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Institute for World Forestry

Forest Condition in Europe

2008 Technical Report of ICP Forests

by

M. Lorenz [1)], R. Fischer [1)], G. Becher [1)], O. Granke [1)],
W. Seidling [2)], M. Ferretti [3)] M. Schaub [4)], V. Calatayud [5)], G. Bacaro [3)], G. Gerosa [6)], D. Rocchini [3)], M. Sanz [5)]

von Thünen-Institute, Institute for World Forestry

[1)] von Thünen-Institute, Institute for World Forestry, [2)] von Thünen-Institute, Institute of Forest Ecology and Forest Inventory, [3)]TerraData, [4)]Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), [5)]Fundación Centro de Estudios Ambientales del Mediterráneo – CEAM, [6)]Dipartimento di Matematica e Fisica "Niccolò Tartaglia", Università Cattolica del S.C. Brescia

Johann Heinrich von Thünen-Institute
Federal Research Institute for Rural Areas, Forestry and Fisheries
Address: Leuschnerstr. 91, D-21031 Hamburg, Germany
Postal address: P.O. Box: 80 02 09, D-21002 Hamburg, Germany

Phone: +40 / 73962-101
Fax: +40 / 73962-299
E-mail: weltforst@vti.bund.de
Internet: http://www.vti.bund.de
http://www.icp-forests.org

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Programme Coordinating Centre (PCC)
von Thünen-Institute, Institute for World Forestry
Leuschnerstr. 91
D-21031 Hamburg
Germany

Authors

M. Lorenz [1)], R. Fischer [1)], G. Becher [1)], O. Granke [1)], W. Seidling [2)], M. Ferretti [3)]
M. Schaub[4)], V. Calatayud [5)], G. Bacaro [3)], G. Gerosa [6)], D. Rocchini [3)], M. Sanz [5)]

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[1)] von Thünen-Institute, Institute for World Forestry, [2)] von Thünen-Institute, Institute of Forest Ecology and Forest Inventory, [3)]TerraData, [4)]Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), [5)]Fundación Centro de Estudios Ambientales del Mediterráneo – CEAM, [6)]Dipartimento di Matematica e Fisica "Niccolò Tartaglia", Università Cattolica del S.C. Brescia

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PREFACE

Forests provide a wealth of benefits to the society but are at the same time subject to numerous natural and anthropogenic impacts. For this reason several processes of international environmental and forest politics were established and the monitoring of forest condition is considered as indispensable by the countries of Europe. 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 the framework of the Convention on Long-range Transboundary Air Pollution (CLRTAP) under the United Nations Economic Commission for Europe (UNECE). The number of countries participating in ICP Forests has meanwhile grown to 41 including Canada and the United States of America, rendering ICP Forests one of the largest biomonitoring networks of the world.

ICP Forests has been chaired by Germany from the beginning on. It is coordinated by the Institute for World Forestry of the Johann Heinrich von Thünen-Institute (vTI). The vTI is the legal successor of the former Federal Research Centre for Forestry and Forest Products. The Institute for World Forestry will continue to host the Programme Coordinating Centre (PCC) of ICP Forests.

Aimed mainly at the assessment of effects of air pollution on forests, ICP Forests provides scientific information to CLRTAP as a basis of legally binding protocols on air pollution abatement policies. For this purpose ICP Forests developed a harmonised monitoring approach comprising a large-scale (Level I) as well as an intensive (Level II) monitoring approach laid down in the ICP Forests Manual. The participating countries have obliged themselves to submit their monitoring data to PCC for validation, storage, and analysis.

The monitoring, the data management and the reporting of results used to be conducted in close cooperation with the European Commission (EC). EC co-financed the work of PCC and of the Expert Panels of ICP Forests as well as the monitoring by the EU-Member States until 2006. Whilst ICP Forests will continue to focus on air pollution effects on forests in fulfilling its obligations under CLRTAP, its well developed monitoring system will be useful also for the other processes of international environmental politics. This holds true in particular for 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. For this reason the EU-Member States are striving for a continuation and thematic widening of forest monitoring in Europe in cooperation with EC for the benefit of a multitude of stakeholders including ICP Forests.

SUMMARY

Of the 41 countries participating in ICP Forests, 30 countries reported national results of crown condition surveys in the year 2007 for 193 466 trees on 12 601 plots. The transnational result on the European-wide scale relied on 104 399 trees on 4 834 plots of the 16 x 16 km grid in 27 out of 35 participating countries.

Mean defoliation of all sample trees of the transnational survey was 20.5%. Of the main species, *Quercus robur* and *Q. petraea* had by far the highest mean defoliation (25.5%), followed by *Fagus sylvatica* (21.2%), *Picea abies* (19.5%) and *Pinus sylvestris* (18.0%). These figures are not comparable to those of previous reports because of fluctuations in the plot sample, mainly due to changes in the participation of countries. Therefore, the long-term development of defoliation was calculated from the monitoring results of those countries which have been submitting data since 1990 every year without interruption. In the period of observation the species group *Quercus ilex* and *Quercus rotundifolia* shows the severest increase in defoliation, with 10.3% in 2000 and 22.2% in 2007. A similar increase in defoliation, namely from 11.1% to 20.4%, was experienced by *Pinus pinaster*. Defoliation of these Mediterranean species is largely attributed to several summer drought events in recent years. In the same period defoliation of *Fagus sylvatica* increased from 17.9% to 20.9%. In contrast, crown condition of *Pinus sylvestris* continued its recuperation. After having reached a peak in defoliation with 27.9% in 1994, defoliation decreased to 20.2% in 2007. Being less sensitive to drought, *Pinus sylvestris* showed no rise in defoliation even after the dry summer of the year 2003. *Picea abies* as well as *Quercus robur* and *Quercus petraea* continue their decrease in defoliation since their highs in 2004 which constituted a response to the drought of 2003.

As a basis of ongoing and future studies the spatial and temporal variation of bulk deposition and throughfall of sulphate, nitrate, ammonium, calcium, sodium and chlorine was analysed. Between 185 and 249 intensive monitoring plots were involved in the study. Mean deposition of the years 2003 - 2005 shows spatial patterns reflecting partly regional emission situations. The temporal variation was calculated for the period 2000 - 2005. Bulk deposition and throughfall of sulphate are highest but show the most pronounced decrease. Sulphur throughfall decreased from 7.9 kg ha^{-1} yr^{-1} in 2000 to 5.9 kg ha^{-1} yr^{-1} in 2005. Bulk deposition shows a similar decrease at a lower level, namely from 6.0 kg ha^{-1} yr^{-1} in 2000 to 4.6 kg ha^{-1} yr^{-1} in 2005. Nitrogen deposition is lower than sulphur deposition in most years and shows a less pronounced rate of decrease.

The exceedances of critical loads for acidity and nitrogen presented in last year’s report were compared with defoliation and its temporal variation. For *Fagus sylvatica* higher defoliation coincides with higher exceedances of nitrogen deposition. No relationships between defoliation and critical load exceedances were found for *Pinus sylvestris*, *Picea abies*, *Quercus robur* and *Quercus petraea*.

Passive sampler data collected from 91 Level II sites were used to compare mean summer concentrations for the years 2000 – 2004. Highest mean concentrations were observed in the exceptionally hot year 2003. Based on the passive sampler data of a subset of these plots, AOT 40 values were modelled. In all years the UNECE critical level of 5000ppb*h was exceeded on more than 75% of the plots. Occurrence of visible ozone injury was evaluated for plots in Spain, Switzerland and Italy. Positive but insignificant relationships were found between the proportion of plant species with ozone symptoms and ozone concentrations as well as modelled AOT 40 exposures. Ozone flux was modelled for five sites with sufficient monitoring data. Results show that stomatal conductance of O_3 may substantially differ from measured ozone concentrations. Thus, flux modeling allows for a more precise ozone risk assessment. However, the extensive data requirements are a severe constraint for this approach.

1. INTRODUCTION

The present Technical Report on Forest Condition in Europe refers to the results of the large-scale transnational survey of the year 2007 and presents results of individual studies of the intensive monitoring data made available by the year 2005. The report is structured as follows:

Chapter 2 describes the sampling of the plots and the trees, the assessment of crown condition, the analyses of the monitoring data, and the results of the large-scale (Level I) survey. In the description of the spatial and temporal variation of crown condition at the European-wide scale, emphasis is laid upon the current status and the development of crown condition with respect to species and regions.

Chapter 3 presents latest results of the intensive (Level II) monitoring. First of all, the annually reported results of the measurements of bulk deposition, throughfall deposition and their trends are updated 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). Also in Chapter 3, the exceedances of critical loads for acidification and eutrophication on Level II plots are compared with forest ecosystem response including changes in species diversity. Moreover, ozone concentrations, ozone impacts on vegetation and the further development of the flux approach are described.

Chapter 4 consists of national reports by the participating countries, focussing on crown condition in 2007 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 some of the 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 2007

2.1.1 Background

The following sections describe the selection of sample plots, the assessment of stand and site characteristics, the assessment of crown condition and the assessment of damage types within the large scale survey (Level I). The complete methods of forest condition monitoring by ICP Forests are described in detail in the "Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests" (ANONYMOUS, 2004a).

2.1.2 Selection of sample plots

2.1.2.1 The transnational survey

The transnational survey reveals the spatial and temporal variation of forest condition at the European-wide scale in relation to natural as well as anthropogenic stress factors - in particular air pollution. It is based on a large-scale 16 x 16 km transnational grid of sample plots. The coordinates of this grid were calculated and provided to the participating countries by EC. In case of already existing plots in a country, these were accepted if the mean plot density resembled that of a 16 x 16 km grid, and if the assessment methods corresponded to those of the ICP Forests Manual and the relevant Commission Regulations. In many countries the plots of the transnational grid constitute a sub-sample of a denser national grid (Chapter 2.1.2.2).

In 2007 crown condition was assessed on 4 834 plots in 27 countries (Table 2.1.2.1-1). The number of plots was by about one fifth lower than in 2006 because some countries did not assess crown condition in 2007. From Turkey, however, defoliation was reported for the first time from 46 plots. These plots are part of the 16 x 16 km grid currently established in Turkey (LORENZ et al. 2007). In addition, 13 plots were assessed on the Canary Islands. They are shown in the respective maps, but not included in the transnational evaluation as they are not located in those geoclimatic regions to which all other plots were assigned. These geoclimatic regions are adapted from those defined by WALTER et al. (1975) and by 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. The spatial distribution of the plots assessed in 2007 in these regions is shown in Figure 2.1.2.1-1. The figures in Table 2.1.2.1-1 are not necessarily identical to those published in previous reports, because previous data may in principle be changed due to consistency checks and subsequent data corrections as well as new data submitted by countries.

Table 2.1.2.1-1: Number of sample plots assessed for crown condition from 1995 to 2007.

Country	Number of sample plots assessed												
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Austria	76	130	130	130	130	130	130	133	131	136	136	135	
Belgium	29	29	29	29	30	29	29	29	29	29	29	27	27
Bulgaria	119	119	119	134	114	108	108	98	105	103	102	97	104
Cyprus							15	15	15	15	15	15	15
Czech Republic	199	196	196	116	139	139	139	140	140	140	138	136	132
Denmark	24	23	22	23	23	21	21	20	20	20	22	22	19
Estonia	90	91	91	91	91	90	89	92	93	92	92	92	93
Finland	455	455	460	459	457	453	454	457	453	594	605	606	593
France	543	540	540	537	544	516	519	518	515	511	509	498	504
Germany	417	420	421	421	433	444	446	447	447	451	451	423	419
Greece	95	95	94	93	93	93	92	91			87		
Hungary	63	60	58	59	62	63	63	62	62	73	73	73	72
Ireland	21	21	21	21	20	20	20	20	19	19	18	21	30
Italy	207	207	181	177	239	255	265	258	247	255	238	251	238
Latvia	94	99	96	97	98	94	97	97	95	95	92	93	93
Lithuania	73	67	67	67	67	67	66	66	64	63	62	62	62
Luxembourg	4	4	4	4	4	4		4	4	4	4	4	4
The Netherlands	13	12	11	11	11	11	11	11	11	11	11	11	
Poland	432	431	431	431	431	431	431	433	433	433	432	376	458
Portugal	141	142	144	143	143	143	144	145	136	133	119	118	
Romania	241	224	237	235	238	235	232	231	231	226	229	228	
Slovak Republic	111	110	110	109	110	111	110	110	108	108	108	107	107
Slovenia	42	42	42	41	41	41	41	39	41	42	44	45	44
Spain	454	447	449	452	598	607	607	607	607	607	607	607	607
Sweden	726	766	758	764	764	769	770	769	776	775	784	790	
United Kingdom	63	79	82	88	85	89	86	86	86	85	84	82	32
EU	4732	4809	4793	4732	4965	4963	4985	4978	4868	5020	5091	4919	3653
Andorra										3		3	3
Belarus			416	416	408	408	408	407	406	406	403	398	400
Croatia	82	83	86	89	84	83	81	80	78	84	85	88	83
Moldova	11	10	10	10	10	10	10						
Norway	386	387	386	386	381	382	408	414	411	442	460	463	476
Russian Fed.	126												
Serbia									103	130	129	127	125
Switzerland	47	49	49	49	49	49	49	49	48	48	48	48	48
Turkey													46
Total Europe	5384	5338	5740	5682	5897	5895	5941	5928	5914	6133	6216	6046	4834

Table 2.1.2.1-2: Distribution of the sample plots assessed in 2007 over the climatic regions.

Climatic region	Number of plots	Percentage of plots
Boreal	718	14.9
Boreal (Temperate)	656	13.6
Atlantic (North)	214	4.4
Atlantic (South)	268	5.5
Sub-atlantic	1103	22.9
Continental	202	4.2
Mountainous (North)	321	6.6
Mountainous (South)	500	10.3
Mediterranean (Higher)	373	7.7
Mediterranean (Lower)	479	9.9
All regions	4834	100.0

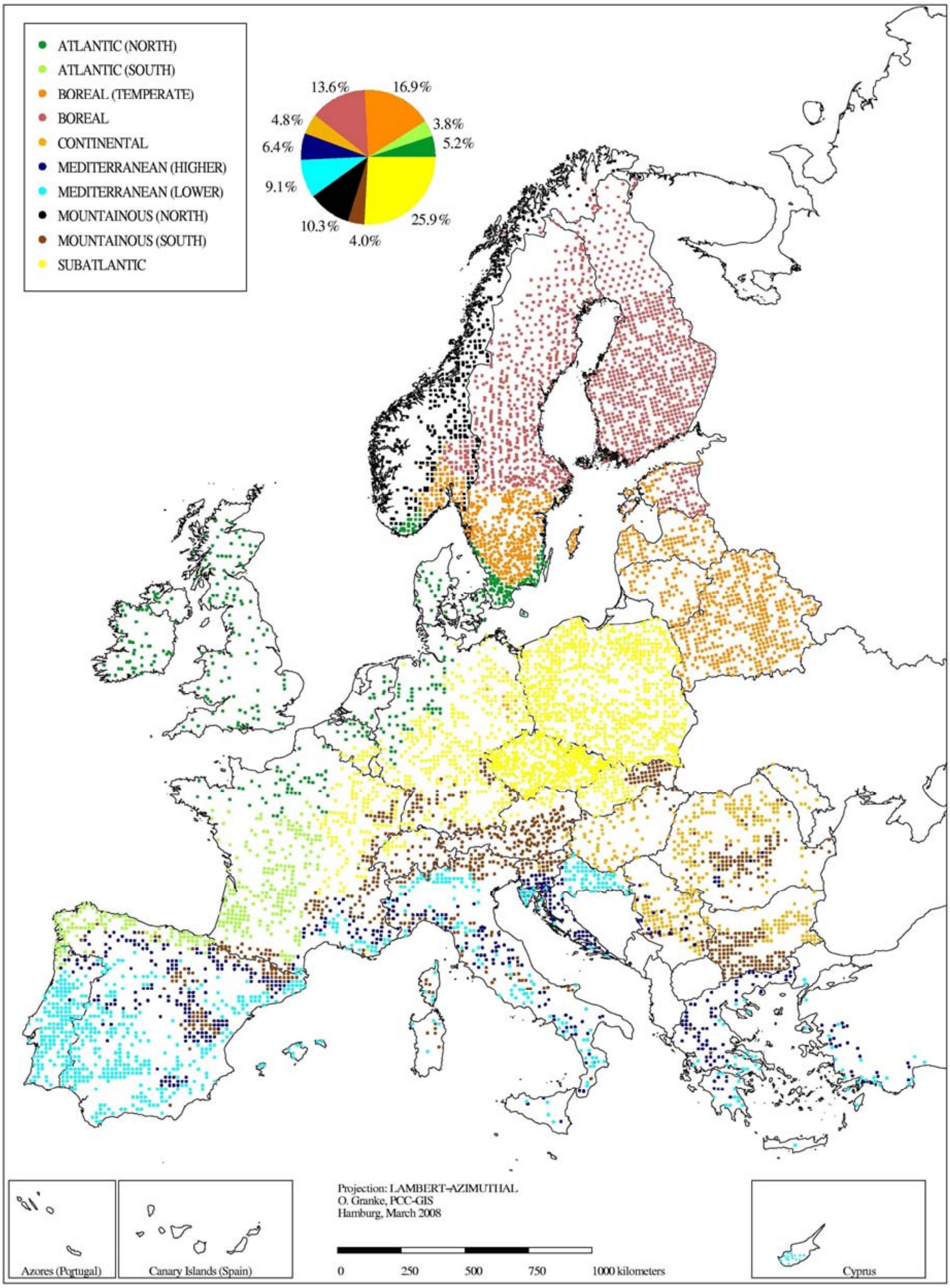


Figure 2.1.2.1-1: Plots according to climatic regions (2007).

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

In addition to defoliation and discolouration the following plot and tree parameters are reported on the transnational plots:
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).
The demonstration project "BioSoil" under the programme "Forest Focus" of EC at Level I included a repetition of the soil survey using a more differentiated classification of soil types than the one reproduced in Table 2.1.3.1-1.

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 (Table 2.1.3.1-2). After having increased gradually over the years, the numbers of plots for which these site parameters were reported had reached almost completeness in 2006. It decreased in 2007, however, because of the non-submission of data by some countries.

Table 2.1.3.1-2: Number of sample plots assessed for crown condition and plots per site parameter.

Country	Number of plots	Number of plots per site parameter					
		Water	Humus	Altitude	Aspect	Age	Soil
Austria							
Belgium	27	27	27	27	27	27	26
Bulgaria	104	104	104	104	104	104	85
Cyprus	15	15	15	15	15	15	0
Czech Republic	132	132	52	132	132	132	52
Denmark	19	19	19	19	19	19	19
Estonia	93	93	93	93	93	93	93
Finland	593	593	593	593	593	593	593
France	504	504	504	504	504	504	504
Germany	419	419	389	419	419	419	308
Hungary	72	60	40	60	60	72	60
Ireland	30	30	20	29	30	30	17
Italy	238	238	238	238	238	238	0
Latvia	93	93	0	93	93	93	93
Lithuania	62	62	62	62	62	62	62
Luxembourg	4	4	4	4	4	4	4
The Netherlands							
Poland	458	458	458	458	458	458	370
Portugal							
Romania							
Slovak Republic	107	0	107	107	107	107	107
Slovenia	44	44	44	44	44	44	44
Spain	607	607	607	607	607	607	431
Sweden							
United Kingdom	32	32	32	32	32	32	32
EU	3653	3534	3408	3640	3641	3653	2900
Percent of EU plot sample		96.7	93.3	99.6	99.7	100.0	79.4
Andorra	3	3	3	3	3	3	3
Belarus	400	398	398	400	400	400	396
Croatia	83	83	83	83	83	83	64
Norway	476	0	443	476	476	476	369
Serbia	125	125	41	125	125	125	125
Switzerland	48	0	0	48	48	48	45
Turkey	46	32	2	46	46	46	0
Total Europe	4834	4175	4378	4821	4822	4834	3902
Percent of total plot sample		86.4	90.6	99.7	99.8	100.0	80.7

2.1.3.2 Defoliation

On each sampling point of the national and transnational grids situated in forests, 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 respective analyses.

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 (ANONYMOUS, 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.

Defoliation is assessed in 5% steps. This 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.

In 2007 the number of trees assessed was 104 299. Table 2.1.3.2-1 shows the total numbers of trees assessed in each participating country since 1995. The figures in the table are not necessarily identical to those published in previous reports for the same reasons explained in Chapter 2.1.2.1.

Of the plot sample of the year 2007, 59.8% of the plots were dominated by conifers and 40.2% by broadleaves (Annex I-2). Plots in mixed stands were assigned to the species group which comprised the majority of the sample trees. The number of species of the tree sample was 100. Most abundant were *Pinus sylvestris* with 28.5% followed by *Picea abies* with 15.9%, *Fagus sylvatica* with 8.3%, and *Quercus robur* with 4.1% of the total tree sample (Annex I-3).

Table 2.1.3.2-1: Number of sample trees from 1995 to 2007 according to the current database.

Country	Number of sample trees												
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Austria	2101	3670	3604	3577	3535	3506	3451	3503	3470	3586	3528	3425	
Belgium	678	684	683	692	696	686	682	684	684	681	676	618	616
Bulgaria	4772	4749	4748	5349	4344	4197	4174	3720	3836	3629	3592	3510	3569
Cyprus							360	360	360	360	361	360	358
Czech Rep	4933	4853	4844	2899	3475	3475	3475	3500	3500	3500	3450	3425	3300
Denmark	576	552	528	552	552	504	504	480	480	480	528	527	442
Estonia	2160	2184	2184	2184	2184	2160	2136	2169	2228	2201	2167	2191	2209
Finland	8754	8732	8788	8758	8662	8576	8579	8593	8482	11210	11498	11489	11199
France	10851	10800	10800	10740	10883	10317	10373	10355	10298	10219	10129	9950	7338
Germany	10907	10980	10990	13178	13466	13722	13478	13534	13572	13741	13630	10327	10217
Greece	2248	2248	2224	2204	2192	2192	2168	2144			2054		
Hungary	1342	1298	1257	1383	1470	1488	1469	1446	1446	1710	1662	1674	1650
Ireland	441	441	441	441	417	420	420	424	403	400	382	445	646
Italy	5703	5836	4873	4939	6710	7128	7350	7165	6866	7109	6548	6936	6636
Latvia	2262	2368	2297	2326	2348	2256	2325	2340	2293	2290	2263	2242	2228
Lithuania	1776	1643	1634	1616	1613	1609	1597	1583	1560	1487	1512	1505	1507
Luxembourg	96	96	96	96	96	96	-	96	96	96	97	96	96
The Netherlands	257	237	220	220	225	218	231	232	231	232	232	230	
Poland	8640	8620	8620	8620	8620	8620	8620	8660	8660	8660	8640	7520	9160
Portugal	4230	4260	4319	4290	4290	4290	4320	4350	4080	3990	3569	3539	
Romania	5688	5375	5687	5637	5712	5640	5568	5544	5544	5424	5496	5472	
Slovak Rep.	5091	5018	5033	5094	5063	5157	5054	5076	5116	5058	5033	4808	4904
Slovenia	1008	1008	1008	984	984	984	984	936	983	1006	1056	1069	1056
Spain	10896	10728	10776	10848	14352	14568	14568	14568	14568	14568	14568	14568	14568
Sweden	10310	10925	10910	11044	11135	11361	11283	11278	11321	11255	11422	11186	
United Kingdom	1512	1896	1968	2112	2039	2136	2064	2064	2064	2040	2016	1968	768
EU	107232	109201	108532	109783	115063	115306	115233	114804	112141	114932	116109	109085	82467
Andorra										72		74	72
Belarus			9974	9896	9745	9763	9761	9723	9716	9682	9484	9373	9424
Croatia	1970	1974	2030	2066	2015	1991	1941	1910	1869	2009	2046	2109	2013
Moldova	263	236	253	234	259	234	234						
Norway	3905	3948	4028	4069	4052	4051	4304	4444	4547	5014	5319	5525	5824
Russian Fed.	2991												
Serbia									2274	2915	2995	2902	2860
Switzerland	824	854	880	868	857	855	834	827	806	748	807	812	790
Turkey													949
Total Europe	117185	116213	125697	126916	131991	132200	132307	131708	131353	135372	136760	129875	104399

2.1.4 Analysis, presentation and interpretation 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 quantified precisely, 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 12 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 26 EU-Member States.

2.1.4.3 Mean defoliation and temporal development

For all evaluations related to a particular tree species a criterion had to be set up to be able to decide if a given plot represents this species or not. This criterion was that the number of trees of the particular species had to be three or more per plot ($N \geq 3$). The mean plot defoliation for the particular species was calculated as the mean defoliation of the trees of the species on that 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. These slopes were considered as "significant" only if there was at least 95% probability that they are different from zero.

Besides the temporal development, also the change in the results from 2006 to 2007 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 see Annex IV.

2.2 Results of the transnational survey in 2007

2.2.1 Crown condition in 2007

In 2007 crown condition was assessed on 4834 plots comprising 104 399 sample trees. Of these trees a share of 21.8% was scored as damaged, i.e. had a defoliation of more than 25% (Table 2.2.1-1). The share of damaged broadleaves exceeded with 25.9% the share of damaged conifers with 18.8%. In Annex I-4 the percentages of damaged trees are mapped for each plot. Table 2.2.1-1 shows also the mean and the median of defoliation. Mean defoliation in total Europe in 2007 was 20.5%. Annex I-5 shows a map of mean plot defoliation for all species. Because of different numbers of participating countries (Chapter 2.1.2.1), defoliation figures of 2007 are not comparable to those of previous reports. The development of defoliation over time is derived from tree and plot samples of defined sets of countries (Chapter 2.2.2).

Table 2.2.1-1: Percentages of trees in defoliation classes and mean defoliation for broadleaves, 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	22.5	49.4	72.0	24.4	2.7	0.9	28.0	23.6	20	35950
	Conifers	32.1	47.3	79.4	18.6	1.3	0.7	20.6	19.7	15	46517
	All species	27.9	48.2	76.1	21.2	1.9	0.8	23.9	21.4	20	82467
Total Europe	*Fagus sylv.*	27.9	47.9	75.8	22.2	1.4	0.4	24.2	21.2	20	8684
	Quercus robur + Q. petraea	17.1	47.7	64.8	31.8	2.3	1.1	35.2	25.5	20	6818
	Broadleaves	26.7	47.4	74.1	22.4	2.6	0.9	25.9	22.5	20	45258
	Picea abies	37.1	37.5	74.6	23.3	1.7	0.4	25.4	19.5	15	15756
	Pinus sylv.	34.5	51.2	85.7	12.9	0.9	0.5	14.3	18.0	15	29724
	Conifers	34.2	47.0	81.2	16.8	1.3	0.7	18.8	19.0	15	59141
	All species	31.0	47.2	78.2	19.2	1.9	0.8	21.8	20.5	15	104399

Frequency distributions of the sample trees in 5% classes 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 highest with 23.9% in the Atlantic (south) region and is lowest with 14.2 % in the Boreal 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. Many plots with less defoliated *Pinus sylvestris* trees are situated in the Boreal and Boreal (temperate) regions.

In contrast, *Picea abies* and especially the main broadleaved species, *Fagus sylvatica* as well as *Quercus robur* and *Quercus petraea,* show highly defoliated plots throughout their habitat.

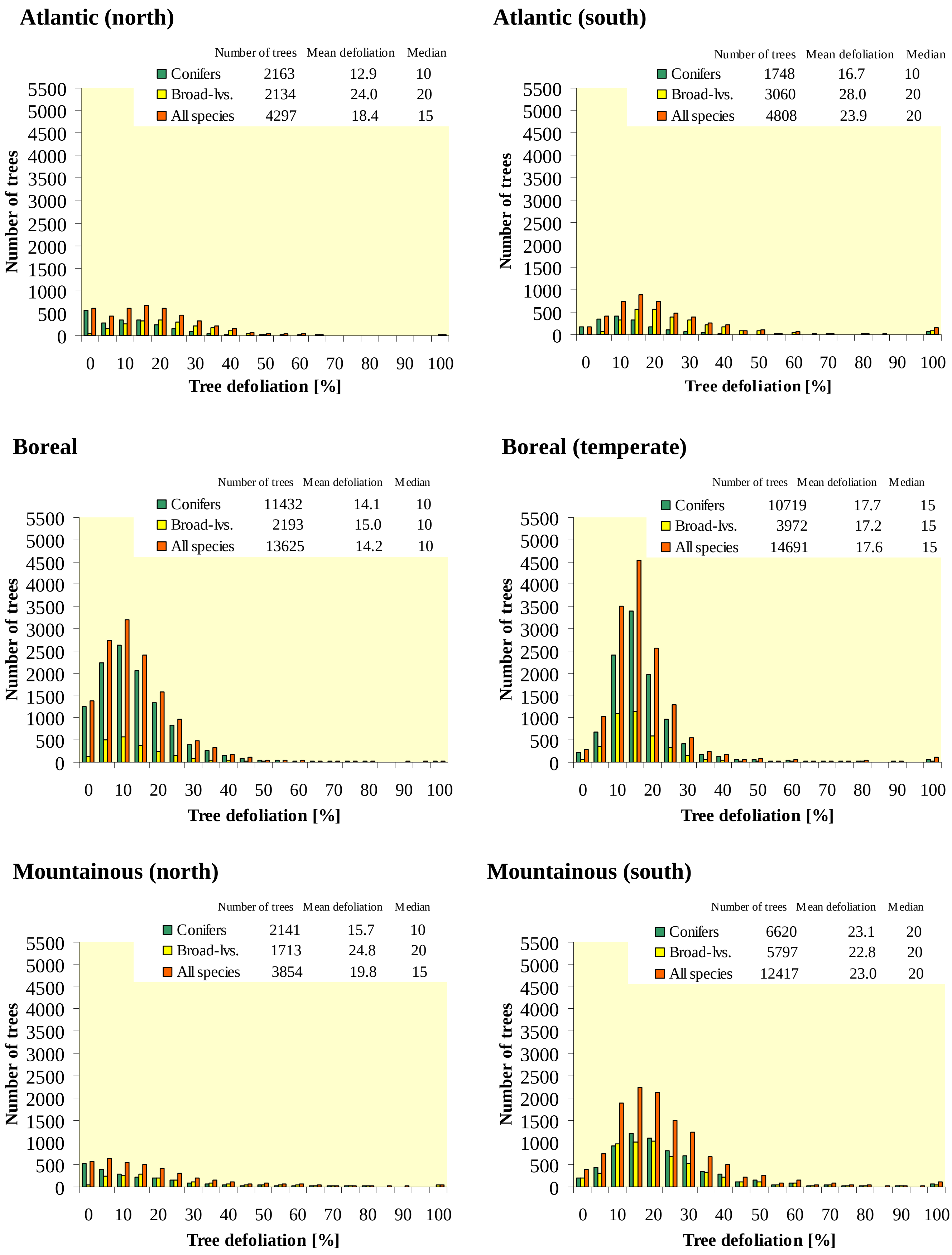


Figure 2.2.1-1a: Frequency distribution of trees in 5%-defoliation steps.

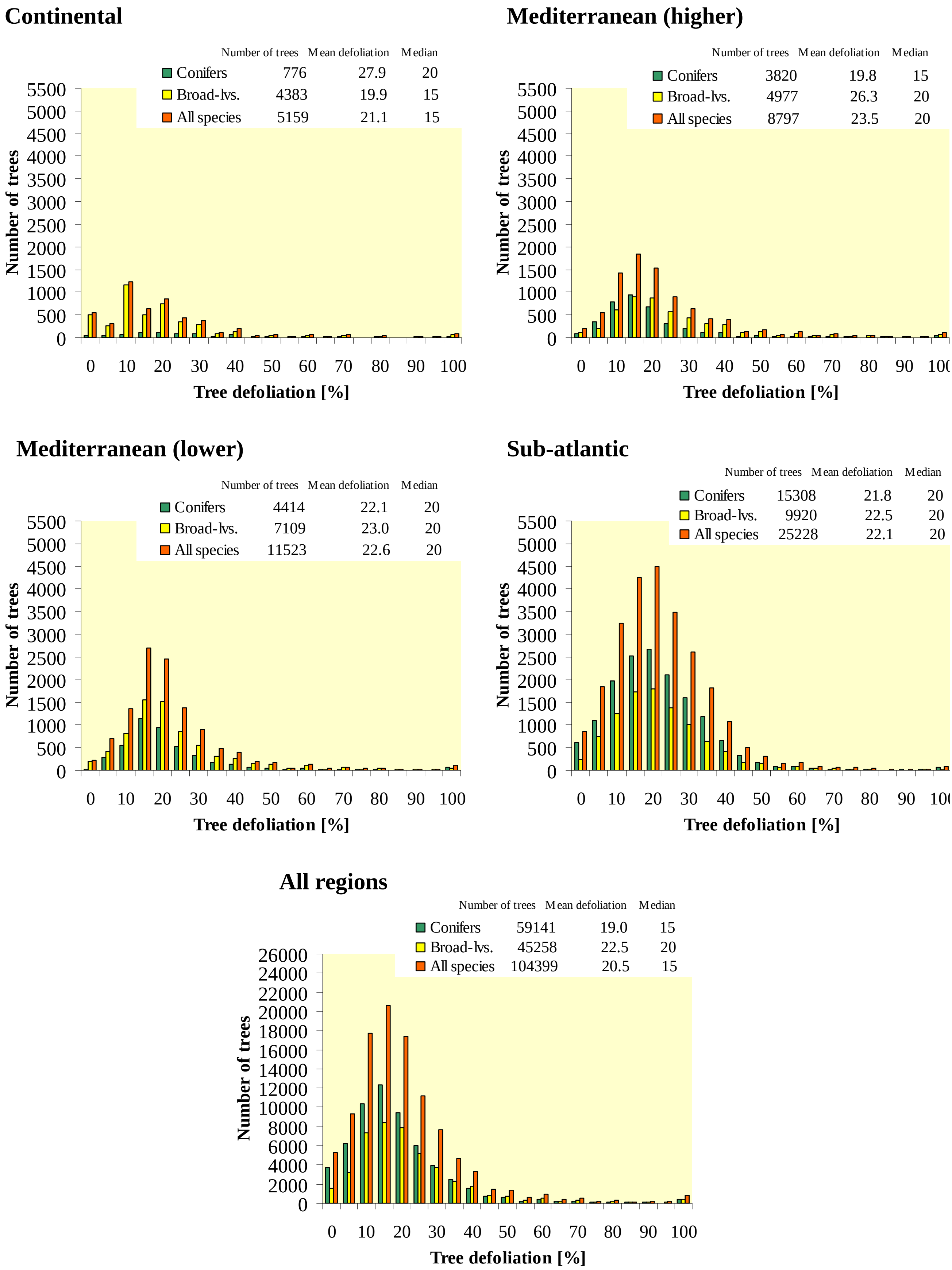


Figure 2.2.1-1b: Frequency distribution of trees in 5%-defoliation steps.

