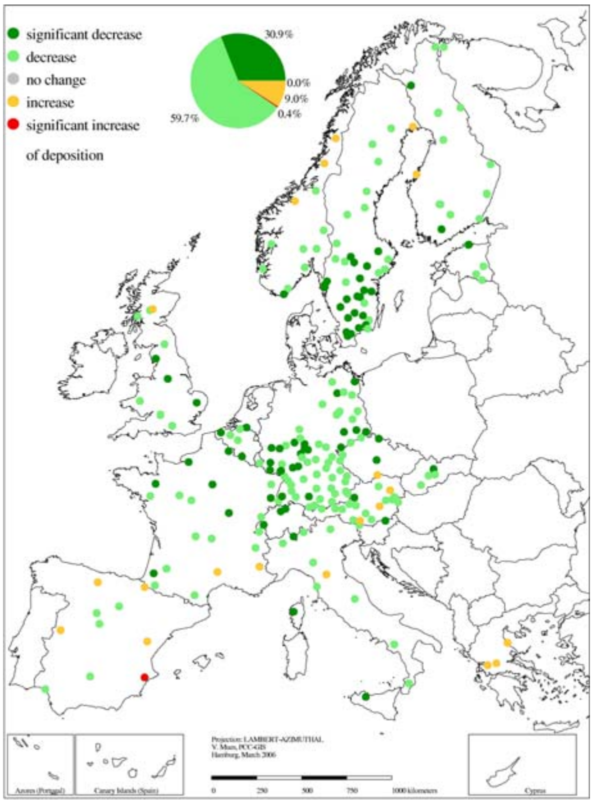

Figure 3.2.3-13: Trends of sulphate (S- SO_4^{2-}) in throughfall deposition 1998 to 2003.

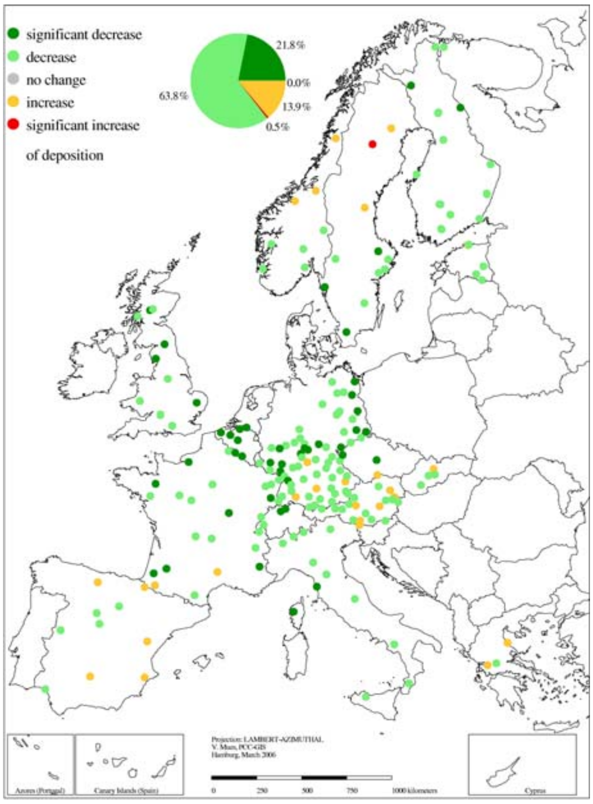

Figure 3.2.3-14: Trends of sulphate (S- SO_4^{2-}) in bulk deposition 1998 to 2003.