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Institute for World Forestry

Forest Condition in Europe

2010 Technical Report of ICP Forests

by

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Work report of the Institute for World Forestry 2010 / 1

Hamburg, June 2010

United Nations Economic Commission for Europe (UNECE)
Convention on Long-Range Transboundary Air Pollution CLRTAP
International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)
www.icp-forests.org

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Citation

Fischer R, Lorenz M, Granke O, Mues V, Iost S, Van Dobben H, Reinds GJ, De Vries W, 2010: Forest Condition in Europe, 2010 Technical Report of ICP Forests. Work Report of the Institute for World Forestry 2010/1. ICP Forests, Hamburg, 2010, 175pp.

Acknowledgements

28 countries supported the preparation of the present report by submission of data and by providing comments and corrections to the text. Several countries granted financial support. Assesments on the monitoring plots were partly co-financed under the LIFE+ Regulation (EC) 614/2007 of the European Parliament and of the Council. A complete list of the national and international institutions participating in ICP Forests is provided in Annex V.

Ms A. Khalil and Ms C. Lübker of PCC carried out technical and administrative work.

CONTENTS

PREFACE

Forest condition in Europe has been monitored since 1986 by the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) in close cooperation with the European Commission (EC). ICP Forests is working under the Convention on Long-range Transboundary Air Pollution (CLRTAP) under the United Nations Economic Commission for Europe (UNECE). Within its 25 years of existence the number of its participating countries has grown to 41 including Canada and the United States of America, rendering it one of the largest biomonitoring networks of the world. From the beginning on, ICP Forests has been chaired by Germany and has been coordinated by the Institute for World Forestry in Hamburg.

Aimed to assess 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. The results obtained by ICP Forests reveal the extent and development of forest damage and contribute to the enlightenment of the complex causes and effects involved. Besides fulfilling its obligations under CLRTAP, ICP Forests with its well developed monitoring system also contributes to other processes of international environmental policies in close cooperation with EC. This comprises the provision of information on indicators for sustainable forest management laid down by the Ministerial Conference on the Protection of Forests in Europe (MCPFE). It also includes 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. In addition to contributions to policy processes ICP Forests maintains close contacts to the forest research community and collaborates with the International Union of Forest Research Organisations (IUFRO).

The monitoring results of each year are summarized in annual Executive Reports. The methodological background and detailed results of the individual surveys are described in Technical Reports. The present Technical Report on Forest Condition in Europe refers to the results of the large-scale transnational survey of the year 2009 and presents results of individual studies of the intensive monitoring data made available by the year 2007.

SUMMARY

Of the 41 countries participating in ICP Forests, 31 countries reported national results of crown condition surveys in the year 2009 for 236 980 trees on 15 591 plots. The transnational result on the European-wide scale relied on 137 209 trees on 7 193 plots of the Level I grid in 30 out of 35 participating countries. The number of plots with submission of annual transnational data was the largest in the history of the programme. A number of countries resumed data submission again in 2009, Russia and Turkey are in the process of installing Level I plots.

Mean defoliation of all sample trees of the transnational survey was 19.2%. Of all trees assessed, a share of 20.2% was scored as damaged, i.e. had a defoliation of more than 25%. Of the main species, *Quercus robur* and *Q. petraea* had by far the highest mean defoliation (23.7%), followed by *Fagus sylvatica* (19.4%), *Picea abies* (18.0%) and *Pinus sylvestris* (16.9%). 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 1991 every year without interruption. In the period of observation the species group *Quercus ilex* and *Quercus rotundifolia* showed the severest increase in defoliation, with 4.4% of trees damaged in 1991 and 29.6% of trees damaged in 1995. Another severe increase in defoliation, namely from 6.4% in 1991 to 28.8% in 2005 was experienced by *Pinus pinaster*. Defoliation of *Quercus ilex* and *rotundifolia* fluctuated in the years following 1995. Defoliation of these Mediterranean species is largely attributed to several summer drought events. For *Fagus sylvatica* the share of trees rated as healthy has been almost constantly decreasing from 49.7% in 1991 to 19.8% in 2004.. Like *Quercus robur* and *Quercus petraea* it showed a peak in defolaiton in 2004, the year following a dry and hot summer in central Europe. *Picea abies* and *Pinus sylvestris* recuperated from peaks in defoliation in the mid 1990s.

Mean troughfall and bulk deposition data for the years 2005 to 2007 were analysed for between 215 and 288 intensive monitoring plots depending on the compound. Throughfall deposition was mostly higher compared to bulk deposition pointing to the importance of the air filtering function of forest canopies. Highest nitrogen and sulphur deposition occurred on plots in Central Europe. The lowest nitrogen deposition was observed in Scandinavia with values mostly below 1.8 kg per ha and year for $N\text{-}NO_3$ and below 1.6 kg per ha and year for $N\text{-}NH_4$. Plots with low sulphur deposition, i.e. with mean annual deposition below 3.3 kg per hectare, were found all over Europe. Depostion trends were calculated for the time period from 1998 – 2007 for around 160 plots. They show decreasing sulphur troughfall on half of the plots whereas for nitrogen compounds a decrease was only detected on between 10 and 20% of the plots.

Data on soil solution chemistry from intensive monitoring plots were analysed. Numbers of plots with available data increased until the year 2000 and remained stable thereafter. For the year 2006, data from 226 plots were available. Evaluations focussed on pH and tree species specific critical limits of BC/Al ratio as taken from literature. Soil acidification played an important role on the observed plots, as for 40.2% of the samplers the critical limit was exceeded in more than 5% of the measurements. In the years 2000 to 2006 there were no consistant trends detected for the sum of all investigated plots; neither towards improvement nor deterioration neither for pH nor for BC/Al ratios.

Ground vegetation was analysed based on the data from 776 intensive monitoring plots from 28 countries. In multivariate statistical models, predictor variables from the intensive monitoring data base were used to explain the occurrence and change of plant species composition. The composition of the ground vegetation mainly depended upon the traditional factors soil, climate and dominant tree species. But in contrast to earlier evaluations based on less comprehensive data sets, there were in addition clearly significant effects of nitrogen deposition on present vegetation species composition. Based on Ellenberg indicator values, a significant change over time towards nitrophytic species could be shown as well and could be linked to nitrogen deposition.

1. INTRODUCTION

In the present report the results of the 23rd European-wide crown condition survey conducted by ICP Forests and EC in the year 2009 are presented. Moreover, the report presents results of analyses of the intensive monitoring of ICP Forests and EC. 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. In contrast to earlier evaluations time trends are presented for a longer time span of 10 years. In the following subchapter a descriptive analysis of soil solution data as well as a comparison with tree species specific critical limits are presented. Critical limits are derived from literature. The development of soil solution pH is included as well. Ground vegetation data from over 700 intensive forest monitoring plots are the basis for a study aiming at detecting spatial and temporal trends of ground vegetation and the related predictor variables. The integrated monitoring of several ecosystem compartments in combination with modelled deposition data provides a unique basis for this evaluation.

Chapter 4 consists of national reports by the participating countries, focussing on crown condition in 2009 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 official UNECE and EU languages. The statistical procedures used in the evaluations are described in Annex IV. Annex V provides a list of addresses.

2. LARGE SCALE CROWN CONDITION SURVEYS

2.1 Methods of the surveys in 2009

2.1.1 Background

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" (ICP Forests, 2010). The following sections describe the selection of sample plots, the assessment of stand and site characteristics and the assessment of crown condition within the large scale survey (Level I).

2.1.2 Selection of sample plots

2.1.2.1 The transnational survey

The aim of the transnational survey is a description of 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 transnational grid of sample plots which has a density of one plot per 256 km^2. The selection of sample plots is under the responsibility of the participating countries. The selection of plots representative for the countries' forests is a prerequisite. In recent years, the integration of the ICP Forests monitoring network and National Forest Inventories has been ongoing in a number of countries. This process has led to the shift of Level I plots in a number of cases. In many countries, the plots of the transnational grid constitute a sub-sample of a denser national grid.

Level I plots were classified based on data base information according to forest categories following a classification scheme of the European Environment Agency (EEA 2007). Due to a restructuring of Level I plots in a number of countries in 2009, 48.6% of all plots with data for 2009 were not yet classified. Evaluation of forest condition stratified according to forest types was thus not carried out in the 2010 report. The classification of the new plots is foreseen for the coming year and a stratified evaluation will then be carried out again.

Within the transnational survey of the year 2009, crown condition was assessed on 7 193 plots in 30 countries (Table 2.1.2.1-1). This constitutes the programme's largest annual number of plots with data submission. The increase is due to the fact that a number of EU countries resumed data submission for 2009 after one or more years without submission (Greece, The Netherlands, Romania, Slovenia, and Sweden). The new data submission is at least partly due to the co-financing of the assessments under the LIFE+ project FutMon. In contrast, there had been no co-financing in 2008. The installation of a monitoring system is ongoing in Russia. This resulted in a first submission of defoliation data based on newly selected plots for western regions of the country. In Turkey, the installation of Level I plots is as well ongoing. Turkey has submitted defoliation data for the second consecutive year and from an increasing number of plots. In Finland, the re-structuring of the monitoring system resulted in an increased number of Level I plots with data submission in comparison to previous years. 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 1997 to 2009.

Country	Number of sample plots assessed												
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Austria	130	130	130	130	130	133	131	136	136	135			
Belgium	29	29	30	29	29	29	29	29	29	27	27	26	26
Bulgaria	119	134	114	108	108	98	105	103	102	97	104	98	159
Cyprus					15	15	15	15	15	15	15	15	15
Czech Republic	196	116	139	139	139	140	140	140	138	136	132	136	133
Denmark	22	23	23	21	21	20	20	20	22	22	19	19	16
Estonia	91	91	91	90	89	92	93	92	92	92	93	92	92
Finland	460	459	457	453	454	457	453	594	605	606	593	475	886
France	540	537	544	516	519	518	515	511	509	498	506	508	500
Germany	421	421	433	444	446	447	447	451	451	423	420	423	412
Greece	94	93	93	93	92	91			87				97
Hungary	58	59	62	63	63	62	62	73	73	73	72	72	73
Ireland	21	21	20	20	20	20	19	19	18	21	30	31	32
Italy	181	177	239	255	265	258	247	255	238	251	238	236	252
Latvia	96	97	98	94	97	97	95	95	92	93	93	92	92
Lithuania	67	67	67	67	66	66	64	63	62	62	62	70	72
Luxembourg	4	4	4	4		4	4	4	4	4	4	4	
The Netherlands	11	11	11	11	11	11	11	11	11	11			11
Poland	431	431	431	431	431	433	433	433	432	376	458	453	376
Portugal	144	143	143	143	144	145	136	133	119	118			
Romania	237	235	238	235	232	231	231	226	229	228	218		231
Slovak Republic	110	109	110	111	110	110	108	108	108	107	107	108	108
Slovenia	42	41	41	41	41	39	41	42	44	45	44		44
Spain	449	452	598	607	607	607	607	607	607	607	607	607	620
Sweden	758	764	764	769	770	769	776	775	784	790			857
United Kingdom	82	88	85	89	86	86	86	85	84	82	32		
EU	4793	4732	4965	4963	4985	4978	4868	5020	5091	4919	3877	3465	5104
Andorra								3		3	3	3	3
Belarus	416	416	408	408	408	407	406	406	403	398	400	400	410
Croatia	86	89	84	83	81	80	78	84	85	88	83	84	83
Moldova	10	10	10	10	10								
Norway	386	386	381	382	408	414	411	442	460	463	476	481	487
Russian Fed.													365
Serbia							103	130	129	127	125	123	130
Switzerland	49	49	49	49	49	49	48	48	48	48	48	48	48
Turkey											46	398	563
Total Europe	5740	5682	5897	5895	5941	5928	5914	6133	6216	6046	5058	5002	7193

2.1.2.2 National surveys

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

2.1.3 Assessment parameters

2.1.3.1 Stand and site characteristics

The following stand and site characteristics are reported on the transnational plots: Country, plot number, plot coordinates, altitude, aspect, water availability, humus type, and mean age of dominant storey. Besides defoliation and discolouration, the tree related data reported are tree numbers, tree species and identified damage types. (Table 2.1.3.1-1). Also recorded is the date of observation. Forest types (EEA 2007) have been assigned based on database information. Validated data are not yet available from the EU demonstration project “BioSoil”.

Table 2.1.3.1-1: Stand and site parameters given within the crown condition 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
Forest type	Forest type	14 forest categories according to EEA (2007)
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).

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
Belgium	26	26	26	26	26	26
Bulgaria	159	159	159	159	159	159
Cyprus	15	15	15	15	15	15
Czech Republic	133	133	54	133	133	133
Denmark	16	16	16	16	16	16
Estonia	92	92	92	92	92	92
Finland	886	886	882	886	886	886
France	500	499	500	500	500	500
Germany	412	371	349	412	412	412
Greece	97	97	97	97	97	97
Hungary	73	73	40	73	73	73
Ireland	32	32	19	32	32	32
Italy	252	252	252	252	252	252
Latvia	92	92		92	92	92
Lithuania	72	72	72	72	72	72
Netherlands	11	11	11	11	11	11
Poland	376	376	376	376	376	376
Romania	231	231	231	231	231	231
Slovak Republic	108		108	108	108	108
Slovenia	44	44	44	44	44	44
Spain	620	620	620	620	620	620
Sweden	857	857	829	857	857	857
EU	**5104**	**4954**	**4792**	**5104**	**5104**	**5104**
Percent of EU plot sample		**97.1**	**93.9**	**100.0**	**100.0**	**100.0**
Andorra	3	3	3	3	3	3
Belarus	410	410	410	410	410	410
Croatia	83	83	83	83	83	83
Norway	487		451	487	487	487
Russia	365			365	365	365
Serbia	130	130	40	130	130	130
Switzerland	48	47	46	48	48	48
Turkey	563	297	41	563	563	563
Total Europe	**7193**	**5924**	**5866**	**7193**	**7193**	**7193**
Percent of total plot sample		**82.4%**	**81.6%**	**100.0**	**100.0**	**100.0**

2.1.3.2 Defoliation

On each sampling point of the national and transnational grids situated in forests, sample trees are selected according to national procedures. On 3 832 out of a total of 7 193 plots sample tree number per plot was between 20 and 24 trees. 1 719 plots had less than 10 sample trees. Due to harmonisation with plot designs of national forest inventories, the variation of numbers of trees per plot has been increasing in comparison to previous years. 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.

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. 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 2009, the number of trees assessed was 137 209. Defoliation scores were available for 136 778 trees (Table 2.2.1-1). Table 2.1.3.2-1 shows the total numbers of trees assessed in each participating country since 1997. 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.

73.4% of the plots assessed in 2009 were dominated by conifers and 26.6% by broadleaves (Annex I-1). Compared to previous years' samples, the share of plots dominated by conifers increased. This is mainly due to the new plots in Finland, Sweden and Russia, which are nearly exclusively coniferous plots. 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 126. Most abundant were *Pinus sylvestris* with 24.3% followed by *Picea abies* with 14.4%, *Fagus sylvatica* with 8.4%, *Betula pendula* with 4.9%, and *Pinus nigra* with 3.9%. In the following evaluations *Quercus robur* and *Q. petraea* are grouped to one species group accounting together for 8.4% of the assessed trees (Annex I-2).

Table 2.1.3.2-1: Number of sample trees from 1997 to 2009 according to the current database.

	Number of sample trees												
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Austria	3604	3577	3535	3506	3451	3503	3470	3586	3528	3425			
Belgium	683	692	696	686	682	684	684	681	676	618	616	599	599
Bulgaria	4748	5349	4344	4197	4174	3720	3836	3629	3592	3510	3569	3304	5560
Cyprus					360	360	360	360	361	360	360	360	362
Czech Rep.	4844	2899	3475	3475	3475	3500	3500	3500	3450	3425	3300	3400	3325
Denmark	528	552	552	504	504	480	480	480	528	527	442	452	384
Estonia	2184	2184	2184	2160	2136	2169	2228	2201	2167	2191	2209	2196	2202
Finland	8788	8758	8662	8576	8579	8593	8482	11210	11498	11489	11199	8812	7182
France	10800	10740	10883	10317	10373	10355	10298	10219	10129	9950	10073	10138	9949
Germany	10990	13178	13466	13722	13478	13534	13572	13741	13630	10327	10241	10347	10088
Greece	2224	2204	2192	2192	2168	2144			2054				2289
Hungary	1257	1383	1470	1488	1469	1446	1446	1710	1662	1674	1650	1661	1668
Ireland	441	441	417	420	420	424	403	400	382	445	646	679	717
Italy	4873	4939	6710	7128	7350	7165	6866	7109	6548	6936	6636	6579	6794
Latvia	2297	2326	2348	2256	2325	2340	2293	2290	2263	2242	2228	2184	2190
Lithuania	1634	1616	1613	1609	1597	1583	1560	1487	1512	1505	1507	1688	1734
Luxembourg	96	96	96	96		96	96	96	97	96	96	96	
The Netherlands	220	220	225	218	231	232	231	232	232	230			247
Poland	8620	8620	8620	8620	8620	8660	8660	8660	8640	7520	9160	9036	7520
Portugal	4524	4470	4470	4470	4500	4530	4260	4170	3749	3719			
Romania	5687	5637	5712	5640	5568	5544	5544	5424	5496	5472	5232		5448
Slovak Rep.	5033	5094	5063	5157	5054	5076	5116	5058	5033	4808	4904	4956	4944
Slovenia	1008	984	984	984	984	936	983	1006	1056	1069	1056		1056
Spain	11064	11160	14664	14880	14880	14880	14880	14880	14880	14880	14880	14880	14880
Sweden	10910	11044	11135	11361	11283	11278	11321	11255	11422	11186			2591
United Kingdom	1968	2112	2039	2136	2064	2064	2064	2040	2016	1968	768		
EU	109025	110275	115555	115798	115725	115296	112633	115424	116601	109572	90772	81367	91729
Andorra								72		74	72	72	73
Belarus	9974	9896	9745	9763	9761	9723	9716	9682	9484	9373	9424	9438	9615
Croatia	2030	2066	2015	1991	1941	1910	1869	2009	2046	2109	2013	2015	1991
Moldova	253	234	259	234	234								
Norway	4028	4069	4052	4051	4304	4444	4547	5014	5319	5525	5824	6085	6014
Russian Fed.													11016
Serbia							2274	2915	2995	2902	2860	2788	2751
Switzerland	880	868	857	855	834	827	806	748	807	812	790	773	801
Turkey											911*	9316*	13219
Total Europe	126190	127408	132483	132692	132799	132200	131845	135864	137252	130367	111755	102538	137209

* data presently under revision; not included in total sum for Europe

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. 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 in the course of regular forest management activities. 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 "all plots") and for the 26 participating 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 2008 to 2009 was calculated (Annex I-5). 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 2009

2.2.1 Crown condition in 2009

In 2009 crown condition was assessed on 7 193 plots (Table 2.1.3.1-2) comprising 136 778 (Table 2.2.1-1) sample trees with defoliation scores. Of the assessed trees a share of 20.2% 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 22.4% the share of damaged conifers with 18.3%. In Annex I-3 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 on all plots in 2009 was 19.2%. Annex I-4 shows a map of mean plot defoliation for all species. Because of different numbers of participating countries (Chapter 2.2.2.1), defoliation figures of 2009 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.

		Percentage of trees in defoliation class							Defoliation		No of
	Species type	0-10%	>10-25%	0-25%	>25-60%	>60%	dead	>25%	mean	median	trees
EU	broadleaves	27.4	46.9	74.3	22.9	2.0	0.8	25.7	21.9	20	42610
	conifers	33.0	45.0	77.9	19.9	1.4	0.8	22.1	19.9	15	48689
	all species	30.4	45.9	76.3	21.3	1.7	0.8	23.7	20.8	20	91299
Total Europe	*Fagus sylv.*	36.1	40.8	76.9	21.8	1.2	0.2	23.1	19.4	15	11470
	Quercus robur + Qu. petraea	21.5	46.8	68.2	29.4	1.7	0.6	31.8	23.7	20	9167
	broadleaves	33.7	43.9	77.6	19.8	1.9	0.7	22.4	20.2	15	60742
	Picea abies	44.1	33.4	77.4	20.3	1.7	0.7	22.6	18.0	15	19694
	Pinus sylvestris	40.1	45.9	86.0	12.6	0.9	0.5	14.0	16.9	15	33322
	conifers	37.7	44.0	81.7	16.3	1.3	0.8	18.3	18.4	15	76036
	all species	35.9	43.9	79.8	17.8	1.6	0.8	20.2	19.2	15	136778

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 Figure 2.2.1-1. Also given are the number of trees, the mean defoliation and the median. Dead trees are indicated by defoliaton values of 100%.

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 seen in Table 2.2.1-1. With 23.7% mean defoliation on the assessed plots the value was highest for *Quercus robur* and *Quercus petraea*. For *Fagus sylvatica*, mean defoliation of 11 470 assessed trees was 19.4%. *Quercus robur* and *Quercus petraea*, show highly defoliated plots throughout their range, for *Fagus sylvatica* clusters of plots with high defoliation are concentrated in central Europe. Of the four main tree species assessed, *Pinus sylvestris* showed the lowest mean defoliation. Clusters of plots with mean defoliation of *Pinus sylvestris* and *Picea abies* above 30% are located in central Europe. Specifically for *Pinus sylvestris* mean defoliation is lower on plots the boreal and hemiboreal regions.