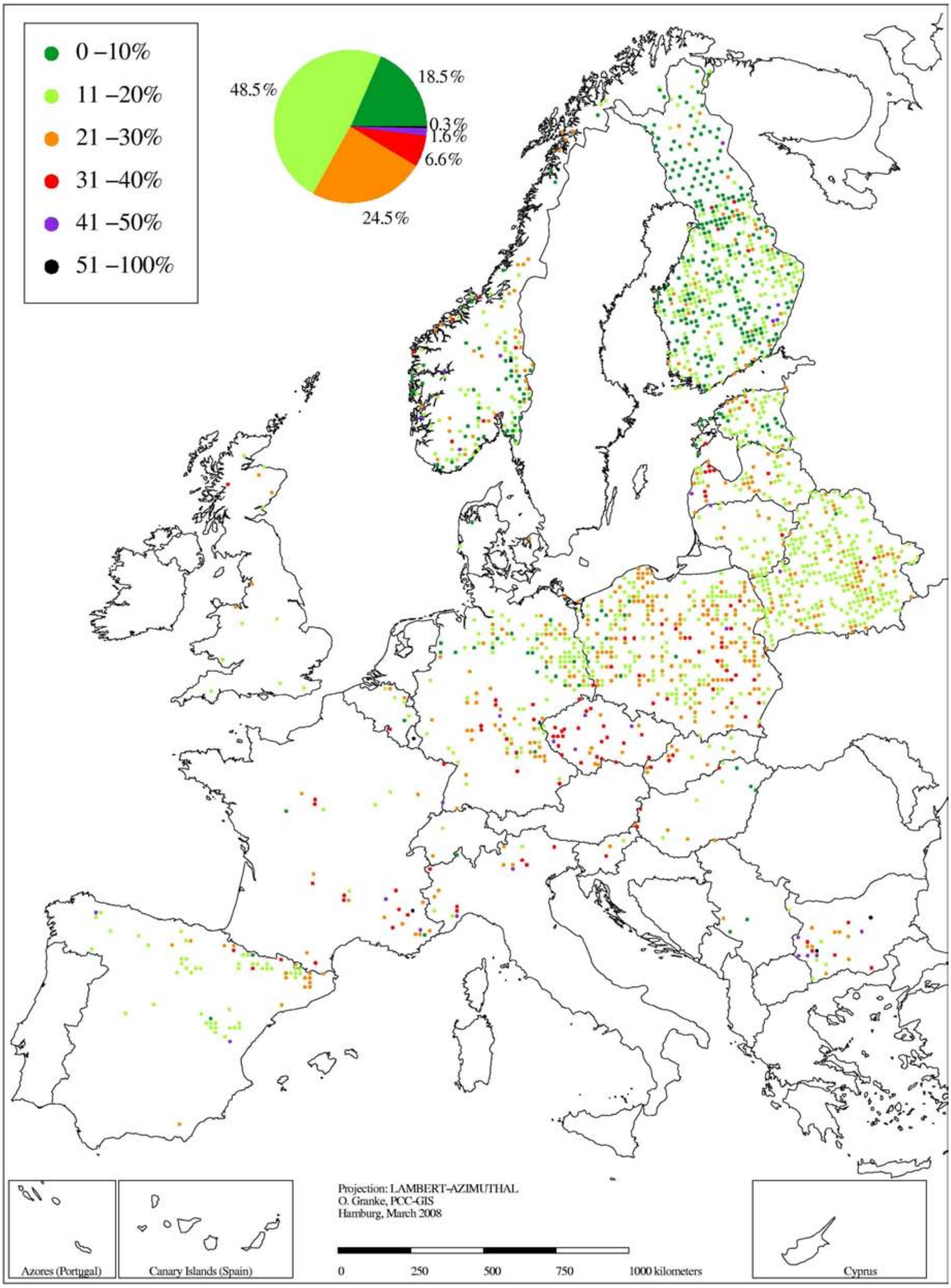


Figure 2.2.1-2: Mean plot defoliation of *Pinus sylvestris.*

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

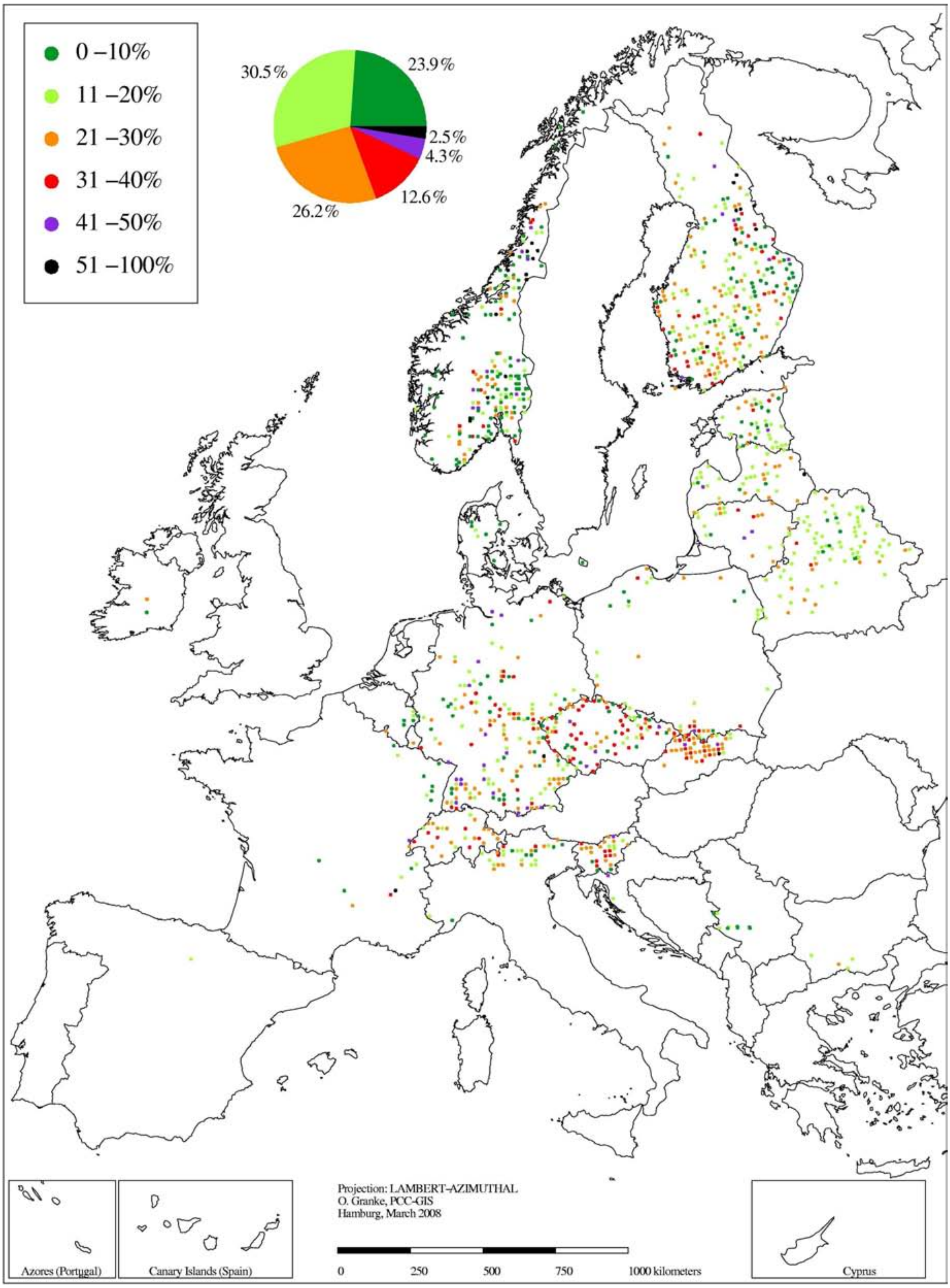


Figure 2.2.1-3: Mean plot defoliation of *Picea abies.*

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

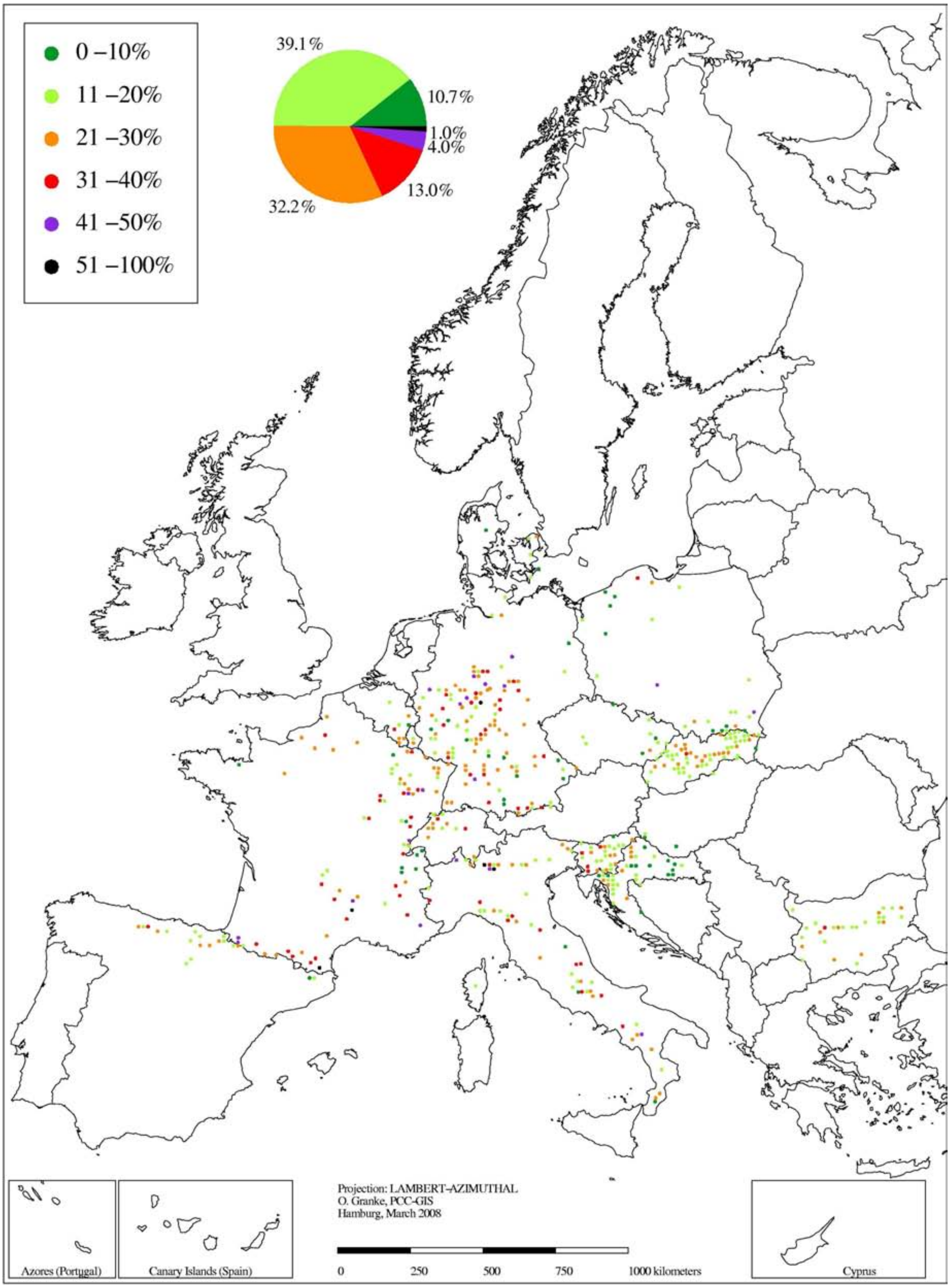


Figure 2.2.1-4: Mean plot defoliation of *Fagus sylvatica.*

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

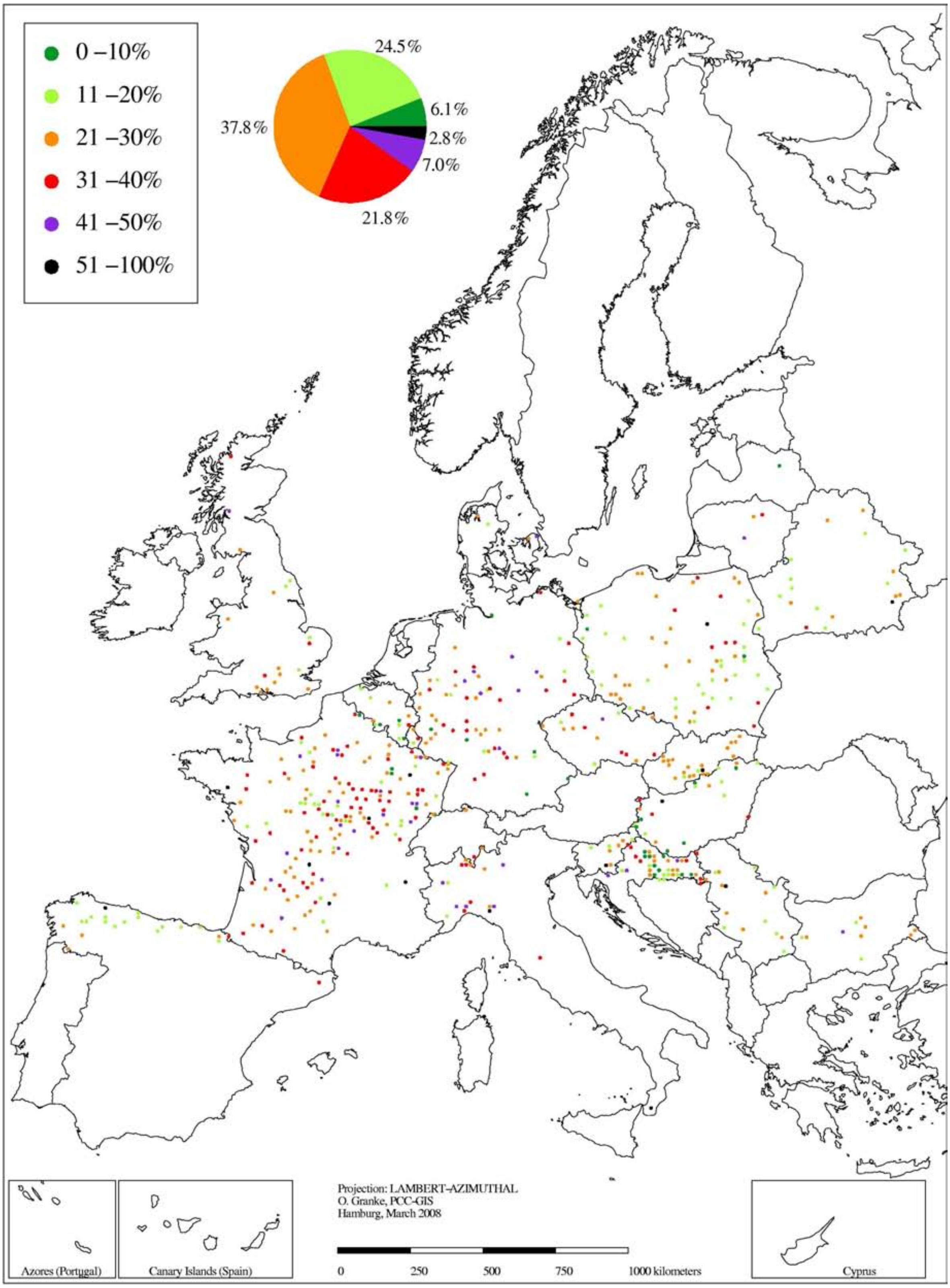


Figure 2.2.1-5: Mean plot defoliation of *Quercus robur* and *Quercus petraea.*

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

For 102 403 trees discolouration was assessed (Table 2.2.1-2). A share of 7.8% of the trees was discoloured, i.e. had a discolouration of more than 10%. A map of mean plot discolouration is shown in Annex I-6.

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	90.1	6.1	2.3	0.4	1.1	9.9	35706
	Conifers	93.0	4.6	1.4	0.2	0.8	7.0	45859
	All species	91.8	5.3	1.7	0.2	1.0	8.2	81565
Total Europe	Broad-leaves	90.0	6.2	2.4	0.4	1.0	10.0	44855
	Conifers	93.8	4.2	1.2	0.2	0.6	6.2	57548
	All species	92.2	5.0	1.7	0.3	0.8	7.8	102403

2.2.2 Development of defoliation

2.2.2.1 Approach

The development of defoliation is calculated assuming that the sample trees of each survey year represent forest condition. Studies of previous years show 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. But 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 1990-2007:
  Belgium, Denmark, Germany (west), Hungary, Ireland, Latvia, Poland, Slovak Republic, Spain, and Switzerland.
- Period 1997-2007:
  Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Poland, Slovak Republic, Slovenia, Spain, Switzerland, and United Kingdom.

These two sets of countries deviate from those analysed in previous years because several countries did not assess crown condition in 2007. Consequently, the development of defoliation deviates partly from the one presented in earlier reports. The development of defoliation is presented in graphs and 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 2.1.4.3.

The spatial pattern of the changes in mean defoliation from 2006 to 2007 across Europe is shown in Annex I-7. The pie diagram shows that an increase in defoliation was found on 12.8% of the plots, whereas only 8.9% of the plots show a decrease. The plots with increasing defoliation are particularly abundant in Norway as well as in parts of the Mediterranean area and of the Balkan.

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

Of the main tree species *Pinus pinaster* shows the severest increases in defoliation in the period from 1990 to 2007 (Figure 2.2.2.2-1). In contrast, *Pinus sylvestris* is the only species with clearly decreasing defoliation since 1990. Its recovery particularly in Poland and in parts of the Baltic States since the mid 1990s renders this species in 2007 in a better condition than at the beginning of the time series. Being less susceptible to drought, *Pinus sylvestris* showed no rise in defoliation even after the dry summer of the year 2003. *Picea abies*, *Fagus sylvatica* as well as *Quercus robur* and *Quercus petraea* continue their recuperation since their highs in 2004 which constituted a response to the drought of 2003. The impact of and the recovery from the drought in 2003 is less pronounced in the time series from 1997 to 2007 (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 1997-2007 are mapped in Figure 2.2.2.2-3. This map is not confined to the main species but includes all species. The share of plots with distinctly increasing defoliation (28.7%) surmounts the share of plots with decreasing defoliation (10.2%). Plots showing a deterioration are scattered across Europe, but their share is particularly high in southern Finland, France as well as in parts of Germany and Spain.

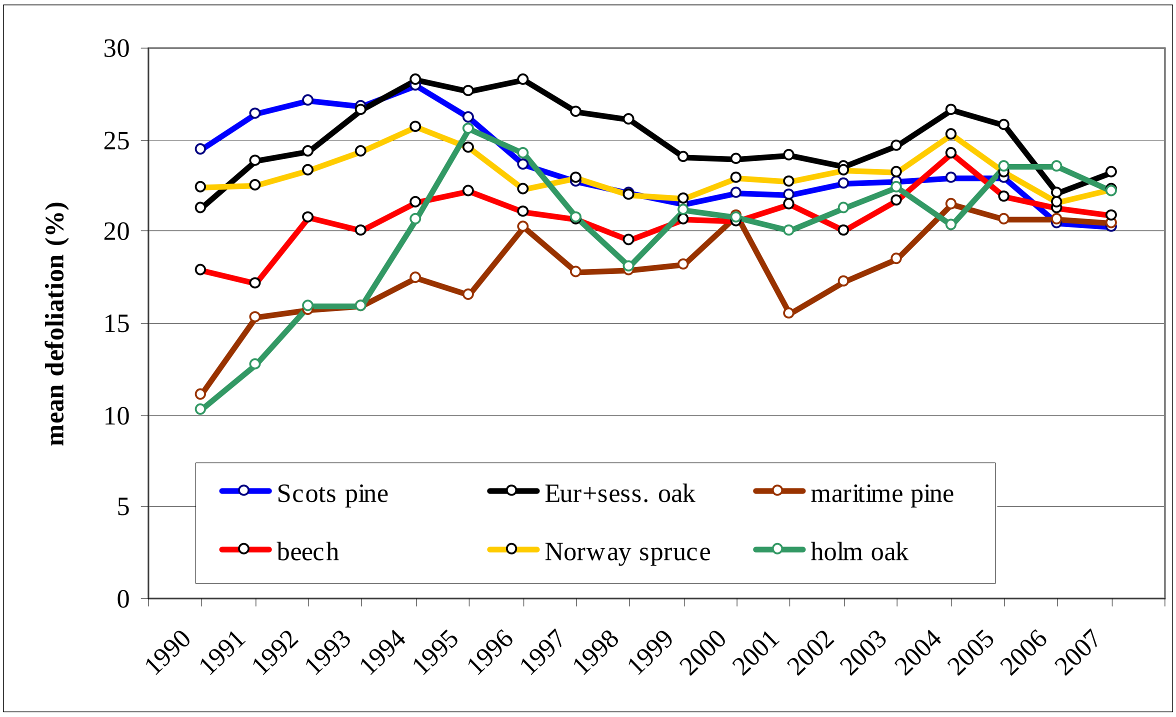


Figure 2.2.2.2-1: Mean defoliation of main species 1990-2007.

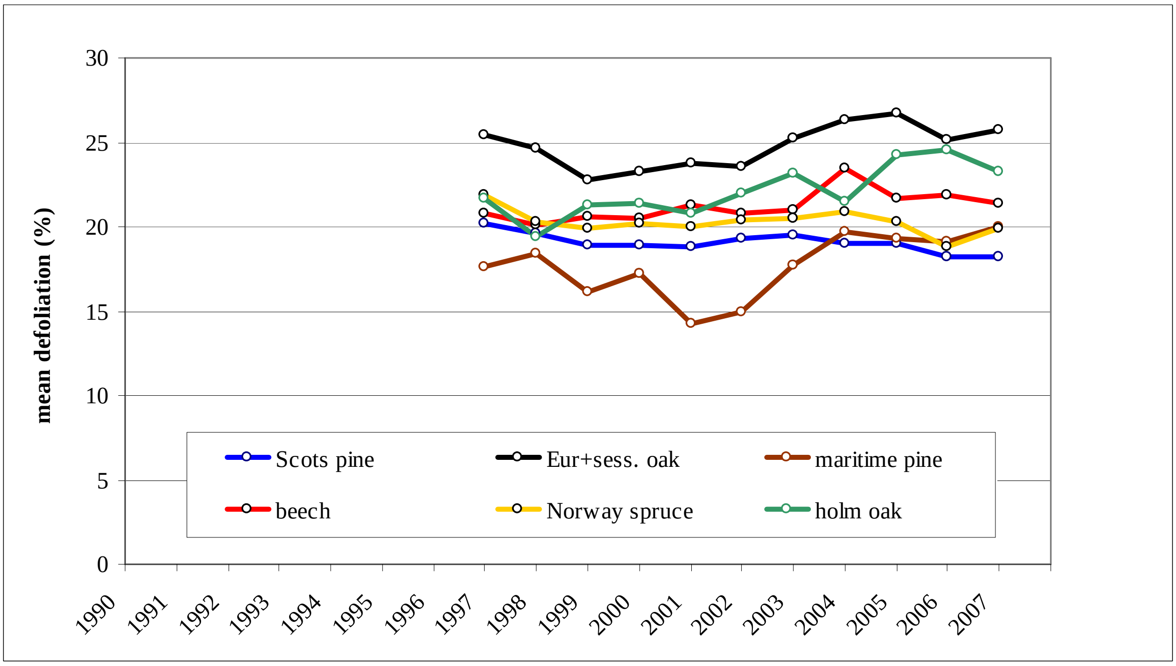


Figure 2.2.2.2-2: Mean defoliation of main species 1997-2007.

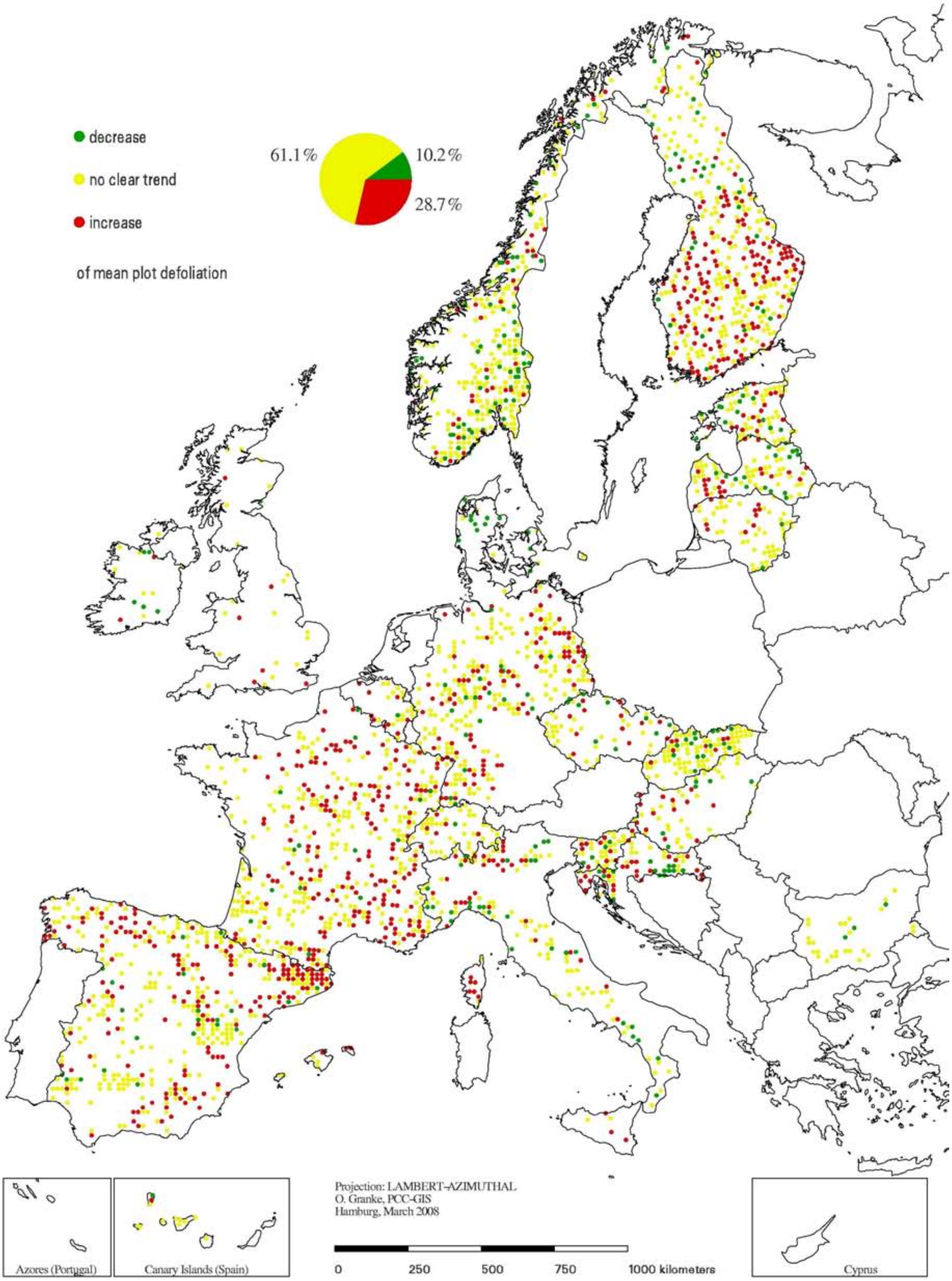


Figure 2.2.2.2-3: Trends of mean plot defoliation of all species over the years 1997 to 2007.

2.2.2.3 Pinus sylvestris

Among all sample trees investigated in the periods 1990-2007 and 1997-2007 *Pinus sylvestris* constitutes the largest share. It is still present in all climatic regions but less frequent in the Boreal region as data from Sweden were not available for 2007.

In the total of all regions, the portion of damaged *Pinus sylvestris* trees shows a pronounced decrease from a peak at 46.7% in 1994 to 18.2% in 2007. This reflects the improvement of health status mainly in the Sub-Atlantic region which represents by far the largest share of the trees. Also in the Atlantic (North) region *Pinus sylvestris* has recovered since 2001 (Figure 2.2.2.3-1).

In the Mediterranean (Higher) region the time series show a continued increase in the percentage of the trees damaged between 2000 and 2006 followed by a marked improvement in 2007 (Figure 2.2.2.3-1).

The spatial distribution of the damage shows that the share of deteriorated plots (24.3%) is much higher than the plots experiencing improvement (12.2%) between 1997 and 2007 (Figure 2.2.2.3-2). The map shows the high number of deteriorating plots in the Boreal region (mainly in Finland). Small clusters of plots with deteriorated health status since 1997 lie in the eastern part of Germany and in Spain close to the French border. A marked improvement can be seen in the north of Finland and in Norway. For the highest share of plots, namely 63.5% no clear trend in forest condition of *Pinus sylvestris* was found.

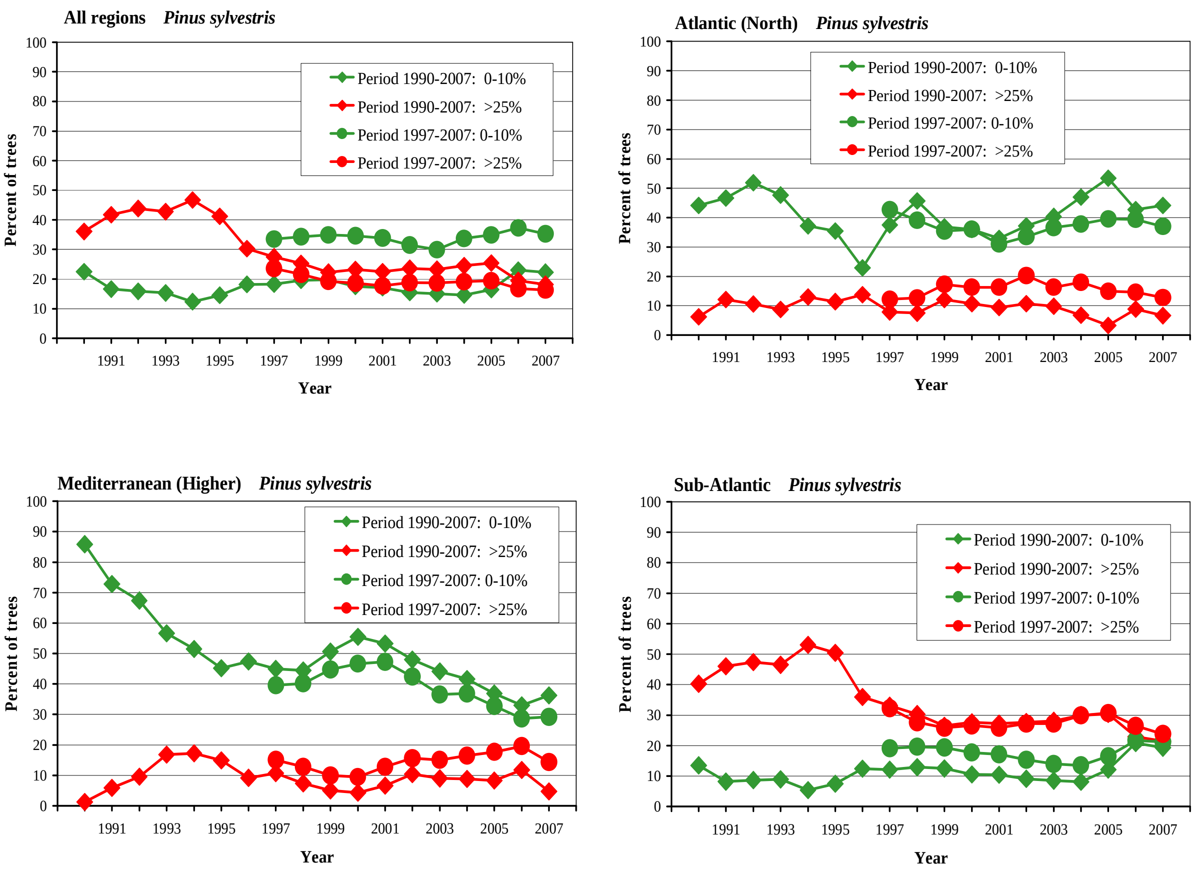


Figure 2.2.2.3-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2007 and 1997-2007).

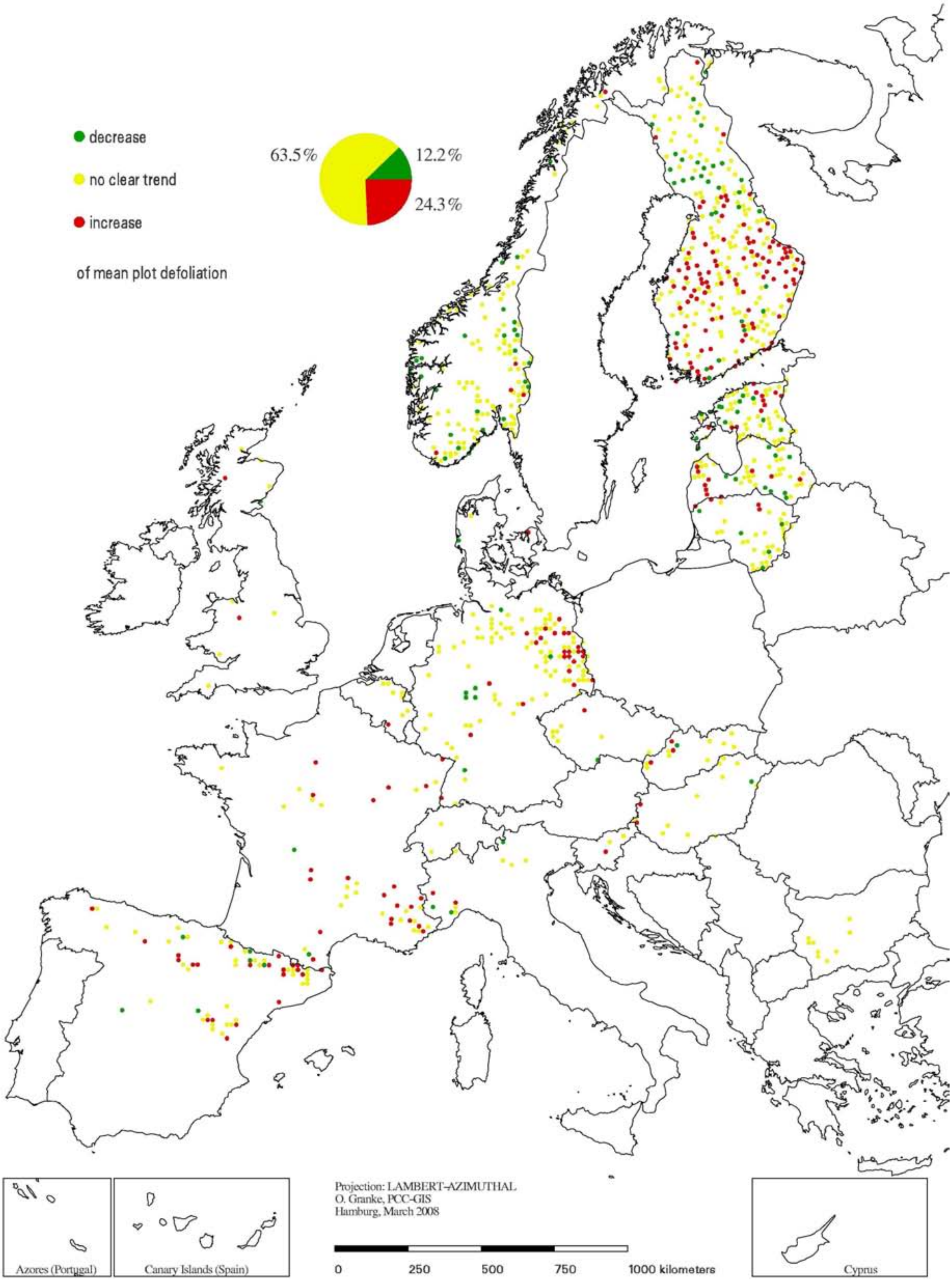


Figure 2.2.2.3-2: Trend of mean plot defoliation (slope of linear regression) of *Pinus sylvestris* over the years 1997 to 2007.