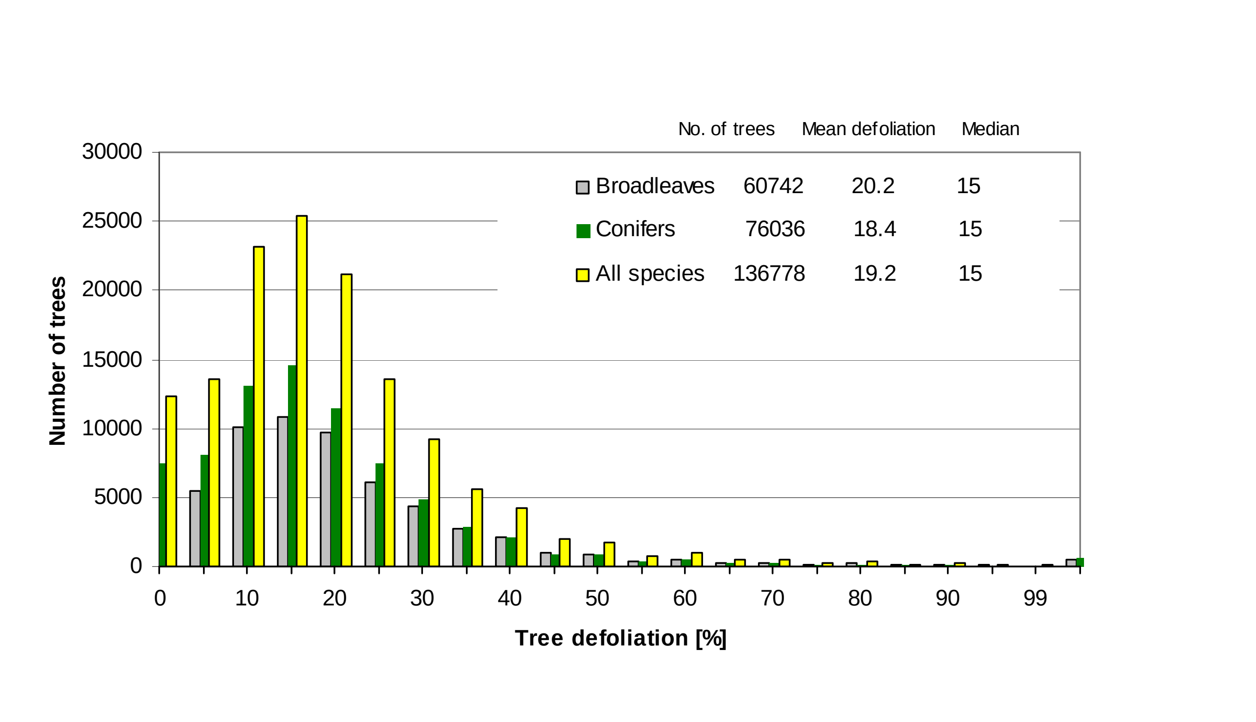

Figure 2.2.1-1: Frequency distribution of all trees assessed in 2009 in 5%-defoliation steps

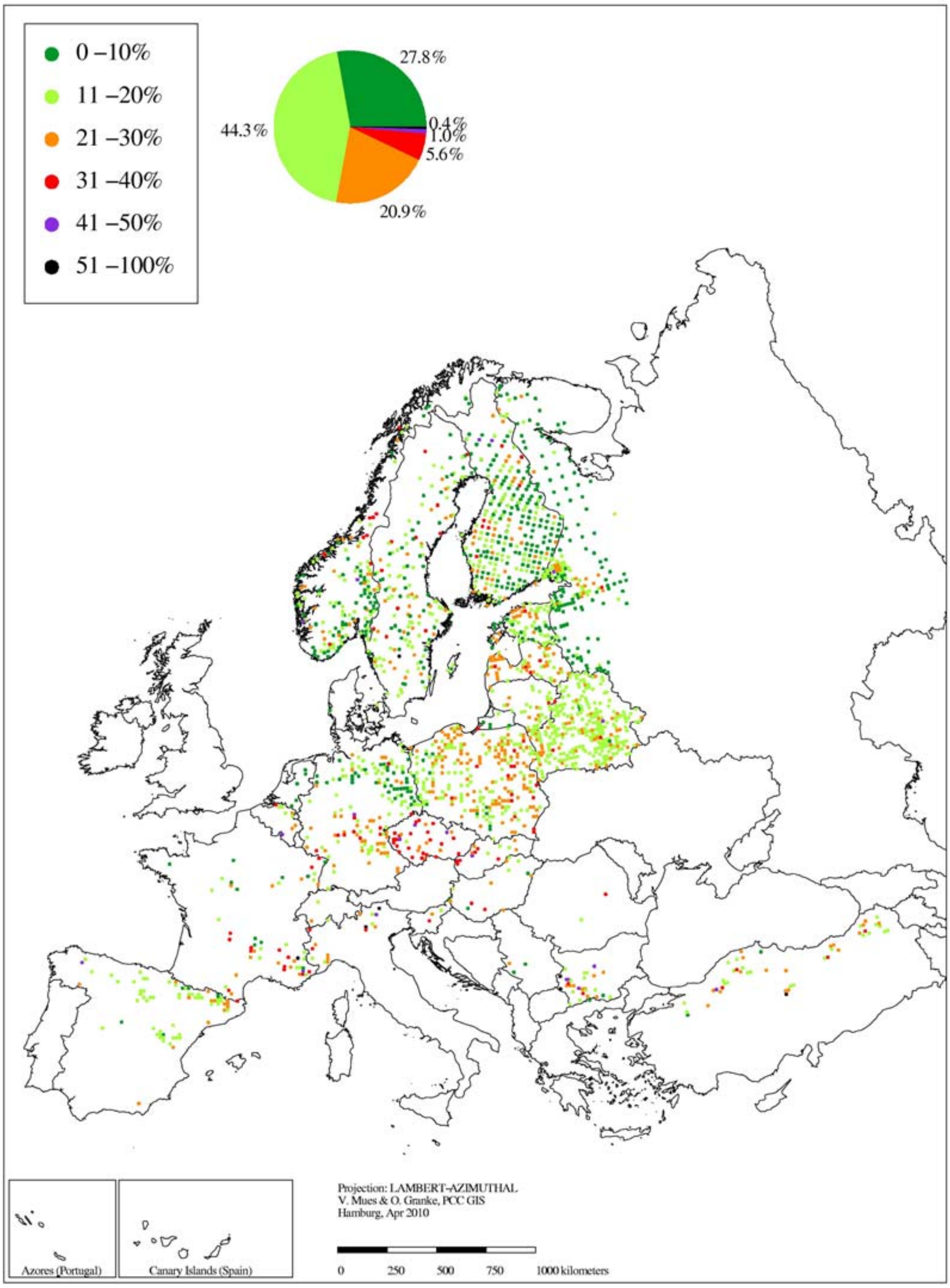

Figure 2.2.1-2: Mean plot defoliation of *Pinus sylvestris* for 2009.

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

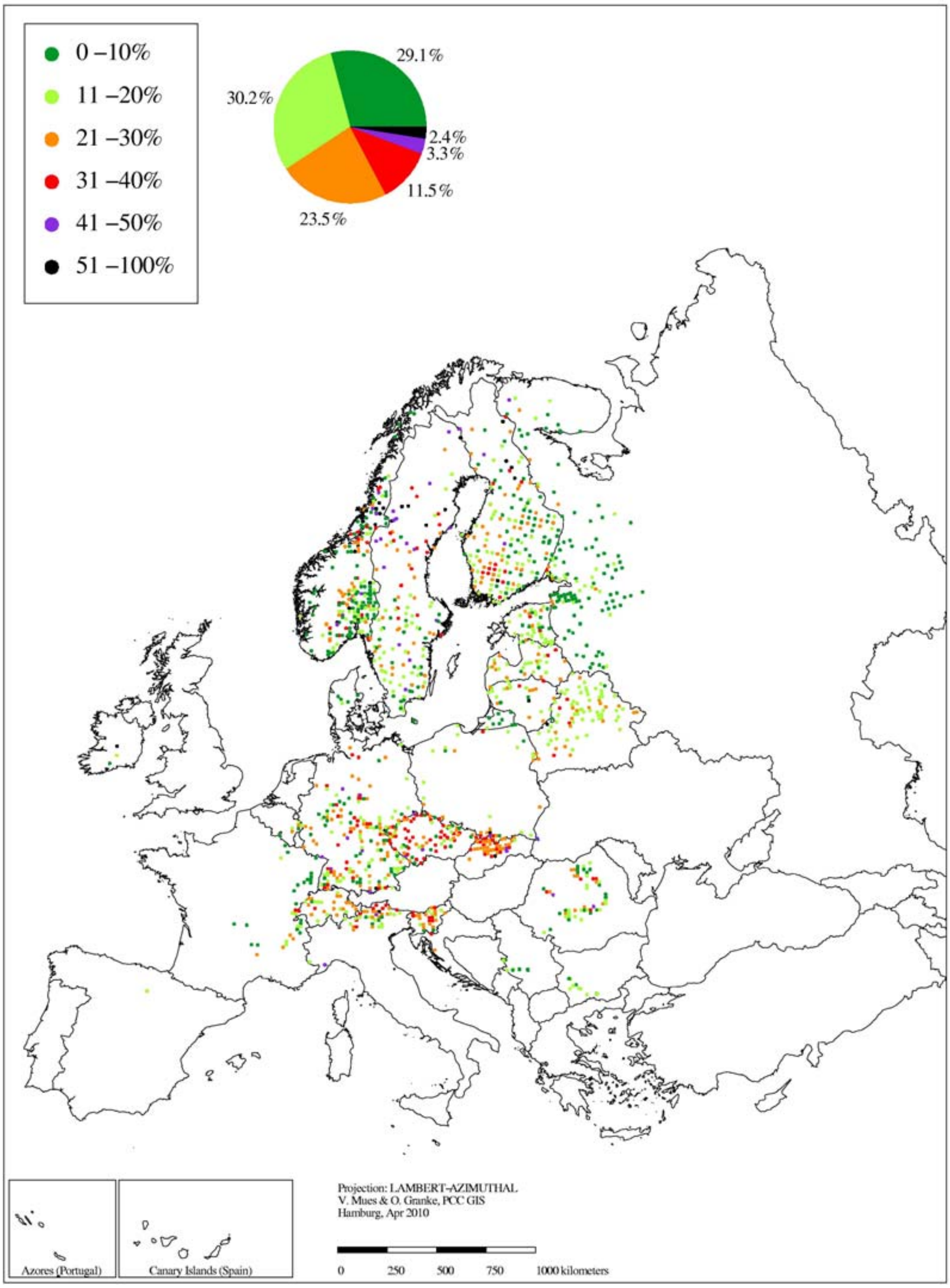

Figure 2.2.1-3: Mean plot defoliation of *Picea abies* for 2009.

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

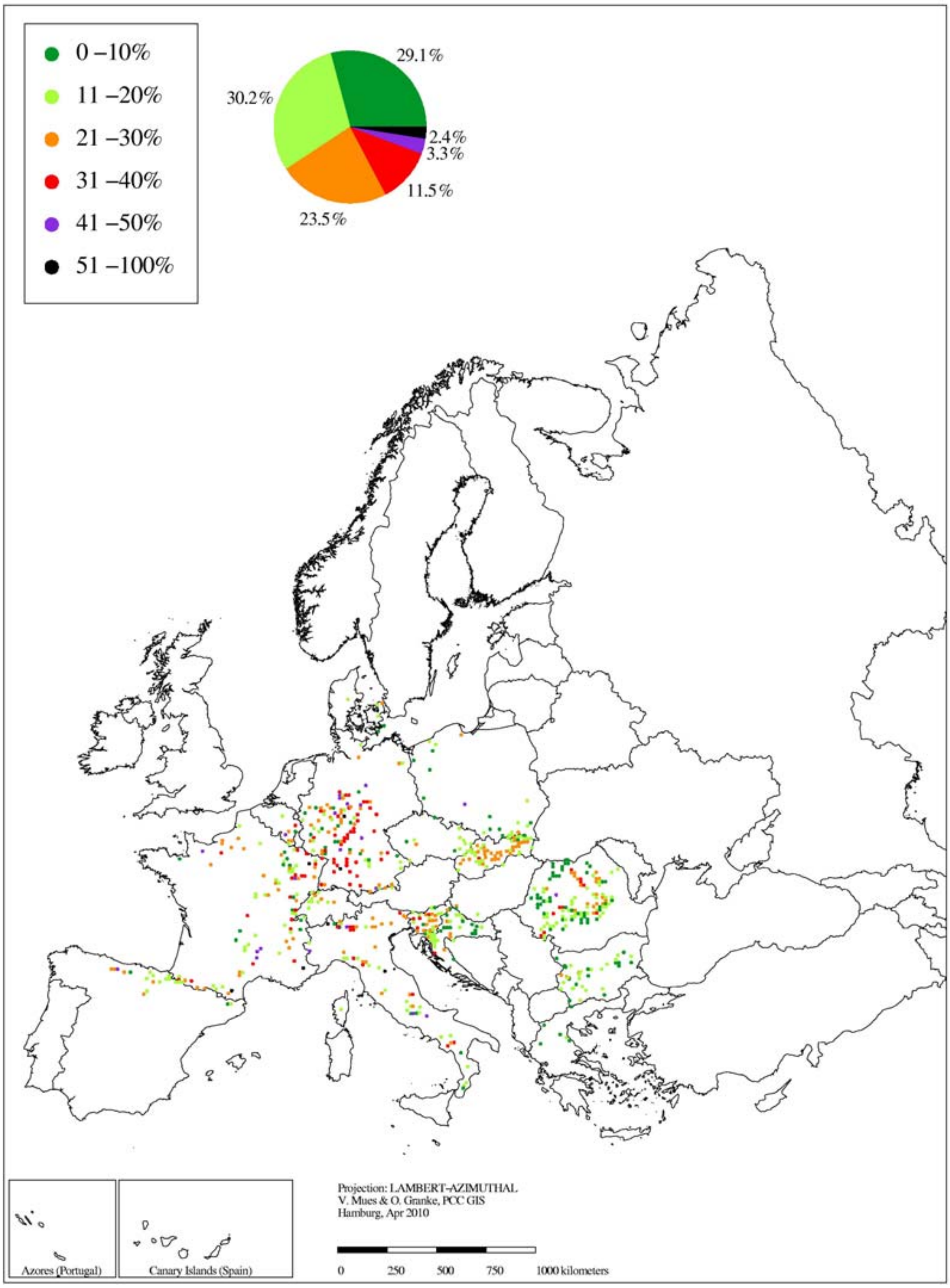

Figure 2.2.1-4: Mean plot defoliation of *Fagus sylvatica* for 2009.

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

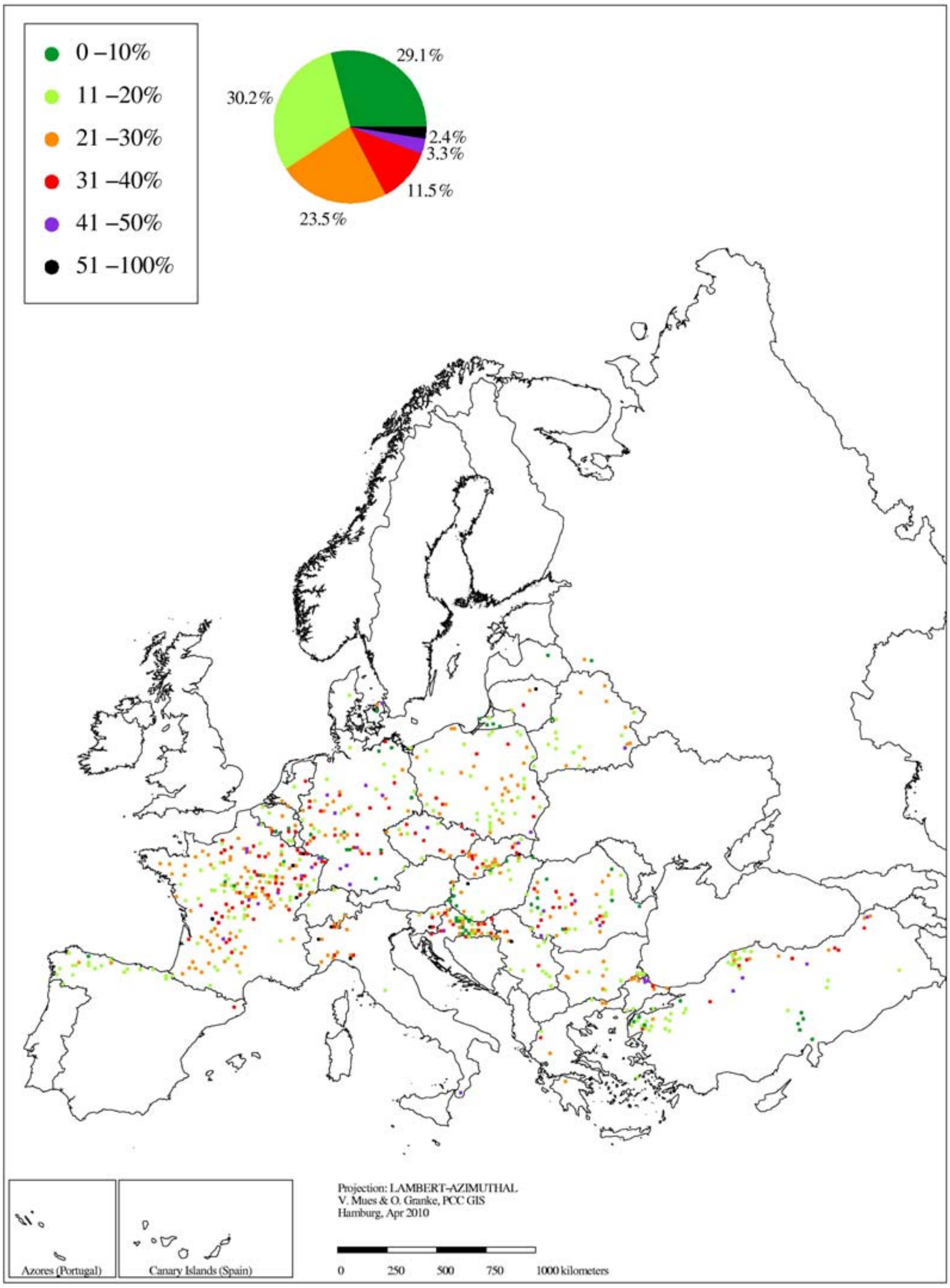

Figure 2.2.1-5: Mean plot defoliation of *Quercus robur* and *Quercus petraea* for 2009.

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

For 126 141 trees discolouration was assessed (Table 2.2.1-2). A share of 9.2% of the trees was discoloured, i.e. had a discolouration of more than 10%.

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	Broadleaves	92.3	4.8	1.9	0.3	0.7	7.7	38531
	Conifers	93.1	4.8	1.1	0.2	0.8	6.9	42365
	All species	92.7	4.8	1.5	0.2	0.7	7.3	80896
all plots	Broadleaves	91.5	5.6	1.9	0.3	0.6	8.5	56529
	Conifers	90.3	7.0	1.6	0.3	0.8	9.7	69612
	All species	90.8	6.4	1.8	0.3	0.7	9.2	126141

2.2.2 Defoliation trends

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. However, fluctuations due to the inclusion of newly participating countries must be excluded, because forest condition among countries can deviate greatly. For this reason, the development of defoliation can only be calculated for defined sets of countries. Different lengths of time series require different sets of countries, because at the beginning of the surveys the number of participating countries was much smaller than it is today. For the present evaluation the following two time series and respectively, the following countries were selected for tracing the development of defoliation:

Period 1991-2009:
Belgium, Czech Republic, Denmark, Finnland, France, Germany, Hungary, Ireland, Italy, Latvia, Poland, Slovak Republic, Spain, and Switzerland.

Period 1998-2009:
Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finnland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Poland, Slovak Republic, Spain, and Switzerland.

Several countries could not be included in one or both time series because of changes in their tree sample sizes, changes in their assessment methods or missing assessments in certain years. Development of defoliation is presented 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. Whereas in graphs all plots of the countries mentioned above are included for the two respective time series, maps only represent plots within these countries that were represented in all surveys. In the last years plots were shifted within Finland, Latvia and parts of Northern Germany (Brandenburg). These plots are not depicted in the maps but are included in the time series calculation.

The spatial pattern of the changes in mean defoliation from 2008 to 2009 across Europe is shown in Annex I-5. The pie diagram shows that on 81.3% of the plots there was no change in defoliation detected. The share of plots with increasing defoliation was 11%, the share of plots with a decrease was 7.7%. There are hardly any spatial clusters of plots with a recorded decrease or increase.

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 present maps indicating trends of mean plot defoliation. They also 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.