2.2.2.4 Picea abies

In both time series, *Picea abies* constitutes the second largest share of trees behind *Pinus sylvestris*. In the period 1990-2007, the share of damaged trees in the total of all regions decreased from its peak of 38.2% in 1994 to 29.1% in 2007 (Figure 2.2.2.4-1). This development reflects largely the situation in the Atlantic (North) and Sub-Atlantic regions where the share of the defoliated trees diminished substantially in the period mentioned above. The latter comprises the largest share of *Picea abies* trees.

The Sub-Atlantic and Mountainous (South) regions show a sudden increase in defoliation from 2003 to 2004 with a subsequent decrease in 2005 and 2006. In 2007 the share of the damaged trees rose again not only in these two regions but also in the boreal forests of *Picea abies*. This development can be interpreted as an effect of the dry and hot summer of 2003 and more favourable weather conditions in 2005.

Figure 2.2.2.4-2 shows the spatial distribution and the percentage of plots with improved and worsened trend in crown condition of *Picea abies*. Of all plots in the map 60.7% do not show any trends. On 24% of the plots investigated an increase of defoliation was found, whereas only 15.3% of them showed a distinct trend towards better health status. According to the trend calculations the health status of *Picea abies* improved in Southern Norway and the Slovak Republic. Regions of deterioration occur in Finland and Estonia.

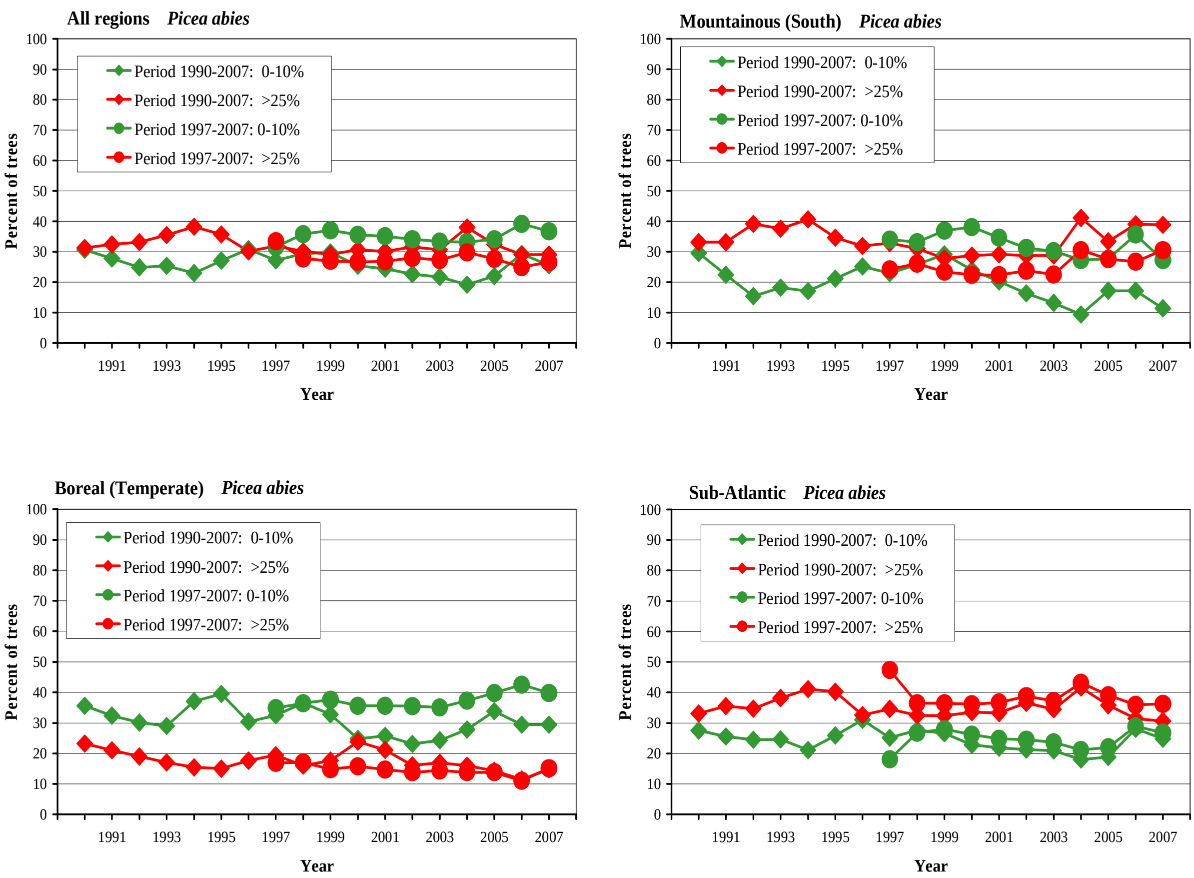


Figure 2.2.2.4-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2007 and 1997-2007).

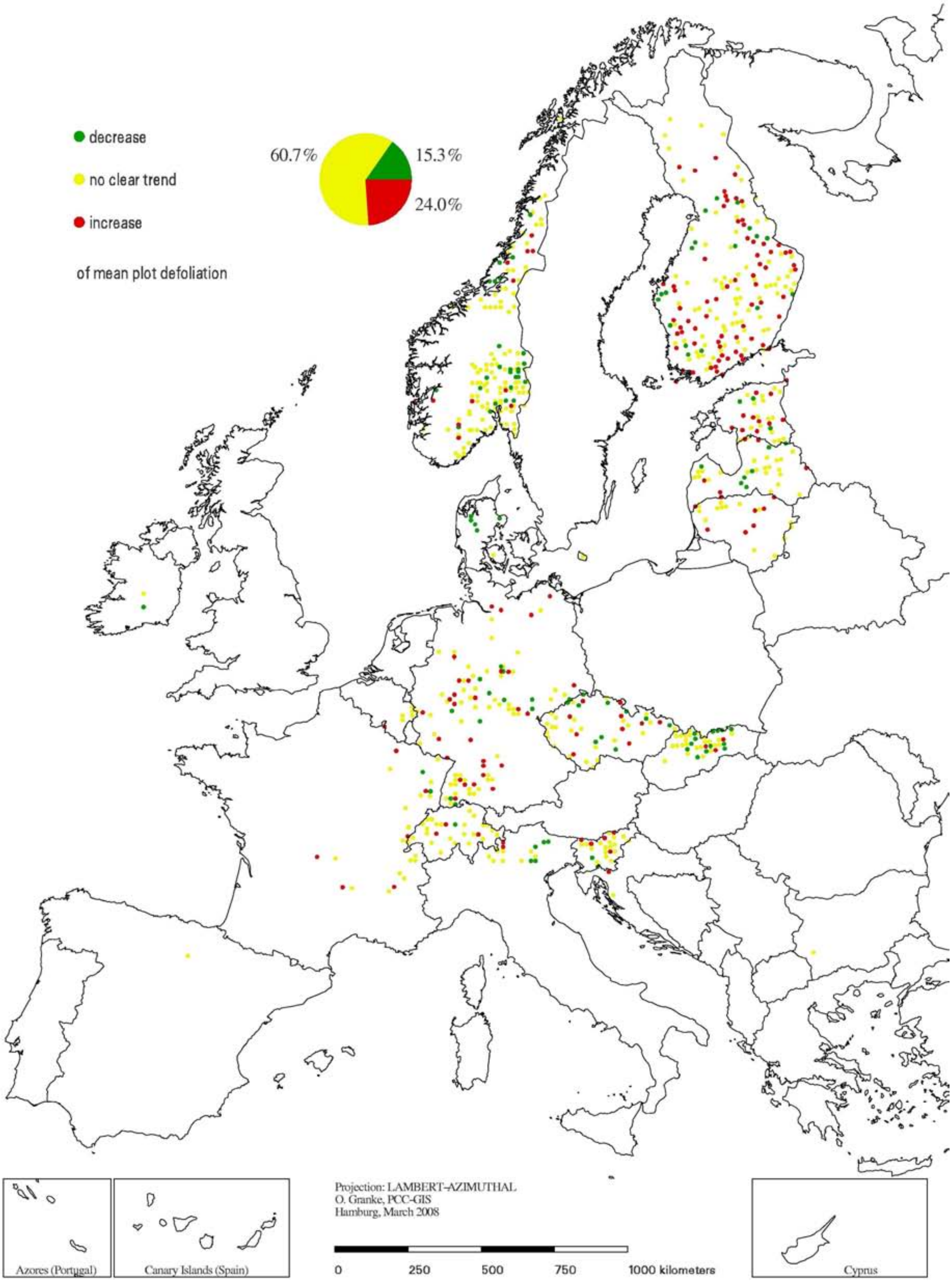


Figure 2.2.2.4-2: Trend of mean plot defoliation (slope of linear regression) of *Picea abies* over the years 1997 to 2007.

2.2.2.5 Fagus sylvatica

Fagus sylvatica is the most frequent tree species among all broadleaves. After a distinct increase in the share of damaged trees between 1990 and 1995 to a total of 30.1% the number of defoliated trees became rather stable from 1996 on. A substantial improvement was observed in 2007 with 21.7% defoliated trees as compared with 2006 showing 25.7% damaged trees (Figure 2.2.2.5-1). A worsened crown condition was found in 2004 in all climatic regions except for Mountainous (South). The cause for the deterioration of the health status was the dry and hot summer in 2003. Most of the trees heavily damaged in 2003 by hot weather conditions obviously recovered from the deteriorated crown condition as the share of defoliated trees decreased substantially already in 2005. This reflects in particular the development of crown condition in the Sub-Atlantic region which constitutes the majority of the *Fagus sylvatica* trees. Both the drought damage and the following recuperation are especially pronounced in the Atlantic (North) region, where the share of damaged trees decreased by 13.6 percent points from 45.8% in 2004 to 32.2% in 2005, and decreased again to 30.7 % in 2007. Another obvious increase in defoliation occurred between 1990 and 1997 in the Mountainous (South) region. There, the share of damaged trees rose from 10.0% in 1990 to 19.4% in 1997. The overall deterioration of crown condition of *Fagus sylvatica* over the whole period of 1997-2007 observed particularly in the Sub-Atlantic region is evident in Figure 2.2.2.5-2. The map shows the spatial distribution of the trends between 1997 and 2007 across Europe. The portion of plots with increasing defoliation is 25.3% against a share of 10.0% of plots showing improving crown condition.

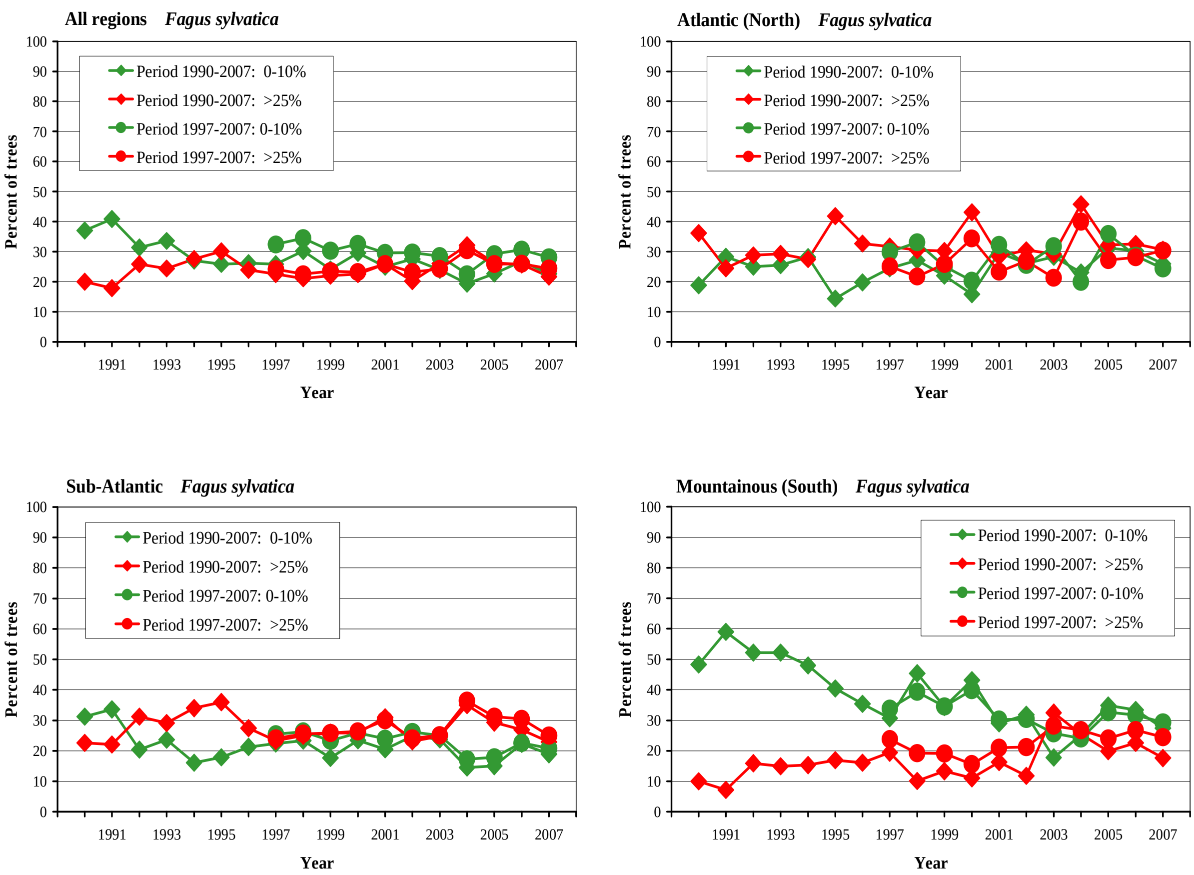


Figure 2.2.2.5-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2007 and 1997-2007).

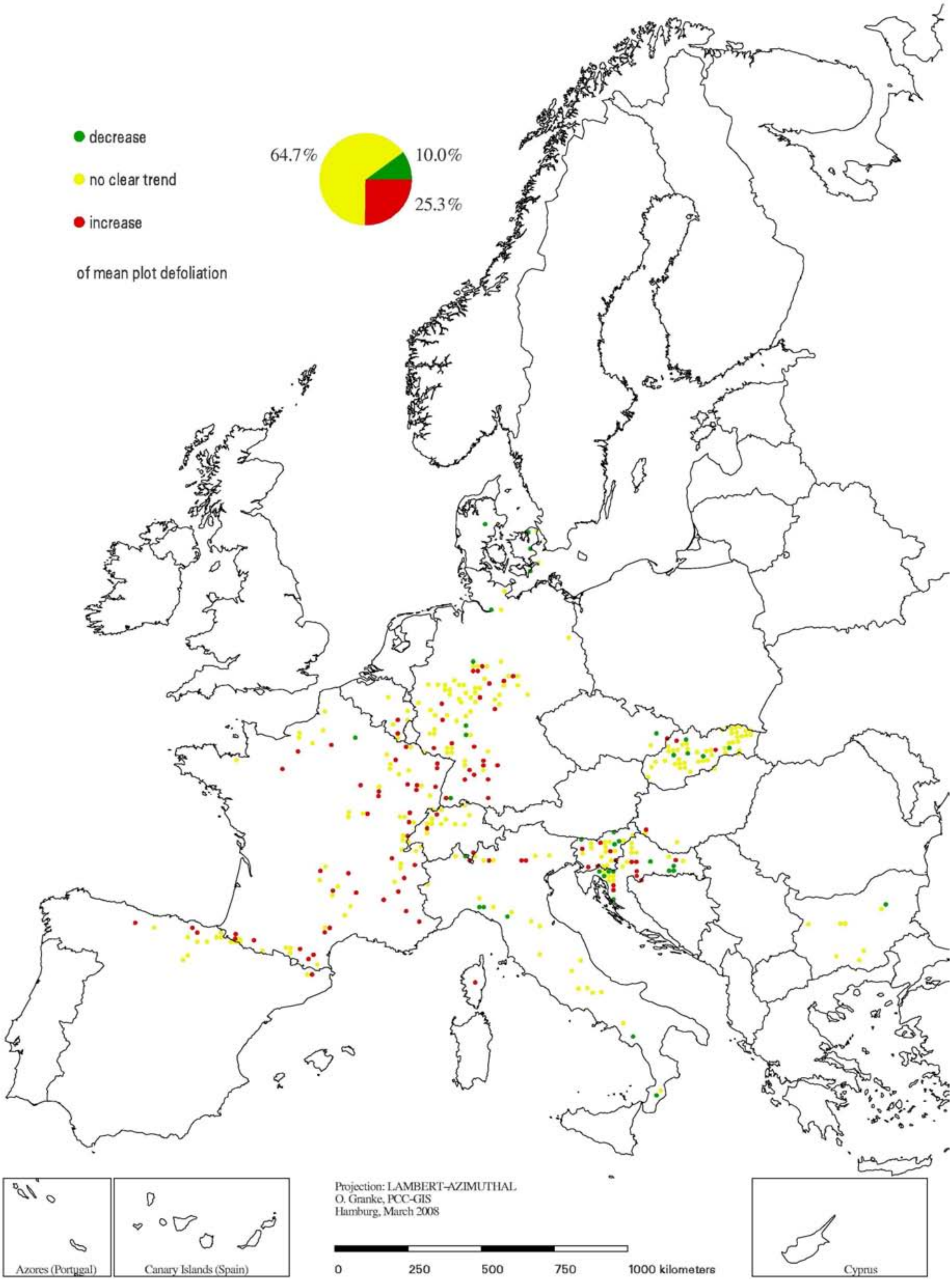


Figure 2.2.2.5-2: Trend of mean plot defoliation (slope of linear regression) of *Fagus sylvatica* over the years 1997 to 2007.

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 48.1% in 1994. After a steady state from 1999 onwards, it increased markedly in 2004 and 2005. This reflects mainly the development of crown condition in the Sub-Atlantic region which constitutes the largest share of the sample trees of this species group. There, the share of damaged trees in the time period 1990-2007 increased by 10.3 percent points from 32.7% in 2002 to 43.0% in 2005, followed by a marked recuperation in 2006. The improved crown condition in this region shows a pronounced decrease in damaged trees to 29.6% in 2007. A recovery of *Quercus robur* and *Quercus petraea* occurred also in the Mountainous (South) region, where the share of damaged trees dropped between 2006 and 2007 by 4.3 percent points. Also in the Continental region the two oak species recuperated in the last two years. Regarded spatially, defoliation of 60.3% of oak plots did not show a clear trend (Figure 2.2.2.6-2). The highest number of plots with increased defoliation is situated in France.

A deterioration in health of both oak species was found on 31.5% plots in the map whereas on only 8.2% plots health status improved in the year 1997 to 2007.

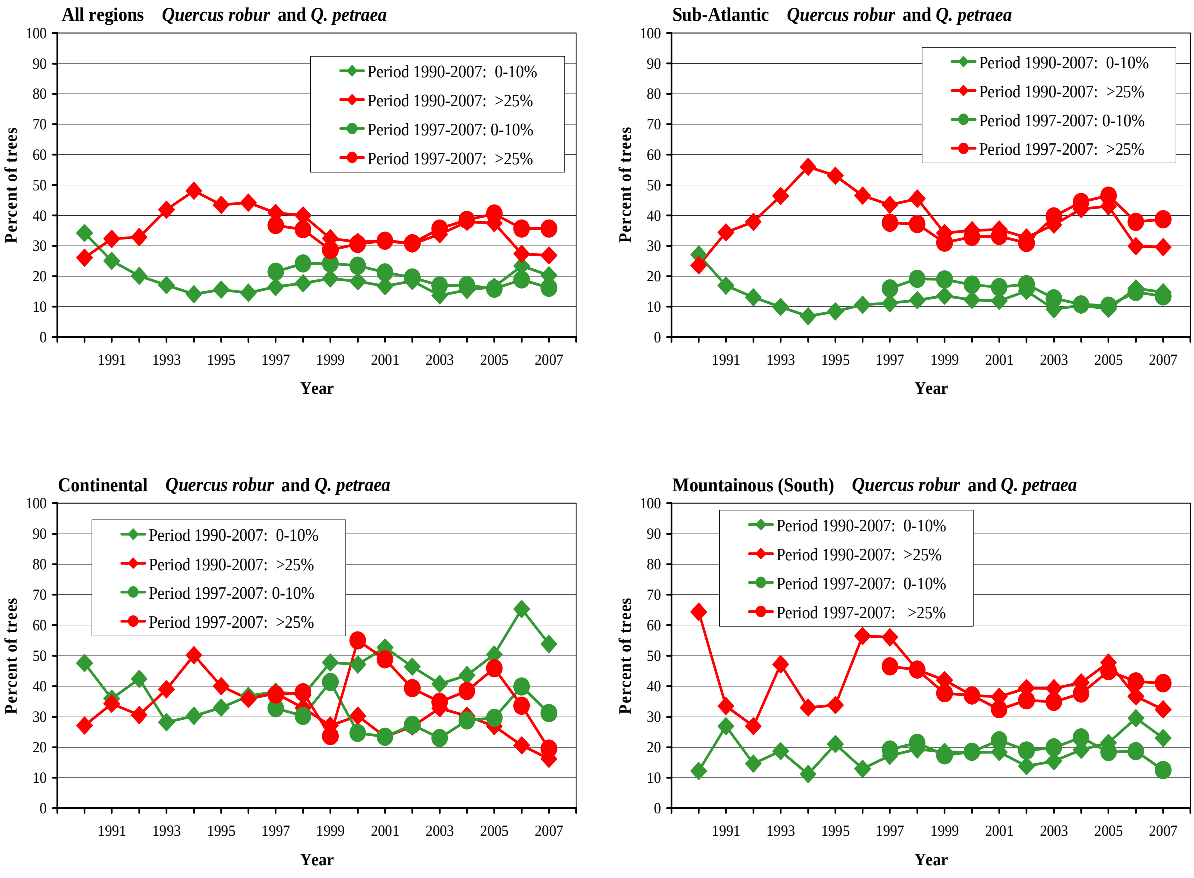


Figure 2.2.2.6-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2007 and 1997-2007).

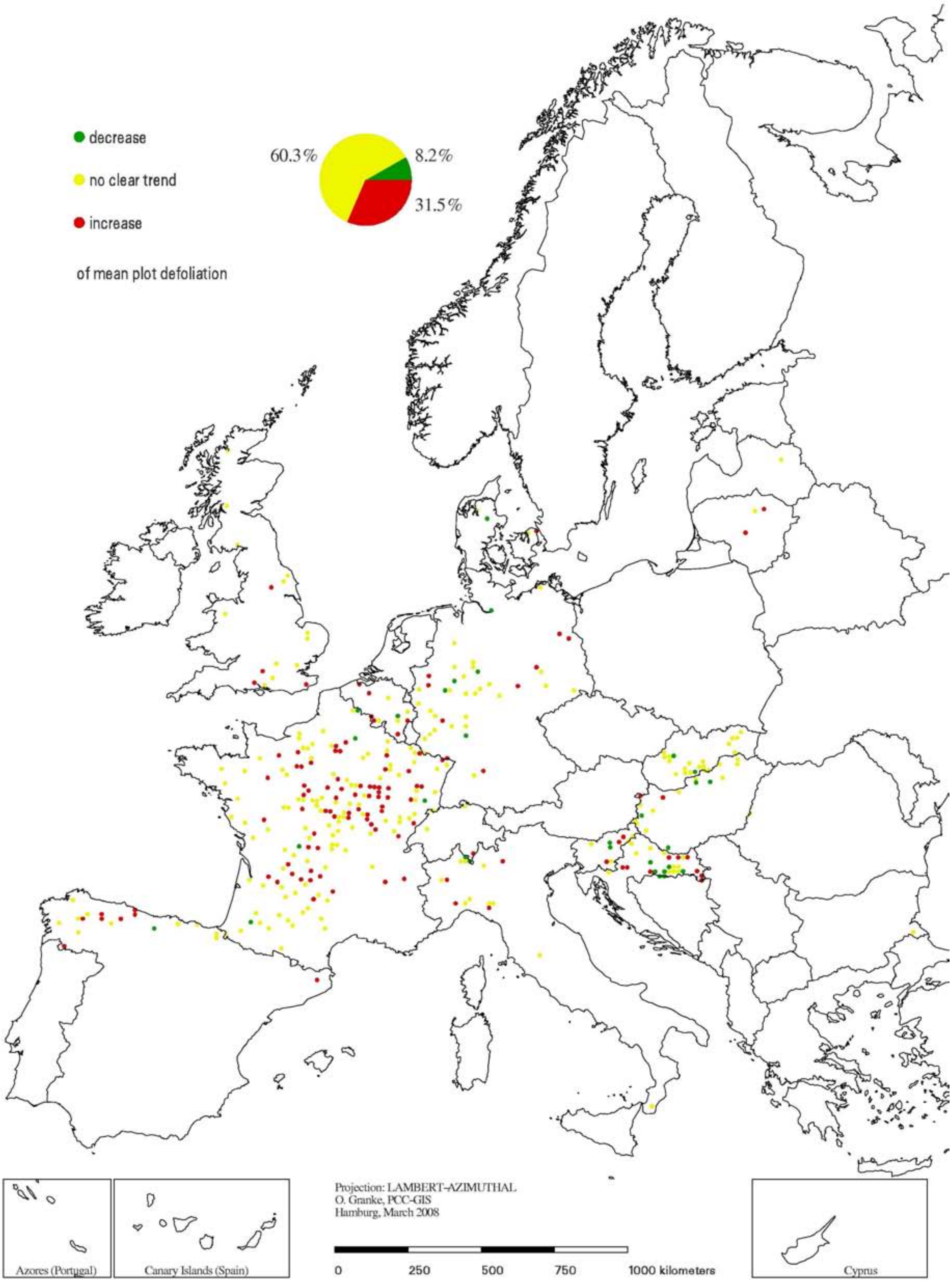


Figure 2.2.2.6-2: Trend of mean plot defoliation (slope of linear regression) of *Quercus robur* and *Quercus petraea* over the years 1997 to 2007.

2.2.2.7 Quercus ilex and Q. rotundifolia

Across all regions, *Quercus ilex* and *Quercus rotundifolia* show an increase in the share of damaged trees to a peak of 32.8% in 1995. This deterioration was followed by a clear recuperation to 12.1% in 1998 (Figure 2.2.2.7-1). Since then the share of damaged trees of both samples (1990-2007 and 1997-2007) fluctuated around 18% until the year 2004. The subsequent sharp increase in 2005 is explained by exceptional summer drought. A slight improvement was found in 2006 across all regions. It became more apparent in 2007, which may be explained by the favorable weather condition reported from Spain. However, the interpretation and significance of the results for the both oak species is difficult as data from Portugal for 2007 are not available. Consequently, the analysis of the temporal and spatial development for both oak species is based only on the data from Spain and on the few plots in Southern France and Italy. Nevertheless, 156 *Quercus ilex* and *Quercus rotundifolia* plots were found in the database. The analysis of the trends for these plots revealed improvement on only 10 plots (6.4%) compared with 59 plots with increasing defoliation in the period 1997 – 2007. Because of the high temporal variation of defoliation in this time span for 55.8% of all plots no clear trend could be identified (Figure 2.2.2.7-2).

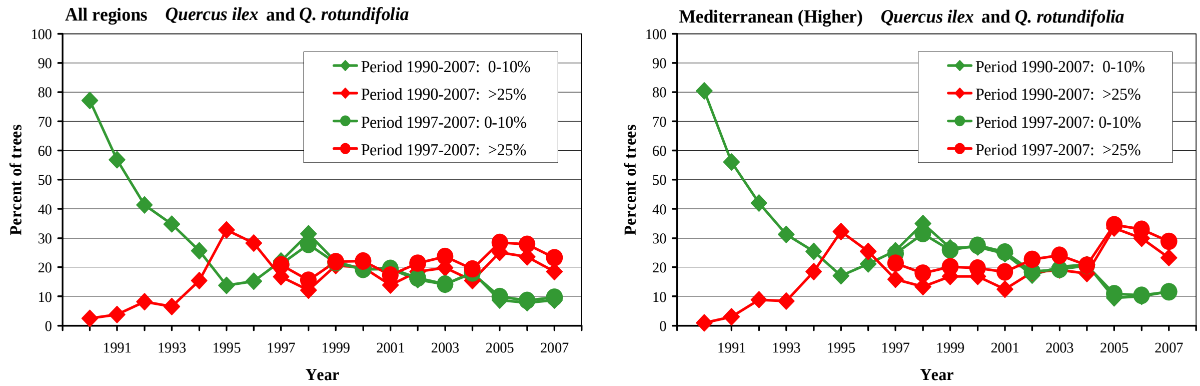


Figure 2.2.2.7-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2007 and 1997-2007).

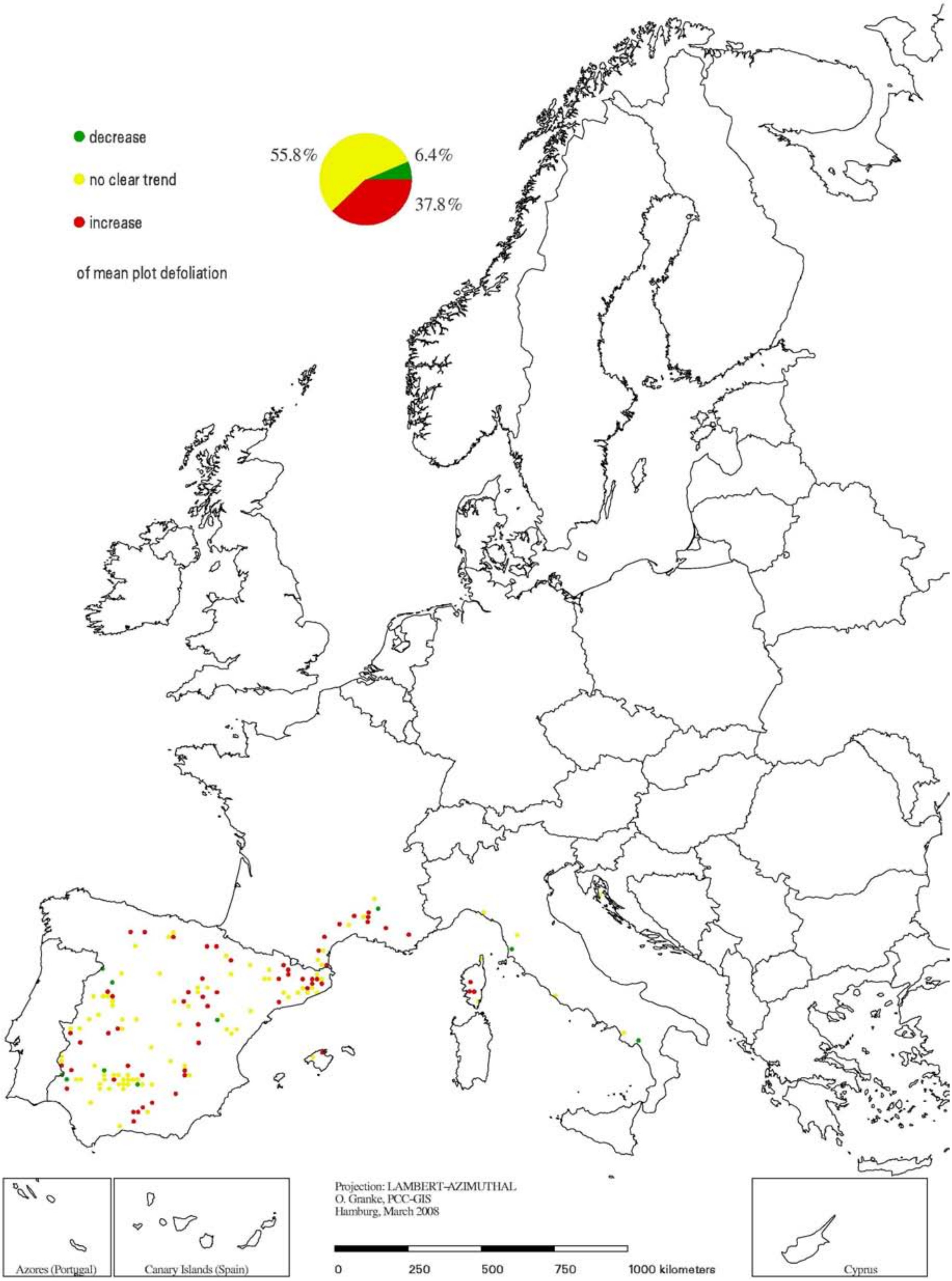


Figure 2.2.2.7-2: Trend of mean plot defoliation (slope of linear regression) of *Quercus ilex* and *Quercus rotundifolia* over the years 1997 to 2007.