2.2.2.2 Main tree species

Of the main tree species assessed, the deciduous oak species *Quercus robur* and *Quercus petraea* show the highest mean defoliation during the last decade. Defoliation peaked in the two following years after the extremely dry and warm summer in 2003 and is only recuperating slowly since the year 2006. Mean defoliation of *Fagus sylvatica* is as well characterized by a clear increase in 2004. After a subsequent recuperation crown condition again deteriorated in 2009. *Pinus sylvestris* shows a clear decrease in mean defoliation during the 1990s followed by a subsequent fluctuation. Defoliation of *Picea abies* does not reveal a distinct trend. The level of defoliation in the 1990s was, however, slightly higher as compared to the last decade. At the beginning of the observation period, mean defoliaton of *Pinus pinaster* was lowest as compared to the other main tree species, but increased until the year 2005. After a slight recuperation it again increased in the last year of observation. *Quercus ilex* is characterized by two marked peaks in defoliation, namely in the years 1995/96 and in the years 2005/06.

For all species depicted, the two time series in Figures 2.2.2.2-1 and 2.2.2.2-2 show very similar trends for mean defoliation due to the fact that most countries included in the short time series are as well included in the evaluation of the long series. The number of sample trees is given in Annex I-6. For *Pinus pinaster* and *Quercus ilex* there is hardly any difference in sample size. Largest differences occur for *Fagus sylvatica* were depending on the year under observation sample size for the long series is only approximately 75% of the number of trees of the shorter time series.

Trends in mean plot defoliation for the period 1998-2009 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 (24.4%) surmounts the share of plots with decreasing defoliation (14.9%). Plots showing a deterioration are scattered across Europe, but their share is particularly high in southern France, at the eastern edge of the Pyrenean mountains and in Czech Republic.

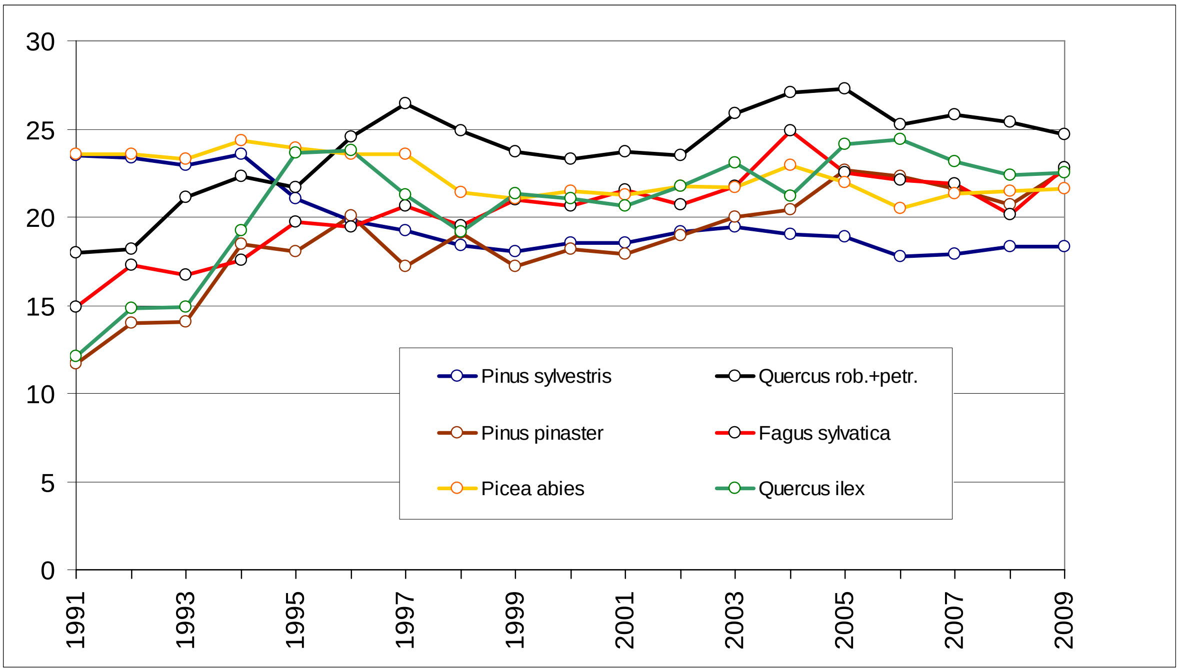

Figure 2.2.2.2-1: Mean defoliation of main species 1991-2009.

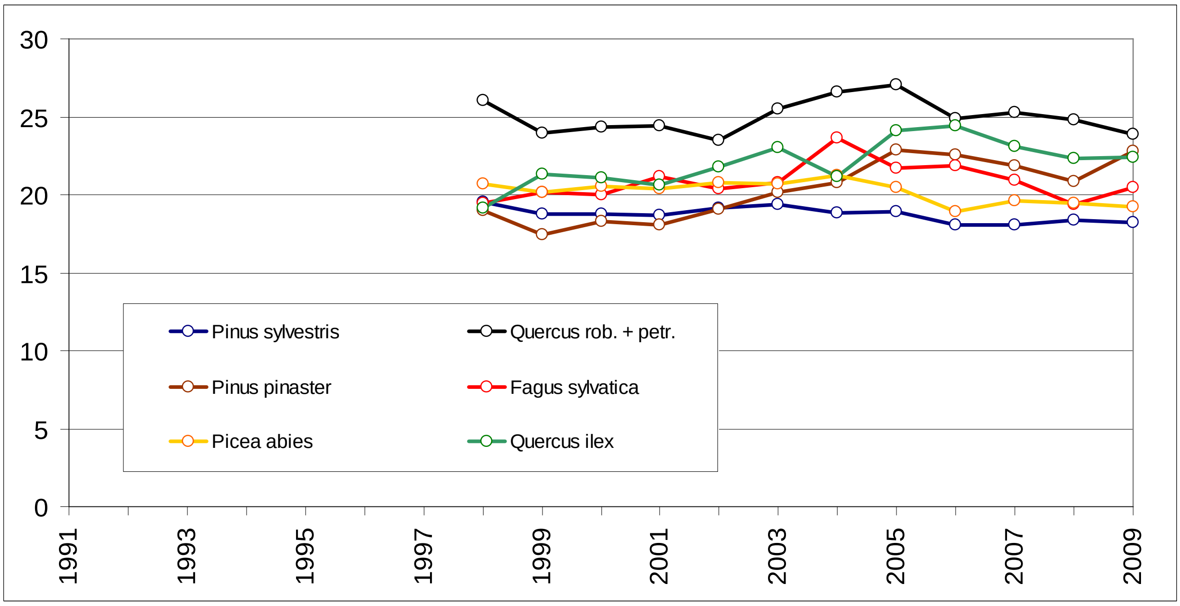

Figure 2.2.2.2-2: Mean defoliation of main species 1998-2009.

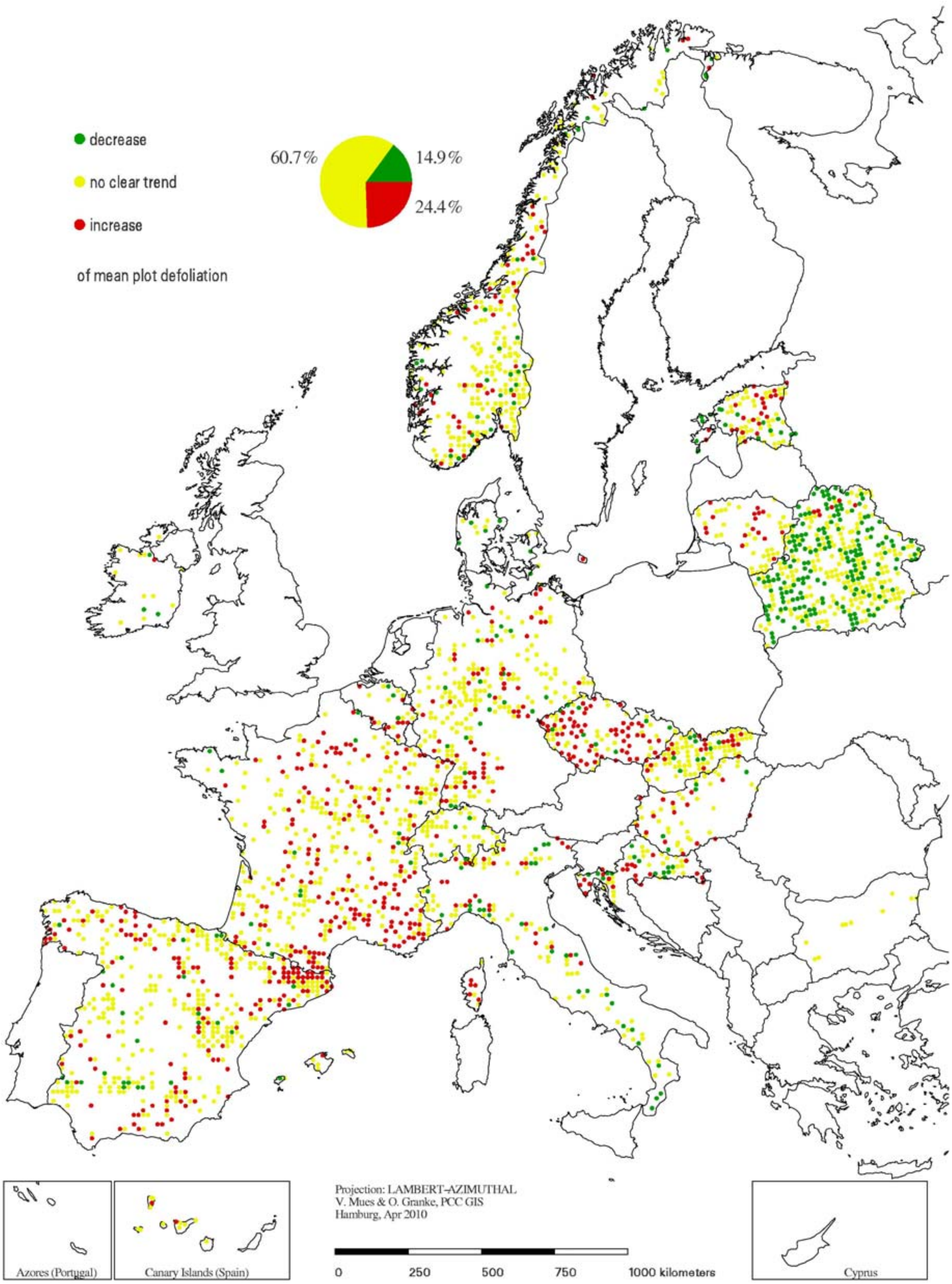

Figure 2.2.2.2-3: Trends of mean plot defoliation of all species over the years 1998 to 2009.

2.2.2.3 Pinus sylvestris

With up to 31 726 trees for the period 1998 – 2009 and up to 21 282 trees for the period 1991 – 2009 *Pinus sylvestris* is the tree species with the largest number of trees in the sample. It covers most regions in Europe and occurs on Level I plots from Northern Scandinavia to the Mediterranean region. Due to the large sample number and its occurrence throughout Europe regional differences in crown condition are levelled off in the aggregated results (Figure 2.2.2.3-1). Crown condition is characterized by a rather constant decrease in the share of healthy trees from around 50% in the mid 1990s to 35.4% in 2009.

This decrease is as well reflected in the map of plots continuously monitored since 1998 (Figure 2.2.2.3-2). The share of plots with increasing defoliation (13.9%) is clearly below the share of plots with a decrease (26.8%). Plots showing a deterioration are scattered across Europe, but are specifically clustered in southern France, at the eastern edge of the Pyrenean mountains and in Czech Republic. Decreasing defoliation is specifically registered on the plots in Belarus.

	N trees	0-10%	>10-25%	>25%
1991	17768	27.1	37.4	35.5
1992	17194	28.4	36.3	35.4
1993	17225	27.6	38.5	33.9
1994	16570	26.8	37.0	36.2
1995	18754	33.4	37.3	29.3
1996	18790	35.2	40.8	24.0
1997	18824	34.8	42.9	22.3
1998	19205	35.9	45.0	19.1
1999	19468	36.1	46.2	17.7
2000	19447	34.5	47.5	18.0
2001	19562	33.4	49.2	17.5
2002	19486	31.2	50.2	18.6
2003	19477	29.9	51.4	18.7
2004	21092	33.2	48.1	18.7
2005	21282	34.5	46.3	19.2
2006	18651	38.1	45.5	16.4
2007	19251	35.6	48.8	15.6
2008	17695	33.9	49.4	16.7
2009	16042	35.4	47.1	17.5

	N trees	0-10%	>10-25%	>25%
1998	30180	29.2	45.8	25.0
1999	30142	30.6	47.6	21.8
2000	29842	30.2	49.9	19.9
2001	29959	30.4	51.3	18.3
2002	29788	32.0	51.6	16.4
2003	30065	31.6	52.0	16.4
2004	31582	35.2	48.3	16.5
2005	31726	35.5	47.5	16.9
2006	28987	37.4	48.1	14.6
2007	29567	34.8	50.9	14.2
2008	28045	32.5	52.7	14.8
2009	26725	33.6	51.4	15.0

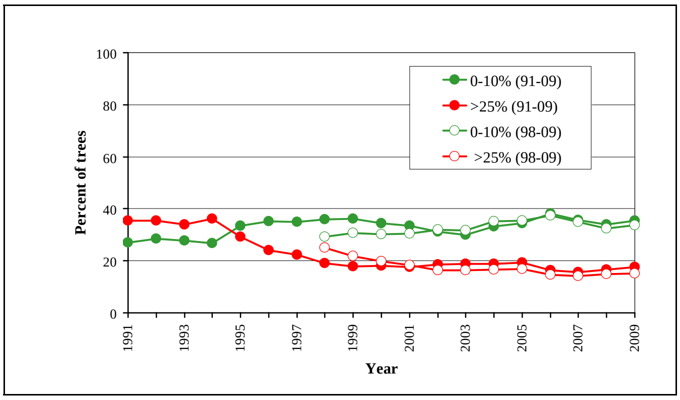

Figure 2.2.2.3-1: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2009 and 1998-2009).

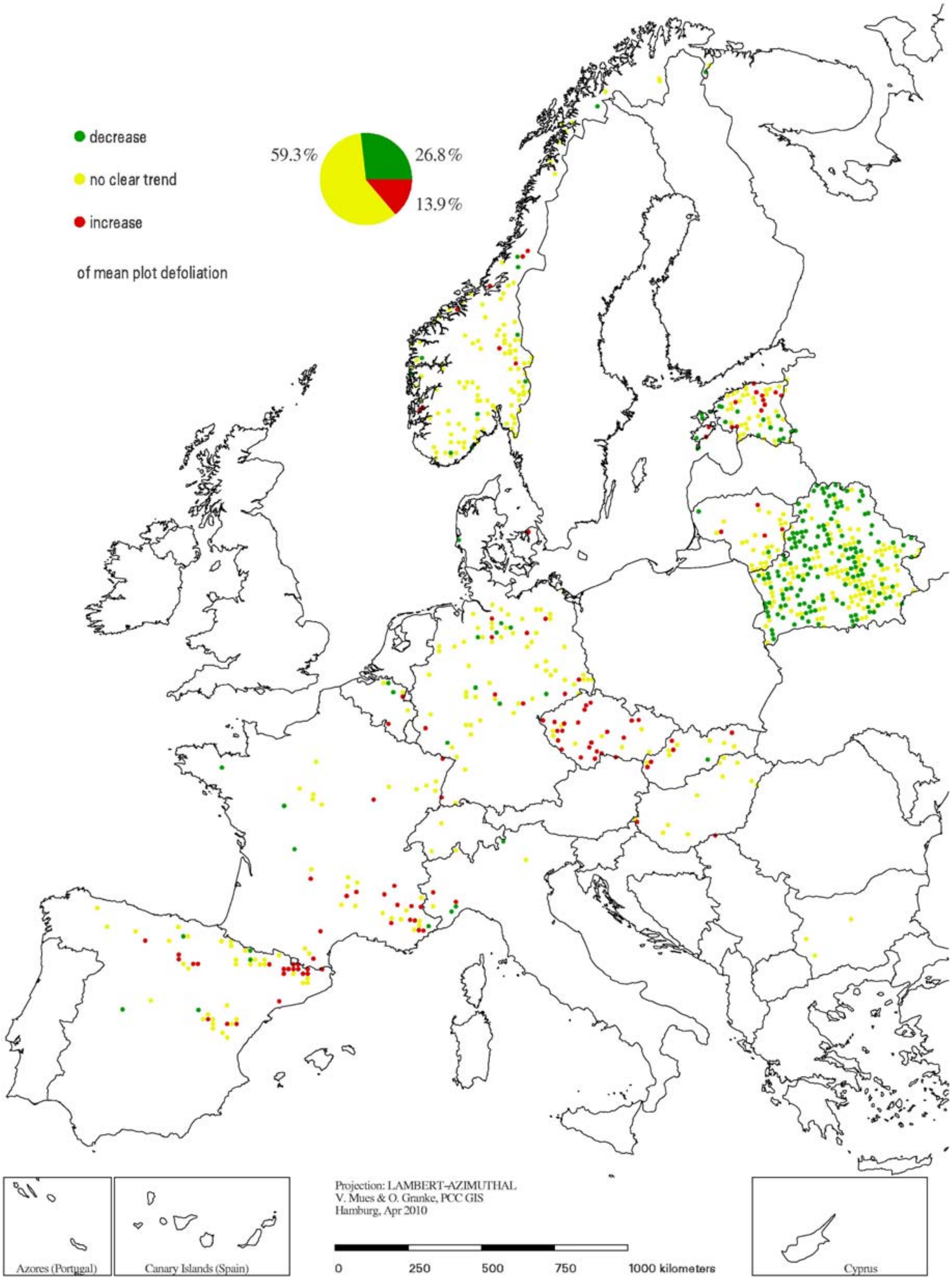

Figure 2.2.2.3-2: Trend of mean plot defoliation (slope of linear regression) of *Pinus sylvestris* over the years 1998 to 2009.

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 1991-2009, the largest share of damaged trees was registered in 1997 (39.1%). It decreased to 29.0% in 2006 and remained on the same level until 2009. In the sample based on the period 1998 to 2009 the distribution of trees within the different damage classes remained rather unchanged. (Figure 2.2.2.4-1). This unchanged general trend is the result of differing trends on plots in the various forest types as has been shown in previous reports.

The map shows that in Belarus and in south-eastern Norway plots with decreasing defoliation prevail. In Czech Republic there are more plots with an increase than plots with a decrease. (Figure 2.2.2.4-2).

	N trees	0-10%	>10-25%	>25%
1991	15088	25.9	37.4	36.6
1992	12296	26.8	37.4	35.8
1993	12473	28.1	37.6	34.4
1994	12810	26.3	35.7	38.0
1995	14476	28.9	33.7	37.4
1996	14435	29.4	32.0	38.7
1997	14230	27.0	33.9	39.1
1998	13729	32.2	36.6	31.3
1999	14129	33.2	36.8	30.1
2000	14175	31.3	38.0	30.7
2001	13899	30.3	39.7	30.0
2002	13936	29.2	39.4	31.3
2003	13930	28.7	40.8	30.5
2004	14365	27.1	38.3	34.6
2005	13915	28.1	40.3	31.6
2006	11914	33.9	37.2	29.0
2007	11404	30.6	39.5	30.0
2008	10991	30.6	39.2	30.2
2009	10283	30.8	38.7	30.5

	N trees	0-10%	>10-25%	>25%
1998	17465	34.0	36.1	29.9
1999	17862	35.1	36.7	28.3
2000	17832	33.1	38.3	28.7
2001	17575	32.6	39.4	27.9
2002	17631	33.2	39.1	27.7
2003	17738	32.6	40.3	27.1
2004	18273	32.8	37.4	29.9
2005	17751	33.8	38.5	27.6
2006	15843	39.2	36.3	24.5
2007	15557	37.3	37.5	25.2
2008	15325	37.4	37.3	25.3
2009	14893	38.5	36.8	24.7

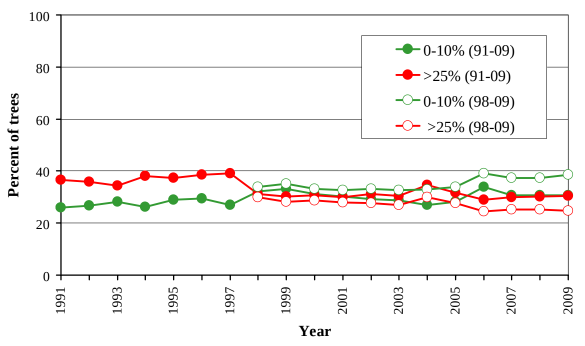

Figure 2.2.2.4-1: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2009 and 1998-2009).