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. The long term deterioration of the health status of *Pinus pinaster* can be recognized more distinctly and easily in terms of decreasing percentage of healthy trees (Figure 2.2.2.8-1). The share of undamaged trees fell from 78.5% in 1990 to 33.6% in 2007. This development reflects largely the one in the Mediterranean (Lower) and Mediterranean (Higher) regions, where almost 75% of all *Pinus pinaster* trees occur.

In the Mediterranean (Higher) region a striking improvement of crown condition occurred in 2007. There, the share of damaged trees decreased from 22.5% in 2006 to 11.7% in 2007. As with the *Quercus ilex* and *Quercus rotundifolia* this result may largely be influenced by the fact that data from Portugal with a substantial share of *Pinus pinaster* plots are not available for the evaluation. The spatial variation of trends in the period 1997-2007 is based only on 89 plots (Figure 2.2.2.8-2). Most of them do not show any trends (70.8%). As only on two plots mean defoliation decreased linear between 1997 and 2007 this trend category can not be considered as reliable trend estimation for *Pinus pinaster*

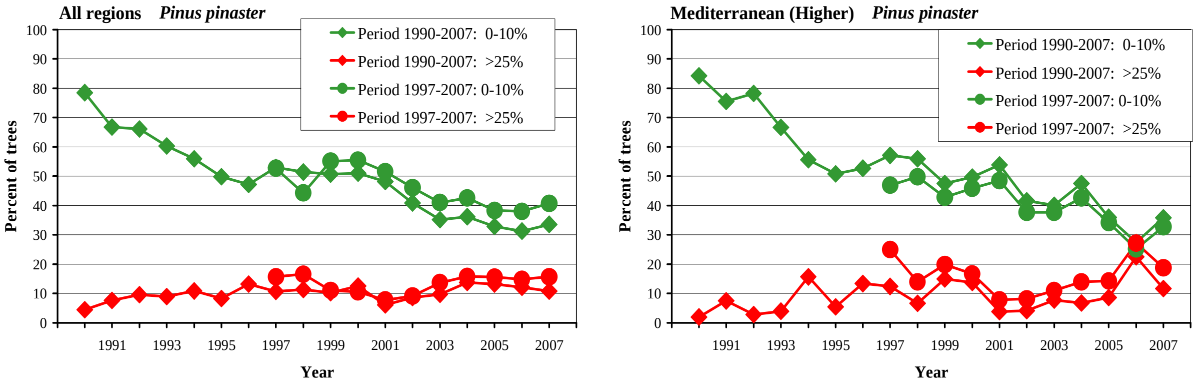


Figure 2.2.2.8-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2007 and 1997-2007).

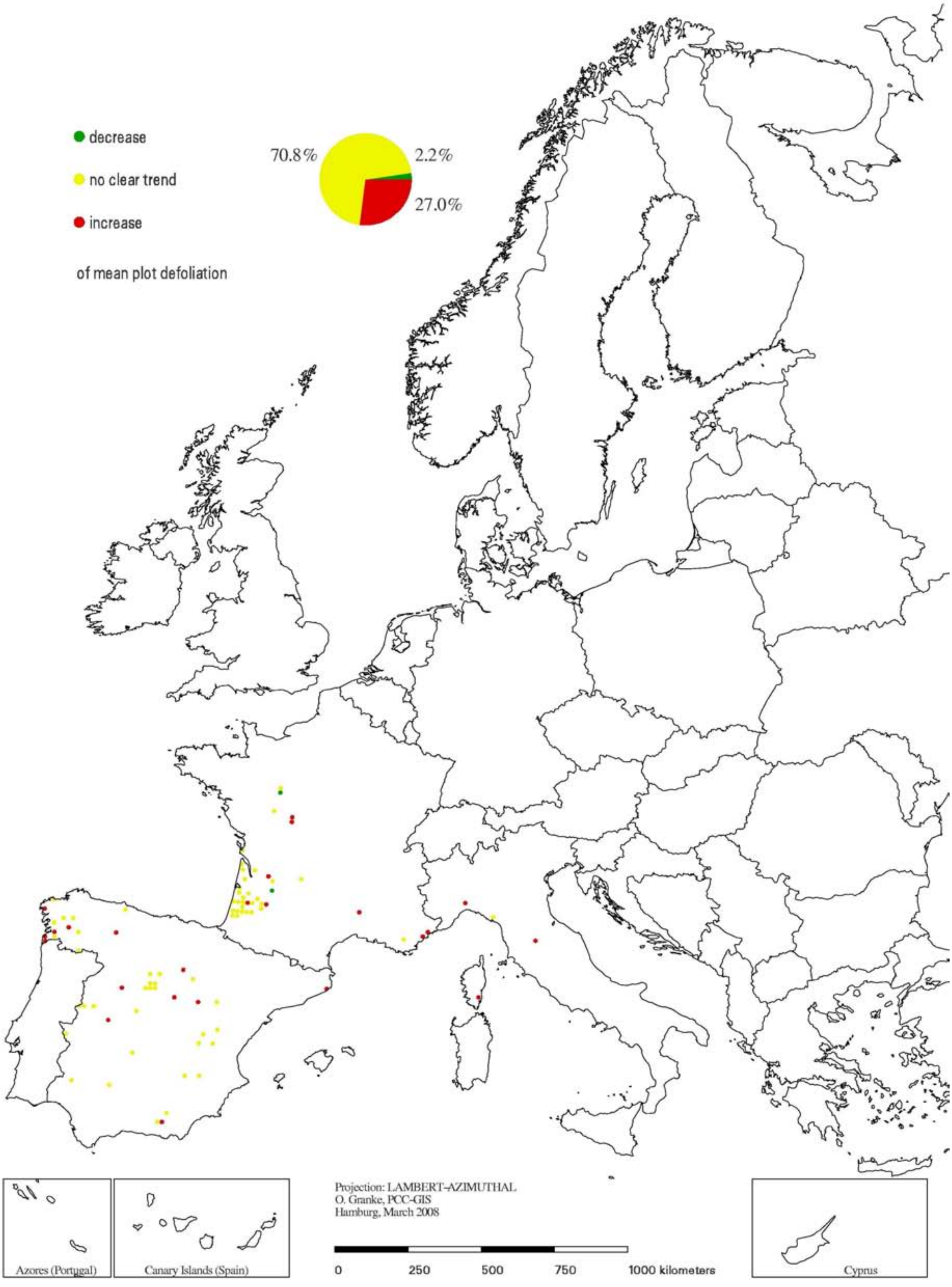


Figure 2.2.2.8-2: Trend of mean plot defoliation (slope of linear regression) of *Pinus pinaster* over the years 1997 to 2007.

3. INTENSIVE MONITORING
3.1 Introduction

For assessments of cause-effect relationships at the forest ecosystem scale more than 860 plots were (Level II) were selected in the most important forest ecosystems of 28 participating countries. The intensive monitoring comprises 11 surveys, but not all of them are conducted on every plot. Also, not all surveys are conducted continuously or annually, but need to be conducted only every few years. For each of the surveys Table 3.1-1 shows the number of installed plots, the number of plots assessed in 2005, and the assessment frequency. The map in Annex I-7 shows the locations of the installed 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, 2004a).

Table 3.1-1: Surveys, numbers of Level II plots installed and assessed in 2005, and assessment frequencies.

Survey	Number of plots		Assessment frequency
	Installed	Assessed in 2005	
Crown condition	800	671	Annually
Foliar chemistry	770	552	Every two years
Soil condition	738	0	Every ten years
Soil solution chemistry	254	197	Continuously
Tree growth	772	287	Every five years
Deposition	548	434	Continuously
Ambient air quality	114	110	Continuously
Ozone induced injury	99	44	Annually
Meteorology	216	217	Continuously
Phenology	149	152	Several times per year
Ground vegetation	723	235	Every five years
Litterfall	114	128	Continuously

Chapter 3.2 of the presents the spatial and temporal variation of sulphur, ammonium, and nitrate deposition as assessed at Level II by the year 2005. These results do not only give evidence of the effectiveness of CLRTAP clean air politics but also constitute the basis for further assessments of critical loads exceedances. The exceedances calculated for last years report (Lorenz et al. 2007) are compared with crown condition data in Chapter 3.3.
Chapter 3.4 deals with ozone concentrations, ozone induced plant injury and the further development of the flux approach.

3.2 Deposition and its trends

3.2.1 Method

Deposition data are collected and analysed on Level II plots according to the ICP Forests Manual (ANONYMOUS 2004a), both in the open field (bulk deposition) and under canopy (throughfall). Bulk deposition reflects the local air pollution situation. Throughfall and in some cases stemflow constitute element fluxes into forest ecosystems. Throughfall 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:

1. Canopy 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.

For the present study, throughfall and bulk deposition of nitrate (NO_3^-), ammonium (NH_4^+), sulphate (SO_4^{2-}), calcium (Ca^{2+}), sodium (Na^+), and chlorine (Cl^-) were calculated as the arithmetic mean of the yearly sums of the deposition in the years 2003-2005 for each Level II plot in kg ha^{-1} yr^{-1}. Changes over time were calculated over the period 2000-2005. In the light of data availability the choice of this period permitted the inclusion of a maximum number of plots. Only those plots were involved in the study on which deposition had been measured continuously over that period, with maximally 30 days of measurements missing per year. Data of missing days were replaced by the average daily deposition of the respective year. Table 3.2.1.-1 shows the numbers of plots included in the study for each substance according to the above-mentioned criteria. Depending on the pollutant considered, throughfall data were available for 215-249 plots. For a large share of these plots bulk deposition was also available.

Table 3.2.1-1: Number of plots which fulfilled the selection criteria.

Variation	Deposition	Na^+	Cl^-	Ca^{2+}	N- NH_4^+	N- NO_3^-	S- SO_4^{2-}
Temporal (2000–2005)	Bulk	193	193	193	192	193	185
	Throughfall	223	223	223	222	223	215
Spatial (2003–2005)	Bulk	216	216	216	216	216	216
	Throughfall	249	249	249	249	249	249

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:

- Decrease: negative slope, error probability lower or equal 5% (green)
- No change: negative slope with error probability greater than 5%, or same deposition in each year, or positive slope with error probability greater than 5%

- Increase: positive slope, error probability lower or equal 5% (red)

Given the time span of only six years, results must be understood as a mere description of the changes over time rather than a trend analysis which would require a longer period. For the interpretation of the results several restrictions have to be watched. In the present study canopy exchange was not taken into account so that throughfall does not reflect total deposition under canopy. Moreover, throughfall deposition may have been underestimated especially in beech stands because stemflow was not taken into account as it had not been measured continuously from 2000 to 2005 on most plots. These restrictions are not in conflict with the aim of the present study to assess spatial and temporal variation of depositions. However, care must be taken when comparing the results of the study with results published in the literature. Bulk and throughfall depositions expressed in kg ha^{-1} yr^{-1} in the text and in the figures refer to the chemical element considered, e.g. to sulphur ($S\text{-}SO_4^{2-}$) instead of sulphate (SO_4^{2-}). No attempt is made to compare the depositions assessed in the study with threshold values, because of poor comparability due to individual site and stand properties. Instead, depositions measured by ICP Forests are used to calculate exceedances of critical loads (Lorenz et al. 2008).

3.2.2 Results

3.2.2.1 Spatial variation

For $S\text{-}SO_4^{2-}$, bulk and especially throughfall deposition show rough spatial patterns across Europe (Figures 3.2.2.1-1 and 3.2.2.1-2). Many of the plots with highest deposition are situated close to coastlines. This holds particularly true for Greece, Italy, and Sweden. Most of these plots show also sodium depositions ranging from 13.1 to 194.7 kg ha^{-1} a^{-1} which indicates seaspray input carrying sulphate. But on plots remote from any coastlines sulphur deposition of more than 5.7 kg ha^{-1} a^{-1} were measured, indicating mainly an anthropogenic origin. This holds true for the Czech Republic, central and eastern Germany, and for the Slovak Republic. The throughfall deposition of sulphur is higher than bulk deposition. On 44.4% of the plots a throughfall higher than 5.7 kg ha^{-1} a^{-1} was found. These plots are mostly located in central Europe. Plots with lowest sulphur throughfall ranging from 0.7 to 3.3 kg ha^{-1} a^{-1} are mainly situated in the Nordic countries and in the Alps.

Also for bulk and throughfall deposition of the nitrogen compounds (Figures 3.2.2.1-3 and 3.2.2.1-6) rough spatial patterns are discernable. For the majority of the plots throughfall is clearly higher than bulk deposition, indicating the importance of dry deposition filtered from the air and washed off the leaves.

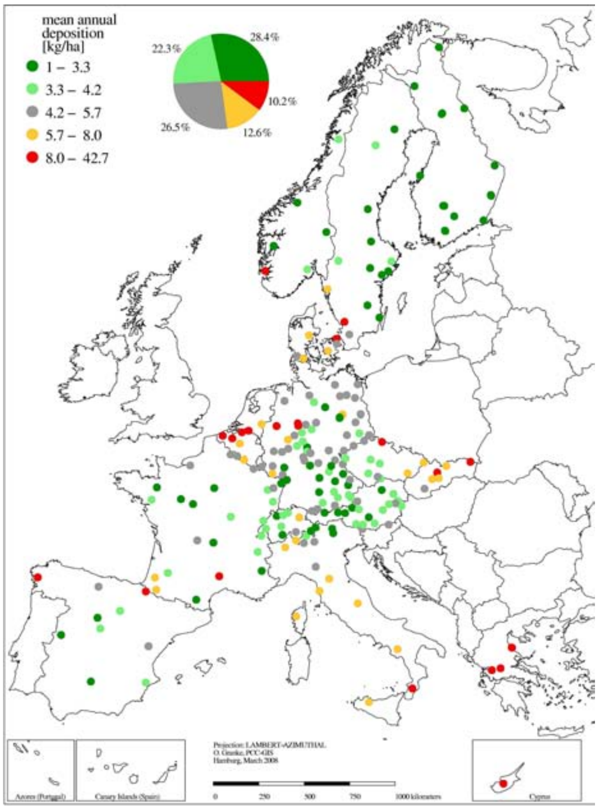


Figure 3.2.2.1-1: Mean annual sulphate sulphur ($S\text{-}SO_4^{2-}$) bulk deposition 2003 to 2005.

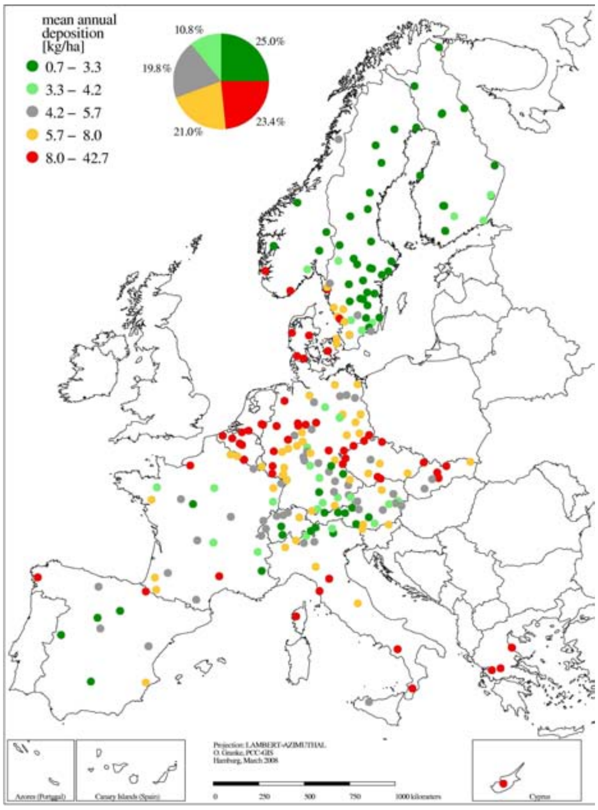


Figure 3.2.2.1-2: Mean annual sulphate sulphur ($S\text{-}SO_4^{2-}$) throughfall deposition 2003 to 2005.

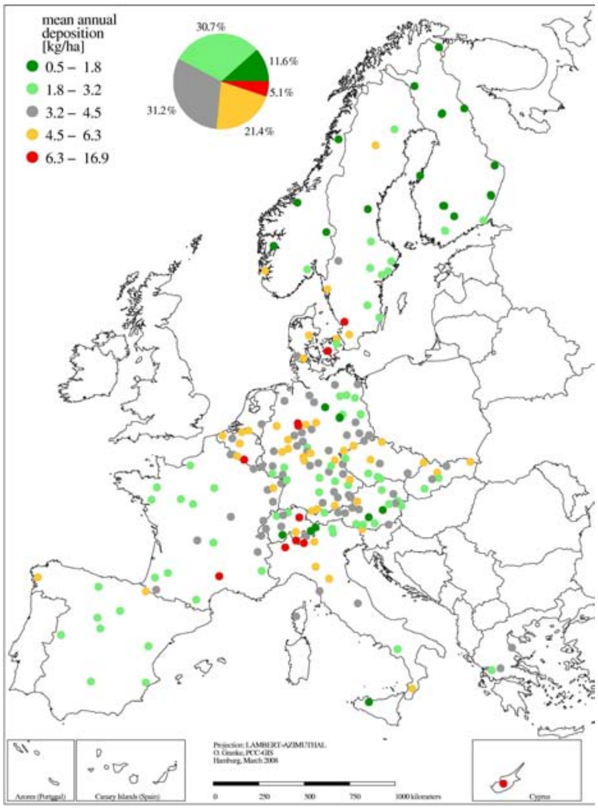


Figure 3.2.2.1-3: Mean annual nitrate nitrogen ($N\text{-} NO_3^-$) bulk deposition 2003 to 2005.

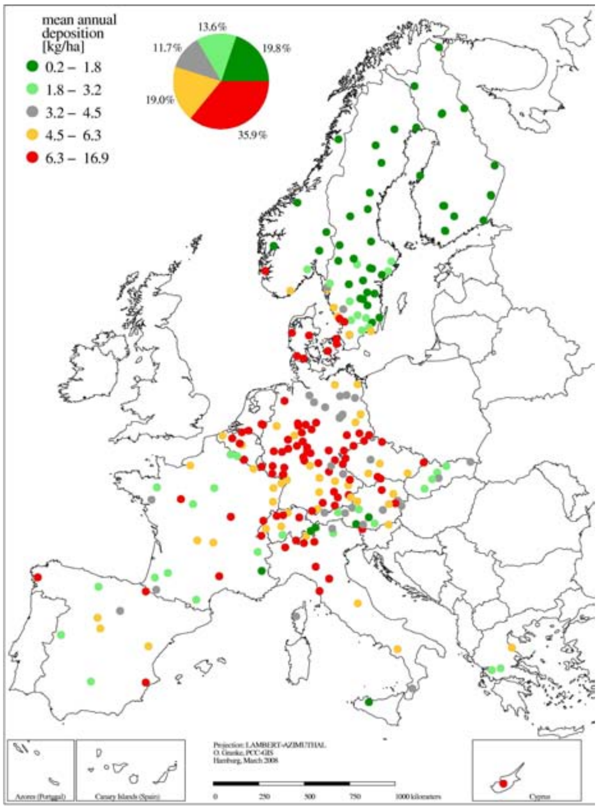


Figure 3.2.2.1-4: Mean annual nitrate nitrogen ($N\text{-} NO_3^-$) throughfall deposition 2003 to 2005.

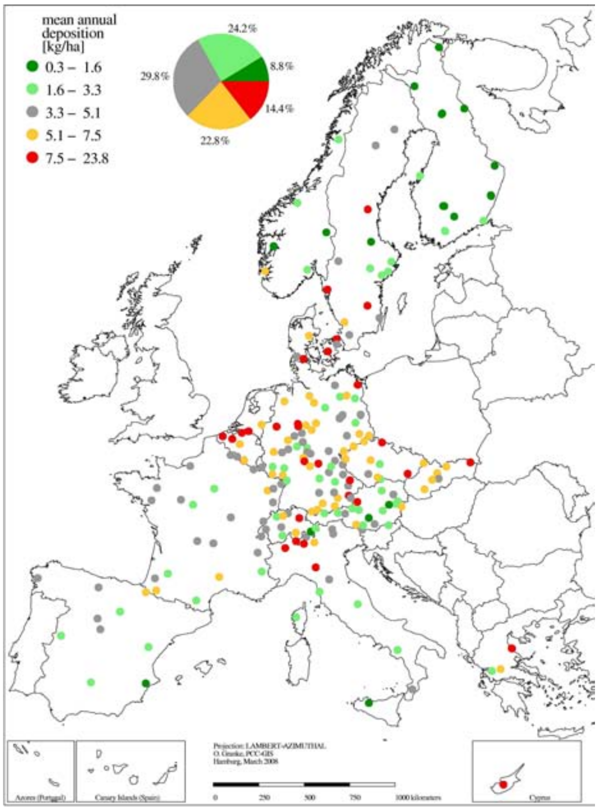


Figure 3.2.2.1-5: Mean annual ammonium nitrogen ($N\text{-}NH_4^+$) bulk deposition 2003 to 2005.

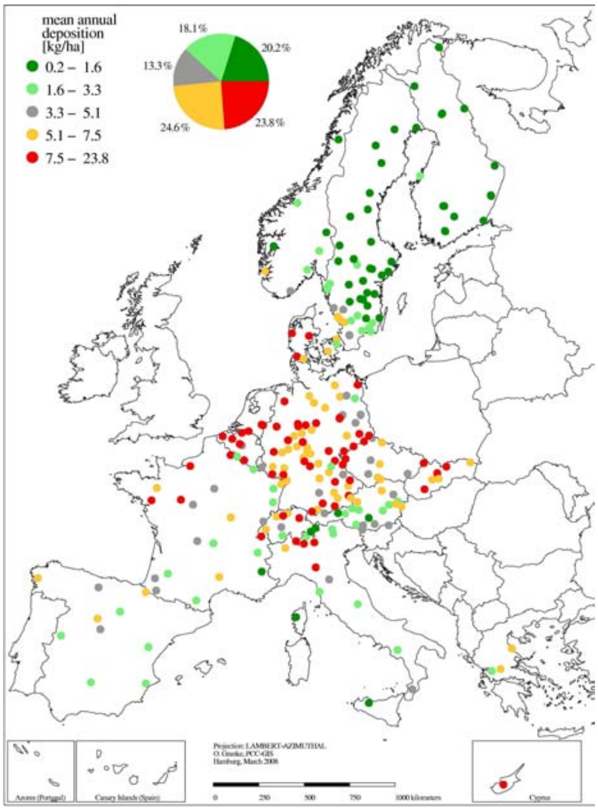


Figure 3.2.2.1-6: Mean annual ammonium nitrogen ($N\text{-}NH_4^+$) throughfall deposition 2003 to 2005.

Due to the higher number of plots with throughfall measurements, spatial patterns are better discernable for throughfall than for bulk deposition. Plots with lowest $N\text{-}NO_3^-$ and $N\text{-}NH_4^+$ throughfall are located in the nordic countries and in the Alps. Plots with highest $N\text{-}NO_3^-$ throughfall were found mainly in central Europe. High abundance of such plots in central Germany and northern Italy may reflect partly areas of high vehicle exhaust due to dense traffic. Also highest $N\text{-}NH_4^+$ throughfall is most abundant in central Europe, but less so in northern Italy.

3.2.2.2 Temporal variation

Figure 3.2.2.2-1 shows the changes in throughfall and bulk deposition of $S\text{-}SO_4^{2-}$, $N\text{-}NH_4^+$, and $N\text{-}NO_3^-$ from 2000 to 2005. The distinctness of the changes varies greatly among the three substances within the five years observation period.

Bulk and throughfall deposition of $S\text{-}SO_4^{2-}$ are highest but show the most pronounced decrease. $S\text{-}SO_4^{2-}$ throughfall decreases by about a quarter from 7.9 to 5.9 kg ha^{-1} a^{-1}. Bulk deposition of $S\text{-}SO_4^{2-}$ shows a similar decrease at a lower level, namely from 6.0 to 4.6 kg $ha^{-1}a^{-1}$. Bulk and throughfall deposition of $S\text{-}SO_4^{2-}$ decrease by a nearly uniform rate every year but show an exceptionally strong decrease in the dry year 2003. This reflects the high dependence of bulk deposition and throughfall of $S\text{-}SO_4^{2-}$ on precipitation. The deposition of $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ is mostly lower than that of sulphate. The rate of decrease in bulk deposition and throughfall of $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ is smaller than that of $S\text{-}SO_4^{2-}$. Moreover, the response of $N\text{-}NH_4^+$ and of $N\text{-}NO_3^-$ deposition to the low precipitation in 2003 is lower than that of $S\text{-}SO_4^{2-}$. Although the influence of precipitation on deposition is considerable, the observed decrease in deposition is not a result of mainly decreasing precipitation (LORENZ et al. 2008). The spatial patterns of the changes in deposition over time are shown in Figures 3.2.2.2-2 to 3.2.2.2-7.

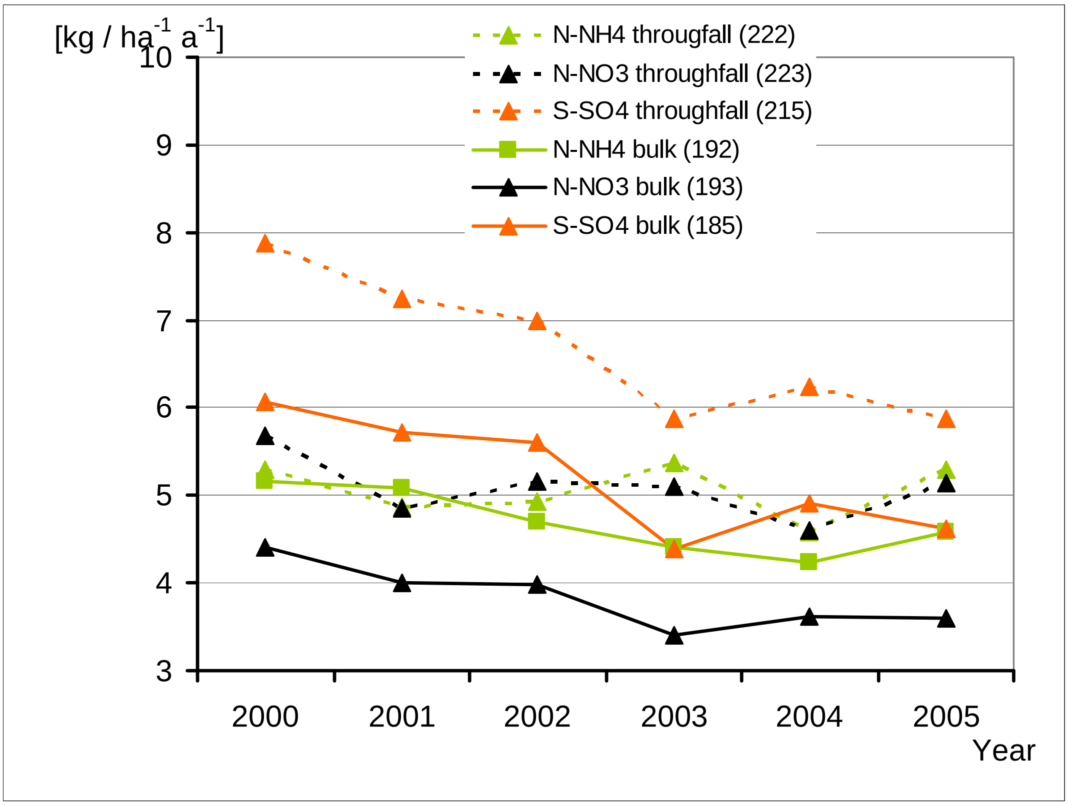


Figure 3.2.2.2-1: Mean annual bulk and throughfall deposition of sulphur, nitrate nitrogen and ammonium nitrogen.

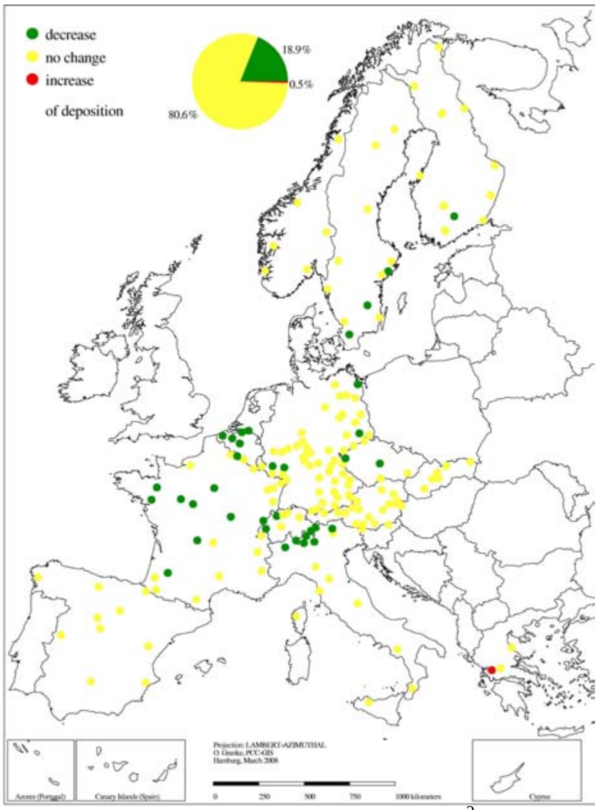


Figure 3.2.2.2-2: Trends in sulphur (S-SO_4^{2-}) in bulk deposition from 2000 to 2005.

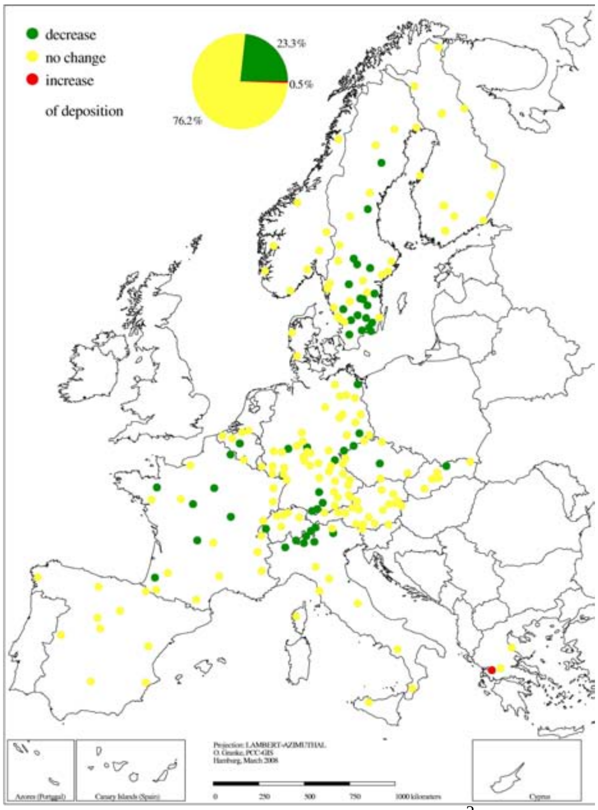


Figure 3.2.2.2-3: Trends in sulphur (S-SO_4^{2-}) in throughfall deposition from 2000 to 2005.

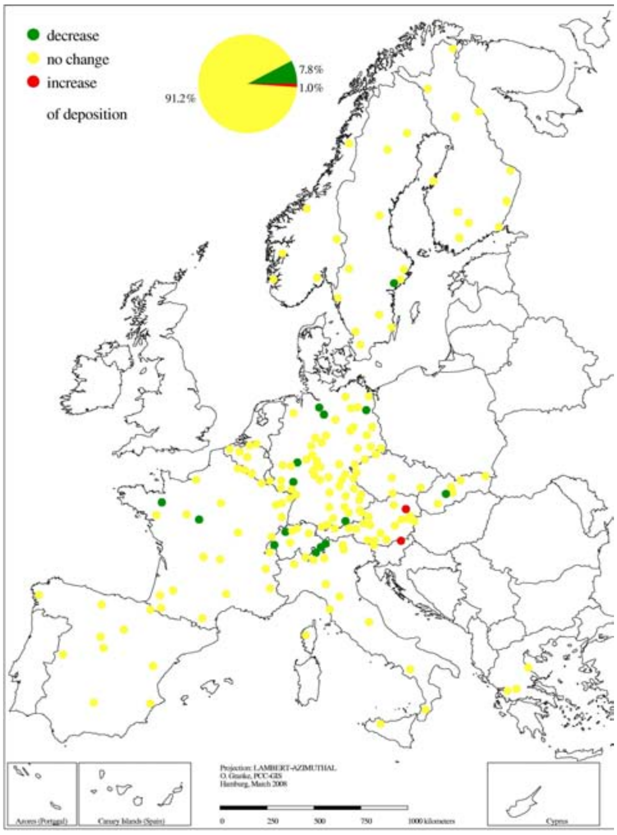


Figure 3.2.2.2-4: Trends in nitrate nitrogen (N-NO_3^-) in bulk deposition from 2000 to 2005.

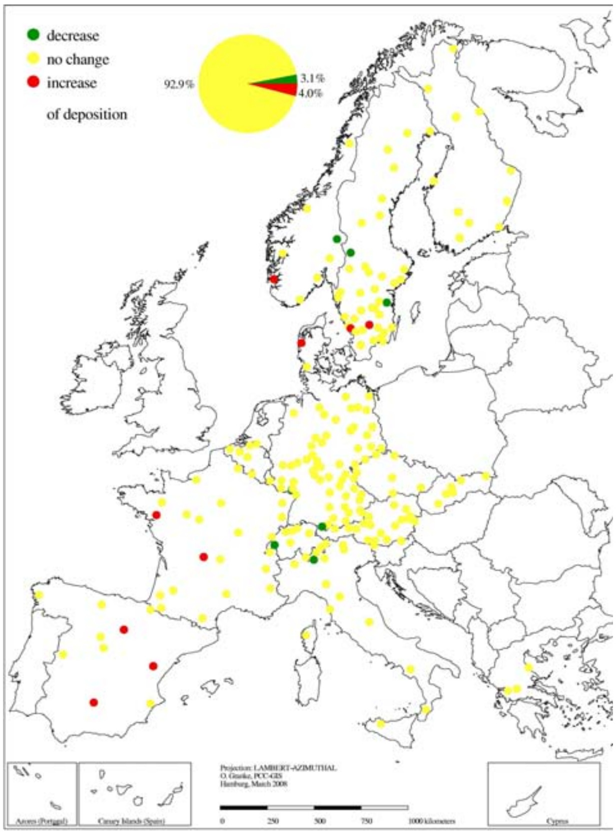


Figure 3.2.2.2-5: Trends in nitrate nitrogen (N-NO_3^-) in throughfall deposition from 2000 to 2005.