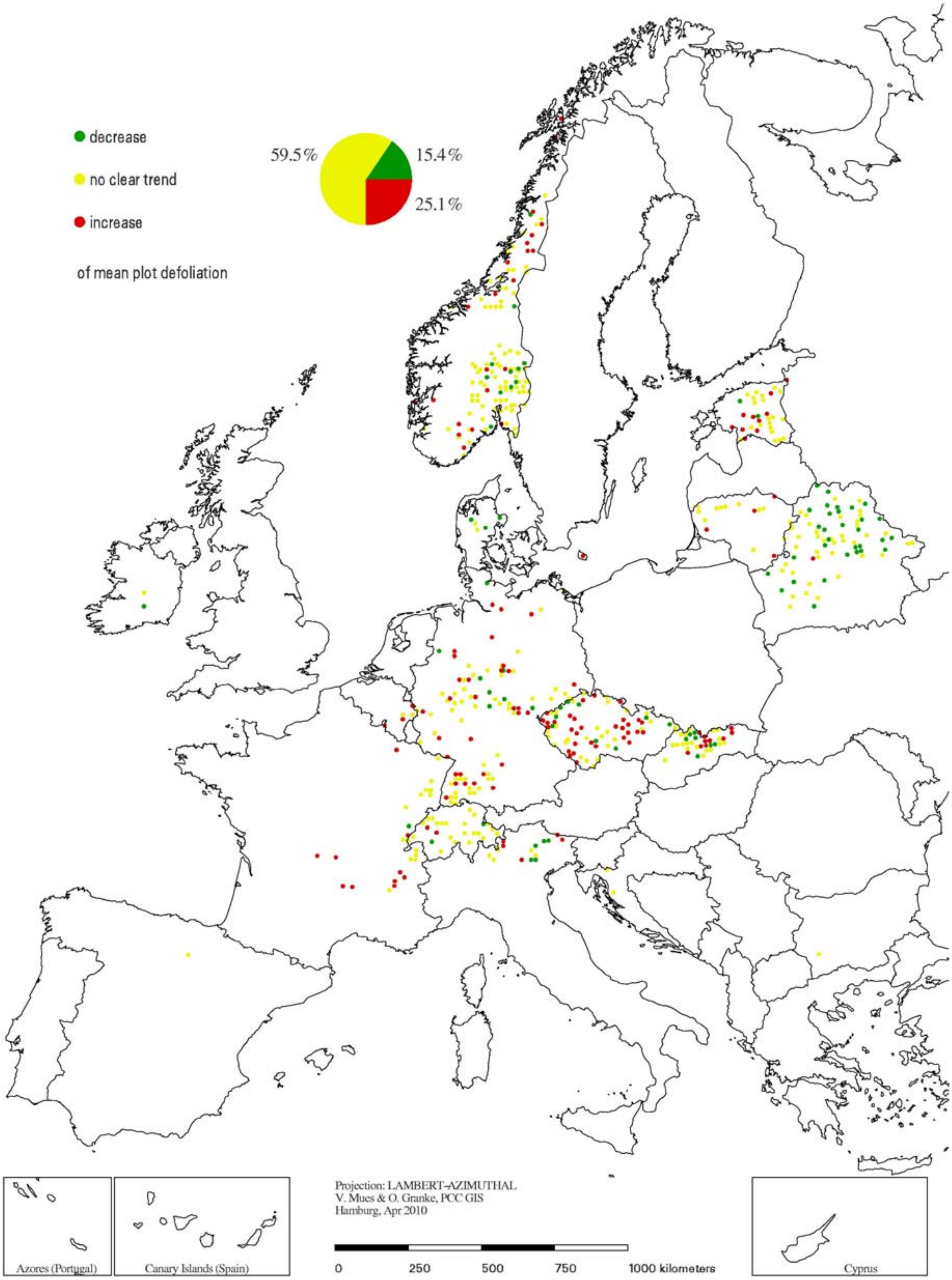

Figure 2.2.2.4-2: Trend of mean plot defoliation (slope of linear regression) of *Picea abies* over the years 1998 to 2009.

2.2.2.5 Fagus sylvatica

Fagus sylvatica is the most frequent tree species among all broadleaves. The share of trees rated as healthy has been almost constantly decreasing from 49.7% in 1991 to 19.8% in 2004. Due to the prevailing representation of the species on plots in central Europe the extremely dry and hot summer occurring in central Europe in the year 2003 is specifically reflected in the crown condition of this species. The share of healthy trees has again been increasing since 2005 and indicates some recuperation (Figure 2.2.2.5-1).

The map reflecting temporal changes on beech plots reveals that on most plots there are no changes in mean defoliation over the period 1998 – 2009. There are, however, minor regional differences. Deteriorating plots are more frequent in France and south-western Germany. Improvements prevail in southern Italy (Figure 2.2.2.5-2).

	N trees	0-10%	>10-25%	>25%
1991	6861	49.7	33.6	16.7
1992	6587	44.0	35.1	20.9
1993	6701	44.7	34.3	20.9
1994	6713	41.7	37.2	21.0
1995	6784	35.6	38.4	26.0
1996	6768	34.2	44.5	21.2
1997	6624	31.3	45.8	22.9
1998	6901	34.0	44.2	21.8
1999	7536	28.0	48.2	23.8
2000	7556	31.2	45.6	23.2
2001	7611	26.8	47.0	26.2
2002	7623	27.2	49.7	23.1
2003	7564	25.1	49.4	25.5
2004	7656	19.8	46.4	33.8
2005	7719	25.5	46.7	27.8
2006	7276	28.4	43.7	27.8
2007	7568	26.4	48.3	25.3
2008	7613	32.0	46.6	21.4
2009	7477	28.2	41.8	29.9

	N trees	0-10%	>10-25%	>25%
1998	8509	36.4	42.6	21.0
1999	8755	32.2	45.8	22.0
2000	8967	35.0	43.2	21.7
2001	8951	30.4	44.6	25.0
2002	9063	31.0	47.0	22.0
2003	8939	29.1	47.8	23.1
2004	8887	23.1	46.5	30.4
2005	9031	29.8	45.1	25.2
2006	8651	32.0	42.5	25.6
2007	9039	30.8	46.3	22.9
2008	9018	35.0	45.5	19.5
2009	9533	34.9	40.4	24.7

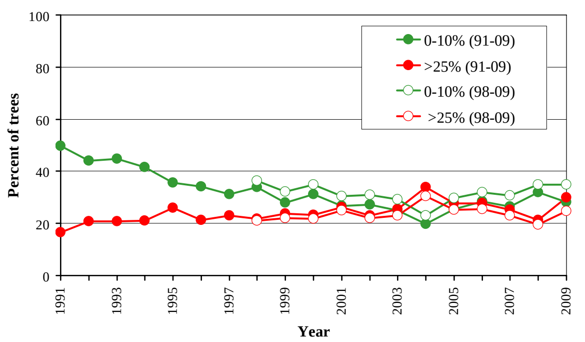

Figure 2.2.2.5-1: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2009 and 1998-2009).

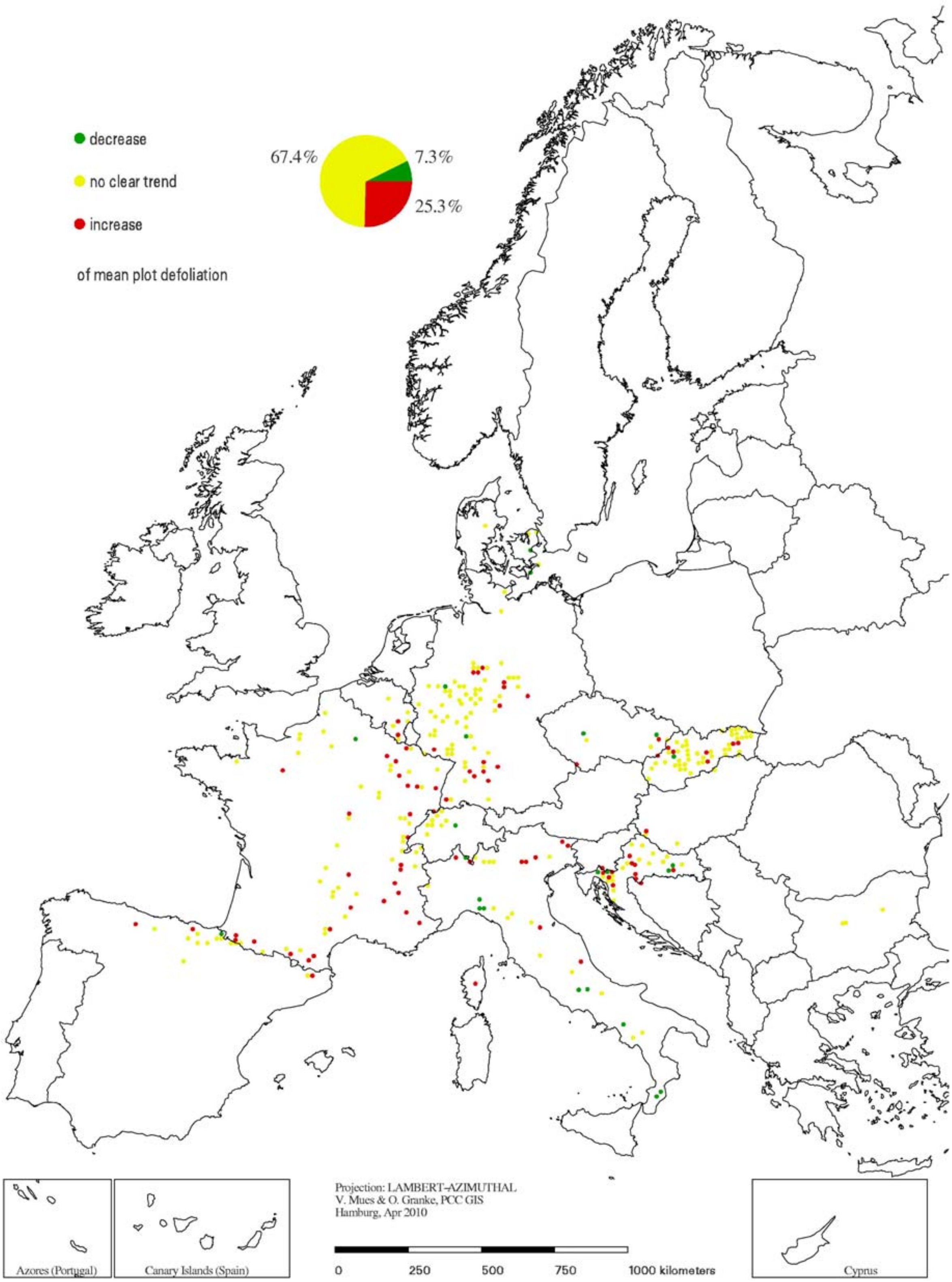

Figure 2.2.2.5-2: Trend of mean plot defoliation (slope of linear regression) of *Fagus sylvatica* over the years 1998 to 2009.

2.2.2.6 Quercus robur and Q. petraea

Defoliation of *Quercus robur* and *Quercus petraea* had two peaks since 1991. The share of damaged trees amounted to 41.1% in 1997 and in 2005 it reached 42.9%. A recuperation has been observed in 2006, whereas in the last three years defoliation remained rather unchanged (Figure 2.2.2.6-1).

A deterioration in health of both oak species was found on 25.7% of the plots in the map whereas on only 7.7% of the plots health status improved in the years 1998 to 2009. Most *Quercus robur* and *Quercus petraea* plots occur in France. Here, as well as in Czech Republic and northern Spain plots with deteriorating defoliation are more frequent than plots with improvements. This trend is reverse in Croatia (Figure 2.2.2.6-2).

	N trees	0-10%	>10-25%	>25%
1991	5732	45.0	32.2	22.8
1992	5296	42.4	35.0	22.5
1993	5379	36.9	32.9	30.1
1994	5598	34.1	31.8	34.1
1995	5451	33.1	36.4	30.6
1996	5424	24.7	39.0	36.3
1997	5437	16.3	42.6	41.1
1998	5591	20.5	42.5	37.0
1999	5711	20.4	47.8	31.7
2000	5740	21.0	48.3	30.7
2001	5758	19.1	49.4	31.4
2002	5771	18.4	50.9	30.7
2003	5770	14.7	47.2	38.1
2004	5872	15.0	44.6	40.4
2005	5882	13.5	43.6	42.9
2006	5388	17.1	46.1	36.8
2007	5494	15.9	47.0	37.1
2008	5647	15.7	48.0	36.2
2009	5580	17.9	46.6	35.5

	N trees	0-10%	>10-25%	>25%
1998	6766	20.2	41.6	38.2
1999	6797	21.1	47.3	31.6
2000	6890	20.2	46.5	33.3
2001	6834	19.1	48.2	32.6
2002	6678	19.0	50.7	30.4
2003	6679	15.5	47.6	37.0
2004	6800	16.3	44.4	39.3
2005	6867	14.8	43.4	41.8
2006	6362	19.4	45.6	35.1
2007	6494	17.8	47.5	34.8
2008	6643	17.2	48.8	34.0
2009	6929	19.3	48.1	32.6

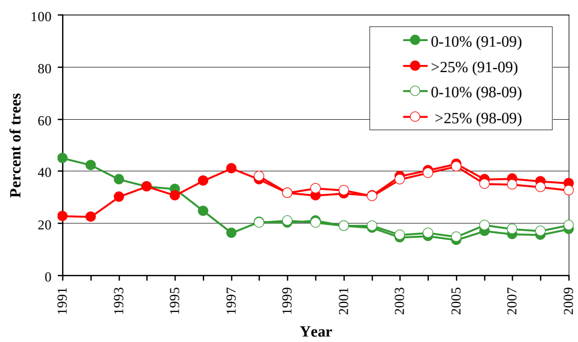

Figure 2.2.2.6-1: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2009 and 1998-2009).

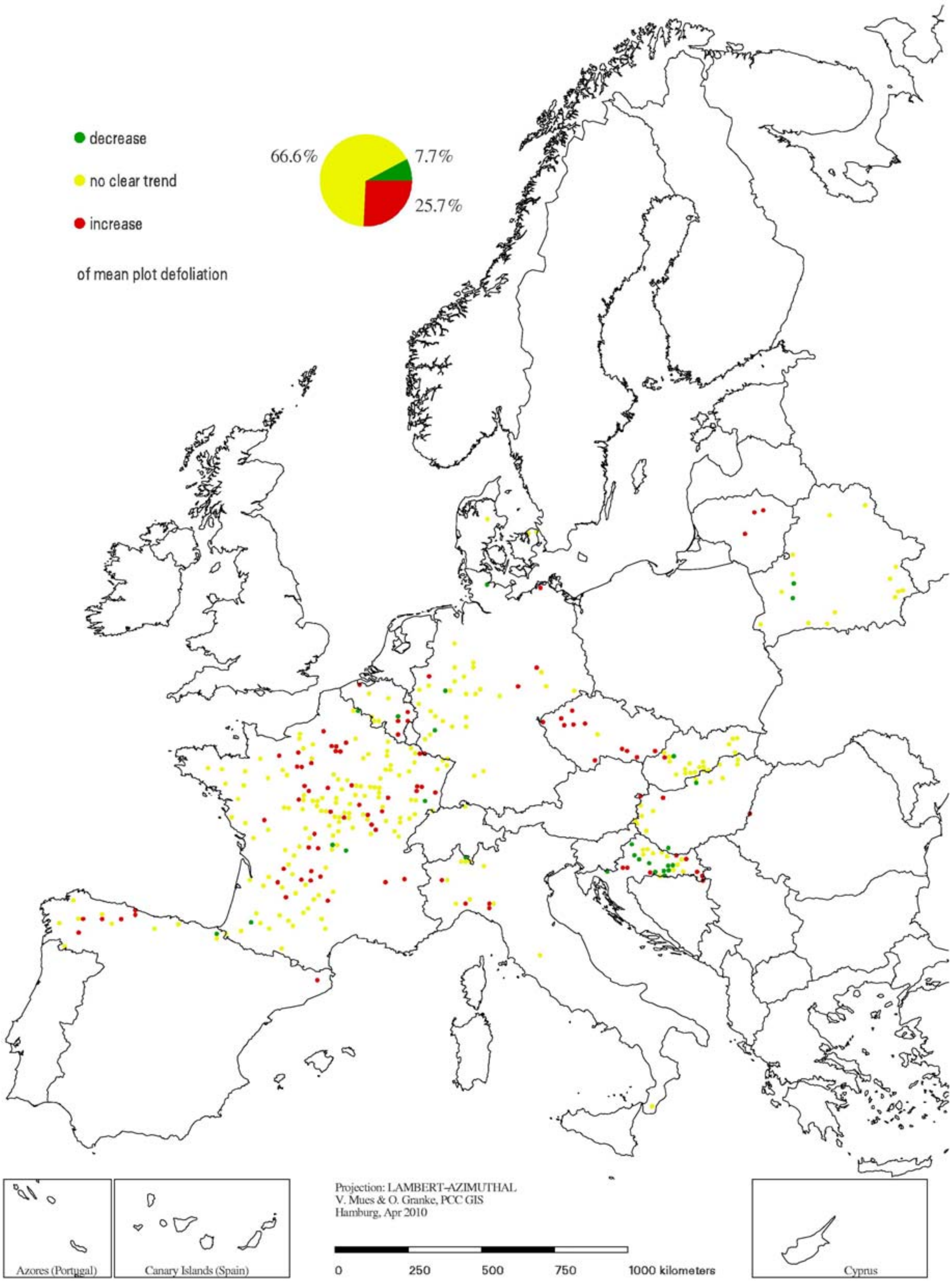

Figure 2.2.2.6-2: Trend of mean plot defoliation (slope of linear regression) of *Quercus robur* and *Quercus petraea* over the years 1998 to 2009.

2.2.2.7 Quercus ilex and Q. rotundifolia

Quercus ilex and *Quercus rotundifolia* trees mostly occur in evergreen broadleaved forests in the western Mediterranean region. Most of the plots are located in Spain. There is a remarkable deterioration in defoliation at the beginning of the observation period. In 1991 4.4% of the trees were rated as damaged whereas 29.6% of the trees were in the respective defoliation class in 1995. After a period with fluctuating defoliation, the share of damaged trees nearly reached the 30% mark in 2005 and 2006 again. Since then, there is some recuperation recorded which might be attributed to favorable weather conditions reported from Spain. From 2007 to 2009 crown condition remained stable (Figure 2.2.2.7-1).

The map clearly shows the importance of Spain with respect to the evergreen oak species, since there are no data from Portugal reported. In the north-east of Spain and in southern France there are hardly any plots with improvements in mean defoliation (Figure 2.2.2.7-2).

	N trees	0-10%	>10-25%	>25%
1991	2942	58.7	36.9	4.4
1992	2961	46.6	45.3	8.1
1993	2961	41.0	51.9	7.1
1994	2954	31.7	53.6	14.8
1995	2999	20.0	50.4	29.6
1996	2976	17.3	54.6	28.2
1997	2974	22.2	58.0	19.7
1998	2933	28.5	56.3	15.2
1999	3776	21.6	56.7	21.6
2000	3829	19.6	59.4	21.0
2001	3845	19.8	63.3	16.9
2002	3831	16.6	62.6	20.8
2003	3763	14.6	62.0	23.4
2004	3808	18.4	62.8	18.8
2005	3770	10.0	62.0	28.1
2006	3778	8.8	63.7	27.5
2007	3831	9.6	67.8	22.6
2008	3870	11.8	67.2	21.0
2009	3854	11.2	67.3	21.5

	N trees	0-10%	>10-25%	>25%
1998	2957	28.3	56.4	15.3
1999	3800	21.6	56.9	21.5
2000	3853	19.5	59.2	21.3
2001	3869	19.8	63.4	16.8
2002	3855	16.5	62.8	20.7
2003	3787	14.5	62.2	23.3
2004	3856	18.2	63.1	18.6
2005	3818	10.0	62.0	28.1
2006	3826	8.8	63.6	27.6
2007	3879	9.9	67.6	22.5
2008	3894	12.1	67.0	20.9
2009	3878	11.6	67.0	21.4

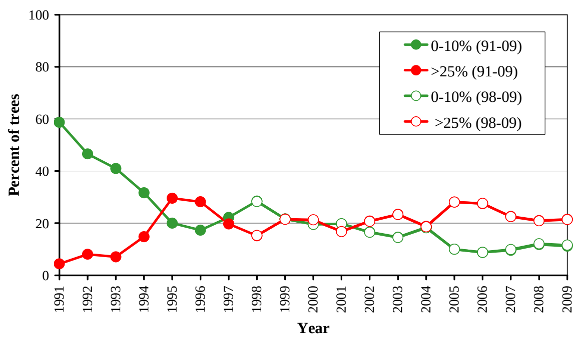

Figure 2.2.2.7-1: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2009 and 1998-2009).

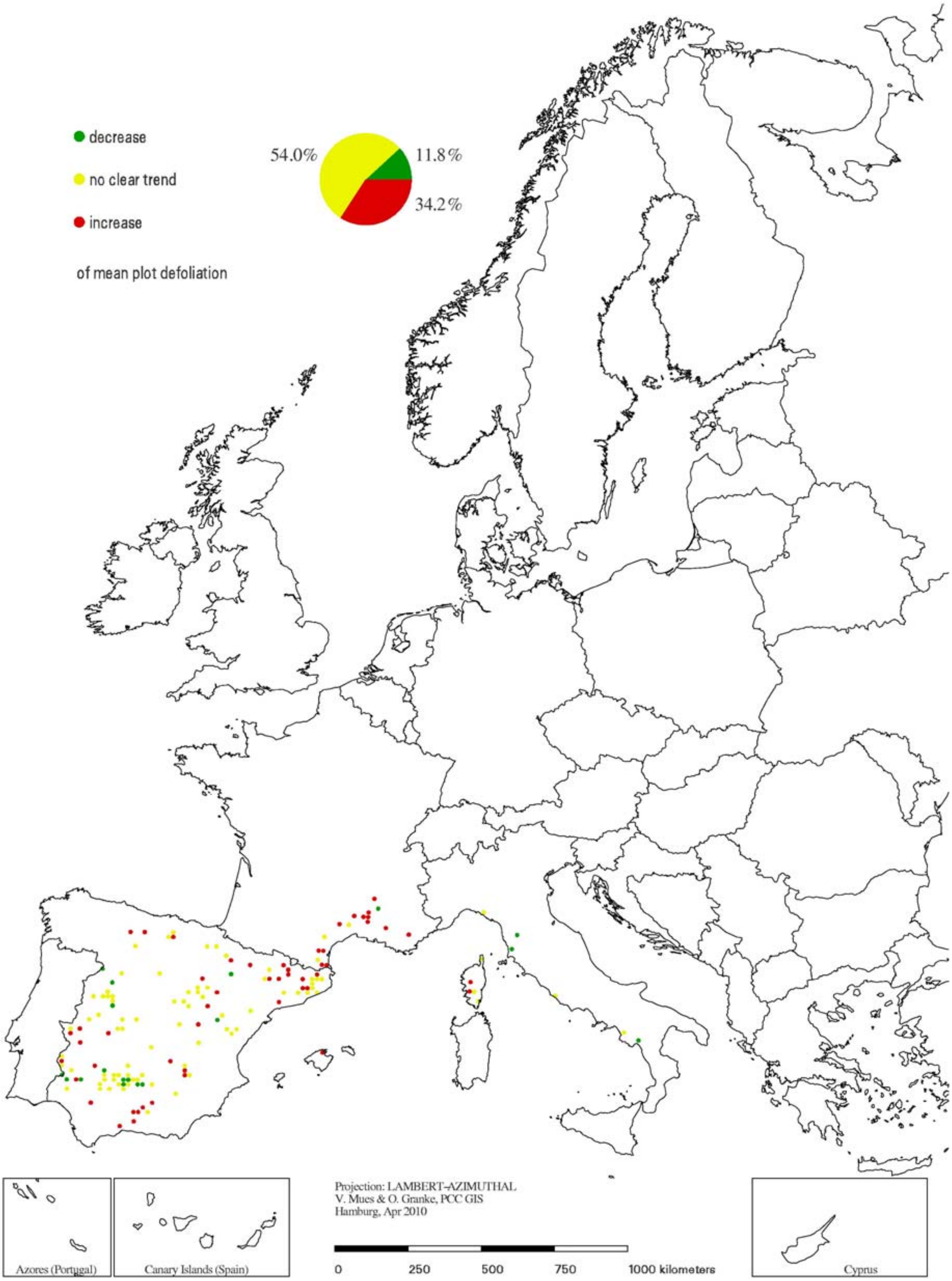

Figure 2.2.2.7-2: Trend of mean plot defoliation (slope of linear regression) of *Quercus ilex* and *Quercus rotundifolia* over the years 1998 to 2009

2.2.2.8 Pinus pinaster

Nearly all of the *Pinus pinaster* trees are growing in Mediterranean coniferous forests. For the sample of continuously monitored trees a distinct decline in crown condition has been observed since 1991 with the share of trees not damaged decreasing from 72.1% in 1991 to 19.2% in 2009 (Figure 2.2.2.8-1).

The worsening trend is as well reflected in the share of plots showing a significant increase in mean plot defoliation. Mean plot defoliation increased on 38.5% of the plots in the past decade. These plots are mainly located along the Mediterranean coast in Spain and France (Figure 2.2.2.8-2).

	N trees	0-10%	>10-25%	>25%
1991	3498	72.1	21.5	6.4
1992	3585	63.7	24.6	11.6
1993	3610	61.8	26.6	11.6
1994	3543	50.5	32.6	16.9
1995	3568	39.9	43.4	16.7
1996	3553	36.9	44.6	18.6
1997	3507	40.4	47.7	11.9
1998	3560	37.1	47.8	15.1
1999	4776	40.8	47.3	11.9
2000	4845	40.0	48.4	11.6
2001	4847	34.7	54.1	11.2
2002	4828	31.1	55.2	13.7
2003	4796	28.1	55.6	16.3
2004	4764	29.5	54.6	15.9
2005	4770	21.9	54.3	23.8
2006	4772	22.0	55.7	22.4
2007	4810	23.7	55.8	20.5
2008	4760	22.4	59.7	17.8
2009	4616	19.2	60.5	20.3

	N trees	0-10%	>10-25%	>25%
1998	3673	37.5	46.9	15.6
1999	4888	39.9	47.4	12.7
2000	4934	39.4	48.4	12.2
2001	4936	34.1	53.8	12.1
2002	4893	30.7	55.0	14.3
2003	4861	27.8	55.2	17.1
2004	4877	28.9	54.0	17.2
2005	4861	21.6	53.6	24.9
2006	4861	21.7	54.8	23.5
2007	4875	23.5	55.4	21.1
2008	4825	22.2	59.4	18.4
2009	4681	18.9	59.9	21.2

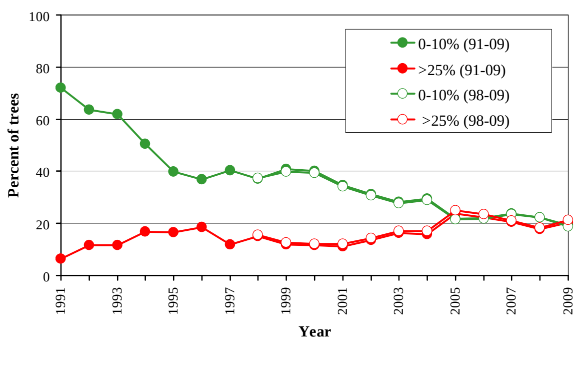

Figure 2.2.2.8-8: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2009 and 1998-2009).

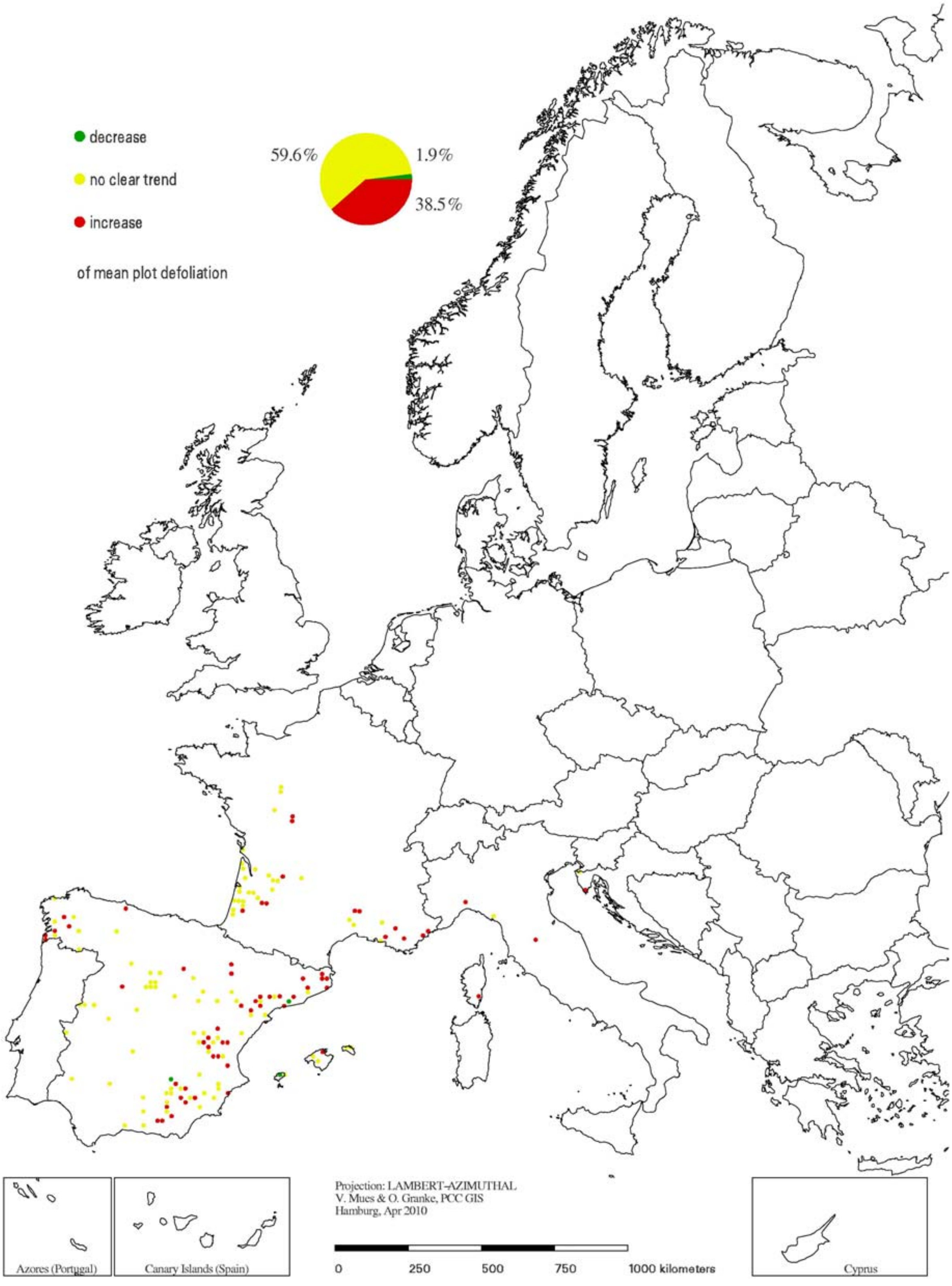

Figure 2.2.2.8-2: Trend of mean plot defoliation (slope of linear regression) of *Pinus pinaster* over the years 1998 to 2009.

2.3 References

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3. INTENSIVE MONITORING

3.1 Introduction

Intensive Monitoring data (Level II) for the survey year 2007 were submitted from 21 countries. In comparison to the 2006 data submission, the number of submitting countries decreased by 7. The numbers of plots with data submission per survey are given in Table 3.1-1. As not all surveys are conducted continuously or annually, the plot numbers vary from year to year. Nevertheless, compared to the 2006 data submission the number of plots decreased for most surveys. The reduction of countries and plot numbers is mostly due to the fact that for the year 2007 the assessments were not co-financed by the European Commission. The methods for intensive monitoring of forest ecosystems 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" (ICP Forests, 2010).

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

Survey	Number of plots		Assessment frequency
	Installed	Data submitted for 2007	
Crown condition	836	462	Annually
Foliar chemistry	904	200	Every two years
Soil condition	615	0	Every ten years
Soil solution chemistry	302	169	Continuously
Tree growth	811	70	Every five years
Deposition	657	353	Continuously
Ambient air quality (active)	84	27	Continuously
Ambient air quality (passive)	254	167	Continuously
Ozone induced injury	114	43	Annually
Meteorology	265	191	Continuously
Phenology	186	58	Several times per year
Ground vegetation	777	67	Every five years
Litterfall	262	105	Continuously

3.2 Sulphur and nitrogen deposition and its trends

3.2.1 Data and Methods

Deposition data are collected on Level II plots in the open field ("bulk deposition") and under canopy ("throughfall"). Whereas bulk deposition is a basis for estimates of total atmospheric deposition rates in open fields, throughfall deposition typically differs from bulk deposition due to a) wash off of dry deposition from the forest canopy, b) element "leaching" from the tree crowns, and c) absorption of elements by the foliage, so-called "canopy uptake". The first two effects lead to increased throughfall rates, the latter one, canopy uptake of elements by the crown foliage, reduces throughfall deposition compared to bulk deposition. Thus, throughfall deposition does not reflect total deposition but reflects the results of total deposition plus net canopy exchange. In addition, throughfall deposition may have been underestimated especially in beech stands because stemflow was not taken into account in the present study as it had not been measured continuously from 1998 to 2007 on most plots.

The observed annual mean throughfall deposition is interpreted always together with the respective bulk deposition in order to allow for an estimation of effective enriching and reducing canopy effects. The plot specific annual sums of bulk and throughfall deposition of nitrate (NO_3), ammonium (NH_4^+), sulphate (SO_4^{2-}), calcium (Ca^{2+}), sodium (Na^+), and chlorine (Cl^-) were basis for the evaluations. 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-}).

Data selection criteria and calculations follow the approach already described by LORENZ et al. (2005) for the calculation of deposition data from 1996 to 2001. The numbers of plots with available data fulfilling the selection criteria for mean annual deposition calculations from the year 2005 to 2007 are presented in table 3.2.1-1. In addition to mean annual deposition rates, the development of throughfall and bulk deposition over time was object of the present study. The slope of plot specific linear regression over the years of observation was used for mapping and quantifying the general temporal devolpments. Whereas in previous reports temporal trends were presented for 6 consecutive years, this evaluation prolongs the period to a time span of 10 years, i.e. to the years from 1998 – 2007. Due to the continuously ongoing monitoring activities this prolongation still resulted in a satisfying high number and spatial resolution of plots fulfilling the selection criteria (Table 3.2.1-1).

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

No. of observations		Na^+	Cl^-	Ca^{2+}	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	$S\text{-}SO_4^{2-}$
Trend 1998 – 2007	Bulk	155	156	155	155	156	151
	Throughfall	163	164	163	163	164	157
Mean 2005 – 2007	Bulk	288	288	288	288	288	288
	Throughfall	215	214	215	215	215	215
	Throughfall > Bulk	169 of 205	179 of 204	187 of 205	131 of 205	162 of 205	168 of 205

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% (yellow)

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

Even with an enlarged time span of ten years, results must be understood as a mere description of the changes over time rather than a trend analysis which would require an even longer period of observation and respective statistical models for time series analyses.

Sulphate is an important constituent of sea salt, and in many coastal areas (e.g. western Norway) most sulphate in deposition may originate from sea salt rather than anthropogenic sources. As the relationship between chloride and sulphate in sea water is almost constant and assuming that chloride is almost entirely derived from sea salt and hardly affected by biogeochemical processes (which may not always be correct), measured sulphate concentrations can be easily corrected for the sea salt contribution using the formula

non-marine $S\text{-}SO_4^{2-}$ = total $S\text{-}SO_4^{2-}$ - (0.054 * Cl^-) ; where all values are in mg/l.

3.2.2 Results

3.2.2.1 Spatial variation

Mean annual throughfall and bulk deposition for the years 2005 to 2007 was calculated for 205 plots (204 plots for Cl) at which both deposition compartments were monitored. For all six compounds deposition was mostly higher in throughfall than in bulk deposition (s. Tab. 3.2.1-1). This points to the importance of dry deposition filtered from the air and washed off the leaves. Only for ammonium this observation is less clear and only on 131 of 205 plots throughfall deposition was higher than bulk deposition. This might suggest a more effective crown uptake of this element. National studies suggest that specifically on plots with rather low nitrogen deposition throughfall is below bulk inputs.

In Figure 3.2.2.1-1 bulk deposition of sulphur on 288 plots is mapped using the same class limits as for mapping of throughfall deposition in Figure 3.2.2.1-2 (215 plots). The pie diagrams in both maps and especially the higher throughfall deposition found for most plots in Germany and the Czech Republic show that sulphate is filtered from the air by the forest canopy. This dry deposition is then washed off from the air filtering leaves/canopies. Apart from a number of plots with very high sulphur depositions along the coastline (s. plots in Denmark, Spain, Italy, Norway, Belgium, The Netherlands, France), most plots with high sulphur deposition are located in central Europe (Poland, Germany, Czech Republic, Slovak Republic, Slovenia and Romania).

Sulphur deposition was corrected for sea salt. The respective maps of corrected bulk and throughfall deposition are presented in Figures 3.2.2.1-3 and 3.2.2.1-4. In analogy to respective maps for deposition of sodium and chlorine (not depicted) they underline the maritime influence on many of the plots. In addition to plots in central Europe also some plots in southern Europe (Spain, France, Italy) show relatively high sulphur deposition, especially in throughfall deposition.

The maps of bulk and throughfall deposition of nitrate and ammonium are presented in Figures 3.2.2.1-5 to 3.2.2.1-8. Highest deposition occurred on plots in Central Europe and in case of nitrate also in the south of France, north of Italy, and Spain. The lowest nitrogen deposition was observed on plots in Scandinavia with values mostly below 1.8 kg per ha and year for $N\text{-}NO_3$ and below 1.6 kg per ha and year for $N\text{-}NH_4$. Specifically for nitrate, throughfall fluxes were higher as compared to bulk inputs. This observation can be explained by the enrichment of throughfall deposition during the canopy passage due to the filter and wash off effect.

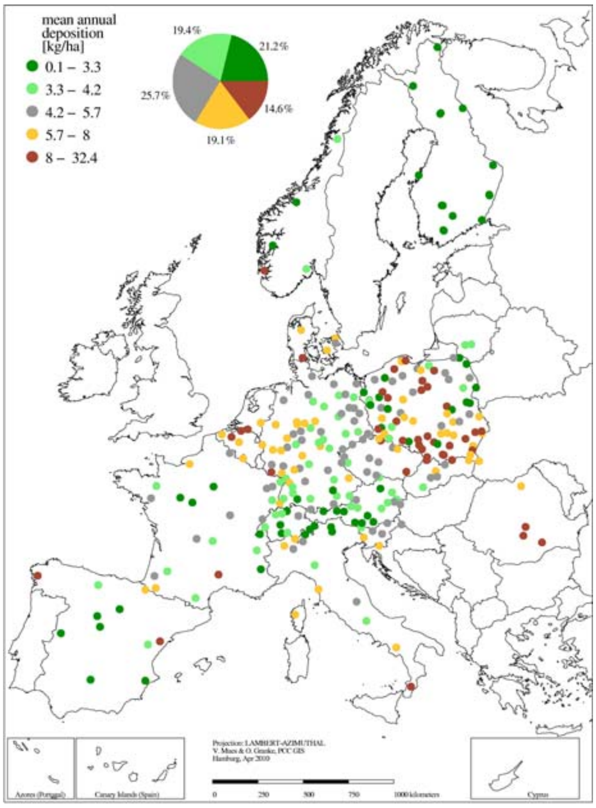

Figure 3.2.2.1-1: Mean annual sulphate sulphur ($S\text{-}SO_4^{2-}$) bulk deposition 2005 to 2007.

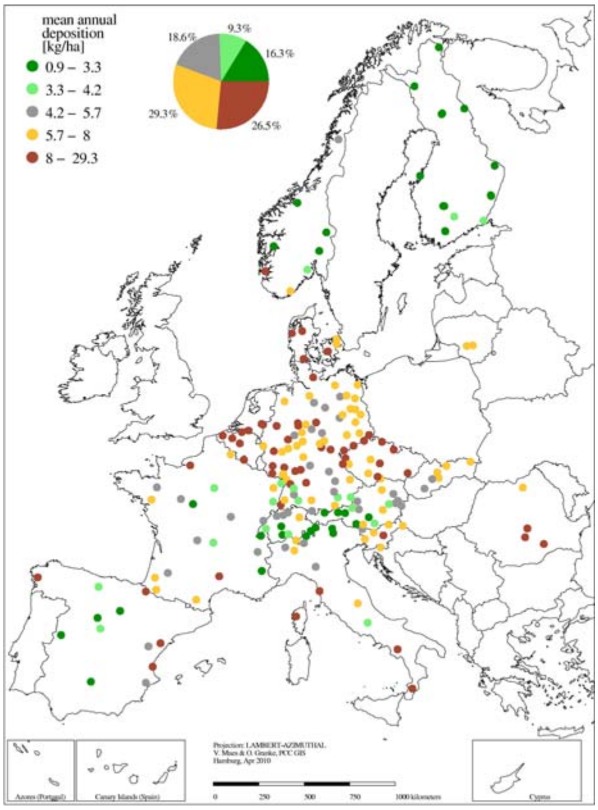

Figure 3.2.2.1-2: Mean annual sulphate sulphur ($S\text{-}SO_4^{2-}$) throughfall deposition 2005 to 2007.

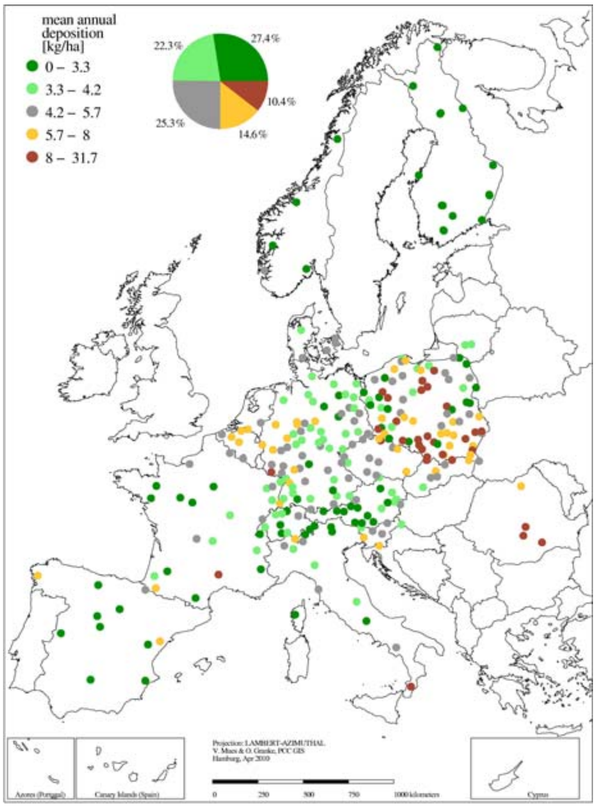

Figure 3.2.2.1-3: Mean annual sulphate sulphur ($S\text{-}SO_4^{2-}$) bulk deposition 2005 to 2007 (corrected for sea salt deposition).