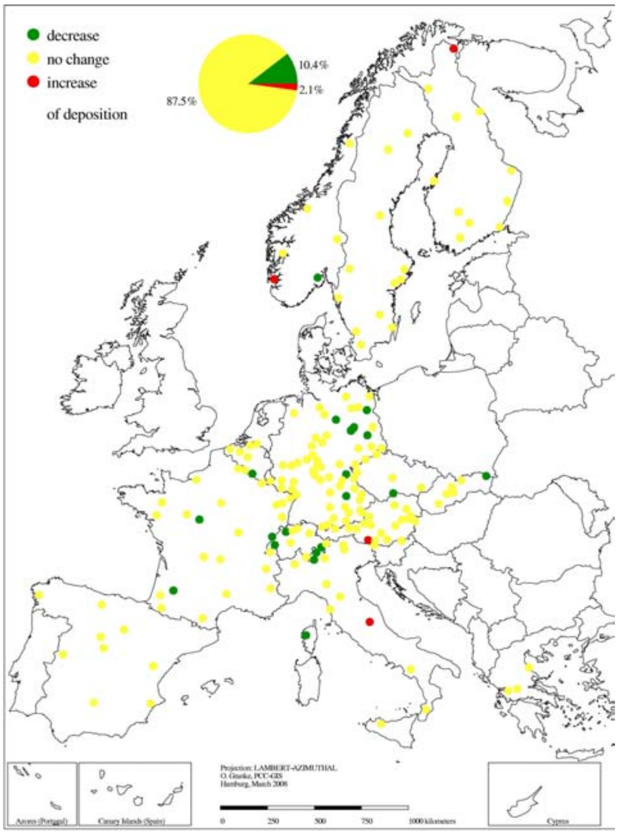


Figure 3.2.2.2-6: Trends in ammonium nitrogen ($N\text{-}NH_4^+$) in bulk deposition from 2000 to 2005.

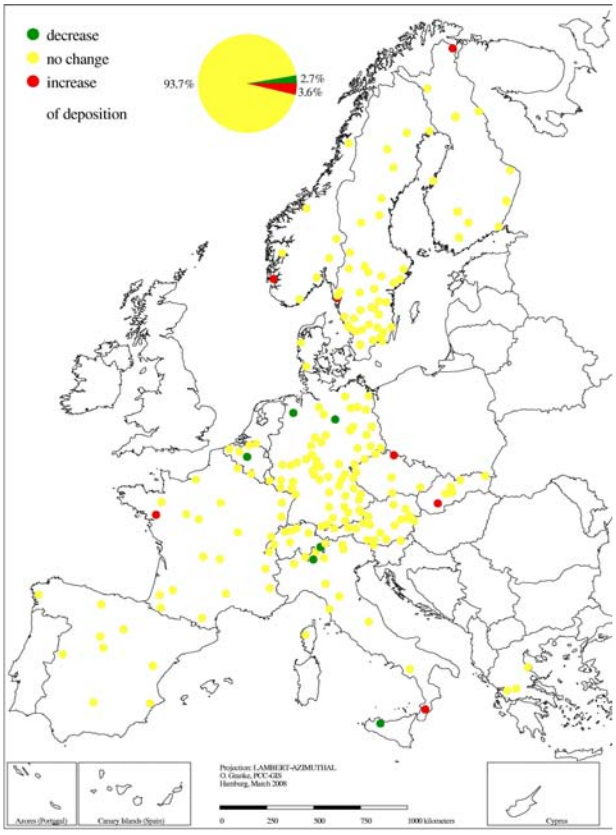


Figure 3.2.2.2-7: Trends in ammonium nitrogen ($N\text{-}NH_4^+$) in throughfall deposition from 2000 to 2005.

3.2.3 Conclusions

Intensive forest monitoring at Level II shows clear patterns in the spatial distribution of depositions of $N\text{-}NO_3^-$, $N\text{-}NH_4^+$ and $S\text{-}SO_4^{2-}$. Obviously the spatial patterns of depositions often vary over large distances, so that even the Level-II grid is dense enough to reveal them, although designed for monitoring on the ecosystem scale rather than on the European-wide scale. The spatial patterns of depositions reflect partly regional emission situations. $N\text{-}NO_3^-$ depositions are particularly high in some regions of dense traffic and high vehicle exhaust like central Germany and northern Italy. $S\text{-}SO_4^2$ reflects partly regional industrial air pollution, but can as well be caused by sea salt, specifically in areas close by the sea. The spatial patterns of depositions of $N\text{-}NO_3^-$, $N\text{-}NH_4^+$ and $S\text{-}SO_4^{2-}$ shown in the present study partly confirm those found by analyses of data measured in earlier years (Lorenz et al. 2008). In addition to the spatial patterns, S and N depositions also show clear temporal patterns, namely a decrease over the five years period of observation. All in all, the results of deposition measurements at Level II reflect the reduction of sulphur emissions (by 70% since 1980) under CLRTAP politics over the last years and the less pronounced reduction of nitrogen emissions in Europe (Sliggers and Kakebeeke 2004).

3.3 Exceedances of critical loads for acidity and nitrogen and forest ecosystem responses

3.3.1 Background and aim of the study

Clean air policy by CLRTAP and EC relies inter alia on critical loads assessment as an appropriate tool to evaluate long-term ecosystem responses to deposition of acidifying and eutrophying pollutants. Budgets of relevant chemical compounds are the main basis for the respective calculations. Biological responses of the forest ecosystems are much more difficult to assess. In this respect the Level II plots provide a unique basis to contribute information to the related policy processes. The aim of the present study is to evaluate statistical relationships between exceedances of critical loads for nutrient nitrogen and acidity on one side and reactions of the forest ecosystems on the other side. Hypotheses to be tested are that

- critical load exceedances are related to forest condition in terms of recent tree crown condition;
- critical load exceedances are related to changes in forest condition in terms of temporal developments of tree crown condition;

It has, however, to be considered that the critical loads concept is a long-term model for ecosystem development. Therefore, exceedances of critical loads may not evoke immediate responses within particular ecosystems. Only if specific critical thresholds (limits) of organisms (e.g. trees) within certain ecosystems are exceeded, a respective response is to be expected.

3.3.2 Methods

3.3.2.1 Critical load exceedances, deposition and soils properties as predictor variables

Based on the results of deposition measurements at Level II, critical loads for acidity and nitrogen as well as their exceedances were presented in the previous report (Lorenz et al. 2007). The methods of these critical loads calculations are laid down in the Manual of ICP on Modelling and Mapping (Anonymous 2004b). The critical load exceedances from the previous report are related to response variables in the present study.

In order to achieve an adequate set of parameters with minimal intercorrelation between the parameters, within both considered domains (deposition and soil solid phase) domain-specific principal component analyses (PCA) was performed. Only those parameters were used, which gained high scores on the first three (deposition) respectively four (soil solid phase) PCA-axes. Additionally stand age - a variable well-known for its positive relationship with defoliation (KLAP et al. 2000, SEIDLING & MUES 2005) - and exceedances of CL for nutrient nitrogen and acidification were included.

3.3.2.2 Response structure crown condition

Crown condition is regarded as a widely available indicator for forest condition in Europe. There are some statistical relationships to deposition which are, however, limited by the fact that they do not take into account the specific status of the concerned ecosystem. This recent status of soil and stand is, however, regarded within the calculation of critical loads. First results from Germany and Canada show that relationships between defoliation and critical loads are closer than relationships between defoliation and deposition. No transnational evaluations have yet been carried out in this field.

3.3.2.3 Statistical approach

In a first step intercorrelations between different deposition measures (throughfall deposition, total deposition, critical load exceedance) were investigated by suitable correlation analyses and by principal component analyses, performed with SAS. Data were provided by ICP Forests. The results provide an appropriate basis for more sophisticated interference analyses between deposition estimates and response variables.

Besides general relationships, for plots stocked by tree species which gain sufficiently high numbers of cases (Figure 3.3.2.3-1), relationships between crown condition on one side and deposition, stand as well as site parameters on the other side have been investigated in more detail. The two oak species *Quercus robur* and Q. *petraea* as well as the two beech species *Fagus sylvatica* and *F. moesiaca* have been pooled. Together with the two coniferous species *Pinus sylvestris* and *Picea abies* these are the main tree species, which are also used in most comparable evaluations. All other tree species do not deliver sufficiently high number of cases for any separate evaluation and should not be merged due to their considerable ecological differences.

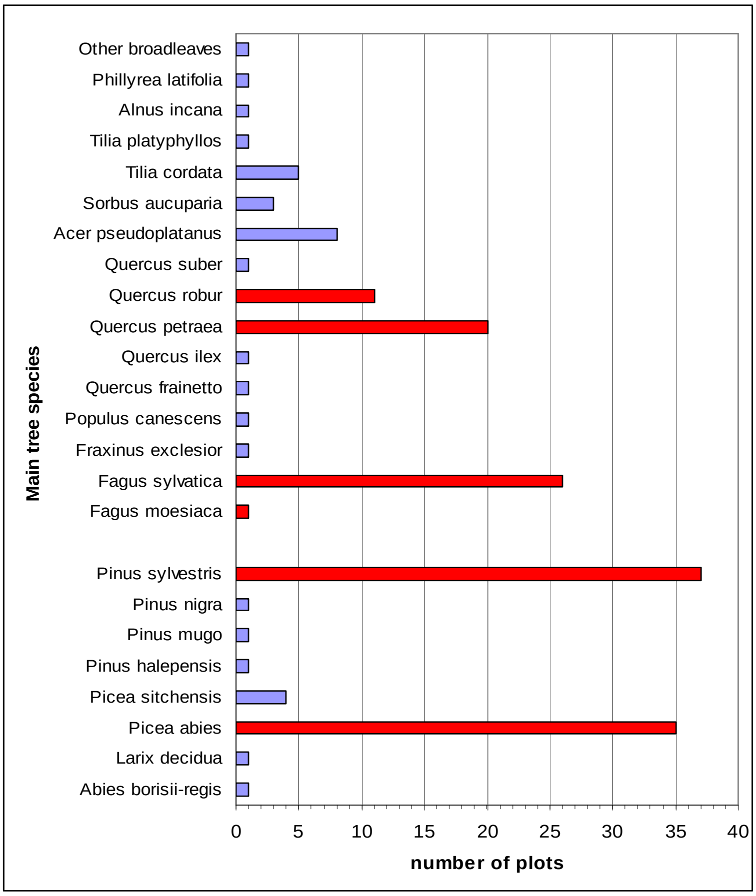


Figure 3.3.2.3-1: Number of plots per main tree species with available calculations of exceedances of critical loads for nutrient nitrogen and exceedances of critical loads for acidity; species with red (dark) bars have been used for all species-specific evaluations; *Fagus sylvatica and F. moesiaca* as well as *Quercus robur* and *Q. petraea* have been pooled.

3.3.3 Results and Discussions

3.3.3.1 Simple interference analyses with defoliation as response variable

Interrelation structure of crown condition in terms of defoliation was screened along with important parameters from the deposition and soil survey and calculations of critical loads exceedances for those Level II plots with available data by a series of bivariate correlation analyses.

Table 3.3.3.1-1: Correlation coefficients (Pearson) and degree of significance (pr > |r| under HO: ρ = 0.05) between defoliation, exceedances of acidity and eutrophying nitrogen and soil and deposition parameters; n = 148 - 303.

	ExEutro	ExAcid	N_through	NO3_bulk	NH4_bulk	stand age	BCE	C_o	N_o	C/N_o
Defoliation	0.046	0.020	0.136	0.083	-0.046	0.325***	0.034	0.247**	0.204*	0.114
ExEutro		0.608***	0.824***	0.360***	0.513***	-0.031	-0.173*	-0.121	0.003	-0.177*
ExAcid			0.537***	0.351***	0.309***	-0.177*	-0.171*	-0.077	-0.063	-0.057
N_through				0.681***	0.648***	0.091	-0.144	-0.104	0.104	-0.304***
NO3_bulk					0.651***	0.111	-0.064	-0.158	0.123	-0.412***
NH4_bulk						0.049	-0.106	-0.120	0.069	-0.312***
stand age							0.032	0.215**	0.270**	-0.032
BCE								0.093	0.009	0.114*
C_o									0.716***	0.340***
N_o										-0.359***

Defoliation: mean defoliation over all tree species, ExEutro: exceedances of critical loads for eutrophying nitrogen; ExAcid: exceedances of critical loads for acidity; N_trough: annual nitrogen thoughfall deposition, NO3_bulk: annual nitrate N bulk deposition, NH4_bulk: annual ammonium N bulk deposition, BCE: exchangeable basic cations; C_o: Carbon content in org. layer, N_o: nitrogen content in org. layer, C/N_o: C/N ratio in org. layer.

Table 3.3.3.1-1 corroborates stand age with a highly significant correlation coefficient as a relevant predictor of defoliation even within this limited sample of Level II plots. Other bivariate relationships for crown condition are the amount of carbon respectively nitrogen within the organic layer, which may indicate that on less productive soils characterised by impeded mineralization trees reveal more transparent crowns. Table 3.3.3.1-1 also shows that all deposition parameters are intercorrelated. Even 68% ($R^2 = 0.8235^2$) of the variation of the exceedances of critical loads for eutrophying nitrogen can be predicted by nitrogen throughfall deposition. Another obvious cluster of significant negative relationships is found for all measured deposition parameters as well as for the C/N ratio of the organic layer. The latter is in accordance with a respective result found by AUGUSTIN et al. (2005).

Results of bivariate species-specific evaluations are displayed by Figure 3.3.2.3-2 and Figure 3.3.2.3-3 as two examples of the relationships between defoliation and critical loads for nutritional nitrogen. While in beech higher defoliation estimates coincide with higher exceedances of nitrogen deposition, for Scots pine no systematic relationship is found. The latter result applies also for oak and Norway spruce. As typical for the use of highly aggregated parameters in interference analyses, it is not easy to identify an underlying causal mechanism for the relationship found in beech. Respective interference analyses between defoliation and exceedances of critical loads for acidity did not reveal any significant statistical relationships for the four species respectively species aggregates.

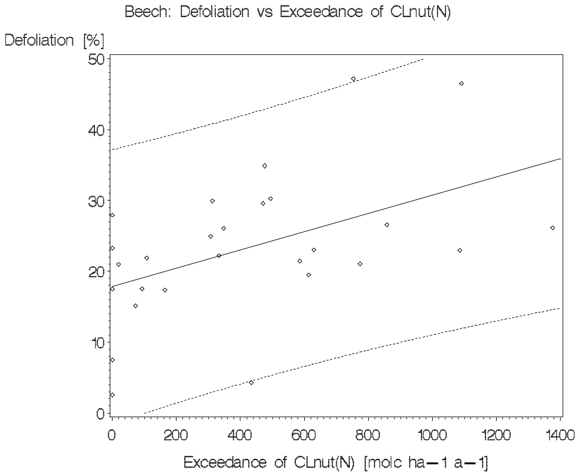


Figure 3.3.2.3-2: Beech (*Fagus sylvatica et moesiaca*): Linear regression (incl. 95% confidence intervals for predicted values) with defoliation as response parameter and exceedances of critical loads for nutritional nitrogen as predictor (n = 27, R^2 = 0.24, p > F = 0.0099).

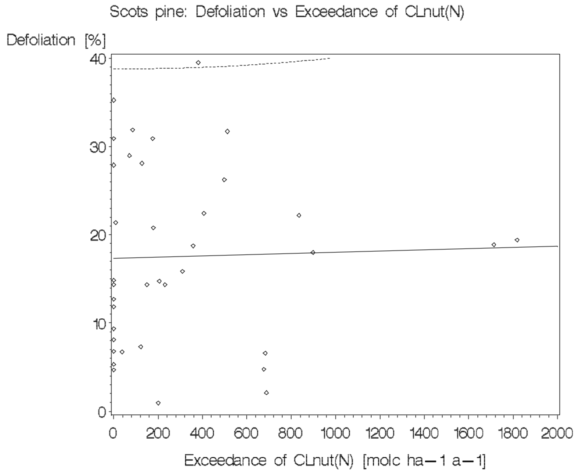


Figure 3.3.2.3-3: Scots pine (*Pinus sylvestris*): Linear regression (incl. 95% confidence intervals for predicted values) with defoliation as response parameter and exceedances of critical loads for nutritional nitrogen as predictor (n = 37, R^2 = 0.001, p > F = 0.865).

3.3.3.2 Multiple interference analyses with defoliation as response variable

Information on natural or anthropogenic drivers of natural phenomena like foliage density of forest trees is seldom complete. Within any empirical approach with statistical means for a sound selection of sets of predictors at least the following two preconditions are to be met: hypotheses about possible dependences and knowledge about results of earlier similar approaches. A typical result of data sets from empirical transboundary evaluations with considerable influence was the affiliation of plots to a country, often called country bias (INNES et al. 1993, DOBBERTIN et al. 1997, KLAP et al. 1997, SEIDLING & MUES 2005). Most of the cited papers are partly or totally based on data from the much denser Level I monitoring network. Nonetheless, this relationship might also exist for Level II sites. Therefore ‘country’ was chosen as a categorical parameter within covariance models with a mixed predictor structure.

Results given in Table 3.3.3.2-1 reveal the smallest respective influence for Scots pine with 42% explained variance by ‘country’. Oaks show with 71% the highest amount of explained variance. Foremost due to the small number of total plots and the unbalanced numbers of plots from different countries, interaction terms between country and age or other predictors cannot be carried out. It is to assume that a certain share of variance explained by ‘country’ is covered by interacting variables like stand age, however, a considerable degree might be left to country-specific estimation practices (cf. MUES & SEIDLING 2003).

In joint Moesian and European beech, besides the well-known influence of country-specific peculiarities (e.g. SEIDLING & MUES 2005), an influence of different components of measured and derived deposition parameters were found. All of these relationships are positive, which means higher defoliation estimates at the included Level II plots coincide with higher deposition of nitrogen and/or sulphur. None of the substrate related parameters were found to influence directly crown condition in beech.

In sessile and pedunculate oak only parameters related to the soil acidity status give significant signals besides a very strong country-related influence. All concerned soil-related parameters are closely related to the acidity status of the substrates and the sign of the relationship denotes oak stands on more acidic soils as those with higher defoliation.

Table 3.3.3.2-1: Summarized results of a series of multiple linear models with mixed predictor structures (Proc GLM in SAS) and defoliation as response variable; *: partially statistically significant at $p < 0.05$, **: $p < 0.01$, ***: $p < 0.0001$; (+), (-): sign of the relationship (checked by adequate regression analyses with country-corrected defoliation estimates).

	Fagus sylvatica et moesiaca	*Quercus robur et petraea*	*Picea abies*	*Pinus sylvestris*
N of cases	27	31	35	37
Country	***	***	**	**
explained variation	0.471	0.711	0.534	0.416
Numeric parameters, with are additionally affiliated by covariance models				
[N] min01				** (+)
[C] min01				* (+)
pH org		* (-)		
pH min01				* (+)
BCE min		* (-)		
CEC				
base saturation		** (-)		
C/N ratio min				
C/N ratio org			** (+)	
N bulk			* (-)	
NH_4-N bulk				
NO_3-N bulk	** (+)			
N throughfall	* (+)		* (-)	
NH_4-N throughfall			* (-)	
NO_3-N throughfall	** (+)			* (+)
SO_2-S throughfall	* (+)			
exacid				
exeutro	* (+)			
mean stand age				

Crown condition on Level II plots mainly stocked by Norway spruce shows – again besides country specific effects – relationships with parameters of soil condition and deposition. It responds negatively towards nitrogen bulk and throughfall deposition, which means that defoliation values are higher at lower rates of N deposition and vice versa. Since the model covers a broad scale of deposition rates, this outcome embraces an obviously broad avenue of the reaction norm of spruce against plant available nitrogen even emphasising its stimulating part. The C/N ratio within the organic layer is concurrently positively correlated with deposition. The C/N ratio shows a negative relationship with all components of deposition (total N and both N compounds within bulk as well as in throughfall deposition and S throughfall deposition). This outcome is in full agreement with the previous one, as lower C/N ratio coincide with higher N deposition

(Table 3.3.3.1-1) The relationship between N deposition and the C/N ratio of the litter layer was similarly found for spruce stands by AUGUSTIN et al. (2005) for Germany and interpreted there as an ecosystem response towards nitrogen deposition.

In Scots pine stands defoliation adjusted towards country specific levels (PAD according to SEIDLING & MUES 2005) is higher at sites with higher N (and intercorrelated C) concentrations in the upper mineral soil layer. Consistently nitrogen throughfall deposition is also positively correlated with defoliation. The fact that pH within the upper mineral soil layer is also positively related with defoliation in pine is factually not consistent with the remaining results for this species within this study.

3.3.3.3 Muliple interference analyses with change in defoliation over time as response variable

The behaviour of defoliation over time is rather complex. For a typical time series analysis a length of 15 years are considered as minimum. Longitudinal approaches can be performed with shorter time series, however, a considerable number of synchronous cases is needed for it. Additionally, adequate predictors are needed in the same temporal resolution as the response variable. This is not the case for critical loads and its exceedances. Therefore the development of defoliation is described by its average behaviour in time, which can be expresses by the slope of the mean annual defoliation regressed over time mainly for the period from 1997 to 2001 (cf. LORENZ et al. 2006). Differences from year to year, which can be considerable, can not be regarded by such an approach. Additionally, the values can strongly be influenced by extreme values especially at the beginning or at the end of the observation period. Table 3.3.3.3-1 displays basic information about the statistical ranges of this parameter.

Table 3.3.3.3-1: Basic statistics of slopes of plot-related defoliation of main tree species; values can be red as increase / decrease of defoliation per year; number of cases per species confer to Figure 3.3.2.3-1.

species	mean	minimum	maximum
Picea abies	0.265	-2.017	10.013
Pinus sylvestris	0.712	-1.522	4.081
Fagus sylvatica et moesiaca	0.191	-1.562	3.073
Quercus robur et petraea	-0.374	-5.258	4.965

The strongest mean increase on the regarded Level II plots over the underlying period reveals Scots pine with 0.7% per year, which is almost 5% over 7 years. The highest maximum exist for a spruce plot in Germany with defoliation values around 18% until 1999 and around 50% from the year 2000 onwards. The two merged oak species are the only taxon with an average decrease of defoliation.

In contrast to the relationship between defoliation and country there is no such strong and continuous relationship for the average change rate of defoliation and country (results not explicitly shown). This is in full agreement with respective statements in the Technical Reports of ICP Forests (e.g. LORENZ et al. 2006). Only in Scots pine there is a weak respective relationship. This hearkens back to a distinct positive relationship between the slope of defoliation over time and the absolute height of defoliation, which means that trees with higher defoliation estimates at the beginning of the evaluation period reveal an even higher increase in defoliation.

Generally ambiguous relationships between the slope of defoliation over time and selected predictors are indicated by the fact that different selection mechanisms within multiple regression models reveal comparatively different predictor structures (Table 3.3.3.3-2 and Table 3.3.3.3-3). While the average change of defoliation per plot in beech is not related to any of the predictors, decreasing defoliation coincides with higher carbon concentrations within the organic soil layer in oak stands, found with the backward selection strategy. At the same time there is a trend that higher C/N ratios in the organic layer coincide with increasing defoliation. While the first result for oak indicates possibly a hint that higher carbon concentrations within the organic layer may stabilise crown condition on a medium time scale, the latter finding supports the idea that less productive soils with a high C/N ratio may enhance defoliation. Interestingly the same relationship between an increasing defoliation and sites with higher C/N ratios is found in spruce, even with both predictor selection strategies. For spruce in the backward elimination strategy model besides this relationship a whole bunch of predictors were kept within the model. Most significant is a positive relationship with nitrogen throughfall deposition and at the same time a negative relationship with exceedances of critical loads of nutritional nitrogen respectively its exceedances. These somewhat contradictory results may be based on the integrating nature (soil, stand) of Critical Loads estimates in contrast to mere deposition measurement. For Scots pine, the stepwise model revealed exchangeable basic cation capacity within the mineral soil as the only statistically significant predictor: At base-rich soils an increase in defoliation is more probable than at more acid soils. However, in the backward model this variable is eliminated from the predictor set. Instead N throughfall deposition and exceedances of CL for nutritional nitrogen are kept in the model, again with opposite signs.

Table 3.3.3.3-2: Summarized results of a series of multiple regression models with stepwise selection (selection limit: p = 0.05, Proc REG in SAS), slope of defoliation over time as response variable, predictors selected by factor analyses (PCA) with soil and deposition related data; *: partially statistically significant at p < 0.05, **: p < 0.01, ***: p < 0.0001; (+), (-): sign of the relationship.

	Fagus sylvatica et moesiaca	*Quercus robur et petraea*	*Picea abies*	*Pinus sylvestris*
Model R^2	0	0	0.223	0.124
n of cases	23	29	34	33
[N] org layer				
[C] org layer				
BCE min				*** (+)**
C/N ratio org			**** (+)**	
NH_4-N bulk				
NO_3-N bulk				
N throughfall				
Exacid				
Exeutro				
stand age				

Table 3.3.3.3-3: Summarized results of a series of multiple regression models with backward elimination algorithm (elimination threshold: $p = 0.1$, Proc REG in SAS), slope of defoliation over time as response variable, predictors selected by factor analyses (PCA) with soil and deposition related data; #: trend at $p < 0.1$, *: partially statistically significant at $p < 0.05$, **: $p < 0.01$, ***: $p < 0.0001$; (+), (-): sign of the relationship.

	Fagus sylvatica et moesiaca	*Quercus robur et petraea*	*Picea abies*	*Pinus sylvestris*
model R^2	0	0.148	0.689	0.334
n of cases	23	29	34	33
[N] org layer			**** (-)**	
[C] org layer		*** (-)**		
BCE min				
C/N ratio org		**# (+)**	***** (+)**	
NH_4-N bulk			**** (-)**	
NO_3-N bulk				
N throughfall			***** (+)**	**** (+)**
S throughfall			**** (-)**	
Exacid				
Exeutro			***** (-)**	**** (-)**
stand age			*** (-)**	

3.3.4 Outlook

3.3.4.1 Crown condition as response structure within interference analyses

All statistical evaluations concerning the relationship between crown condition and exceedances of critical loads for nutrient nitrogen and for acidity have been performed with plots spread over a large part of Europe and - at the same time - with a comparatively thin and irregular coverage. Apart from the lack of a peculiar specifity of defoliation as biological response parameter for impacts of immissions (e.g. INNES 1991), this may cause generally problems for all kinds of interference analyses, as boundary conditions for forest trees are quite different over such a large area. This may result in a high amount of deterministic (and stochastic) noise, which cannot be compensated by any comprehensive and at the same time adequate structure of introduced covariates. At the same time the number of valid cases (plots) is low, which limits strongly the number of variables introduced within each of the applied statistical models. Even the well-known positive relationship between stand age and defoliation could not always be established, which is partly based on a narrower range of ages of Level II stands in comparison to Level I stands, where most of the comparable evaluations have been performed so far.

Further combined evaluations with crown condition or other parameters from the intensive (Level II) monitoring as response structure and deposition parameters including exceedances of critical loads calculations as predictors are definitely promising in combination with data from the large-scale monitoring (Level I). Up-scaling (cf. SCHALL & SEIDLING 2004) and down-scaling approaches should support such evaluations.

3.3.4.2 Change in crown condition as response within interference analyses

The largely inconsistent results of the different models with slopes of defoliation estimates over time are not satisfying in substantial terms. This may be due to different reasons:

- The observation time is generally short. Therefore annual peculiarities especially at the beginning or the end of this period may strongly influence the slope. For instance the outlaying value of 10% a^{-1} for spruce is not the result of a constant increase of defoliation, but rather a sudden rise of mean defoliation from 18% to 48% from 1999 to 2000 as consequence of a considerable number of dead trees (defoliation = 100%) in 2000.
- Change in defoliation might be a long-term process, probably characterised by different phases, which is not adequately represented by a slope over the comparatively short period from 1997 to 2001.
- The rather erratic geographic distribution of the Level II plots with estimates of Critical Loads respectively its exceedances is too small and therefore not random enough to perform rather bias-free analyses. For instance, influences by different climatic factors (cf. SEIDLING 2007) etc. should additionally be regarded.
- The use of slopes alone as response variable might be generally problematic, since the starting value is also of great importance. Plots with high defoliation at the beginning might have a decreasing development, however, these stands might still be in a bad condition at the end of a medium-term observation period in comparison to a forest stand starting with no defoliation and with slightly higher values at the end of the observation period. Models with two response values (slopes and absolute mean defoliation value) at the same time (canonical correlation) might therefore be an adequate option.
- The number of case is generally low to perform more sophisticated analyses especially with the inclusion of categorical variables and respective interaction terms.

3.4 Ozone concentration, exposures, and visible injury

3.4.1 Introduction[1]

Ozone (O_3) is the most pervasive and dangerous regional air pollutant for forest vegetation in Europe and elsewhere and its potential impact is likely to increase in the near future (e.g. Fowler et al., 1999; Emberson et al., 2001; Percy et al., 2003). When attempting to estimate the risk to forests due to O_3 in Europe, the status of the needed information can be summarized as follows:

i) measurement-based, consistent and harmonized O_3 concentration data, which is a basic requirement for a risk assessment, are infrequent at remote forest sites. This situation even prevented the estimation of a potential risk assessment to forests, which – in Europe – is based on cumulative exposure in terms of AOT40 (Accumulated Over a Threshold of 40 ppb O_3) (UN/ECE 2004; Directive 2002/3/ EC).

ii) A concentration-based approach for risk analysis is ambiguous in itself and site-based estimates of stomatal flux for a more biologically sound risk analysis is very much data intensive. Reported exceedance of critical levels in Europe are not easy to interpret in terms of effects on forests (Matyssek and Innes, 1999). This is because O_3 effects on forest vegetation depend on a variety of factors that may influence the uptake of O_3 by the foliage (the O_3 stomatal flux, e.g. Emberson et al., 2000) and the plants' response (Reich, 1987). Since high exposures do not automatically lead to a physiologically active, high dose absorbed by plants, an approach based on the O_3 flux into the plant/forest ecosystem has been promoted (e.g. Karlsson et al., 2002; 2007; Matyseek et al., 2007). However, flux calculation is data intensive (Emberson, 2002) and, when data are not available, the use of *default* values (see e.g. UN/ECE 2004, p. III-39) may perhaps introduce more uncertainty than benefits in site-related risk assessment (Gerosa and Anfodillo, 2003). In addition, while stomatal flux is measured in (few) dedicated field experiments (e.g., Nunn et al., 2002), and large scale meteorological and O_3 models may provide input data for flux estimates (e.g. Zierl, 2002), the lack of data to validate these models' outputs is a limiting factor. On the other hand, to our knowledge very few attempts have so far explored the feasibility of the flux approach under the routine condition of the forest monitoring programs, at the large-scale and on the basis of site related, measurement-based data (e.g. Schaub et al., 2007a).

iii) Field evidence of O_3 effects on forests is limited and extrapolation of experimental results to *the real world* is problematic. In addition, investigations in the field carried out in the framework of routine forest monitoring usually concentrate on non-specific response indicators such as tree defoliation and tree growth which are subject to many other stressors than O_3 (Spiecker et al., 1996; Braun et al., 1999; Percy and Ferretti, 2004; Ferretti et al., 2003b). Visible O_3-like symptoms were considered only recently as response indicators in Europe (Innes et al., 2001; EC and UN/ECE, 2003).

With this background, and despite their limitations, large-scale monitoring programs are highly relevant for both scientists and policy makers as they offer the chance to *link forest health monitoring to O_3 monitoring* (Karnosky et al., 2003). In this chapter, the main

[1] Out of Ferretti et al., 2007

results obtained by the investigations on tropospheric ozone carried out at the Level II plots are evaluated. Specific emphasis is put on

(i) information on ozone concentration at the Level II plots;

(ii) estimates of AOT40 for the same plots;

(iii) a synthesis of ozone visible injury assessment;

(iv) an evaluation of relationships between visible injury and exposure to ozone; and

(v) an evaluation on the feasibility of the flux approach with standard Level II data.

3.4.2 Methods

3.4.2.1 Measurement of ozone concentration[2]

The number of plots with available ozone passive sampler data varied among countries and years (Table 3.4.2.1-1). The analyses of the period 2000-2004 conducted in the present report are however based on data subsets which fulfill more restrictive requirements for data coverage (Tables 3.4.2.1-2 and Table 3.4.2.3-1).

Table 3.4.2.1-1: Number of plots per country and year with available passive sampler ozone data.

	2000	2001	2002	2003	2004
Denmark	2	2	-	-	-
France	26	26	27	-	25
Germany	8	10	40	35	19
Greece	4	-	3	3	3
Italy	22	26	26	25	27
Luxembourg	2	2	2	-	2
Lithuania	-	-	-	-	2
Spain	12	12	12	13	13
Sweden	20	25	25	26	1
Switzerland	6	6	16	16	15
UK	-	-	13	9	-
Total	**102**	**109**	**164**	**127**	**107**

Ozone concentrations were measured using different methods of passive sampling systems and following the recommendations of the Submanual for Monitoring of Air Quality (Lövblad et al., 2000). Details of the types of passive samplers used are provided in Sanz et al. (2007). The seasonal period selected for this study was from 1st April to 30th September, according to the vegetative period of trees, and the time window recommended for calculating the AOT40 for forests (Fuhrer et al., 1997). Although under Mediterranean conditions the vegetative period may be longer (e.g. in Spain passive samplers are exposed during the entire year), only measurements from this 6-month period have been taken into

[2] Out of Sanz et al., 2007

account for this study. For most countries, passive samplers were collected on a regular basis every 2 weeks, but also 1-week (Italy) or 4-week (Germany, Sweden) exposure periods were carried out. Measured ozone concentrations are weighed using the number of exposure days, so that slight differences in duration between exposure periods (e.g. a given period with 16 days instead of the regular 14-days period) in a given plot are taken into account to calculate the 6-month average. This was not possible for the data submitted under deposition (DEA) format (Sweden, Germany- 2000, 2001 and 2004-, and Greece -2000-). In these cases, simple means were used instead. For every year, only plots with a data coverage of >70% during the April-September period, were taken into account. Differences in the frequency of ozone classes among the different years (Figure 1) were based on the only 30 plots with complete data that were available over the 5 years. For spatial representation of the 5-year mean ozone concentrations (Figure 2) and altitudinal trends (Figure 3.4.3.1-3), less restrictive requirements were applied: plots having at least 4 out of the 5 years (a total of 91 plots, Table 3.4.2.1-2) were considered.

Table 3.4.2.1-2: Number of plots with 5 years (2000-2004) of measurements with a data coverage of >70% during April-September (common plots), and summary of the number of plots per country and year fulfilling the requirement of having at least 4 out of the 5 years with >70% data coverage.

	2000	2001	2002	2003	2004	Plots with 4-5 years 2000-2004	Common 5-years plots 2000-2004
France	24	24	24	-	24	24	-
Germany	4	4	4	4	-	4	-
Greece	3	-	3	3	3	3	-
Italy	19	23	24	24	24	24	18
Luxembourg	2	2	2	-	2	2	-
Spain	11	12	12	12	12	12	11
Sweden	18	18	18	18	-	18	-
Switzerland	2	3	4	4	4	4	1
Total	**83**	**86**	**91**	**65**	**69**	**91**	**30**

3.4.2.2 Estimation of hourly ozone concentrations and AOT40 by means of passive sampling[3]

There were several attempts to estimate hourly values and cumulative or summation indices (as the AOT40) starting from integrated mean O_3 concentration obtained from passive samplers (Gerosa et al., 2001; Krupa et al., 2001; Krupa and Nosal, 2002; Tuovinen, 2002; Krupa et al., 2003; Mazzali et al., 2002; Gerosa et al., 2007). Recently, Gerosa et al. (2003, 2007) estimated AOT40 at 81 Level II monitoring plots located in France, Italy, Spain and Switzerland, and on which O_3 was measured by passive sampling in 2000, 2001 and 2002. The technique is based on Loibl et al. (1994) and Loibl and Smidt (1996). They reported a function describing the hourly O_3 concentration as a function of the relative altitude (h_r) of the site, i.e. the difference between the altitude of the concerned site and the lowest altitude within a 5 km radius:

[3] Out of Gerosa et al., 2007

$$\mathbf{O}_3(\mathbf{h}_r, \boldsymbol{t}) = \boldsymbol{a}_1 + \boldsymbol{a}_2\, \mathrm{e}^{-(\boldsymbol{t}-\boldsymbol{a}_3)^2 \boldsymbol{a}_4} \cdot \ln\left(\frac{\mathbf{h}_r}{100} + \frac{\boldsymbol{b}_1\boldsymbol{t}^2 + \boldsymbol{b}_2\boldsymbol{t} + \boldsymbol{b}_3}{\boldsymbol{b}_4\boldsymbol{t}^2 + \boldsymbol{b}_5\boldsymbol{t} + 10000}\,\mathrm{e}^{-\boldsymbol{b}_6\boldsymbol{t}}\right) \qquad (1)$$

where

$\mathbf{h_r}$ is the relative altitude in meters (see below),

t is the daytime,

$\mathbf{a_1, a_2, a_3, a_4}$ and $\mathbf{b_1, b_2, b_3, b_4, b_5, b_6}$ are coefficients obtained from the fitting.

The function was obtained as the best fit of a series of O_3 measurements carried out at more than 100 sites distributed over a range of h_r in Austria. Although the function was proven to fit well also for forest sites in southern Europe (Gerosa et al., 2003; 2007), it should be considered that the best fit represents a mean, an ideal value which may be subjected to interferences such as O_3 advection from areas with high photochemical production and O_3 depletion by nearby NO_x emissions. For this reason, deviations in hourly concentrations can be expected according to the situation of individual sites, and, at the same site for individual days.

The pattern of the O_3 daily profile was modeled for each site according to equation (1) and using the h_r calculated for each site. Then, the O_3 daily profile was adjusted in order to match the mean O_3 concentration measured by the passive samplers, assumed as the 24-hour daily average over the measurement window covered by passive sampling. The resulting O_3 daily profile was replicated for each day of the measurement window (i.e. 7 or 14 days). The underlying, simplifying assumption is that the invariance of the daily O_3 profile, which is considered to be the same every day of the measurement period (Mazzali et al., 2002). Thus, deviations between measured and modeled hourly O_3 concentrations for individual days are implicit in the assumption of the model, but they are expected to compensate over the April-September period (i.e., the computational period of AOT40). In this respect, passive sampling on a weekly basis is more suitable than on a fortnightly or monthly basis. This is because the strength of the assumption needed is somewhat proportional to the length of the measurement window. As a consequence, the uncertainty of estimates is expected to increase with the length of the exposure period of passive samplers.

The modeled O_3 concentration of the hours with global solar radiation >50 $W{\cdot}m^{-2}$ were considered to estimate AOT40 values ($AOT40_e$) for each site. When direct radiation measurements were not available, assumed global solar radiation > 50 $W{\cdot}m^{-2}$ was assumed occurring between dawn and sunset, and the number of hours was estimated by means of an astronomic model based on latitude, longitude of the site, the calendar date and the time of the day (Strahler, 1984; Scire et al., 1989). In order to avoid underestimation of the AOT40 in the case of missing data, the "raw" AOT40 calculated on the basis of the available measurements was weighted by a coefficient given by the reciprocal of the ratio between the number of the valid days of measurements available (N_{dA}) and the total number of the days (N_{dT}) of the measurement period (equation 2).

$$AOT40 = \frac{AOT40_{raw}}{N_{dA}} N_{dT} \qquad (2)$$

3.4.2.3 Data completeness for the 2000-2004 analysis

The following rules were considered:

- consider only plots for which start-end of each exposure period is known
- consider only plots with 1 and 2 week long exposure periods
- consider only plots with at least 80% of the April-September period covered

For the 2000 - 2004 ozone data, countries with 1-2 weeks exposure periods and a data coverage >80% included Denmark, France, Italy, Luxembourg, Spain and Switzerland for a total of 85 Level II plots. Table 3.4.2.3-1 reports the percentage of plots that comply with the 80% data coverage. However, only 18 of the plots fulfill the data completeness requirements for each year. The major reason for this was the lack of data from France in 2003.

Table 3.4.2.3-1: Frequency (%) of plots with data coverage >-80% for each country over the 2000-2004 period; n is the total number of plots operational in each country; n.a. data not available. Only countries providing data with 1-2 weeks sampling frequency were considered.

Year	Denmark (n=2)	France (n=24÷27)	Italy (n=22÷26)	Luxembourg (n=2)	Spain (n=12)	Switzerland (n=5÷15)
2000	100	96.2	85.7	100	100	n.a.
2001	100	100	96.2	100	100	n.a.
2002	n.a.	100	96.2	100	100	33.3
2003	n.a.	n.a.	91.7	n.a.	100	66.6
2004	n.a.	100	91.7	100	25	46.7

3.4.2.4 Assessment of ozone visible injury

Since ozone pollution leaves no elemental residue that can be detected by analytical techniques, visible injury on needles and leaves is the only easily detectable evidence in the field (Innes et al., 2001; Schaub et al., 2002). However, the diagnosis must be accurate and requires skilled surveyors. In addition, within-species sensitivity may vary as well as symptom's expression, and other factors (e.g. leaf senescence) may mimic ozone symptoms, thus rendering the assessment subjected to many constrains (e.g. Bussotti et al., 2003). Within the ICP Forests Program for the Assessment of Ozone Injury on European Forest Ecosystems, number of species and number of symptomatic species have been assessed at the Level II forest edge (i.e. Light Exposed Sampling Site LESS;), once a year during late season of 2002-2004.

Based on The Submanual for the Assessment of Ozone Injury on European Forest Ecosystems (see http://www.gva.es/ceam/ICP-forests), the following definitions and rules were applied for the analyses of the 2001-2004 data:

1. Symptomatic species: any plant species classified as symptomatic in terms of ozone visible injury as described in the Submanual.
2. Symptomatic quadrate: any sampled quadrate where at least one symptomatic species was recorded.
3. Only data sets from years and countries with validated symptoms were considered.

In 2000 – 2003 the forest edge was treated as one plot and all plants and species were assessed, in 2004 a new monitoring method was applied. As described in the Submanual for the Assessment of Ozone Injury on European Forest Ecosystems, the forest edge, i.e. Light Exposed Sampling Sight (LESS), was divided into a number of x sampling quadrates, depending on the total length of the LESS. Depending on the preferred precision level (adjusted sample size allowing a 10 or 20% error), a number of y quadrates were randomly selected and sampled allowing the statistical analysis of frequency for symptomatic species.

Therefore, the 2002-2003 data are not comparable with the 2004 data and analyzed separately from each other.

For all sampling units, simple univariate statistics were applied as follows:

- mean and standard deviation of total plant species richness collected within each plot (i.e. LESS);
- mean and standard deviation of symptomatic species for the randomly selected set of sampled quadrates within each plot;
- mean and standard deviation of the ratio symptomatic vs. total species for the randomly selected set of sampled quadrates within each plot;
- mean and standard deviation of symptomatic quadrates within the plot;
-

For the number of symptomatic species per quadrate within each plot and for the number of symptomatic quadrates per plot, asymmetric confidence intervals (CI, confidence level = 95%) were evaluated. In order to calculate CI, the assumption on the probability density function (p.d.f.) from which observed data were drawn, should be assessed. The first step of fitting distributions consists of choosing the mathematical model or function to represent data in a statistical appropriate way. Considering that symptomatic species and symptomatic quadrates (count data) occurred at very low frequencies (most of the obtained values were 0), the Poisson distribution was applied as the reference p.d.f. The Poisson distribution is classically used to model count data. Typically, such data are the numbers of occurrences of a given event during a defined time period and within a defined space, when the probability of an event occurring during a very short time (or within a small space) is low and the events occur independently from each other.

According to equation 3, the density function of Poisson shows the probability of obtaining a count of *x* when the mean count per unit is *λ* (Crawley 2007):

$$f(x,\lambda) = e^{-\lambda}\frac{\lambda^x}{x!} \qquad (3)$$

where $x = 0, 1, 2, \ldots$

In order to test whether or not it is reasonable to assume that the random samples follow the specified Poisson distribution, a “distribution free” test was applied with the following null- and alternative-hypotheses:

H_0: Sample data follow the stated distribution

H_1: Sample data do not follow the stated distribution

For this, the X^2 test was used.

Finally, the CIs were calculated with respect to each mean. As expected for count data which are following the Poisson distribution, estimated CIs were asymmetric. In fact, it should be considered that the lower CI could not be negative and that it equaled 0 in those cases where the number of occurrences (e.g., presence of symptomatic species with respect to total number of plant species) was very low.

All analyses were performed using the R software (R Development Core Team, 2008)

3.4.3 Results

3.4.3.1 Ozone concentration at the intensive monitoring plots

The analysis of the 2000–2004 ozone data shows differences in the seasonal (April-September) ozone concentrations among the five years considered (Figure 3.4.3.1-1). Some of the highest ozone levels in forest areas of Europe were measured during 2003, a season with one of the hottest summers on record in Europe; relatively high levels were also recorded in 2001 and 2004. During 2002, a season characterized by a rainy summer, and also during 2000, lower ozone values were measured. Mean seasonal ozone levels for the years 2000-2004 are represented in Figure 3.4.3.1-2: they increased from Atlantic and Northern Europe to the Mediterranean region. In Southern Europe, levels ozone formation is particularly favoured by the intense solar radiation, high temperatures, and re-circulation processes of the polluted air masses (Sanz et al., 2007). Based on a 5-year dataset, a tendency to increase (R^2=0.54, P<0.001) ozone levels with elevation is confirmed within the plots of the monitoring network covering European Forests (Figure 3.4.3.1-3).

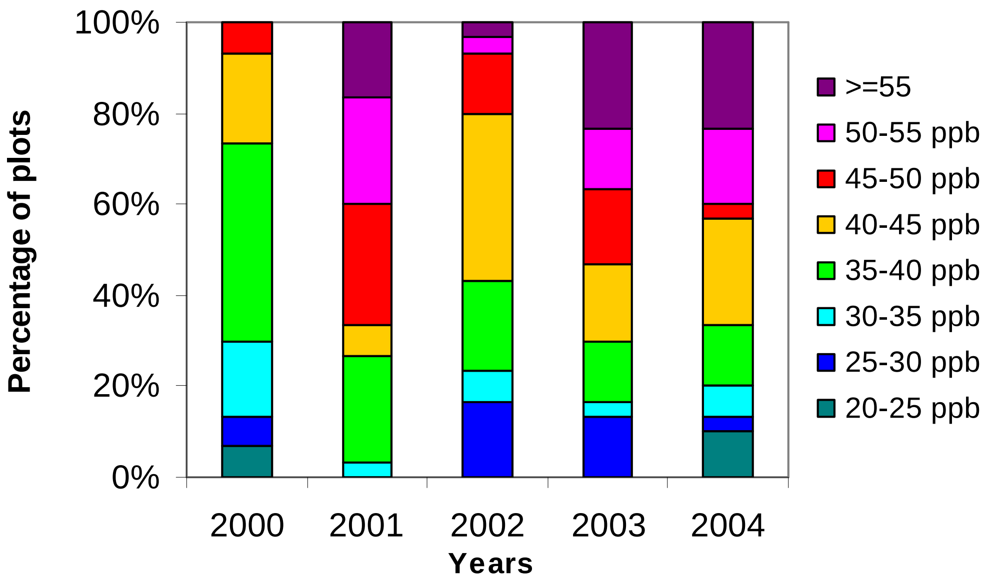


Figure 3.4.3.1-1: Frequency of plots belonging to 8 classes of ozone concentrations (April-September) for each year, based on N=30 common plots (plots where data completeness >70% was met during the 5 years).

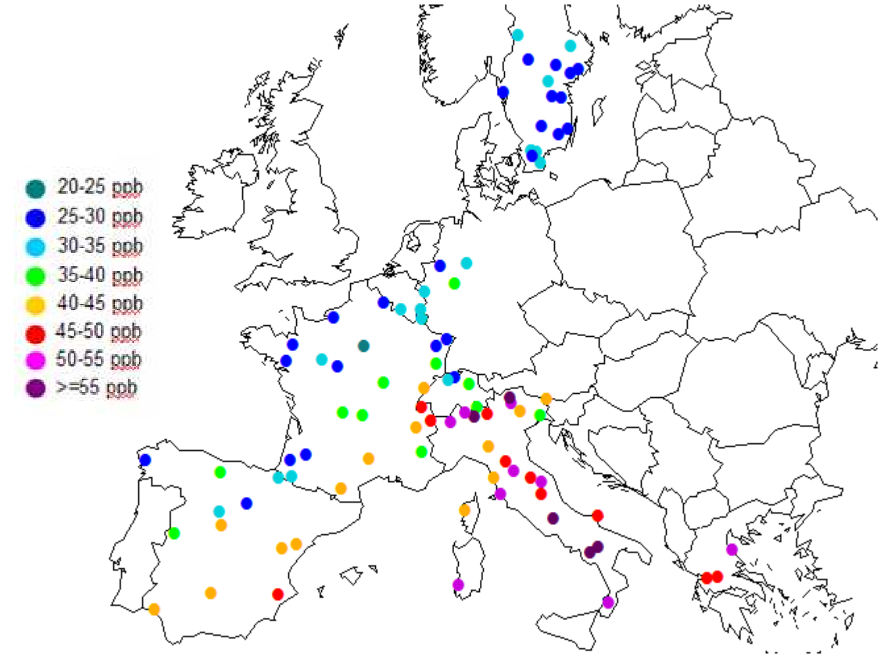


Figure 3.4.3.1-2: Mean ozone concentrations (April-September) for the 2000 – 2004 seasons, based on N=91 plots with 4-5 measurement years with data completeness >70%.

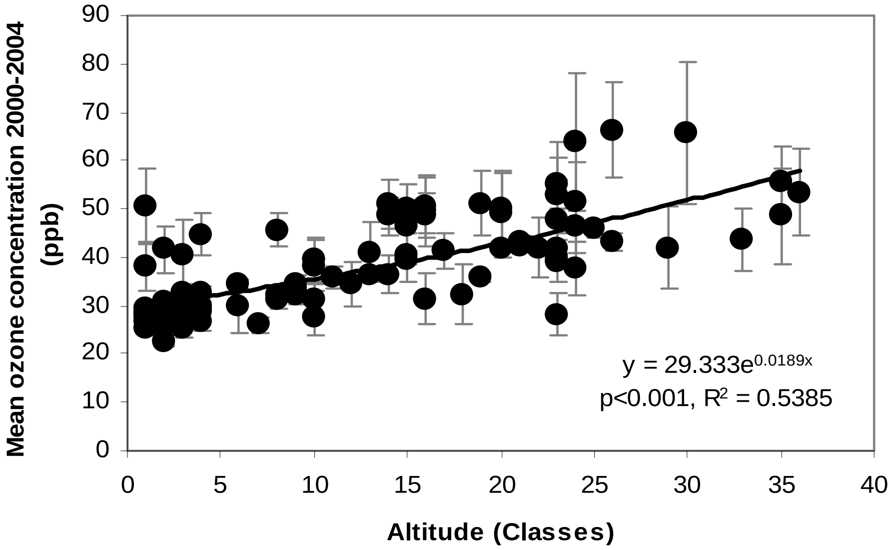


Figure 3.4.3.1-3: Correlation between altitude and seasonal ozone concentrations for the 2000 – 2004 seasons, based on N=91 plots with 4-5 measurement years with data completeness >70%.

3.4.3.2 Ozone exposure (AOT40)

Table 3.4.3.2-1 and Figure 3.4.3.2-1 report the April-September AOT40 estimates obtained from the plots which fulfilled the data requirements. The number of sites varies from year to year. The UN/ECE critical level for a potential risk for sensitive forest species under sensitive conditions set at 5’000 ppb.hrs is frequently – and largely – exceeded at many sites and years.

However, considerable variation exists between sites and years. As far as the time development is concerned, relatively low values can be observed in 2002 (characterized by a cool summer) and high peaks during in 2003 and 2004 (Figure 3.4.3.2-1). The same trend applies at the sub-set of common plots (Table 3.4.3.2-1).

The performance of the estimates was evaluated in a previous paper by Gerosa et al. (2007): measured and estimated values were highly related (R^2=0.90, P<0.0001, standard error of estimate=3’271 ppb.hrs). In general, the values below 10’000 ppb.hrs are underestimated where as the values above 40’000 ppb.hrs are overestimated. Estimated and measured data are not significantly different (Wilcoxon matched pair test, P=0.054).

Table 3.4.3.2-1: Descriptive statistics of AOT40 (ppb.hrs) at the Level II plots. Plots considered are those where passive sampling is carried out with 1-2 weeks sampling frequency and data completeness was ≥80%. All plots: all plots where requirements were met; common plots: plots where requirements were met at for all years.

	2000	2001	2002	2003	2004
All plots					
N	58	68	71	46	58
Min	1’908	2’048	2’639	1’408	2’814
25th	7’702	9’642	7’391	12’982	9’503
50th	13’970	18’306	13’845	28’253	20’056
75th	22’663	36’003	19’486	41’806	42’060
Max	60’221	83’091	54’737	97’440	123’577
Common plots					
N	18	18	18	18	18
Min	8’858	8’407	3’277	8’383	6’041
25th	17’002	32’440	12’756	29’241	26’952
50th	23’449	36’608	16’438	36’846	41’639
75th	29’193	47’370	21’706	43’725	55’420
Max	42’474	58’843	42’009	82’905	123’577

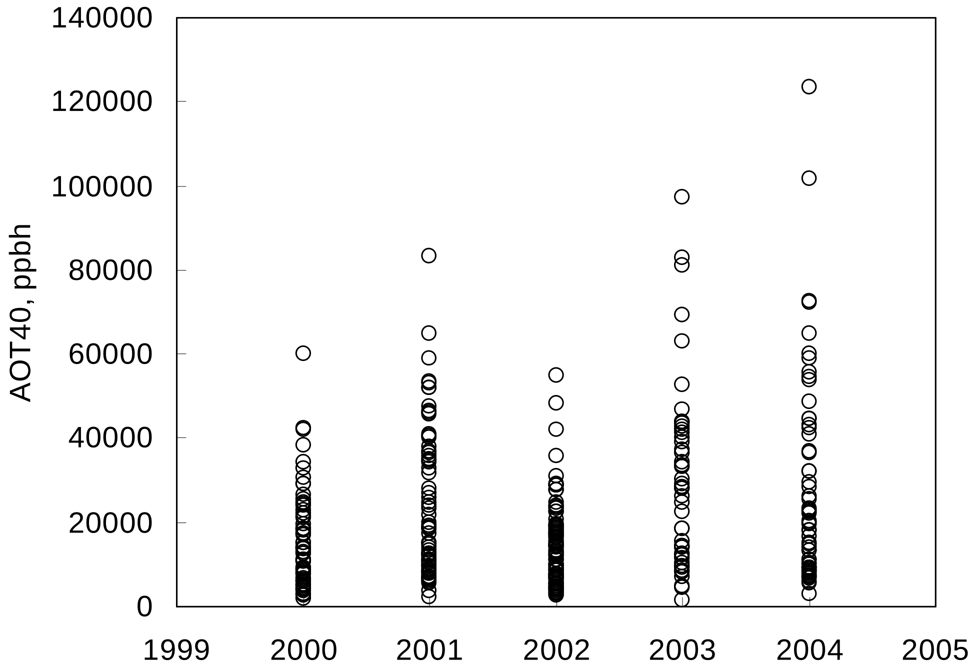


Figure 3.4.3.2-1: AOT40 (ppb.hrs) estimates obtained for individual Level II plots over the period of 2000 – 2004. The number of plots and the number of country differ from year to year (see Table 3.4.3.2-1).

3.4.3.3 Visible injury and correlations to ozone concentrations and AOT40 exposures

Symptom data were available from 2002 – 2004 submitted by seven countries. Three out of seven countries made use of the available tools to validate symptoms. Four countries submitted data of symptoms which were not validated. The original data contained errors such as misspelled species names. For example the species *Fagus sylvatica* was represented in three different versions: '*Fagus sylvatica*' (correct version), '*Fagus silvatica*' and '*Fagus silvatica*'. The latter version contained two spaces between '*Fagus*' and '*silvatica*' which was registered by the data base as a different species.

Each species and genus was designated to a unique species code from the Flora Europaea data base, including approximately 13'000 different codes for both, species and genus. Among the codes, the submitted data sets contained non-existing codes such as '072.010.???' for the species *Sedum sp*. For data analyses, the above indicated errors were corrected and only the countries which submitted validated symptom data were considered.

For 2002 - 2004, three countries assessed a total of 249 different species for ozone visible injury. In 2002, Spain delivered data for both, symptomatic (2) and non-symptomatic (23) species, whereas Switzerland delivered data of symptomatic (23) species only (Figure 3.4.3.3-1).

In 2003, Spain delivered data with 1 species being symptomatic and 19 species being non-symptomatic, whereas Switzerland delivered data of symptomatic (19) species only. For 2002 an 2003 Italy delivered no data for ozone visible injury.

The new sample approach including the establishment of LESS and quadrates, as applied from 2004 on, allows descriptive statistics for the sampled plots.

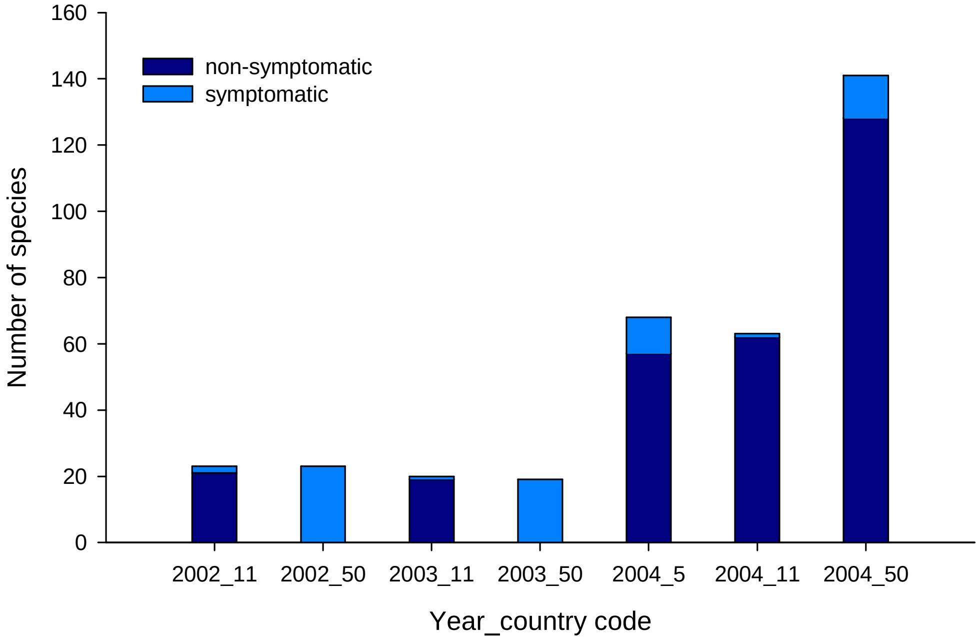


Figure 3.4.3.3-1: Total number of symptomatic and non-symptomatic species assessed at the LESS for Spain (11), Switzerland (50) and Italy (5) in 2002 – 2004.

Considering the new assessment approach with a randomly selected number of quadrates per LESS in 2004, the average proportion of symptomatic species per plot varied between 0 and 15%. Data from a total of 3 countries, 18 plots, including 389 quadrates fulfilled the data requirements. On average, 28 different species per plot were assessed of which 2 species (7%) were symptomatic.

There is a positive and non-significant trend between the average proportion of symptomatic species per quadrate and the average seasonal ozone concentration for 2004. The transformation of ozone concentration into the AOT40 exposure indices results in a stronger but still non-significant trend between symptom development and ozone exposures (Figures 3.4.3.3-2 and 3.4.3.3-3).

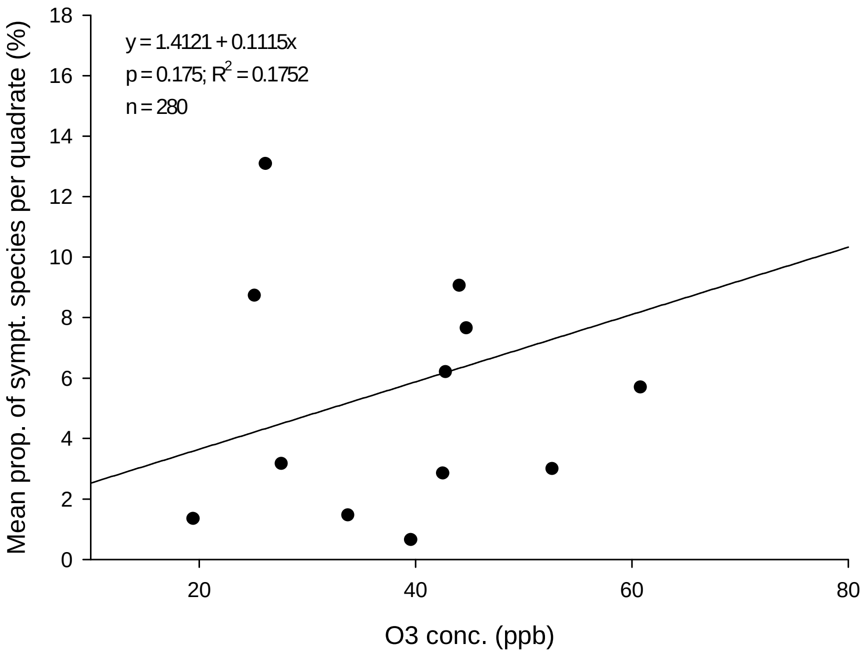


Figure 3.4.3.3-2: Correlation between mean proportion (%) of total number of symptomatic and non-symptomatic species vs. average seasonal ozone concentrations (ppb) per plot in 2004.

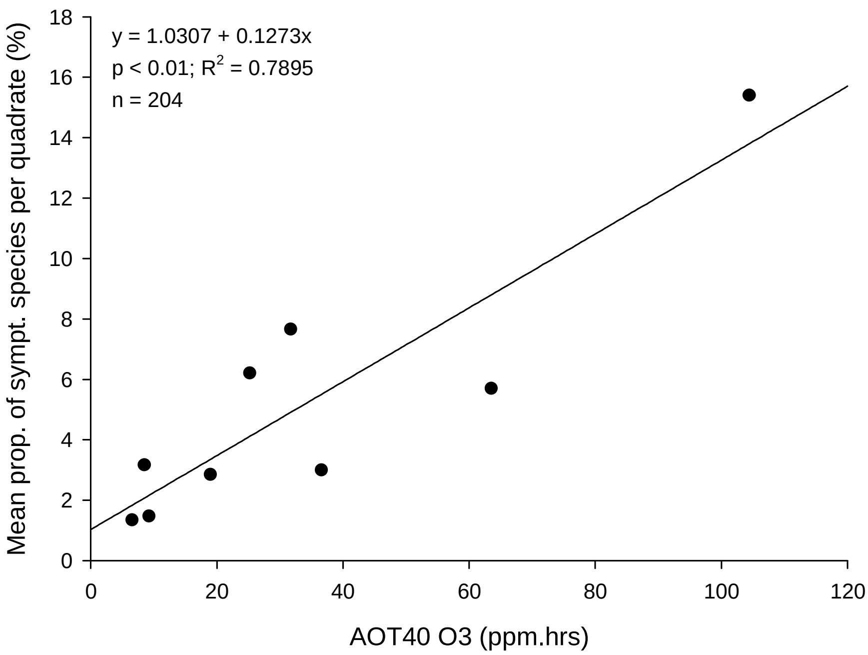


Figure 3.4.3.3-3: Correlation between mean proportion (%) of total number of symptomatic and non-symptomatic species vs. average, seasonal AOT40 exposures (ppm.hrs) per plot in 2004.

3.4.3.4 Feasibility of the flux approach at the Level II sites[4]

Data sets of the EU and ICP-Forests monitoring network are examined regarding their suitability for the modeling of ozone uptake in trees in the view of risk assessment. The objective of this study was to establish whether EU and ICP-Forests monitoring data provide i) the variables necessary to apply the flux-based modeling methods and ii) meet the quality criteria necessary to apply the flux-based critical level concept.

The stomatal conductance term, which is central to the leaf O_3 flux model, is calculated using the multiplicative algorithm in equation (4)

$$g_{sto} = g_{max} \times \lfloor \min(f_{phen}, f_{O3}) \rfloor \times f_{light} \times \max\{f_{min}, (f_{temp} \times f_{VPD} \times f_{SWP})\} \qquad (4)$$

where g_{sto} is the actual stomatal conductance for O_3 and g_{max} is the receptor-specific maximum stomatal conductance, (both in mmol O_3 m^{-2} PLA s^{-1}).

The required input parameters, as they are monitored by the routine EU and ICP-Forests monitoring procedures, are shown in Table 3.4.3.4-1. These parameters necessary to run the O_3 flux model were derived using standard techniques from meteorological data collected according to the EU and ICP-Forests monitoring guide lines (EU/UN-ECE, 2004). Further details as how the various parameters were derived from field data are described by Schaub et al. (2007a).

Table 3.4.3.4-1: Input parameters required for stomatal O_3 flux modeling according to the UN-ECE Mapping Manual (UN-ECE, 2004).

Input parameters	Units
Hourly O_3 concentration (O_3)	ppb
Hourly wind speed (*WS*)	$m\ s^{-1}$
Hourly photosynthetic photon flux density (*PPFD*)	($u$mol m^{-2} s^{-1})
Hourly and daily air temperature ($temp_{air}$)	°C
Hourly relative humidity (*RH*)	%
Daily precipitation (*P*)	mm

[4] Out of Schaub et al., 2007.

Application of this model has been possible using environmental data collected from the EU and ICP-Forests monitoring network in Switzerland and Italy for 2000–2002. The test for data completeness and plausibility resulted in 6 out of a possible total of 20 *Fagus sylvatica* L. plots being identified as suitable from Switzerland, Italy, Spain, and France. Each of these plots was represented by data sets with a completeness of ≥ 97% for at least one of the years between 2000 and 2002. For most of the data sets that did not meet the criteria, irradiance (PAR) or wind speed were the limiting factors, i.e. not monitored. Most data sets were only available for 2002 and the more complete input data set of the Italian plot Calabria 1 provided data from 1 May – 30 September, allowing a comparison of all three seasons (2000–2002).

The modeling results show that the collected data allow the identification of different spatial and temporal areas and periods as having higher risk to ozone than those identified using the AOT40 approach (Figure 3.4.3.4-1).

However, it was also apparent that the quality and completeness of the available data may severely limit a complete risk assessment across Europe (Schaub et al., 2007a).

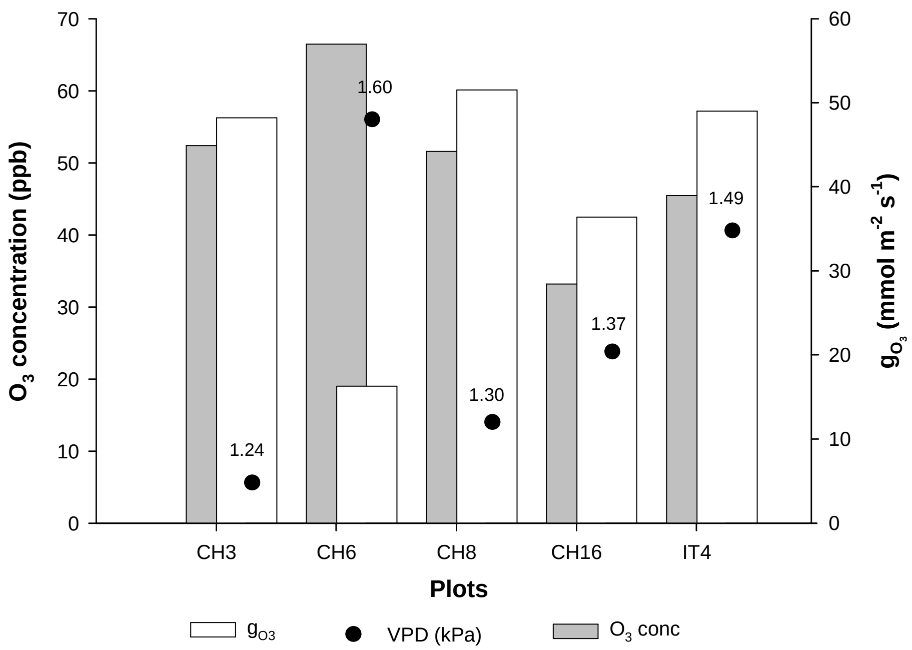


Figure 3.4.3.4-1: Monthly means for stomatal conductance of O_3 (g_{O_3}), vapor pressure deficit (VPD) and O_3 concentration (ppb) at four Swiss and one Italian ICP-Forests monitoring plot for June 2002.

3.4.4 Conclusions

For the AOT40 exposure analysis, considerable exceedances of the critical level were detected at the majority of sites over the period 2000-2004. Exceedances are by far larger in southern plots, namely in Italy and Spain. However, it should be pointed out that our findings are based only on part of the plots for which ozone concentration data were available. This is because many sites did not fulfill the data requirements as set to limit the assumption needed to apply the estimation methods. Passive sampling across Europe is still not fully harmonized in terms of frequency of sampling, and considerable gaps were obvious in the data coverage. Considerable progress in the translation of the given guide lines into the field is necessary.