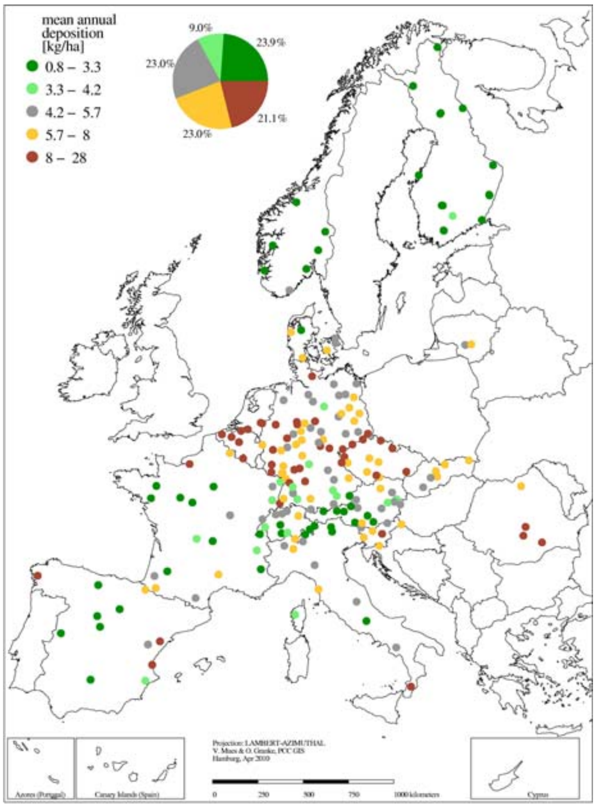

Figure 3.2.2.1-4 Mean annual sulphate sulphur ($S\text{-}SO_4^{2-}$) throughfall deposition 2005 to 2007 (corrected for sea salt deposition).

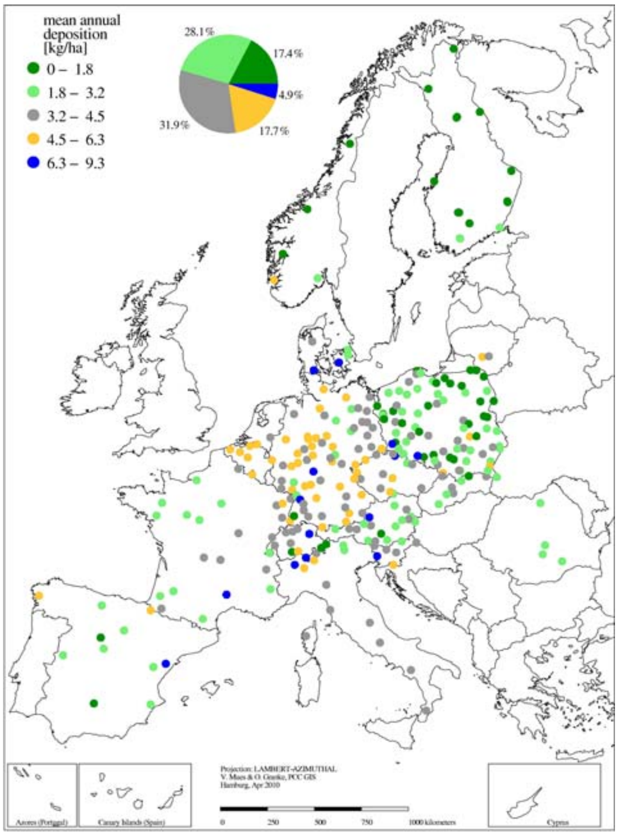

Figure 3.2.2.1-5: Mean annual nitrate nitrogen (N-NO_3^-) bulk deposition 2005 to 2007.

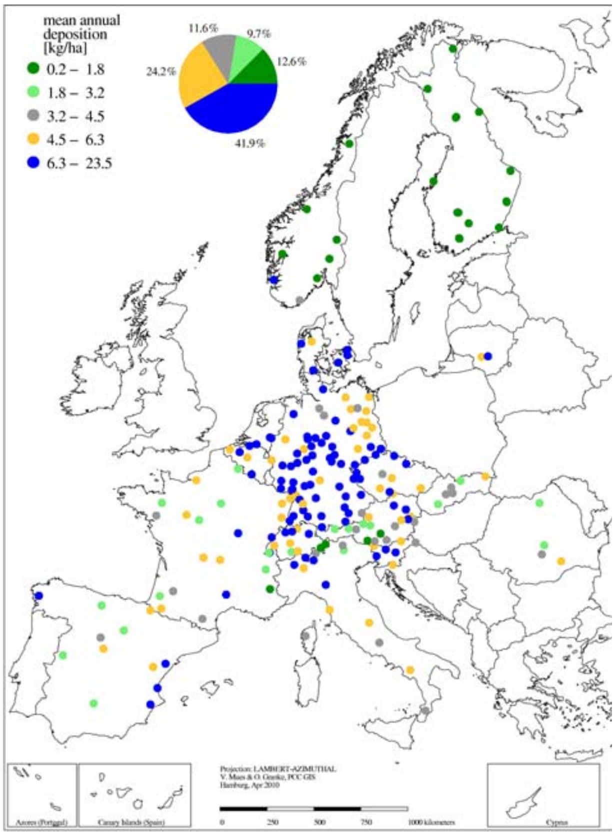

Figure 3.2.2.1-6: Mean annual nitrate nitrogen (N-NO_3^-) throughfall deposition 2005 to 2007.

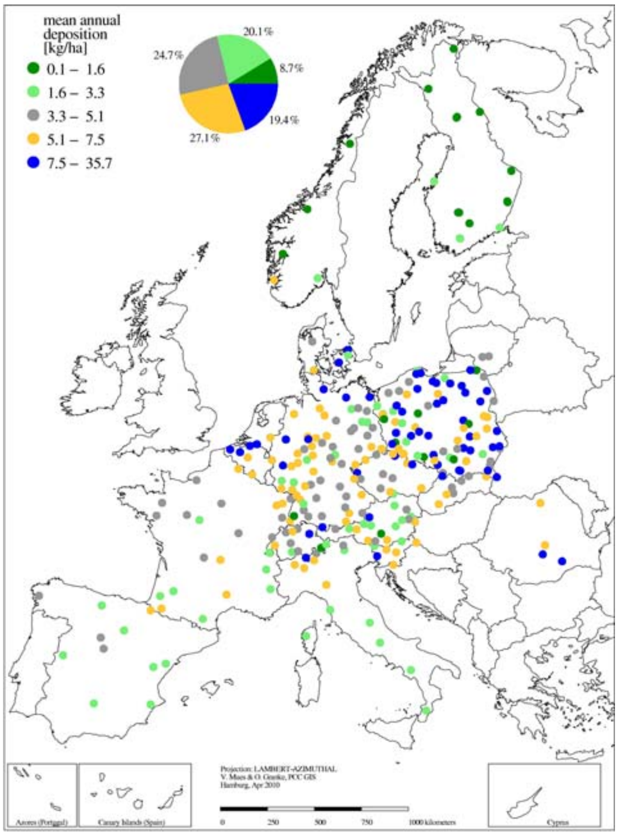

Figure 3.2.2.1-7: Mean annual ammonium nitrogen (N-NH_4^+) bulk deposition 2005 to 2007.

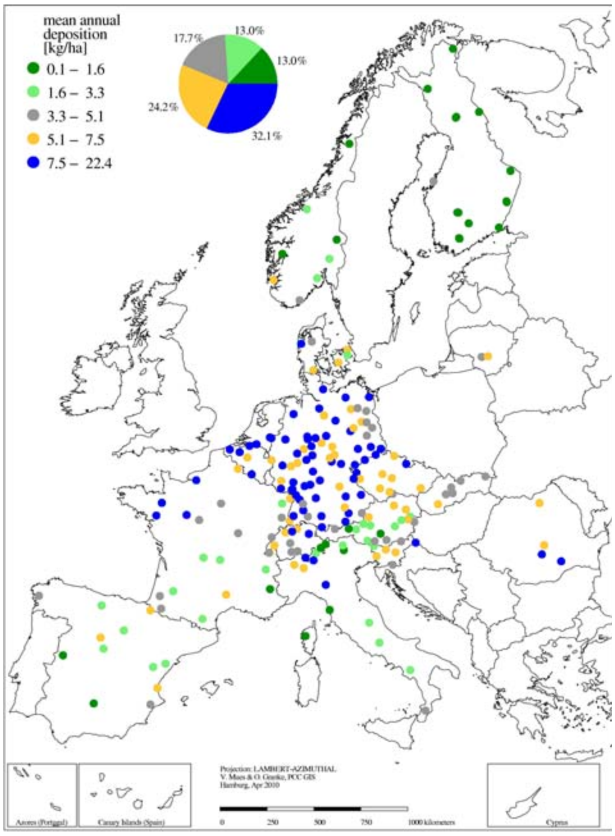

Figure 3.2.2.1-8: Mean annual ammonium nitrogen (N- NH_4^+) throughfall deposition 2005 to 2007.

3.2.2.2 Temporal variation

Earlier reports described a decrease in sulphur deposition based on periods of the last 6 available years with data submission. As nowadays also longer time series can be calculated without a significant reduction in number of observations compared to a six years period, the deposition in the 10 years from 1998 to 2007 was the basis for the present study. Figure 3.2.2.2-1 shows the decrase of mean annual sulphur deposition from 1998 to 2007. The strong decrease in sulphur deposition in the exceptionally dry year 2003 reflects its dependance from precipitation (not depicted). Nevertheless, the strong decrease in sulphur deposition from 1998 to 2007 (e.g. for sulphur throughfall deposition from 10.0 to 6.6 kg per ha and year) indicates a clear reduction of sulphur depsosition in this period. Thus, the influence of precipitation on deposition is considerable, but the observed decrease in deposition (see also Figures 3.2.2.2-3 and 3.2.2.2-4) over 10 years is not mainly a result of decreasing precipitation (LORENZ et al. 2008).

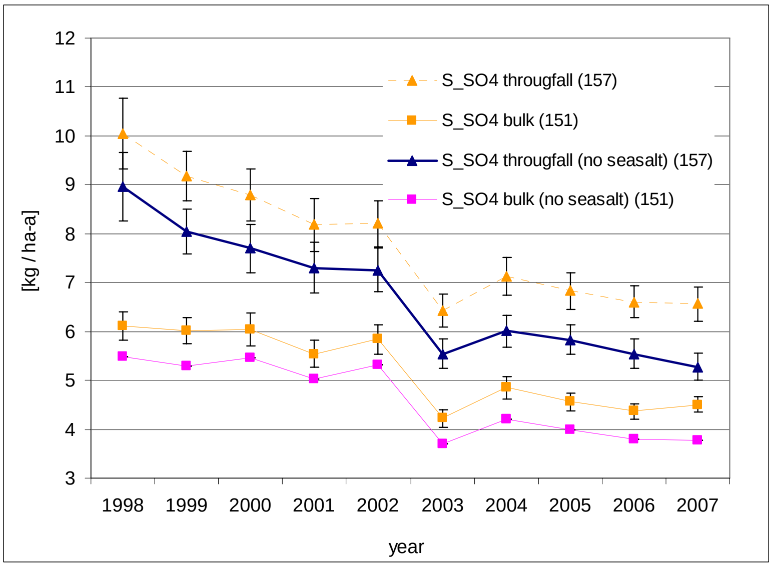

Figure 3.2.2.2-1: Changes in mean annual bulk and throughfall deposition (with standard error of the mean) of sulphate, with and without correction for sea salt, from 1998 to 2007.

The temporal development of ammonium and nitrate deposition is shown in Figure 3.2.2.2-2. Whereas for bulk deposition a more or less clear decrease in nitrogen deposition is observed, this is not the case for throughfall. This is as well reflected by the maps of the plot specific regression slopes in Figures 3.2.2.2-5 to 3.2.2.2-8. A significant increase in nitrogen throughfall deposition was even observed on some plots scattered across Europe.

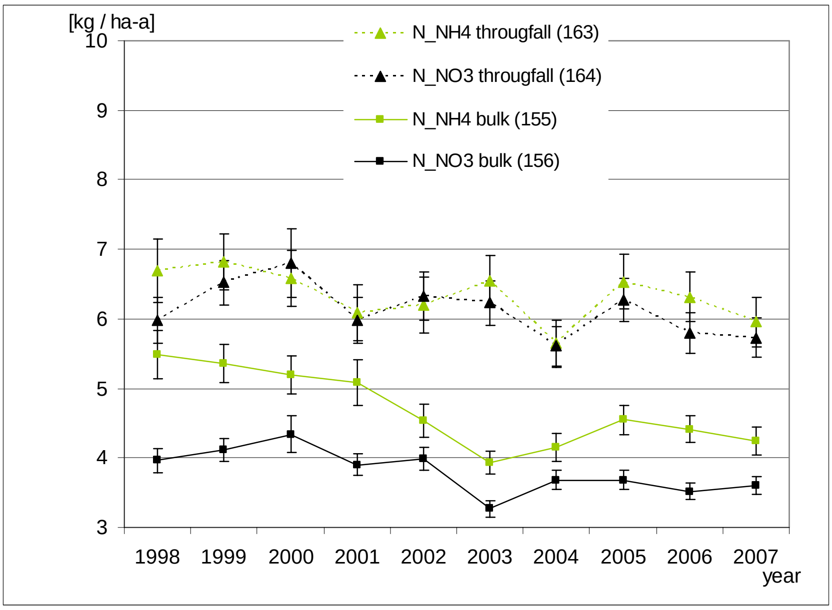

Figure 3.2.2.2-2: Changes in mean annual bulk and throughfall deposition (with standard error of the mean) of nitrate nitrogen and ammonium nitrogen from 1998 to 2007.

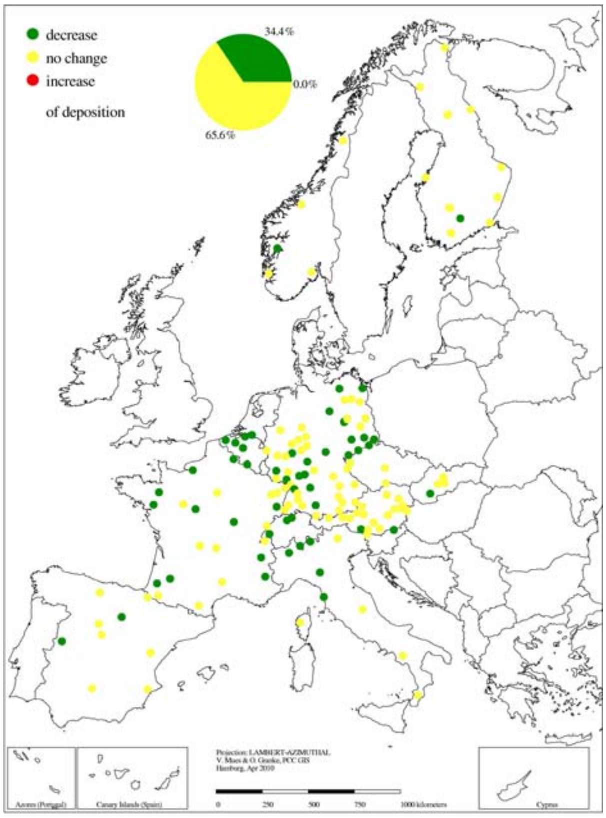

Figure 3.2.2.2-3: Trends in sulphur (S-SO_4^{2-}) in bulk deposition from 1998 to 2007.

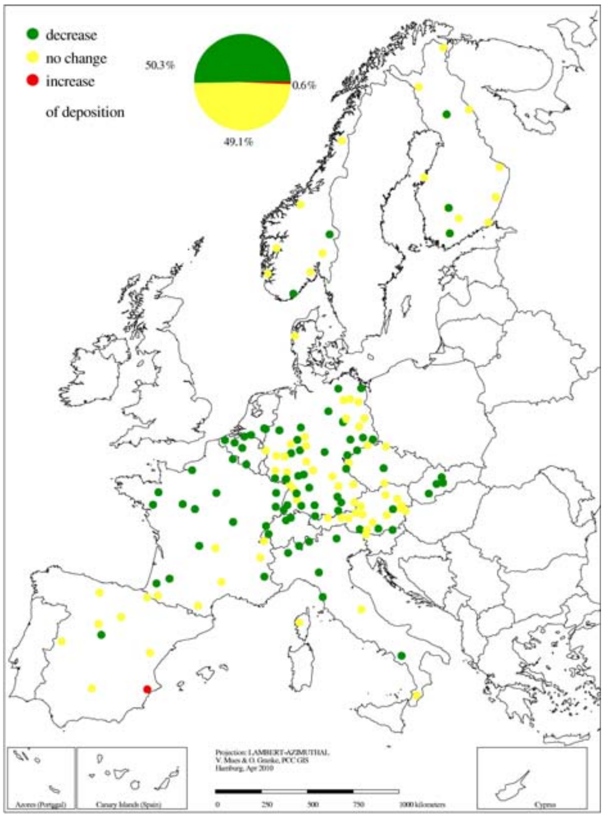

Figure 3.2.2.2-4: Trends in sulphur (S-SO_4^{2-}) in throughfall deposition from 1998 to 2007.

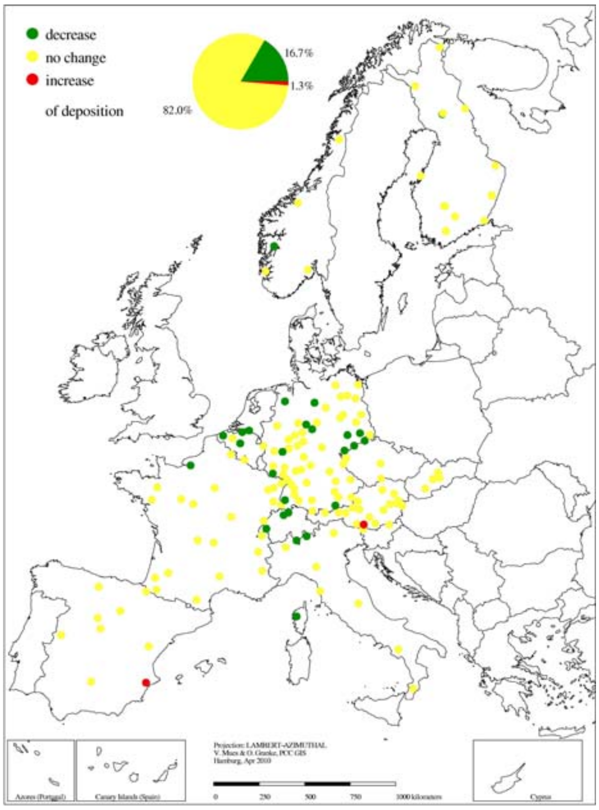

Figure 3.2.2.2-5: Trends in nitrate nitrogen (N-NO_3^-) in bulk deposition from 1998 to 2007.

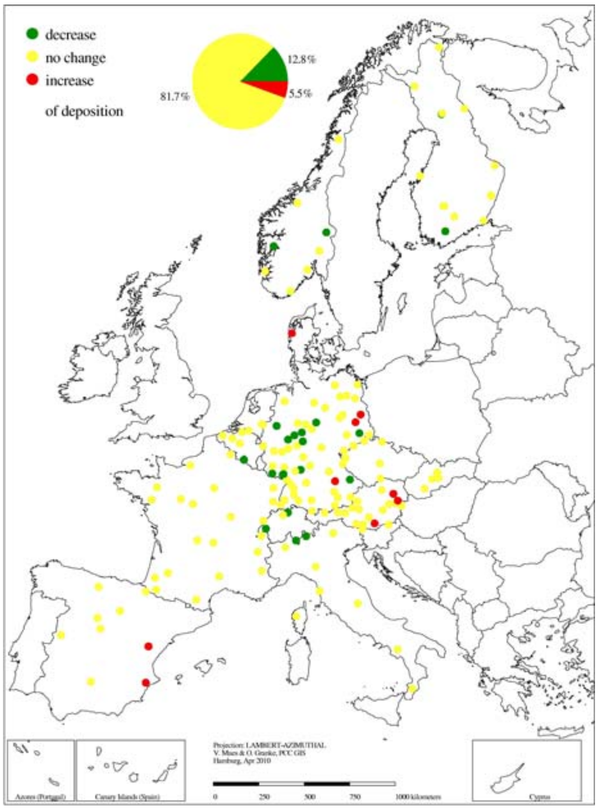

Figure 3.2.2.2-6: Trends in nitrate nitrogen (N-NO_3^-) in throughfall deposition from 1998 to 2007.