The analyses of the 2002-2004 data for ozone induced symptoms demonstrate that elevated ambient ozone exposures harm the plant and cause visible symptoms on natural vegetation, every season. Although not significant and based on a few data, a positive trend between symptom development and increasing ozone concentrations could be detected and even more so for the AOT40 exposure values. However, the poor coverage of the data which fulfilled the data requirements does not allow any conclusions for temporal or regional trends. Based on the available data sets, it turned out that the countries do not make use of the available tools for symptom validation. The Submanual for the Assessment of Ozone Injury on European Forest Ecosystems (see http://www.gva.es/ceam/ICP-forests) offers and recommends the following tools which allow the validation of ozone-like symptoms on a broad scale such the ICP-Forests network:

- Pictorial atlas
- On-line data base at www.ozone.wsl.ch
- Pictorial field guide by Innes et al., 2001
- Guide lines for the microscopic differential diagnosis
- Annual intercalibration courses
- Contact addresses of Co-ordination and regional Validation Centres

Considerable progress is needed to convince the participating countries of the importance of data quality in general, and symptom validation particular.

There is a general agreement that cumulative ozone uptake, the instantaneous rate at which ozone is absorbed via the stomatal opening, would lead to a biologically more relevant estimate of ozone risk as compared to external exposure indices such as AOT40, SUM0, and mean ambient ozone concentrations (e.g. Matyssek et al., 2004).

It has been demonstrated that a risk assessment based on ozone flux to receptor sites within the leaf, rather than ozone exposure, could provide an improved estimate of the relative degree of risk of ozone damage to vegetation on a local as well as European scale. A comparison of estimated flux values with plant effects such as visible ozone injury or reduced growth is very much needed to confirm this hypothesis and further apply this approach.

This study did not only assess the suitability of the data collected by the EU and ICP-Forests monitoring program for making flux-based risk assessments but, through these initial attempts to apply the flux-based methods, it identified and may initiate development of methods to derive the necessary input data that are not directly available from observations made at the monitoring sites. This will provide information on the necessary procedures for data acquisition, data processing, and quality assurance that European countries will need to implement in order to perform flux-based O_3 risk assessments in the future and help to identify data requirements and recommendations as how to proceed with the data collection in the future.

As such, the establishment of methods to utilize EU and ICP-Forests monitoring data for O_3 flux modeling may be useful for those countries which intend to undertake O_3 risk assessments using the flux-based approach in combination with the EU and ICP-Forests monitoring procedures, i.e. with O_3 passive samplers, for future analyses at remote sites and wider geographical scales.

Species specific differences in ozone sensitivity, differences in microclimatic conditions and species composition (number of ozone sensitive species) are the main factors making it difficult to relate visible injury with ozone exposures or flux to determine critical levels or fluxes. The use of a bio-indicator plant species as a reference across all plots may solve the difficulties caused by species specific differences in ozone sensitivity and differences in species composition. Furthermore, the assessment of a few, well-known and investigated plant species as bio-indicators may help to resolve the encountered issues with data coverage, harmonization and validation. A harmonized bio-indicator approach would be in line with approaches so far chosen for non-forest vegetation by ICP-Vegetation. A test campaign with the ozone sensitive genotype of a *Populus* spp. clone planted in the vicinity of a subset of Level II plots was initiated by Schaub (2007). The experiences which will be gained from the establishment of bio-indicators on the ICP Forests Level II plots will be important for the improvement of the UNECEC/ICP-Forests ozone symptom assessment program in particular and will provide important data for the validation of ozone risk assessment modeling.

4. NATIONAL SURVEY REPORTS IN 2007

Reports on the results of the national crown condition surveys at Level I of the year 2007 were received from 32 countries. For these countries, the present chapter presents summaries. Besides that, numerical data on crown condition in 2007 were received from 30 countries. These results are tabulated in Annex II. In Annex II-1 basic information on the forest area and survey design of the participating countries is given. The distribution of the trees over the defoliation classes for all species is given in Annex II-2. Annexes II-3 and II-4 contain the data for conifers and for broad-leaved trees, respectively. The annual changes in crown condition are presented for all species in Annex II-5, for the coniferous trees in Annex II-6, and for broad-leaved trees in Annex II-7. Graphical presentations of the results are given in Annex II-8. It has to be noted, however, that it is not possible to directly compare the national survey results of individual countries. The sample sizes and survey designs may differ substantially and therefore conflict with comparisons. Gaps in the Annexes, both tabulated and plotted, may indicate that data for certain years are missing. Gaps also may occur if large differences in the samples were given e.g. due to changes in the grid, or the participation of a new country.

4.1 Andorra

In 2007, the crown condition survey in Andorra was conducted on 3 permanent Level I plots of the 16 x 16 km transnational grid. The survey, which was undertaken during the first week of October, included 72 trees, 42 *Pinus sylvestris* and 30 *Pinus uncinata*.

Defoliation and discolouration results obtained in 2007 have shown a worsening in forest condition after a light improvement registered in 2006.

In 2007, trees were classified mainly in defoliation classes 1 (slightly 37.5%) and 2 (moderately 44.5%), with similar values for both pine species.

There was a decrease in the number of trees in defoliation classes 0 and 1 and an increase in the number of trees in class 2. In 2007, moderate defoliation was registered for 44.4% of the trees, compared to 16.2% in 2006 and 25% in 2004.

Related to discolouration, for both pine species, there has been an important increase in class 2 (moderate discolouration). For *Pinus sylvestris*, classes 0 and 1 decreased whereas for class 2 an important increase was registered, from 0% in 2006 to 28.5% in 2007. For *Pinus uncinata* the considerable increase in class 2 (from 3.3% in 2006 to 43.3% in 2007) corresponds to a decrease in class 1.

In 2007 the most frequent damage in Andorran forests was caused by the fungus *Cronartium flaccidum*, which affected the 6% of the sampled trees distributed over all plots. Pine caterpillar (*Thaumetopoea pityocampa*) has not been reported since the 2004 survey.

4.2 Belarus

The assessment of crown condition in Belarus in 2007 included 9 425 trees on 400 plots of the transnational network. 78% plots were dominated by coniferous tree species, 22% by broadleaves. The mean defoliation of all tree species was 17.1%, which is 0.5 percent points above the mean of 2006. The mean defoliation of the conifers was 17.3% and 16.5% for broadleaves.

Pinus sylvestris contributed 62.9% of all observed trees. Crown condition of this species thus considerably influences the mean defoliation of the total sample. Compared to 2006, the share of trees without defoliation decreased by 5.8 percent points to 31.6% and the share of damaged trees (defoliation classes 2–4) increased by 0.3 percent points to 8.1%. As in previous years, the highest mean defoliation was recorded for *Quercus robur* and *Fraxinus excelsior*. For the oak species it was 22.0% compared to 23.1% in 2006. For *Fraxinus excelsior* it was 28.8% compared to 30.6% in 2006. The share of trees without defoliation decreased from 23.5% to 19.5% and from 25.0% to 15.9%, respectively. Lowest mean defoliation was recorded for *Betula* spp. (15.5%) and *Alnus glutinosa* (15.1%).

21.0% of all observed trees had visible damage symptoms. The most frequently observed causes of injuries were fungal diseases (4.5%), mechanical injuries (3.5%) and insects (3.3%). Fungi were most often observed on *Pinus sylvestris* (4.0% of all trees), *Picea abies* (6.0%) and *Fraxinus excelsior (*21.7%). Mechanical injuries were most often observed on *Picea abies* (6.1% of all trees) and *Betula pendula* (4.6%). Insects were observed on *Alnus glutinosa* (34.0% of all trees), *Populus tremula* (14.3%) and *Quercus robur* (10.4%).

Over all, forest condition in Belarus remained good and stable.

4.3 Belgium

Flanders

The crown condition survey was conducted on 72 plots on a 4 x 4 km grid. Ten of these plots are part of the international 16 x 16 km grid. In 2007, 1 732 trees were assessed.

The mean defoliation was 21.1%, and 17.3% of the trees were in defoliation classes 2-4. 0.2% of the sample trees died. The share of damaged trees was 18.8% in broadleaves and 14.1% in conifers. There was a smaller difference in mean defoliation: 21.5% in coniferous trees and 20.8% in broad-leaved species.

Compared to last year, mean defoliation decreased by 0.2 percent points while the share of damaged trees decreased by 1.1 percent points. Most of the tree species showed an improvement in crown condition.

Pinus sylvestris is the species with the best crown condition. Moderate to severe needle loss was observed only on 11.3% of the sample trees. *Pinus nigra subsp. Laricio* revealed on average a higher defoliation level than *Pinus sylvestris*, with 24.8% trees being damaged. *Pinus nigra* suffered from fungal infection and one sample tree died because of *Sphaeropsis sapinea*-infection. In some pine stands infection by *Scirrhia pini* (Red band needle blight) was recorded.

The least affected broad-leaved species was *Quercus rubra* with 12.3% of the trees in defoliation classes 2-4. *Fagus sylvatica* was the only species with a higher defoliation score in comparison to 2006. 13.3% of the trees showed moderate to severe defoliation. *Populus* sp. remained the species with the worst crown condition, with a high proportion of damaged trees (33.3%). Although population densities of *Thaumetopoea processionea* were high in 2007, especially in the eastern part of the Flemish Region, the share of moderately to severely defoliated *Quercus robur* trees remained stable (19.2%).

The warm and dry weather circumstances during the month of April did not have a negative influence on the crown condition. Because of wind damage 1.7% of the sample trees had to be replaced. In several conifer stands discolouration due to hailstorms was observed.

Wallonia

The 2007 survey concerned 1131 trees on 49 plots, on the regional 8 x 8 km systematic grid. The percentage of trees with a defoliation >=25% shows different long term trends for conifers and broad-leaves:

Conifers were two times more defoliated in the beginning of the nineties, but they stay now at a lower rate than the broad-leaves with 13.5% of the trees.

Broadleaves showed an increasing from 10% in 1990 to about 20% in 2005. The damage was mainly due to the degradation of the beech (*Scolytidae* in 2000-2002, drought in 2003 followed by fruiting in 2004) and of the European oak (drought in 2003).

For the first time, an improvement of the mean defoliation was observed for the main species, especially for beech (18.2%) and sessile oak (8.3%) in 2006. This improvement is confirmed in 2007 for those species, while European oak shows a slight degradation (16.5). Spruce is quite stable around 10%.

Discolouration has continuously decreased both for broad-leaves and conifers since the high level of 2003, despite of the high temperature in July 2006; about 10% of the broad-leaved trees and 8.4% of the conifers show more than 25% of discolouration, which is lower than before 2003. But in 2007, a slight increasing was observed, with about 12% of the trees with a significant rate of discolouration, both for conifers and broad-leaved. Weather during 2007 does not explain this evolution: even if the mean temperatures were high every month, no drought was observed after April. The rainfalls were particularly high from May to July.

4.4 Bulgaria

In 2007, the forest condition survey was carried out at 145 plots on a grid net of 16 x 16 km, 8 x 8 km and 4 x 4 km. A total of 4926 sample trees was assessed, 2 586 of them conifers and 2 340 broadleaves. For all species, there was a slight improvement in crown condition. The share of moderately to severely damaged trees (defoliation classes 2-4) decreased compared to the 2006 results. The share of trees without visible defoliation increased from 17.3% in 2006 to 20.50% in 2007.

For conifers, the percentage of damaged trees decreased slightly. As compared to the previous year, trees without visible defoliation increased by 3.6 percent points. The share of severely defoliated trees remained almost the same and that of dead trees decreased by 5.5 percent points.

For *Pinus nigra*, some of the damage was caused by needle-rust and blight shoot fungi including *Sphaeropsis sapinea.* Conifer stands were attacked by defoliating insects like *Evetria buoliana.*

Defoliation of broadleaves (*Quercus* spp. and *Fagus sylvatica*) was lower in 2007 as compared to 2006. The share of the trees without any defoliation increased by 3.4 percent points, compared to the 2006 results. The share of dead broad-leaved trees decreased. *Quercus* trees were attacked by pathogens such as *Nectria* spp., *Hypoxilon mediterraneum, Ophiostoma* spp. Beech stands suffered from mining insects such as *Rhynchaenus fagi* and *Ectoedemia Liebwerdella Zim* and pathogens like *Nectria* spp., *Fomes fomentarius and Ascodihaena rugosa.*

Abiotic agents like weather extremes (drought, snow, ice) and anthropogenic factors such as silvicultural operations at nearby trees were identified as damage causes. As in previous years, no specific damage factor was observed for more than half of the trees.

4.5 Canada

This report compiles information from regional surveys or initiatives with Natural Resources Canada's partner agencies which contribute to the national picture of the status of forests in Canada.

Canada's Forest Inventory

Canada's Forest Inventory (Can FI) provides tabular summaries of data in order to meet commitments to report to Parliament annually on the State of Canada's Forests, to provide data to the United Nations Global Forest Resources Assessment, and to report on sustainable development through Criteria and Indicators processes. This inventory is a national compilation of 57 individual source inventories into a common format. http://www.bookstore.cfs.nrcan.gc.ca/detail_e.php?recid=12586209. The most recent report on criteria and indicators (2006) can be accessed at

http://www.ccfm.org/current/ccitf_e.php .

National Forest Inventory

A new National Forest Inventory (NFI) program was implemented in 2000 to address weaknesses with CanFI and to meet new and emerging information needs. It is a plot-based design consisting of permanent observational units located on a national grid. By collecting and reporting information to a set of uniform standards, it allows for consistent reporting across the country on the extent and state of Canada's land base to establish a baseline of where the forest resources are and how they are changing over time. In addition to providing consistent estimates for traditional forest inventory attributes, the NFI provides a framework for collecting additional data relevant to the reporting of progress towards sustainable forest management (e.g., socio-economic indicators), as well as data related to forest health (e.g., insect damage, disease infestation), biodiversity and forest productivity. Initial results and the baseline report of the NFI are planned for release in 2008. A mock-up of the report is available at http://nfi.nfis.org/.

The Earth Observation for Sustainable Development project has enhanced the NFI by contributing land cover mapping of forested and non-forested areas and other land cover products such as maps of forest composition, change over time, and biomass. The Biodiversity Monitoring with Earth Observation Data (BioSpace) project is currently integrating ground based and remotely sensed data to determine the potential for an earth observation biodiversity monitoring system. The project has developed four indices based on land cover, topography, productivity and disturbance that are currently being tested.

Recommendations from a study to determine the compatibility of the current NFI framework with other land-based monitoring programs in Canada and to assess the potential for partnerships and synergies indicated that the NFI should establish a long term partnership with ICP Forests to learn and share the wealth of information that this program has gathered over the past two decades. The upcoming International Union of Forest Research Organizations' Division 4 meeting and scientific forum on *Extending Forest Inventory and Monitoring over Space and Time* to be held in Quebec City, Canada

May 20-22, 2009 will provide an opportunity for exchange between the two groups.

Regional monitoring

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

Because of the significant ecological importance of trembling aspen (*Populus tremuloides*) as the most widely distributed tree species in North America and for its value as a carbon stock and a commercial species for fiber, the CIPHA project was initiated in 2000. A network of 150 long term research plots was established in 72 aspen stands along a regional climate gradient.

Annual assessment of health, mortality and changes in aboveground biomass show that drought and insects are major agents of disturbance that could cause a sustained, regional-scale decrease in aspen productivity and carbon uptake under the projected climatic changes over coming decades. One of the major challenges is in "scaling up" these patchy, stand-level impacts to the regional scale. Field measurements are being related to satellite remote sensing data in the development of methods for detecting, quantifying, and mapping aspen dieback and mortality.

(RÉSEF: Réseau québécois d'étude et de surveillance des écosystèmes forestiers)

Quebec's Ecosystem Study and Monitoring Network (RESEF), initiated in 1986, now comprises 31 sites where soil, vegetation and atmosphere are monitored on a five year cycle. A report released in 2007 identified impacts of insect defoliation, freezing rain and maple dieback on forest dynamics. Two key changes in forest composition were observed; the invasion of beech in stands experiencing maple die back and the conversion of spruce stands to balsam fir. The report can be accessed at

http://www.mrnf.gouv.qc.ca/publications/forets/connaissances/recherche/Duchesne-Louis/Memoire149.pdf

Turkey Lakes Watershed Study

The 1000 ha Turkey Lakes Watershed Study area was established in 1980 by Environment Canada, Canadian Forestry Service, and the Department of Fisheries and Oceans to study the impacts of the long-range transport of air pollutants on aquatic and terrestrial ecosystems. In 1997 a study was established in a remnant old-growth sugar maple-yellow birch forest on a shallow, Precambrian-derived till soil, in the lower part of the watershed, to examine the impacts of harvesting practices on the ecosystem and to calibrate a range of harvesting prescriptions to this important forest type. More recently, research on the effects of climate change has been included. Research and monitoring are carried out by various government agencies with more than 200 publications being generated from this site to date.

Acid Rain

The most recent progress report on the 1991 Canada–United States Air Quality Agreement (2006) indicates that over the last two years Canada has continued to reduce its emissions of sulfur dioxide and nitrogen oxides, the major contributors to acid rain, by targeting major sources such as electric generating units, industrial sources, and on-road and non-road transportation. Canada’s total sulfur dioxide emissions are almost half of the 1980 level and 28% below the national cap of 3.2 million 20-22 tonnes. Despite this overall progress, in eastern Canada, acid rain continues to damage sensitive ecosystems, and in 2005 the provinces of Nova Scotia, Quebec, and Ontario developed stricter regulations to reduce emissions from major sources. In western Canada, however, due to a booming energy production sector, acid rain may become more problematic.

Many areas of eastern Canada are continuing to experience levels of acidic deposition that exceed critical loads (the maximum amounts of acidifying deposition ecosystems can tolerate in the long term without being damaged). Acid deposition is especially a concern for eastern forests because the region is a major receptor of long-range transported air pollutants, forest health is poor in some areas, and forest soil fertility is marginal in many areas. Scientists have concluded that the critical loads of many sensitive terrains fall below the current target of 20 kilograms of wet sulfate per hectare per year, and even with full implementation of the commitments made in the 1980s and 1990s, it is anticipated that almost 800,000 km^2 in southeastern Canada will receive harmful levels of acidic deposition.

The New England Governors/Eastern Canadian Secretariat (NEG/ECS) Acid Rain Program initiated a forest mapping project to determine sustainable levels of acidic deposition for forest soils in eastern Canada and found that 52% of eastern Canada receives acid deposition that exceeds critical loads. The highest exceedances occur in eastern Ontario and southern Quebec. Preliminary estimates show that more than 48% of the upland forest area in Ontario and Quebec and over 35% of the upland forest area of Nova Scotia and insular Newfoundland receive acid deposition that exceeds critical loads.

In the Lac Clair Watershed in Quebec, research done by the NEG/ECS found that atmospheric pollution adds more than twice as much acidity to the ecosystem as it does beneficial mineral nutrients and that water runoff containing atmospherically deposited sulfur and nitrogen leaches away more nutrients than are added to the system from mineral weathering. The research concluded that the present rates of atmospheric deposition of sulfur and nitrogen exceed their long term sustainable rates where nutrient losses would be matched by nutrient supply.

Ozone

Three regions of Canada are known to have elevated levels of ozone: the Fraser Valley in British Columbia, the Windsor to Quebec corridor and the southern Atlantic region. Symptoms of ozone damage have been observed on eastern white pine in southern New Brunswick and in Ontario white pine has exhibited chlorotic dwarfism. Ozone-like symptoms have been noted on fourteen species of woody plants in the Fraser River Valley.

Fire

In Canada, neither the number of fires nor the area burned has exhibited particular trends between 1975 and 2006. The fluctuations in forest fires are primarily due to the variability of weather. In the 2006 fire season, there were 9713 fires covering 2.1 million hectares: both figures only slightly exceed the 10-year averages. The mild winter with below normal snow and moisture levels experienced in many regions as well as the early arrival of spring likely were contributing factors to the incidence of forest fire in Canada in 2006. Due to natural variations and lack of data, the precise influence of humans cannot be determined, but between 1990 and 2004, human-induced fires account for, on average, 51% of annual fires. In the same period, lightning strikes were responsible for 82% of the burnt area.

Insects

Insects are considered the leading cause of disturbances in Canadian forests in terms of total area affected. Overall, the total area damaged by insects in Canada has decreased steadily since 1975. The spruce budworm (*Choristoneura occidentalis*) and the forest tent caterpillar (*Malacosoma disstria*), both species native to Canada, have had the most significant impacts on Canadian forests by removing tree foliage and consequently reducing growth. In 2006, the forest tent caterpillar affected 5.8 million hectares of forests, while in 2005 the spruce budworm impacted 0.7 million hectares. Invasive alien species are also causing damage to Canadian forests. The brown spruce longhorn beetle (*Tetropium fuscum*), and the emerald ash borer (*Agrilus planipennis*) are two species that Canada is battling.

The mountain pine beetle (*Dendroctonus ponderosae)* is a native insect that kills trees through a combination of larval feeding on tree tissue and the introduction of a fungus. The province of British Columbia has been disproportionately affected and, by the time the infestation has run its course, it is expected to kill as much as 80% of lodgepole pine (*Pinus contorta*) in BC. In 2006, aerial surveys showed roughly 9.2 million hectares of BC forests were in a stage of red-attack by the mountain pine beetle. Though it has mostly affected BC, scientists believe that Alberta’s jack pine (*Pinus banksiana*) forests could also be at risk and in an effort to contain the infestation, control measures are being focused in the major mountain passes between the two provinces.

4.6 Croatia

83 sample plots on a 16 x 16 km grid network were included in the forest condition survey in 2007. The percentage of trees of all species within defoliation classes 2-4 in 2007 (25.1%) was hardly higher than in 2006 (24.9%) and comparable to the year 2004 (25.2%). For broadleaves the share of trees in classes 2-4 (20.0%) was slightly higher than in 2006 (18.2%). For conifers, the percentage of damaged trees in classes 2-4 (61.1%) is significantly lower than in 2006 (71.7 %) and in 2005 (79.5%), and even lower than in 2004 (70.6%). Although the percentage of moderately to severely damaged conifers is still high, it does not have a stronger impact on the overall percentage of trees of all species for the same damage class, due to the low representation of coniferous trees in the sample (252 coniferous trees vs. 1760 broad-leaved trees in 2007).

Abies alba was still the most damaged tree species, the percentage of moderately to severely damaged trees recorded in 2007 was 67.9%, compared to 69.7% in 2006. The lowest value, 36.6% of moderately to severely damaged trees was recorded in 1988, whereas in 1993 the respective share was 70.8%. In the year 2001, it reached 84.5%, and after a slight decrease in 2002 (81.2%), the trend of increasing defoliation continued with 83.3% of moderately to severely damaged trees in 2003, 86.5% in 2004 and 88.5 % in the year 2005.

The lowest percentage of damaged or dead *Quercus robur* was recorded in 1988 (8.1%), the highest percentage in 1994 (42.5%), and it has been fairly constant later at around 25-30% until the year 2000. Afterwards it decreased to values below 20% (15.4% in 2003, 18.5% in 2004). In 2005, a slight increase was recorded with 22.1% of moderately to severely damaged oak trees. In 2006, it was slightly lower at 20.5%, and in 2007 it was again lower at 19.6%.

Fagus sylvatica remained the least damaged tree species in Croatia. The maximum percentage of moderately to severely damaged beech trees was recorded in the year 2001 (12.5 %), and in subsequent years even lower values were recorded: 5.1% in 2003, 7.5% in 2004, 7.0% in 2005, 6.3 % in 2006, and 7.6% in 2007.

Overall, the state of crown defoliation in Croatia remained the same as in the last year. Despite that, the condition of some important and sensitive tree species, such as *Abies alba* and *Quercus robur* continued to improve.

4.7 Cyprus

The annual assessment of crown condition was conducted on 15 Level I plots, during the period September - November 2007. The assessment covered the main forest ecosystems of Cyprus and a total of 360 trees.

The last six years results of crown assessment in Cyprus show a decrease in the percentages of trees in classes 0, 2 and 3 and an increase in the percentage of trees in class 1. This is mainly attributed to the drought in 2007; affecting negatively the trees at this survey.

For *Pinus brutia*, 10.7% of the sample trees showed no defoliation, 70.3% were slightly defoliated, 18.7% were moderately defoliated and 0.3% were severely defoliated. Compared to 2006, no changes have been observed in class 0. In class 1 an increase of 4.7 percent points and for classes 2 and 3 a decrease of 4.3 and 0.3 percent points, respectively, were registered. For *Pinus nigra*, 5.6% of the sample trees showed no defoliation, 91.7% of the trees were slightly defoliated while the remaining 2.8% were moderately defoliated. Comparing to previous year's results the percentage of trees in class 0 decreased by 11.1 percent point, while the percentage of trees in class 1 increased by the same amount. For *Cedrus brevifolia*, 12.1% of the sample trees showed no defoliation, 79.2% of them were slightly defoliated and the remaining 8.3% were moderately defoliated. Compared to previous year's results, a decrease of 4.2 percent points in class 0, an increase of 8.4 percent points in class 1 and a decrease of 4.2 percent points in class 2 has been observed.

From the total number of sample trees assessed, 51.9% showed signs of insect attack and 14.2% showed signs of attack by "*other agents*". Compared with previous year's results, there is an increase of 6.1 percent points of sample trees showing signs of insect attack and an increase of 2.2 percent points for other agents.

Most frequently observed insect attacks were related to *Thaumetopoea wilkinsoni*, *Tomicus* spp. *Leucaspis* spp. as well as to unspecified defoliators.

The data analyses show that unspecified insect defoliators and *Thaumetopoea wilkinsoni* were the major biotic factors causing defoliation during the year 2007. No damage was attributed to any of the known pollutants. However, the poor edaphic conditions and the adverse climatic condition prevailing in Cyprus should be considered as additional factors contributing to the defoliation of trees.

Forest fires are a serious problem for the forests in Cyprus due to drought conditions, low precipitation and high temperatures prevailing on the island. However, due to the effective system and infrastructure in preventing and suppressing forest fires, the annual burnt area was kept small. During 2007, 25 forest fires damaged 617 ha of state forests. From this burnt area 539 ha were coniferous forests, 73 ha were broad-leaved forest and 11 ha were other forest cover type. The main causes of fires were: carelessness of forest visitors and farmers, malicious, unknown and natural causes. Forest fires didn't cause any damage to the Level I plots in 2007.

4.8 Czech Republic

In 2007, no important change in the total development of defoliation for coniferous tree species in both age categories (stands up to 59 years and 60 year old and older) was observed when compared with the preceding year. A slight change in defoliation was evident only for *Larix decidua* in the older stands where the share of trees dropped in the defoliation class 2 and increased in class 1. Compared to the last year, *Picea abies* showed no substantial changes in both age categories. In the long-term, defoliation of the younger coniferous species (up to 59 years) was lower than that of younger deciduous species. The reverse is true for the older stands (60 years old and older) where defoliation is distinctly higher for conifers than for deciduous species. The development of total defoliation in deciduous tree species did not change in the category of younger trees (stands up to 59 years) but differences were obvious for individual tree species. A slight improvement of defoliation in younger *Fagus sylvatica* stands was observed. A slight worsening in the defoliation of younger *Betula pendula* trees was recorded. Development of total defoliation in deciduous tree species of the older age category (stands 60 years old and older) showed a worsening trend documented by an increase of trees in class 2 from 28.9% in 2006 to 33.2% in 2007. Of the individual deciduous tree species the worsening was most distinct for *Quercus* spp. For this species group the proportion of trees in defoliation class 2 increased from 54.7% in 2006 to 69.9% in 2007.

During the winter season (January) forest stands in some forest regions, mainly in southern Bohemia, were mechanically damaged by the storm “Kyrill”. In the late summer season damage by strong wind was again observed in southern Bohemia and in eastern Bohemia as well. During the vegetation period higher occurrence of cambiophagous insects was observed in some forest areas, mainly in spruce stands.

In 2007 no important change was reported for the main pollutants (particulate matter, SO_2, NO_x, CO, VOC). During the last years their development has been fluctuating.

4.9 Denmark

The Danish forest condition monitoring in 2007 was carried out on a reduced number of Level I plots, but results were supplemented by NFI data for *Picea abies*, *Quercus* (*robur* and *petraea*), *Fagus sylvatica* and *Fraxinus excelsior*. Monitoring showed that most tree species had satisfactory health, based on both Level I and Level II and NFI plots.

However, *Fraxinus excelsior* has serious problems with extensive dieback of shoots and a high average defoliation of 45% on Level I and 34% for all monitored ash trees. The cause of the disease is considered to be *Chalara fraxinea*, and damaged trees are often attacked and killed by honey fungus (*Armillaria* sp.).

Average defoliation scores of *Picea abies* and *Quercus* (*robur* and *petraea*) were a little lower than in previous years. Most other tree species had slightly increased defoliation, except for *Fagus sylvatica* which remained at the same level. Attacks in conifers by the bark beetle *Ips typographus* were still common, but most forest districts were successful in their effort to control the problem.

Based on both Level I and II and NFI plots, the results of the crown condition survey in 2007 showed that 81% of all coniferous trees and 58% of all deciduous trees were undamaged. 12% of all conifers and 33% of all deciduous trees showed warning signs of damage, and 7% of all conifers and 10% of all deciduous trees were damaged. The mean defoliation of *Picea abies* decreased to 7% in 2006, and the share of damaged trees rose slightly to 7% in 2007. Mean defoliation of *Fagus sylvatica* remained at 10%, but only 4% of the beech trees were damaged. The mean defoliation of *Quercus* spp. decreased to 17 % and the share of damaged trees to 15%.

Looking back at almost 20 years of forest health monitoring it may be concluded that in Denmark there were serious problems in the mid-eighties. In the nineties, defoliation remained high, mostly due to dry summers around 1995. Since then defoliation has decreased, and most tree species except for *Fraxinus excelsior* are in good health, in spite of various problems with insects, fungi and storms. Data from the state forest districts corroborate the monitoring results.

4.10 Estonia

Forest condition in Estonia has been systematically monitored since 1988. In 2007, altogether 2 209 trees were assessed on 92 permanent Level I sample plots from July to October. 596 *Picea abies*, 1496 *Pinus sylvestris*, 92 *Betula* spp. and 25 other broadleaved trees were assessed.

In Estonia, the most defoliated tree species has been *Pinus sylvestris* over the last years. A clear improvement of crown condition of *Pinus sylvestris* was observed in 1994–2000. In the following years, a certain decline was registered until 2003 and in 2004 a clear improvement started. In 2006, 39.6% and in 2007 46.1% of the *Pinus sylvestris* trees were not defoliated (defoliation class 0). In 2007, 47.2% were slightly (defoliation class 1), 5.3% moderately (defoliation class 2) and 1.4% were severely defoliated or dead (defoliation classes 3 and 4).

The increase in defoliation of *Picea abies* which started in 1996 stopped in 2002 and remained on the same level up to 2005. In 2006 and 2007, some worsening in crown condition occurred. In 2006, 59.8% and in 2007 58.4% of the trees were not defoliated (defoliation class 0). In 2007 only 20% were severely defoliated or dead (defoliation classes 3 and 4) compared to 2.2% in 2005 and 0.7% in 2006.

Needle cast (315 trees damaged) and shoot blight (554 trees damaged) were the most significant biotic damage types. The highest number of biotic damage was observed in 2002, 406 pines damaged by needle cast and 739 by shoot blight.

The condition of deciduous species was estimated to be better than that of the conifers. In 2007, 57.6 % of *Betula* spp. were not defoliated (defoliation class 0).

4.11 Finland

The 2007 forest condition survey was conducted on 593 sample plots arranged in 16 x 16 km and 24 x 32 grids. A slight (less than 1 percent point) increase in the average defoliation level was observed between the years 2006 and 2007. Of the 11 218 trees assessed in 2007, 51.5% of the conifers and 54.9% of the broadleaves were not suffering from defoliation (leaf or needle loss 0-10%). The proportion of slightly defoliated conifers (11-25%) was 38.1%, and that of moderately defoliated (over 26%) 10.4%. For broadleaves the corresponding proportions were 34.2% and 10.5%, respectively. In general, the average tree-specific degree of defoliation was 10.4% (9.6% in 2006) in *Pinus sylvestris*, 18.3% (17.4 in 2006) in *Picea abies* and 12.6% (12.1% in 2006) in broadleaves (mainly *Betula* spp.). On mineral soils the average defoliation degree was 10.4% (9.7% in 2006) in *Pinus sylvesris*, 18.5% (17.5%) in *Picea abies* and 13.0% (12.5%) in broadleaves, and on peat lands 10.2% (9.2%), 16.4% (16.0%) and 11.2% (10.7%), respectively. A total of 30 (incl. 19 trees with broken top/crown) trees (0.3%) died during 2006-2007 (0.4% in 2005/2006).

The proportion of discoloured *Picea abies* increased from 5.1% to 7.3% and that of *Pinus sylvestris* decreased clearly from 6.8% in 2006 to 1.7% in 2007. Most of these discoloured trees belonged to discolouration class 10 to 25%, and moderate or severe discolouration was rare. Also leaf discolouration on broadleaves decreased from 4.8% to 3.7%. The most frequent discolouration symptoms on *Pinus sylvestris* were needle yellowing and browning, and the symptoms were mainly concentrated on older than current-year needles.

Snow caused some damage during winter 2006/2007 in most of Finland, especially in South-eastern Finland. The extent of wind damage was comparably small, as it was last year, too. Spring and summer started early. The average summer temperatures in 2007 were about the same or slightly higher than the long-term average all over Finland, and the precipitation was 90 to more than 160% of the long-term average. Autumn 2007 was mild and protected. Pine defoliators were abundant and increased population levels of the pine sawfly, *Neodiprion sertifer*, were observed on some 150 000 ha in Southern and Central Finland. Fungal diseases occurred at the average level.

In general, current levels of sulphur and nitrogen deposition are low in Finland compared to e.g. in Central-Europe. However, a slight co-occurrence between *Pinus sylvestris* defoliation and sulphur (Spearman's rho, r = 0.184) and nitrogen (r = 0.195) deposition (Finnish Meteorological Institute 2005), and broadleaf defoliation and nitrogen deposition (r = 0.155), was detected at the national level. No correlation was found between the defoliation pattern of *Picea abies* and the modelled sulphur or nitrogen deposition in 2007.

4.12 France

In 2007, the forest damage monitoring in the French part of the systematic European network comprised 10 071 trees on 504 plots.