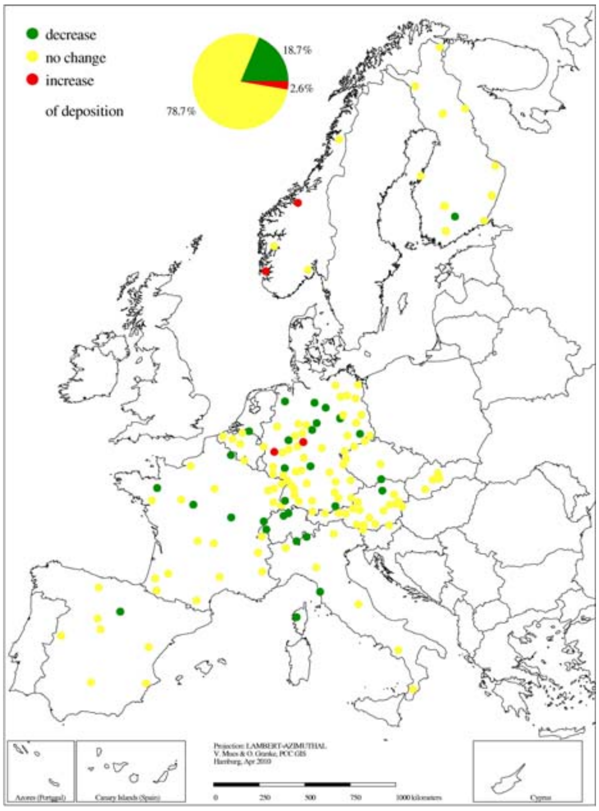

Figure 3.2.2.2-7: Trends in ammonium nitrogen (N-NH_4^+) in bulk deposition from 1998 to 2007.

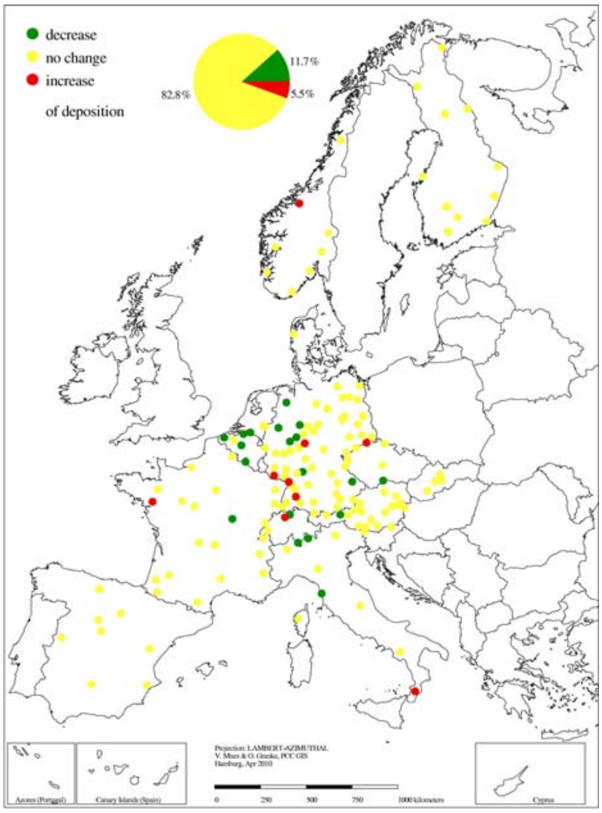

Figure 3.2.2.2-8: Trends in ammonium nitrogen (N-NH_4^+) in throughfall deposition from 1998 to 2007.

3.2.3 Conclusions

A high spatial variability of nitrogen and sulphur deposition could be detected in the present study and confirms results found in earlier years (e.g. Lorenz et al. 2008, Lorenz et al. 2009). In general, atmospheric sulphur and nitrogen deposition is higher in central Europe and some plots in southern Europe as compared to northern Europe and alpine regions.

The prolongiation of the evaluation period which still relies on a sufficiently high number of plots showed a more comprehensive picture of the temporal development of deposition across Europe as compared to eaerlier evaluations based on shorter periods. Specifically for sulphur a very clear reduction of deposition was observed in the period from 1998 to 2007. This trend is less clear for nitrogen but also obvious at least in bulk deposition which is not influenced by canopy interaction effects. The small share of plots with decreasing nitrogen deposition is in line with Rogora et al. (2006) who investigated long-term deposition time-series from 1990-2002 and only found significant decreasing nitrate deposition trends for about half of the investigated sites in the Alpine Arc. It even seems obvious that at least in some regions of Europe an increase in nitrogen deposition is observed which should be analysed in more detail.

It has to be taken into account that Level II is not a statistically representative network. However, the monitoring results reflect regional patterns and trends and partly regional industrial air pollution. Due to the large number of plots and the wide geographical coverage it is an important basis for monitoring air pollution effects in Europe. Increasing time series will still enlarge the possibilities for more detailed data analyses in the forthcoming years.

The quantification of inputs through sea salt in coastal areas is a field for further methodological improvements. The clear identification and quantification of canopy interaction processes also require further development.

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3.3 Soil solution chemistry and its trends

3.3.1 Introduction

Effects of atmospheric deposition need to be regarded with respect to the receptor. Most important effects on soil solution (and as such on solid soil phase) are a change of buffer range as a result of acid deposition and mobilisation of potentially toxic elements as well as nutrient imbalances and resulting nutrient deficiencies. These soil and soil solution mediated processes affect vegetation in terms of reduced growth resulting from impaired nutrient uptake, fine root dieback and general stress reactions of the vegetation like excessive flowering (Koch and Matzner, 1993; Løkke et al., 1996; Sverdrup and Warfvinge, 1993).

An important tool to describe risks of atmospheric pollution is the calculation of critical loads and their exceedances, aiming at the protection of forest ecosystems from harmful effects on forest structure or function (Augustin et al., 2005). The critical load concept is accepted as the basis for air pollution abatement strategies, in order to reduce or prevent damage to the functioning and vitality of forest ecosystems caused by transboundary acidic deposition (Løkke et al., 1996).

Critical loads are defined as “a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge” (Spranger et al., 2004). Critical load calculations balance the depositions to which the ecosystem is exposed with its capacity to buffer the input, take up or remove it from the system without harmful effects within or outside the system (Spranger et al., 2004). Critical loads can be derived empirically or can be calculated by means of a simple mass balance or dynamic models. The so-called Simple Mass Balance (SMB) model can be considered a standard model for calculating critical loads for terrestrial ecosystems under CLRTAP (Spranger et al., 2004). Critical loads can be calculated for acidifying substances, eutrophying N compounds and heavy metals.

Model-based approaches for calculating critical loads aim at linking deposition of air pollution with its biological effects to the ecosystem. As the biological effects often are of complex nature, chemical criteria are mostly used to simplify the modelling. This calls for appropriate (soil) chemical criteria with proven (empirical) relationships to biological effects. For theses chemical criteria values have to be defined that mark the threshold below which harmful effects on the specified biological indicator are not expected (Spranger et al., 2004). Exceedances of critical limits do not necessarily result in instant dieback of trees or ecosystems but do illustrate an enhanced risk for trees to be more susceptible to additional stressors. Exceedances may result in a loss of assimilation area, growth reductions and nutrient imbalances (Augustin et al., 2005). Consequently critical loads are a function of the chosen chemical threshold values (critical limits) applied within the model (Hall et al., 2010).

This chapter presents pH and basic cation to aluminium ratio in the soil solution of a broad share of Level II plots and evaluates these parameters against well documented critical limits. The results presented in the following sub-chapters are a first analysis. The temporal analysis of BC/Al ratio and pH values is not sufficient to describe the changes in soil solution chemistry. Concentrations of BC, Al and main anions (NO_3, SO_4) need to be investigated in follow-up studies.

3.3.2. Methods

3.3.2.1 Number of plots

In the 1990s, soil solution chemistry assessment started at a restricted number of Level II plots. Until the year 1998 the number of Level II plots with data availability in the transnational data base increased to over 200 plots and remained rather unchanged until 2006. From 1990 to 2006 soil solution chemistry data are available from 298 different plots in 24 countries. In 2006, soil solution data were collected at 226 plots in 21 countries. Due to a number of administrational and technical changes in data base administration in the past decade, the quality of soil solution data in the transnational data base was not satisfactory. After intensive data quality assessment and consultation of the submitting countries in 2009 data quality for the monitoring years up to 2006 could be remarkably improved.

Table 3.3.2.1-1: Number of plots with available soil solution data for all monitoring years and submitting countries. Striped green marks "no data submitted", striped orange marks "data quality assessment still ongoing".

COUNTR	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06
FR						15	15	15	15	15	13	14	14	14	14	14	14
BE							8	8	8	8	8	6		7	7	7	7
NL	11		11		11	14	11	14	14	14	14	7	3	3	3	3	3
DE			1	1		1	49	67	78	78	68	79	79	76	76	76	76
IT										2	2	2		2	2	4	8
UK							6	7	7	7	7	7	9	9	9		
IE	1	4	4		4	3	3	3	3		3		3	3	3	3	3
DK							16	15	10	10	7	9	6	8	8	8	8
GR							2	2	2					1	1	1	1
ES											2	2	2	3	3	3	
SE							41	39	41	41	44	45	46	47	45	43	43
AT								1	2	2	2	2	2	2	2	2	2
FI								6	16	15	16	16	16	15	15	15	17
CH										8	8	7	7	7	7	7	7
HU																	1
RO																	4
PL																1	1
NO							17	16	18	17	15	14	14	13	8	8	8
SK																3	3
LT										1	1	1	1	1	1	2	2
CZ									1	1	3	3	3	2		9	11
EE										2	2	2	3	4	4	4	5
SI															2	2	2
BG														3	1		
LV															1	1	1
CY																2	2

3.3.2.2 Methodology of soil solution sampling

Soil solution sampling on the monitoring plots is harmonized with regard to sampled horizon and sampling technique. 91.5 % of all soil solution samplers are located in mineral horizons, 7.9 and 0.7 % in organic and hygromorphic horizons, respectively.

Since 2002, only lysimeters are used for soil solution collection. In 2006, 72% of all samplers were tension lysimeters and 28% were zero-tension lysimeters. In the years before, centrifugation of soil samples and saturation extraction had rarely been used for soil solution collection.

Evaluation of soil solution data is based on single samplers that are of a defined type (i.e. tension and zero tension lysimetry) and that sample soil solution in a defined layer and soil depth. On each plot more than one sampler may exist in each sampling depth. Most countries submit data for one ‘sampler’ per soil depth and plot. This ‘sampler’ can represent a mean of different single measurements per soil depth and plot or one single measurement of a sample that was pooled from different lysimeters in one soil depth of the same plot. If data for more than one lysimeter per soil depth and plot were submitted, means were calculated for each sampling depth and plot and evaluated as one ‘sampler’.

Data availability was best for the calculation and evaluation of (Ca+Mg+K)/Al ratio. Data were available for 2054 samplers on 263 plots. From the total of these, only those samplers were included in the analysis from which data were available for at least 6 months per year in 2006 and in at least three more previous, consecutive years, i.e. complete data availability in the years 2003 – 2006 was a criterion for plot selection. This resulted in 160 plots with 396 soil solution samplers in different soil depths.

Mean sampler pH and trend of pH were calculated for all samplers that continuously provided data from 2000 to 2006 with at least four measurements per monitoring year.
The calculation of trends of BC/Al ratio used all samplers that continuously provided data from 2000 – 2006 and at least six single measurements per monitoring year. Following these criteria, linear trends for BC/Al were calculated for 111 samplers on 58 plots and for pH 166 samplers at 66 plots. From single measurements annual arithmetic means were calculated. Trends were evaluated using regression coefficients and significance of linear regression analysis of monitoring year and annual mean.

Soil solution has been sampled in different soil depths. The manual of ICP Forests (Submanual on Soil Solution and Analysis, updates 6/2002) (ANONYMOUS, 2004) suggests sampling depths for soil solution chemistry assessment of 10-20 cm (within the rooting zone) and 40-80 cm (below the rooting zone). Both suggested sampling depths are well represented; about 77% of all samplers are located in the upper 20 cm and 17% below the rooting zone. About 10% of the samplers had been located below 90 cm soil depth. Table 3.3.2.2-1 gives an overview on data availability for all monitoring years of parameters that are mandatory or optional according to the ICP Forests manual. Even though those parameters are mandatory to assess following the current version of the ICP Forest manual they are not available from all plots.

Table 3.3.2.2-1: Data availability in percent of all measurements for parameters of soil solution survey

Parameter	Mandatory/optional	Availability (% of all data sets)	
pH	mandatory	69.2	
Conductivity µS/cm	mandatory	58.0	
K (mg/l)	mandatory	65.8	
Ca (mg/l)	mandatory	69.7	
Mg (mg/l)	mandatory	69.8	
N-NO3- (mg/l)	mandatory	52.1	
S-SO4 (mg/l)	mandatory	69.8	
Al (mg/l)	mandatory if pH < 5	61.5	92.5% of all data sets with pH >5
DOC mg/l	mandatory	57.5	
Na (mg/l)	Optional	59.4	
Al-labile (mg/l)	Optional	6.4	
Fe (mg/l)	Optional	4.6	
Mn (mg/l)	Optional	45.6	
P (mg/l)	Optional	9.2	
N-NH4 (mg/l)	Optional	40.9	
Cl (mg/l)	Optional	58.9	
Cr (µg/l)	Optional	5.6	
Ni (µg/l)	Optional	6.1	
Zn (µg/l)	Optional	17.8	
Cu (µg/l)	Optional	8.7	
Pb (µg/l)	Optional	6.5	
Cd (µg/l)	Optional	8.0	
Si (µg/l)	Optional	17.4	
Alkalinity (µmol/l)	Optional if pH > 5	9.6	30.0% of all cases with pH >5

3.3.2.3 Critical limits

In a first step the BC/Al ratio was calculated for each single measurement. This BC/Al ratio was compared with a main tree species specific critical limit (see Table 3.3.2.3-1). The critical limit was exceeded if the calculated BC/Al ratio was smaller or equal to the chosen critical limit.

Table 3.3.2.3-1: Tree species specific critical limits of BC/Al ratio that imply growth reductions to 80% of mean growth according to Sverdrup and Warfvinge, 1993 and Lorenz et al., 2008 (n.s. not specified)

Tree species	English name	BC/Al_{crit} (growth reduced to 80%)	Notes
Betula pendula	Birch	0.8	
Fagus sylvatica	Beech	0.6	
Fraxinus excelsior	Ash	1.8-2.2	
Quercus cerris	Turkey Oak	n.s.	Quercus spec. 0.6
Quercus petraea	Sessile Oak	n.s.	Quercus spec. 0.6
Quercus robur	Oak	0.6	
Abies alba	Silver Fir	n.s.	Abies spec. 1.2
Larix decidua	Larch	2	
Picea abies	Norway Spruce	1.2	
Picea sitchensis	Sitka Spruce	0.4	
Pinus cembra	Cembra Pine	1.2	
Pinus nigra	European Black Pine	n.s.	Pinus spec. 1.2
Pinus sylvestris	Scots Pine	1.2	
Pseudotsuga menziesii	Douglas Fir	0.3	

3.3.3. Results

3.3.3.1 BC/Al and pH

Overall variation of BC/Al and pH in all measurements for four different soil depth classes is displayed in Figures 3.3.3.1-1 and 3.3.3.1-2. In all soil depths overall variation was large and differences between lysimeter types were small. Mean pH slightly increased with sampling depth, for BC/Al no such trend can be detected. BC/Al ratio and pH positively correlated for all available measurements (r_s = 0,55; p = 0,01).

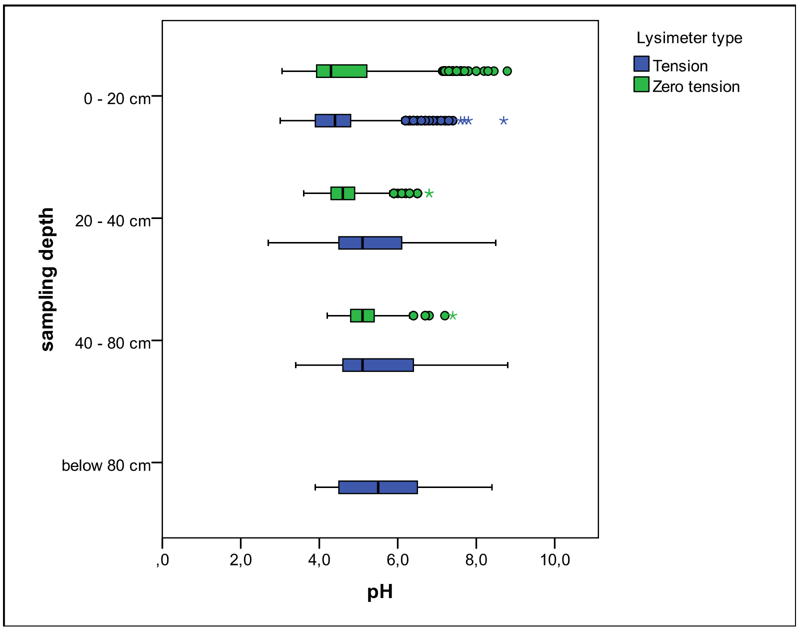


Figure 3.3.3.1-1: Overall variation within all single measurements of pH in different sampling depths; Boxes represent first and third quartile and median; whiskers represent 5 and 95% of all data; dots and stars represent outliers and extremes. N = 4 739 for zero tension lysimetry; N = 14 836 for tension lysimetry.

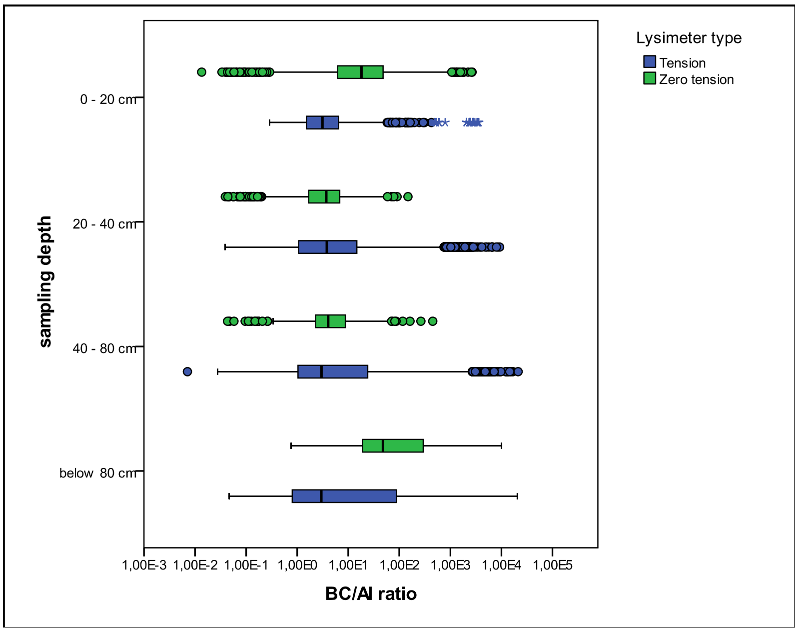


Figure 3.3.3.1-2: Overall variation within all single measurements of BC/Al ratio in different sampling depths; note logarithmic scaling of Y-axis. Boxes represent first and third quartile and median; whiskers represent 5 and 95% of all data; dots and stars represent outliers and extremes. N = 7 704 for zero tension lysimetry; N = 24 233 for tension lysimetry.

3.3.3.2 Spatial trends for the BC/Al ratio and pH 2003 – 2006

At 40.2% of all evaluated 396 soil solution samplers the tree species specific critical limit was exceeded in 5% or more of all measurements. For 183 samplers corresponding to 46.2% the samples, critical limit was exceeded in none of the cases. For 40.2% of the samplers the critical limit was exceeded in more than 5% of the mesurements. For 3.8% of the samplers the measured BC/Al ratio permanently exceeded the critical limit (more than 95% of all measurements). The number and percentage of samplers with different percentages of exceedances is given in Table 3.3.3.2-1.