The climatic conditions of the year were favourable to the forest vegetation except:

- a special hot and dry month of April on most part of the territory;

- a very strong drought, for the fifth successive year, on the extreme south-east (Corsica and half east of Provence).

The foliage loss remained stable for most of the broad-leaved species, whereas it slightly increased for conifers. Nevertheless, broad-leaved trees still remained at a higher defoliation level than conifers. *Quercus pubescens* and evergreen oak, species which are frequent in the South East of France, still had the worst crown condition of all monitored species in 2007.

Death of sampled trees stayed at a relatively low level (about 0.4 %). The mortality rate of branches increased in 2007, especially for hardwood like pedunculate oak, sessile oak, pubescent oak, evergreen oak, wild cherry and ash, and also for Douglas fir.

The number of discoloured trees was still low (less than 10%) except for poplars, beech, wild cherry, larch and Aleppo pine.

Damage was reported on about a third of the sampled trees, mainly on broad-leaved species. Attacks by defoliating caterpillars amounted to about a half of the reports of damage. Nevertheless, spring and summer observations showed that their impact on the foliage was quite low, and seldom went beyond 30%. The other most important causes of damage were mistletoe (*Viscum album*) on *Pinus sylvestris*, chestnut canker (*Cryphonectria parasitica*) and the oak buprestid (*Coroebus florentinus*) on *Quercus* spp. Abnormally small leaves were observed on different species, specially on *Quercus* spp., mainly on evergreen and pubescent oaks.

4.13 Germany

The 2007 crown condition survey included 10 241 trees on 420 plots of the 16 x16 km grid. Forest condition continued to improve. Mean defoliation showed a slight decrease, from 21.0% in 2006 to 20.7% in 2007. Compared to 2004, when mean defoliation reached 22.8% as a result of drought and heat during summer 2003, this is a clear improvement.

24.9% of the assessed trees were rated as damaged in 2007. The respective values were 28.2% for *Picea abies*, 13.0% for *Pinus sylvestris* and 38.7% for *Fagus sylvatica*.

In contrast to this general trend, *Quercus petraea* et *robur* showed higher mean defoliation than in the previous year. Mean defoliation increased from 26.6% in 2006 to 28.0% in 2007. The percentage of damaged trees increased by 4 percent points to 49.1%.

On 18 and 19 January a heavy winter storm ("Kyrill") stroke parts of Germany. Wind speeds reached more than 200 km/h on mountain peaks and around 145 km/h in the plains. Severe mechanical damage from storm occurred mainly in Northrhine-Westphalia, and insome neighbouring *Länder*. The overall volume of storm damaged timber in Germany from this event was about 37 million m^3.

The month of April 2007 was the warmest and driest ever recorded since the beginning of regular records in 1901. There were only 7% of the normal amount of precipitation and in some regions it did not rain at all during April. During the vegetation period from May to September temperatures exceeded the long-term average by several degrees but this was compensated by high amounts of rainfall.

4.14 Hungary

In general, the health condition of the Hungarian forests improved slightly compared to the previous year. The defoliation of *Quercus robur* et *petraea, Populus* spp., *Pinus sylvestris, Carpinus betulus* decreased, whereas the defoliation of *Robinia pseudoaccacia, Quercus cerris,* and *Pinus nigra* increased.

At the country level the gradation of *Lymantria dispar* collapsed. However, stands in the Great Hungarian Plain in Bács-Kiskun county were still considerably infected. The infection with bark beetles (*Ips typhographus*) mainly in the Western part of Hungary and in Borsod- Abaúj- Zemplén county were a continuous problem for forest operations. The only option for the forest managers are sanitary cuttings and finally the change of tree species to resistant ones.

The infection caused by *Cryphonectria parasitica* is unchanged. The *Castanea sativa* trees are infected all over the country even in mixed stands were single trees of this species are occurring. Another problem is the infection of young planted *Quercus petraea* stands where about 20% of the trees are affected.

The most important abiotic damaging factor in 2007 was the country wide drought in summer and the late-frost in May. These events are expected to have effects on forest condition as well in 2008.

4.15 Italy

The 2007 Level I survey in Italy included 6 636 trees on 238 permanent plots. 35.7% of all assessed trees were in defoliation classes 2-4. The respective shares for conifers and broadleaves were 22.7% and 40.4% of all assessed trees. 39.9% of the conifers and 18.4% of the broadleaves were without any defoliation (defoliation class 0). Among the young conifers (<60 years), *Pinus sylvestris* and *Picea abies* had 32.2% and 8.8% of the trees in classes 2-4, followed by *Larix decidua* (16,1%), and *Pinus halepensis* (11%). Among the old conifers (≥60 years), the highest share of trees in defoliation classes 2–4 was recorded for *Pinus sylvestris* (43.8%), followed by *Larix decidua* (36.0%), *Picea abies* (20.8%), *Abies alba (*20.8%), and *Pinus nigra* (4.9%).

Among the young broadleaves (<60 years), *Castanea sativa* and *Quercus pubescens* had 58.9% and 56.2%, respectively, in the classes 2- 4, followed by *Quercus cerris* (16.7%), *Fagus sylvatica* (26.8%), and *Ostrya carpinifolia* (37.3%). Among the old broadleaves (≥60 years), *Quercus pubescens* had 92.1% in the classes 2-4, followed by *Castanea sativa* (71.9%), *Quercus cerris* (31.3%) and *Fagus sylvatica* (32%). *Quercus ilex* had the lowest level of defoliation with 14% of trees in the classes 2-4.

From 2005 on, a new methodology for a more detailed assessment of biotic and abiotic damage factors was introduced. The main results are as follows: Most of the observed symptoms were attributed to insects (22.4%) mostly including “needle mining” (2.3% of the trees) and defoliators (15.8). Abiotic agents were recorded on 6.4% of the sample and fungi on 2.4%. 92.6% of the conifers and 93.8% of the broadleaves did not show any discolouration

4.16 Latvia

The 2007 forest condition survey comprised 8 278 sample trees on 349 permanent sample plots on the national grid (8 x 8 km), including 93 plots on the transnational grid (16 x 16 km). 72.7 % of all assessed trees were conifers (*Pinus sylvestris* and *Picea abies*) and 27.3 % were broadleaves (e.g *Betula* spp., *Populus tremula*, *Alnus* spp., etc.).

Mean defoliation of all tree species was 20.2%, which is nearly the same as in the previous year. The distribution of all tree species in the defoliation classes is very close to that of the 2006 survey. 20.0 % of all trees were not defoliated, 65.0% slightly defoliated, and 15.0% were assessed as moderately to severely defoliated or dead. Neither for conifers nor for broadleaves the changes in mean defoliation was statistically significant.

Pinus sylvestris constitutes approximately a half of all assessed trees, thus influencing strongly the mean defoliation level of the set of all tree species. Mean defoliation of *Pinus sylvestris* was 21.5% in 2007, which is practically the same as in 2006 (21.7%), however slightly higher than in the previous years. The share of trees in classes 2-4 increased in both years, 2006 and 2007, reaching 15.9% in 2007. Mean defoliation of the second most common coniferous species, *Picea abies*, was 20.2% and it has changed insignificantly compared to 2006. *Picea abies* showed a quite stable situation in crown condition already since 2001 –changes in mean defoliation between two subsequent years never exceeded 1.1percent points. Mean defoliation of *Betula* spp., which is the most common broad-leaved tree species, was 18.4% and the share of moderately defoliated to dead trees was 12.9%.

Damage symptoms were observed for 18.7% of the assessed trees. Most frequently recorded damage was caused by insects (41.2% of all cases), direct action of man (10.9%) and fungi (10.2%). As a result of the 2005 windstorm and favourable weather conditions for the development of bark beetles, high population densities of the bark beetle *Ips typographus* were observed in a number of regions of Latvia during the last years, including 2007. Two annual bark beetle generations have been observed during the last 5 years. Also for the coming years there remains a risk of high bark beetle damage to mature *Picea abies* stands. *Pinus sylvestris,* mostly in western Latvia, continues to suffer from the attacks of *Neodiprion sertifer,* which is one of the causes for the increase in mean defoliation for *Pinus sylvestris*.

4.17 Lithuania

The forest condition survey was carried out on 271 sample plots on the transnational Level I (16 x16 km) and on the national (8 x 8 km) grid net. In total 6538 sample trees representing 17 tree species were assessed. The main tree species assessed were *Pinus sylvestris*, *Picea abies*, *Betula pendula*, *Betula pubescens*, *Populus tremula*, *Alnus glutinosa*, *Alnus incana*, *Fraxinus excelsior*, and *Quercus robur*.

Mean defoliation of all tree species was 19.9%, i.e. by 0.6 percent points lower than in 2006 (20.5%). 20.2% of all sample trees were not defoliated (class 0), 67.3% slightly defoliated (class 1), and only 12.4% were assessed as moderately and severely defoliated and dead (classes 2-4). Mean defoliation of conifers was 18.8% (19.7% in 2006) and of broadleaves 22.4% (21.9% in 2006).

The number of *Pinus sylvestris* trees amounts to 51.4% of all sample trees, and thus its condition significantly influences the overall annual rates for forest health. Mean defoliation of *Pinus sylvestris* was 18.7% (19.6% in 2006). Starting from 1998, mean defoliation of *Pinus sylvestris* has not exceeded 21.0%. Mean defoliation of *Picea abies* was with only 0.8% significantly lower than in 2006 (19.9%).

Populus tremula had the lowest mean defoliation and the lowest share of trees in defoliation classes 2-4. Mean defoliation of *Populus tremula* was 17.1% (16.5% in 2006), and the share of trees in defoliation classes 2-4 was 7.5% (7.5% in 2006). Mean defoliation of *Alnus glutinosa* was 18.8% (18.7% in 2006), and the share of trees in defoliation classes 2-4 was 10.6% (7.6% in 2005). Mean defoliation of *Betula* spp. Was 0.6 percent points higher than in 2006 (20.4%).

The condition of *Fraxinus excelsior* as well as of *Quercus robur* has been improving but has still remained the worst. These tree species had the highest defoliation since 2000. Mean defoliation of *Fraxinus excelsior* has been decreasing during the last few years and has now reached 39.5% (44.4% in 2006). The share of not defoliated trees (class 0) was

11.9% (7.0% in 2006), and the share of trees in defoliation classes 2-4 was 22.0% (32.3% in 2006).

11.7% of all sample trees showed some kind of identifiable damage symptoms. The most frequent damage was caused by abiotic agents (3.2%), direct action of man (2.3%), and fungi (1.9%). The highest share of damage symptoms was assessed for *Fraxinus excelsior* (43.5%) and for *Populus tremula* (34.5%), the least for *Pinus sylvestris* (8.2%).

The condition of Lithuanian forests can be defined as relatively stable, because the mean defoliation of all tree species has varied inconsiderably from 1997 to 2007.

4.18 Macedonia

Out of the total number of 48 plots, 34 were examined, and 23 of these matched the criteria for assessment according to the ICP Forests Methodology. 14 plots are still in the process of installation. Plot installation has been ongoing accordingly during the last year. Increased efforts need to be undertaken to assess all plots in the future.

In 2007, a total of 507 trees was assessed, of which 476 were deciduous, while 32 were conifers. Most common was *Quercus frainetto* (19.7% of the total), while among the conifers *Pinus nigra* (5.3% of the total) was the most common species.

Results of the assessment of defoliation show that 45.8% of the total number of assessed trees did not show any symptoms of defoliation; 31.2% were in the warning stage; 22.8% were in defoliation classes 2 and 3, whereas 0.2% of the trees were dead. Compared to last year, the state can be regarded as practically unchanged. Like in 2006, there was hardly any discolouration observed. Insects were registered on 300 trees, all of them being deciduous species. They have were detected most abundantly on *Fagus moesiaca (*118 trees); *Quercus pubescens (*69 trees), and *Quercus frainetto* (55 trees). The most abundantly detected insect was *Orchestes fagi*. Fungi were identified on 81 deciduous trees, mostly on *Quercus frainetto* (48 occurrences). Damage by game and grazing of livestock has been registered in 12 cases.

Other biotic factors were registered on 53 deciduous trees, and on 5 conifers. Abiotic factors were registered 30 times, all on deciduous trees. Causative agents which were assessed but not identified appeared in 27 cases. Direct damage by human activities was registered on 24 trees.

In 2007 forest fires incidence was extremely high, so that large areas of forest land were damaged or destroyed. On the plots, fire has been registered 14 times, all on deciduous trees. One plot was not assessed because it was located on a site of a recent forest fire. Atmospheric pollution was not registered damage cause for defoliation.

4.19 Republic of Moldova

Climate conditions of the year 2007 during the highest vegetative activity of trees and bushes were □ulphur□able, including long periods without precipitations and with high air temperature. This resulted in reducing productive moisture within the upper soil layer (1 m depth), and alteration of physiological condition of trees. These facts led to unfortunate results: early defoliation of some species at the end of July – beginning of August. Data on forest monitoring demonstrate this. As compared to the last year, an increase of trees in defoliation classes 2-4 was observed, from 27.6% in 2006 to 32.5% in 2007. The number of trees without any damage decreased from 44.3% in 2006 to 36.1% in 2007.

High temperatures caused burnings of the leaf body. This phenomenon was manifested by the changing of colour from grey to brown in a periphery way through leaf layer, but sometimes burnings totally affected the leaf with following defoliation. Thus, trees in discolouration classes 2-4 constituted 20.2% in 2007 in comparison to 8.6% in 2006

An essential increase of trees in defoliation classes 2-4 was observed on *Robinia pseudoacacia* with 54.2% trees in these classes in comparison to 35.3% in 2006. For *Quercus robur* the share of trees in classes 2-4 was 35.1%. Regarding *Fraxinus excelsior,* an increase of trees in defoliation classes 2-4 up to 28.7% was assessed. Data analysis shows that the state of the plantations became worse.

The number of trees with identified damage type constituted 1541 trees or 10.8% of the total. The most often type of injury are those caused by pests, they constitute 87.9% of all identified injuries.

4.20 Norway

The results for 2007 show a general increase in crown defoliation compared to the year before. The mean defoliation for *Picea abies, Pinus sylvestris* and *Betula* spp. Was 17.4%, 18.1% and 24.5%, respectively. After a peak with low defoliation for both *Picea abies* and *Pinus sylvestris* in 2004, the last years represent deterioration in defoliation. Birch had the lowest defoliation in 2001. Since then, defoliation has increased.

Of all the coniferous trees, 42.3% were rated as not defoliated in 2007, which is the same percentage as the year before. Only 31.5% of the *Pinus sylvestris* trees were rated as not defoliated, while 50.4 % of all Norway spruce trees were not defoliated. For *Betula* spp. 21.9% of the trees were observed in the class not defoliated, representing a decrease of 10.8 percent points compared to the year before. The percentage of severely defoliated birch trees was 5.7%, representing a decrease compared to the year before. Birch had a slightly higher percentage of trees with severe defoliation in 2007 than spruce.

There has been observed a slight increase in discolouration for *Picea abies*. 8.7% of the spruce trees showed signs of discolouration, compared to 6.9% in 2006. For *Pinus sylvestris*, only 3.6% of the assessed trees were discoloured, reflecting an improvement from the year before. For *Betula* spp., a slight decrease in discolouration was observed with 8.2% of the birch trees having no signs of discolouration in 2007.

The overall mortality rate for all species was 0.6%. The mortality rate was 0.3%, 0.1% and 1.8% for spruce, pine and birch, respectively. No serious attacks by pests or pathogens were recorded.

In general, the observed crown condition values result from interactions between climate, pests, pathogens and general stress. According to The Norwegian Meteorological Institute the summer (June, July and August) of 2007 was regarded as relatively warm and humid.

The middle temperature for the whole country was 1°C above normal and the precipitation was 110% of the normal for these months.

4.21 Poland

In 2006, the integration of the ICP Forests monitoring network with the national forest inventory started. The first stage of the integration included the establishment of 458 permanent observation plots on a 16 x 16 km grid according to the ICP geographical coordinates for Poland, among them 376 in stands above 20 years old were subjected to evaluation. In 2007, plots on a 8 x 8 km grid were established as the national grid. In total in 2007 the national grid consists of 2 200 plots, the survey was carried out on 1 910 plots. In contrast to the former grid the new one covers not only the state forest but also all types of forest ownership. Changes in the localization of plots, in the extension of the grid to private forest and in the inclusion of stands between 20-40 years resulted in difficulties by comparing data of 2007 data with earlier years.

25.1% of all sample trees were without any symptoms of defoliation. 19.5% of all trees were classified as severely damaged or dead (classes 2-4).

23.2% of the conifers were rated as not defoliated. For 19.1% of the conifers, defoliation of more than 25% (classes 2-4) was observed. With regard to the three main coniferous species, *Picea abies* remained the species with the highest defoliation. A share of 22.5% of spruce trees up to 59 years old and 27.7% of spruce trees 60 years old and older were in defoliation classes 2-4.

29.0% of the assessed broad-leaved trees were not defoliated. The proportion of trees with more than 25% defoliation (classes 2-4) amounted to 20.1%. As in the previous survey, the highest defoliation amongst broad-leaved trees was observed in stands of *Quercus* spp. In 2007, a share of 21.6% of oak trees up to 59 years old and 36.4% of oak trees 60 years old and older was in defoliation classes 2-4.

In 2007, discolouration (classes 1-4) was observed on 0.9% of the conifers and on 2.2% of the broadleaves.

4.22 Romania

In 2007, the assessment of forest condition at Level I in Romania was carried out on the 16 x 16 km transnational grid net. 5 232 trees were assessed on 218 permanent plots. From the total number of trees, 1 104 were conifers and 4 128 broadleaves. Trees on three plots were harvested in the course of the last year and seven plots were not accessible due to natural causes such as windfall in the vicinity and floods.

For all species, 34.7% of the trees were rated as healthy, 42.1%, as slightly defoliated, 21.6% as moderately defoliated, 1.3% as severely defoliated and 0.2% were dead. The percentage of damaged trees (defoliation classes 2-4) was 23.2%.

For conifers 21.8% of the trees were classified as damaged (classes 2-4) and 78.2% were in defoliation classes 0-1. *Picea abies* was the least affected coniferous species with 18.5% of the trees damaged (defoliation classes 2-4).

23.5% of the broad-leaved trees were assessed as damaged or dead (classes 2-4) and 76.5% as healthy and slightly defoliated (classes 0-1). From all broad-leaved species, *Fagus sylvatica* was the healthiest with 15.9% of the assessed trees in defoliation classes 2-4 and the most affected species was *Robinia pseudoaccacia* with a share of 50.7% damaged or dead trees (classes 2-4). For *Quercus* sp. A share of 35.6% trees was rated as damaged or dead.

Compared to 2006, the percentage of damaged trees (classes 2-4) increased by 2.0 percent points. Forest health status was directly influenced, mainly for broadleaves, by the excessive drought in the second half of the 2007 vegetation season. In contrast, the beginning of the vegetation season was characterized by good soil water reserves.

4.23 Serbia

In the Republic of Serbia, the 16 x 16 km grid consists of 103 sampling plots. In the last year, 27 new plots on a 4 x 4 grid have been added. Forest condition monitoring is not carried out in the provinces of Kosovo and Metohija. The total number of trees assessed on all sampling plots was 2 860, of which 339 were coniferous and 2 521 broad-leaved trees. Main coniferous tree species are *Abies alba, Picea abies, Pinus nigra* and *Pinus silvestris,* and the most important broad-leaved tree species are *Carpinus betulus, Fagus moesiaca, Quercus cerris, Quercus frainetto* and *Quercus petraea.*

Among the conifers, *Pinus nigra* had the highest share of moderately to severely damaged or dead trees, namely 48.5%. *Picea abies* had the lowest share, namely 0.7%. For the broad-leaves, *Quercus freinetto* was the most severely damaged species with 34.0% in defoliation classes 2-4. *Fagus moesiaca* had only 5.7% of the assessed trees in these defoliation classes. Moderate or severe discolouration was detected on 3.8% of the broad-leaves and on 7.4% of the conifers.

The presence of sample trees with moderate and severe degrees of defoliation does not necessarily imply a reduction of vitality caused by the effect of adverse agents like climatic stress, insect pests, and pathogenic fungi as there is as well some natural variability in crown density.

4.24 Slovak Republic

The 2007 national crown condition survey was carried out on 107 Level I plots on the 16 x 16 km grid net. The assessments covered 4 904 trees, 4 023 of which being assessed as dominant or co-dominant trees according to Kraft.

Of the 4 023 assessed trees, 25.6% were damaged (defoliation classes 2-4). The respective figures were 37.5% for conifers and 16.6% for broad-leaved trees. Compared to 2006, the share of trees defoliated more than 25% decreased by 2.5 percent points. Mean defoliation for all tree species together was 23.1%, with 27.4% for conifers and 19.7% for broad-leaved trees. Results show that crown condition in the Slovak Republic is still worse than on the European average. This is mainly due to the condition of coniferous species.

From the beginning of the forest condition monitoring in 1987 until 1996 results show a significant decrease in defoliation and visible forest damage. Since 1996, the share of damaged trees (25-32%) and average defoliation (22-25%) has been relatively stable. The recorded fluctuation of defoliation depends mostly on meteorological conditions.

As a part of crown condition survey, damage types were assessed. The most frequent damage was caused by insects, followed by fungi and logging activities at tree stems. Epiphytes had the most important influence on defoliation. 67% of trees damaged by epiphytes revealed defoliation above 25%. In addition, abiotic agents had a direct link to defoliation.

4.25 Slovenia

The large-scale forest condition survey 2007 was carried out on 44 systematically arranged sample plots (16 x 16 km grid net) and encompassed 1 056 trees. The sampling scheme and the assessment method was the same as in the previous years.

Mean defoliation of all tree species was estimated to 25.4% while the share of trees with more than 25% unexplained defoliation (damaged trees) reached 35.7%. The change is significant in comparison to the results of 2006 when the mean defoliation was 23.3% and the share of trees with more than 25% unexplained defoliation was 29.4%.

Like in the previous years conifers were still more damaged than broad-leaves. While their mean defoliation and the share of damaged trees were assessed to 24.6% and 36.6%, respectively, (in 2006 24.6% and 32.2%) the values of both indicators for broad-leaves were assessed to 25.9% and 35.7% (in 2006 22.6% and 27.8%). It is concluded that the health condition of sample trees is worse than in 2006.

The most damaged tree species were *Quercus robur* and *Q. petraea* whose mean defoliation increased from 29.2% in 2006 to 31.2% in 2007. On the other side the health status of *Abies alba* improved. Ist mean defoliation decreased from 32.0% (2006) to 29.1%.

4.26 Spain

In 2007, 82.4% of all assessed trees were classified as healthy: they corresponded to defoliation classes 0 and 1 (defoliation between 0 and 25%). 15.8% of the trees were assigned to classes 2 and 3, with defoliation levels higher than 25%. These values show a remarkable improvement compared to the previous year’s survey.

The improvement is related to both, conifers and broad-leaves. For broadleaves it was, however, more pronounced with a remarkable increase of the percentage of healthy trees (80.5%), accompanied by a similar decrease in the number of damaged trees, reaching a percentage of 17.9%. For the conifers the improvement is less notable, with an increase in the percentage of healthy trees to 84.2% and a decrease of the share of damaged trees to 13.8%. Though the improvement compared to the previous year is less pronounced for conifers, the crown condition was better for this group of species, having a higher percentage of healthy trees.

The parameters defoliation and discolouration were related to possible causal agents. The most frequently reported damage cause for trees assigned to classes 2 and 3 (moderate and serious defoliation) was “drought”, followed by damages caused by insects, mainly defoliators and to a lesser extent other damages as the ones due to the lack of light, competition, damages caused by parasitic and epiphytic plants. Unidentified damages were recorded for 7.6% of the moderately and severely defoliated trees. Damages due to the direct action of man were recorded for less than 1% of all trees assessed. The importance of atmospheric pollution for the evolution of forest condition is a factor which can not be quantified directly, as it is frequently disguised by other kind of processes which are more apparent. However, it contributes (in combination with other agents) to the degradation processes of the forests falling under their influence. The continuous and periodic evaluation of the plots belonging to the European Level I grid net is a useful and an effective method for the assessment of tree condition, and the evolution of the forests health status.

4.27 Sweden

The national results are based on the assessment of the main tree species *Picea abies* and *Pinus sylvestris* in the National Forest Inventory (NFI), and concern as previously only forest in thinning age or older. In total, 7 208 trees on 3 554 sample plots were assessed. The separate Level I plots are included in the NFI grid, but are not assessed annually and not all Level I sample trees are included in the sample.

The proportion of trees with more than 25% defoliation is in *Picea abies* 26.4% (30.5% in 2006) and in *Pinus sylvestris* 10.2% (9.9% in 2006). The share of discoloured *Picea abies* trees is 3.5%. In *Pinus sylvestris* discolouration still is less frequent, 1.4%.

The forests in southern Sweden still suffer from the after-effects of severe storms during the most recent years. The latest storm occurred in January 2007 mainly north of the area affected in 2005. In the 2007 storm about 12 million m^3 timber was wind thrown. The bark beetle (*Ips typographus*) populations increased in 2006, but in 2007 due to unfavourable weather conditions the expected population increase did not take place. The estimated volume of wind thrown spruce affected by *Ips typographus* in 2007 was 1.3 million m^3. The populations of *Tomicus* still are large in southern Sweden. Large amounts of dropped gnawed pine shoots can be detected in the forests. In the northernmost Sweden an outbreak of resin top disease affected in young pine stands. An inventory in north-eastern Sweden showed that needle rust affected 50 000 ha of young pine stands. The damage is probably caused by *Cronartium flaccidum*.

4.28 Switzerland

In 2007, the Swiss national forest health inventory was carried out on 48 plots of the 16 x 16 km grid using the same sampling and assessment methods as in the previous years. Due to the inclusion of additional dominant and co-dominant trees outside of the fixed-area plot to have at least 10 trees in the ICP forest survey, in 2007 one plot had only trees outside the fixed-area plot. This plot has, therefore, no trees used for calculation in the Swiss National Forest Survey, which uses only trees in the fixed-area plots.

Crown condition in 2007 remained almost identical to 2006. In 2007 22.4% of the trees had more than 25% unexplained defoliation (i.e. subtracting the known causes such as insect damage, or frost damage; 2006: 22.6%) and 30.7% of the trees had more than 25% total defoliation (2005: 30.3%). Annual mortality rates were 6 out of 1000 trees, which is higher than normal, but due to the small sample size within the margin of error. On the Swiss Level II plots results were similar, but varied by plot and species. No consistent differences between species or regions were found. Fructification in common beech was low as compared to the year 2006 with high fructification rates.

4.29 Turkey

Turkey started the Level I and Level II monitoring programmes of EC/ICP Forests on forest ecosystems in 2006. Level I plots were selected on a systematic grid net of 16 x 16 km. The standard plot lay-out of 4 clusters of 6 trees was applied.

Plot installation is still ongoing, it is expected that Turkey will have around 800 Level I plots in the near future. From 2006 to the end of 2007 in total 274 plots have been installed, but 53 plots had insufficient trees to install the 4 clusters with 6 trees.

In the summer of 2007 the first crown condition survey on 48 Level I plots dominated with *Pinus brutia* was conducted in four Regional Forest Directorates in the Aegean and Mediterranean regions. The mean defoliation of *Pinus brutia* on sample trees in these plots is about 13%**.**

In 2006, also the development of the Intensive Monitoring Programme Level II started In total, approximately 50 Level II plots are foreseen to be installed including 10 plots where deposition, meteorology, phenology, etc. are foreseen to be monitored. In 2006, 3 Level II plots were installed and in 2007 additionally 8 plots were installed in managed and research forests representing the main tree species of Turkey. Ground vegetation was assessed on 4 Level II plots and deposition samplers and litterfall collectors were installed on one Level II plot. In addition, ozone injury on vegetation was investigated and crown condition was assessed on some Level II plots.

For 2008, 17 Level II plots are planned to be selected and installed and further implementation of forest monitoring in line with the technical specifications of the ICP Forests manual will be carried out.

4.30 Ukraine

In 2007, 36 596 sample trees were assessed on 1 551 forest monitoring plots in 24 administrative regions of Ukraine (about 95% of the total area of the country). For the total sample, some improvement in tree condition was observed compared to the previous year. In 2007, the percentage of healthy trees slightly increased (68.6% against 68.3%). At the same time, the share of slightly to moderately defoliated trees decreased from 31.1% to 30.1%. Mean defoliation of conifers was 10.7% and of broad-leaved trees 11.6%. These changes may be considered, however, as being related to changes in the tree sample, because 33 new forest monitoring plots were established in 2007.

For the sample of common sample trees (CSTs) (35 016 trees) there were hardly any changes detected. Mean defoliation of all species in 2007 was 11.2% and 11.3% in 2006. Changes are characterised by a decrease in the shares of defoliation class 1 and an increasing in classes 2 and 3, but these changes are insignificant. Some improvement in tree condition was registered for the CSTs of *Pinus sylvestris*. A statistically significant increase by 3.5 percent points was observed in class 0 against a decrease in class 1 by 3.8 percent points. The similar tendency was observed for the CSTs of *Fagus sylvatica* and *Fraxinus excelsior*. For *Quercus robur* an increase in classes 1, 2 and 3 was observed and a decrease in class 0. Visible damage symptoms were recorded for 4 203 sample trees. Some deterioration of the trees condition may be explained by the hot and dry weather condition in summer 2007 and by and increase of defoliating insects.

4.31 United Kingdom

The scope of the Level I survey undertaken in the UK during 2007 was reduced in comparison with previous years and only *Quercus robur* and *Pinus sylvestris* were assessed. As a result, the defoliation and discolouration data for all species, all conifers and all broadleaves in 2007, are not directly comparable with the preceding time series of UK data which included assessments of *Fagus sylvatica*, *Picea sitchensis* and *Picea abies*. The following discussion considers only the changes in condition of the species surveyed this year.

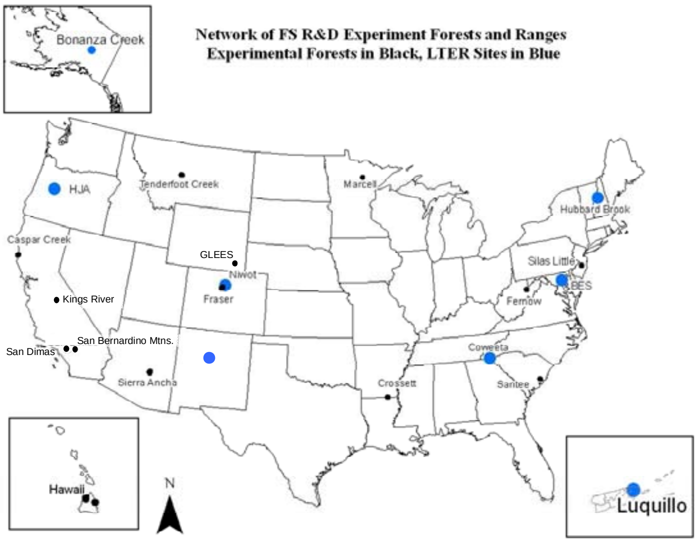
Following a winter which was warmer and wetter than average, weather conditions in the early spring of 2007 were extremely warm and dry with record mean and maximum temperatures being recorded in most parts of the UK during April. However, the period from May to July was uncharacteristically wet, and for the remainder of the 2007 growing season monthly temperatures and rainfalls were close to their long-term averages across the country. As a result, growing conditions for trees during 2007 were generally good and the crown densities of both surveyed tree species increased slightly compared with 2006.

The mean crown density of *Quercus robur* has fluctuated little since 2002 and increased only slightly in 2007 despite a marked reduction in the severity of crown dieback recorded this year. Whilst only 22.5% of trees displayed a reduction in crown density of 5% or more due to dieback alone, this improvement in condition was partially offset by an increase in insect damage which was adjudged to be moderate to severe on 68% of trees in 2007 compared with 58% of trees in 2006. As in previous years, severe defoliation due to attacks by larvae of the moths *Operophtera brumata* and *Erannis defoliaria* were most prevalent in the north of the country. Damage which was attributable to living agents other than insects was relatively uncommon this year but the proportion of trees displaying powdery mildew infections rose from 0.9% in 2006 to 2.9% in 2007, possibly as a result of the damp conditions which prevailed in late spring and early summer.

Following a 1% increase between 2006 and 2007, the crown density of *Pinus sylvestris* was higher this year than at any time in the preceding decade. Foliage retention of the species was largely unchanged compared with last year but the incidence and extent of shoot death was unprecedentedly low: only 20% of trees displayed any dead shoots and shoot death was adjudged to be common or abundant on only 0.2% of trees. Correspondingly, damage attributed to the pine shoot beetle (*Tomicus piniperda*) was much reduced with current attacks reported from 25% of plots in 2007 compared with 45% of plots in 2006.

4.32 United States of America

In 2008, the US Forest Service (USFS) established a Synthesis Network that will allow for measurements resembling those at the ICP Forests Level II plots. The network consists of 18 Experimental Forests and 3 additional sites (Figure 1) across the United States. The network has been equipped with the state-of-science instrumentation that will allow for collection of air, water, soils and vegetation data needed for calculation of critical loads for nitrogen & sulfur deposition. This initiative will help to establish trends and risks caused by atmospheric deposition to U.S. forests in various ecosystems and climatic scenarios. It is planned that these activities will be in the future linked to the USFS Forest Inventory and Analysis (FIA) and its Phase 3 (Forest Health Monitoring) focusing on evaluation of forest growth and condition. A five year Intensive Site Monitoring (ISM) study will start in summer 2008 in the San Bernardino Mountains of southern California. The study will: (1) characterize effects of air pollution, insects, pathogens, and drought on stand composition and structure, soil chemistry and water balance using intensive study sites that combine ICP Forest Level II site, and intensive monitoring useful for developing estimates of critical loads and linking process level information to FIA, FHM and remotely sensed data; (2) develop an integrated forest health monitoring system useful for identifying spatial patterns of forest changes in southern California in response to changing climate and wildland fire impacts; and (3) develop maps of forest health stress and risk useful for managers to understand future forest changes likely to occur in Southern California Mountains.


Network of FS R&D Experiment Forests and Ranges
Experimental Forests in Black, LTER Sites in Blue
Bonanza Creek
HJA
Tenderfoot Creek
Marcell
Hubbard Brook
Caspar Creek
GLEES
Niwot
Fraser
Silas Little
Fernow
Kings River
San Bernardino Mtns.
San Dimas
Sierra Ancha
Coweeta
Crossett
Santee
Hawaii
N
Luquillo

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Annexes