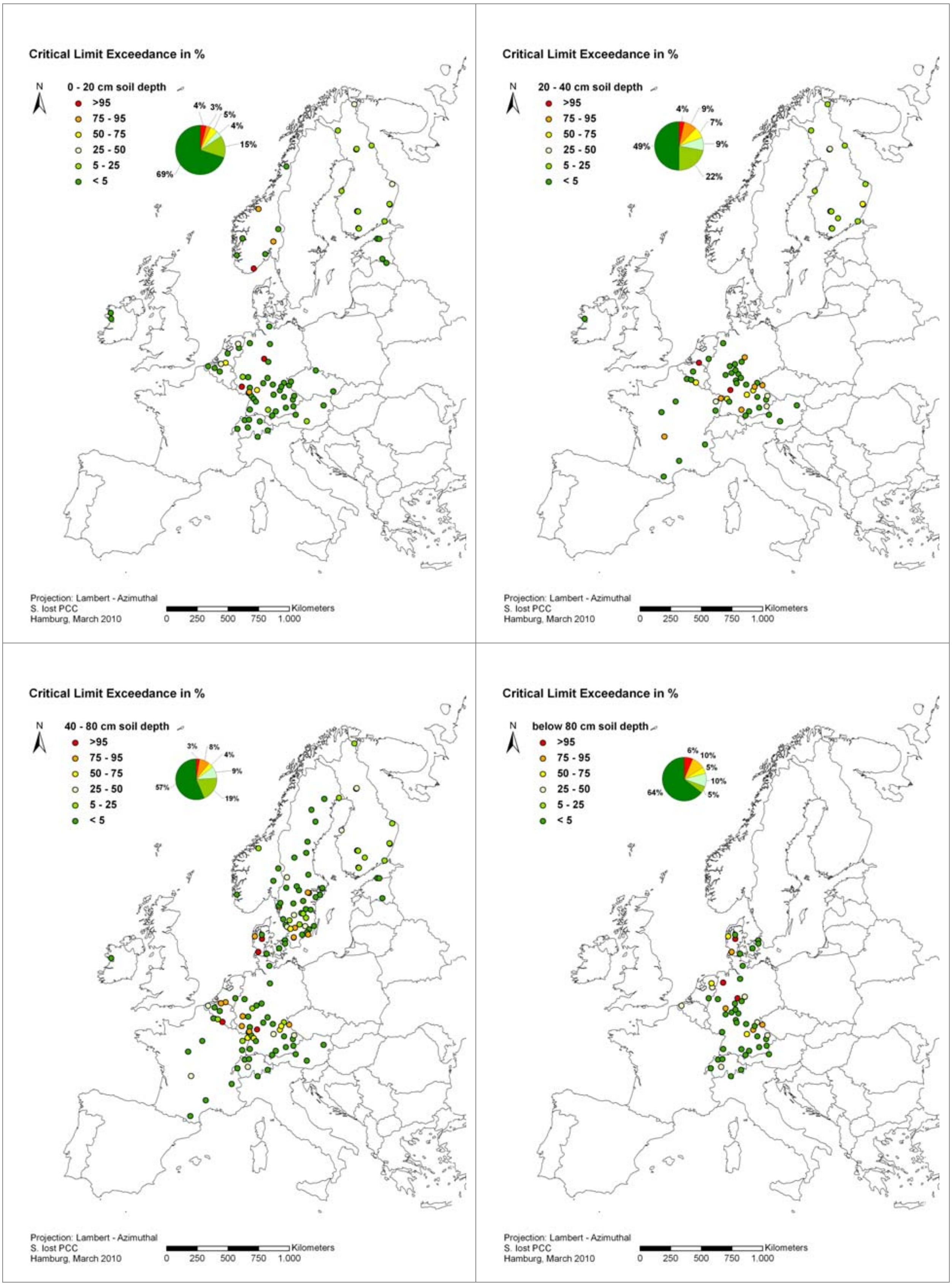
Table 3.3.3.2-1: Percentage of critical limit exceedances; n=396 samplers in different soil depths.

Percentage of exceedance	N (sampler)	% (sampler)	Cumulated %
> 95%	15	3.8	3.8
> 75 and <=95%	28	7.1	10.9
> 50 and <=75%	20	5.1	15.9
> 25 and <=50%	31	7.8	23.7
> 5 and <=25%	65	16.4	40.2
> 0 and <= 5%	54	13.6	53.8
0 %	183	46.2	100.0
Total	396	100.0	

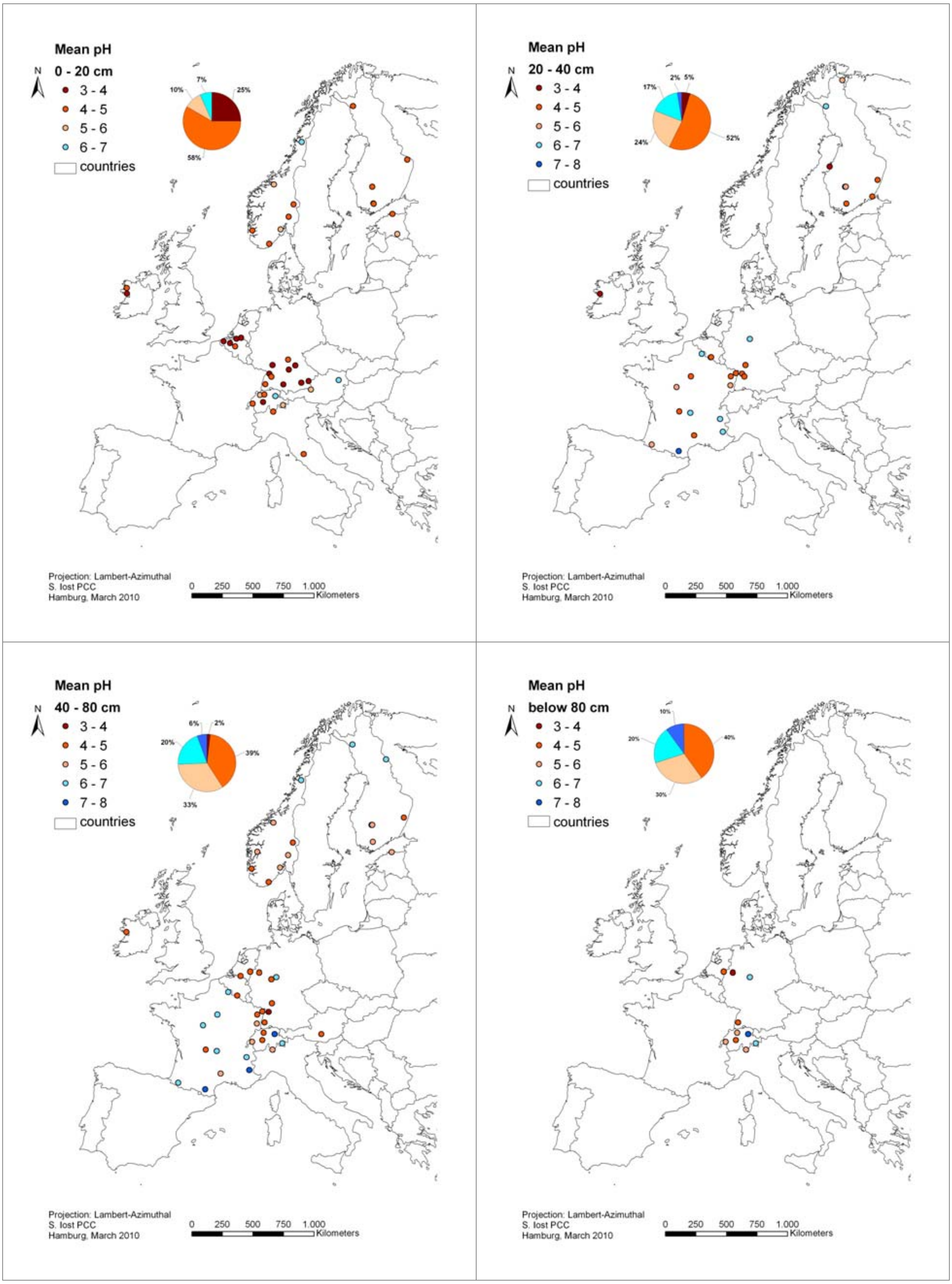
Critical limit exceedances peaked in 20-30 and 40-50 cm soil depth. 59 samplers corresponding to 70% of all samplers in the respective soil depth had at least one critical limit exceedance in the respective monitoring period. Plots with *Picea abies* as dominant main tree species had the highest percentage of critical limit exceedances.

Figures 3.3.3.2-1 – 3.3.3.2-4 display the distribution of exceedance classes for tension and zero tension lysimeters over all analysed plots in four soil depth classes. In all soil depths the displayed exceedance classes are quite evenly distributed over the plots, no distinct spatial trend can be distinguished. The share of samplers at which the critical limit is rarely exceeded varies between 69% and 49% depending on the soil depth. At these plots aluminium concentrations in the soil solution do not pose a serious threat to forest health. On between 7% and 16% of the samples critical limits are exceeded in more than 75% of the cases, depending on the soil depth. In this first study exceedances of BC/Al ratios were not evaluated with respect to soil chemical properties which largely influence the ratios. Such an in depth evaluation needs to be subject of follow-up evaluations.

Figures 3.3.3.2-5 – 3.3.3.2-8 show the distribution of pH for tension and zero tension lysimeters over Europe. Differences between the lysimeter types were small which allowed the presentation in one map for each soil depth class. As for BC/Al ratio no spatial trends can be distinguished over all plots. In the upper two soil depth classes the percentage of measurements below pH = 5 is higher than for the lower part of the soil profile.



Figures 3.3.3.2-1 - 3.3.3.2-4: Exceedances of plot main tree species specific critical limit of BC/Al ratio in four sampling depth classes. Only plots with measurements for at least four consecutive years up to 2006.

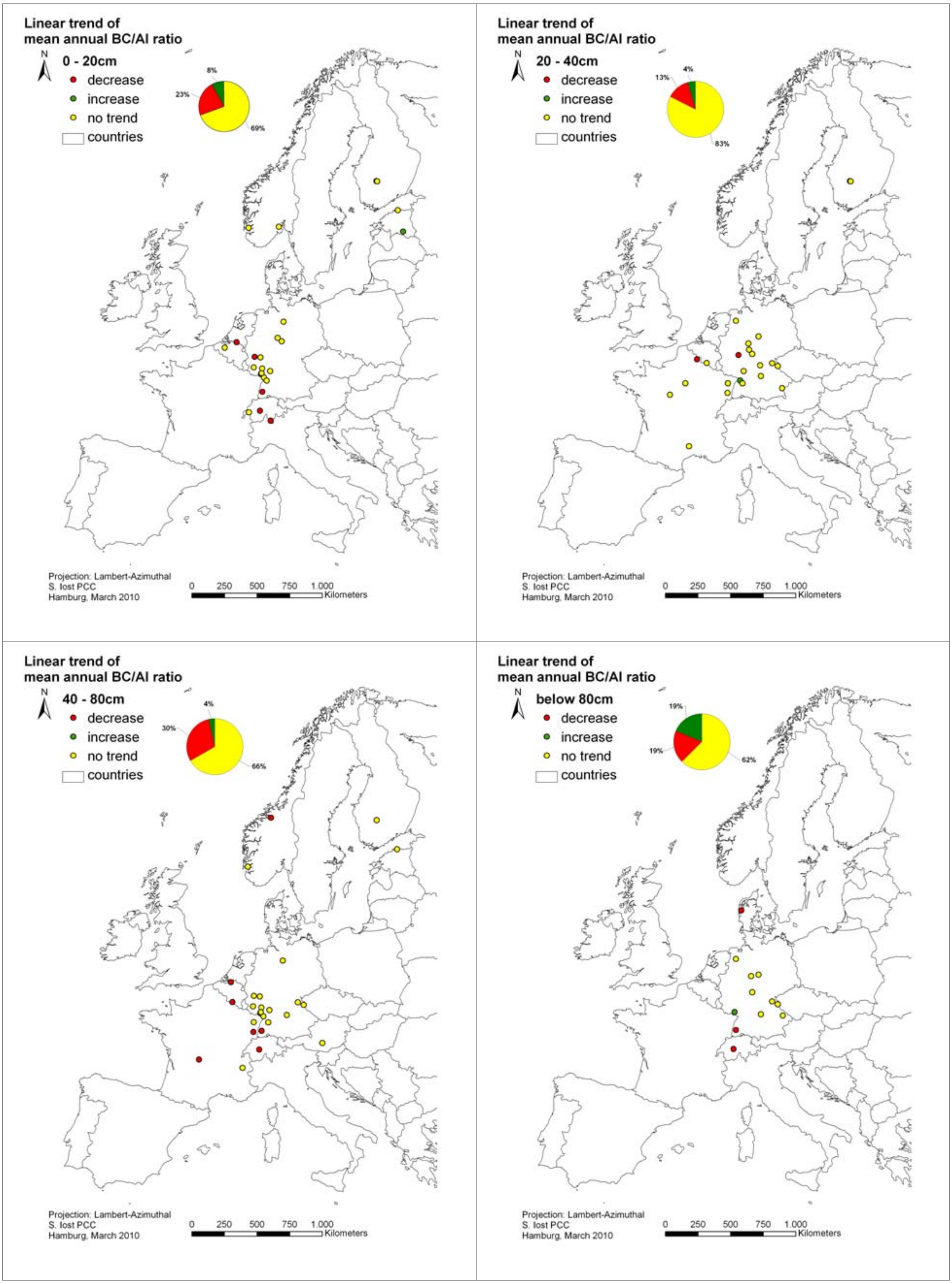


Figures 3.3.3.2-5 - 3.3.3.2-8: Mean pH for single lysimeters in four sampling depths classes, for all plots with measurements available from 2000 to 2006.

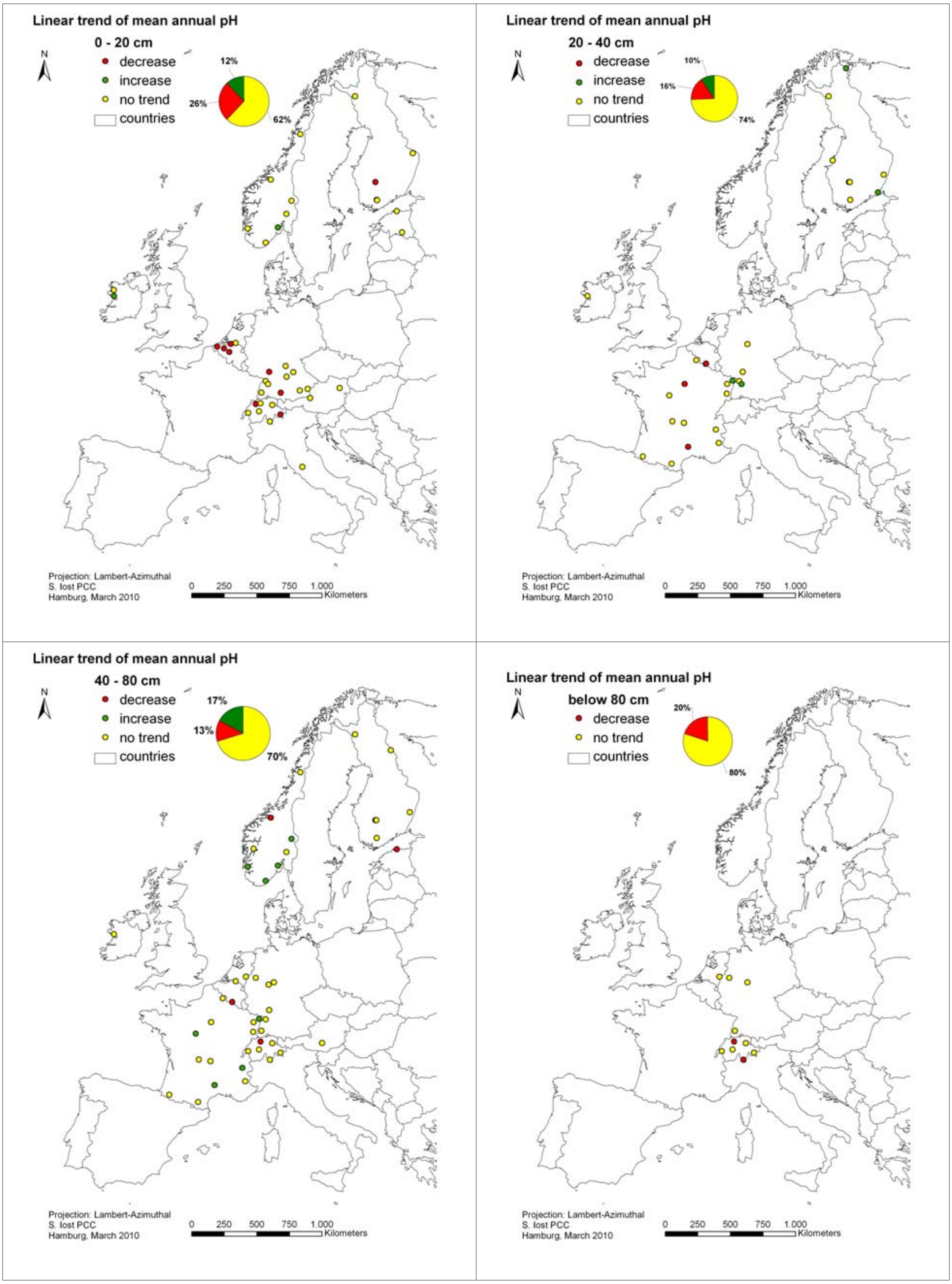
3.3.3.3 Temporal trends of BC/Al ratio and pH 2000 – 2006

For the majority of lysimeters no significant trends were detected for the BC/Al ratio and pH (Figures 3.3.3.3-1 to 3.3.3.3-8). But both parameters decreased for 13 to 30% of all samplers included in the analysis. For both parameters, the share of plots with a significant decrease was larger as compared to the share of plots with an increase. The only exception was the BC/AL ratio below 80 cm soil depth were the share of plots with a decrease was equal to the share with an increase and the trend of pH between 40 and 80 cm soil depth were the share of plots with an increase was slightly higher as compared to the share of plots with a decrease. BC/Al and pH trends did not show distinct spatial patterns.

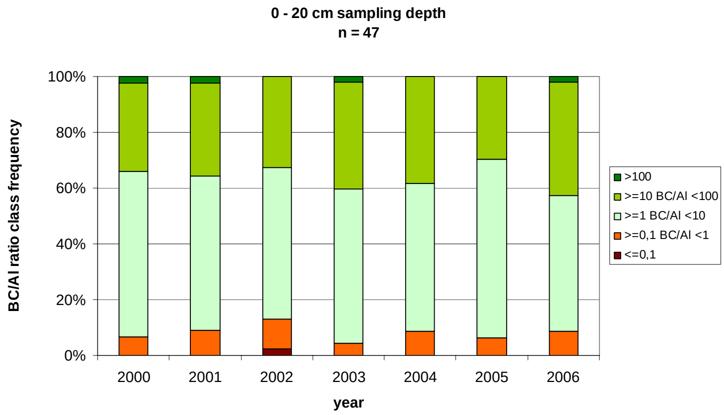
Figures 3.3.3.3-9 – 3.3.3.3-12 show that the relative frequency of the BC/Al ratio below 1, which often is used as a general critical limit, did not follow a temporal trend in any of the different soil depth classes but in general increased with increasing depth. Figures 3.3.3.3-13 – 3.3.3.3-15 show that the topsoil (0 – 20 cm) and also the main rooting zone (20 – 40 cm) are subject to more acid conditions than the lower parts of the profile. Relative frequencies of soil pH did not change during the specified evaluation period.

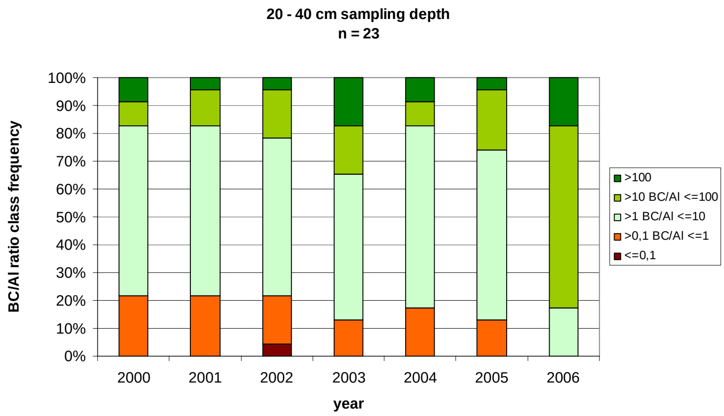


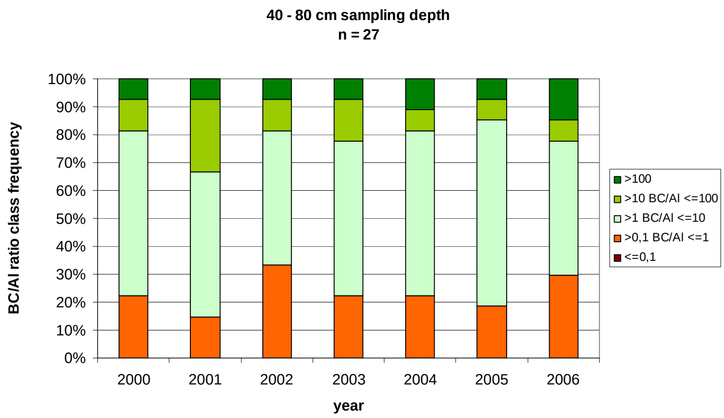
Figures: 3.3.3.3-1 – 3.3.3.3-4: Linear trend of mean annual BC/Al ratios 2000 – 2006 in four sampling depth classes.

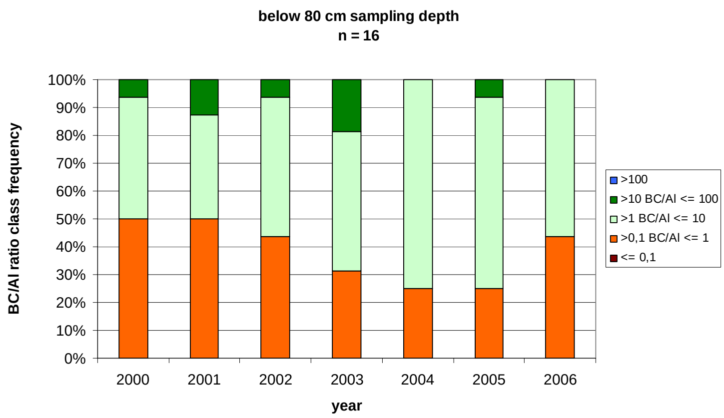


Figures 3.3.3.3-5 – 3.3.3.3-8: Linear trend of mean annual pH 2000 – 2006 in four sampling depth classes

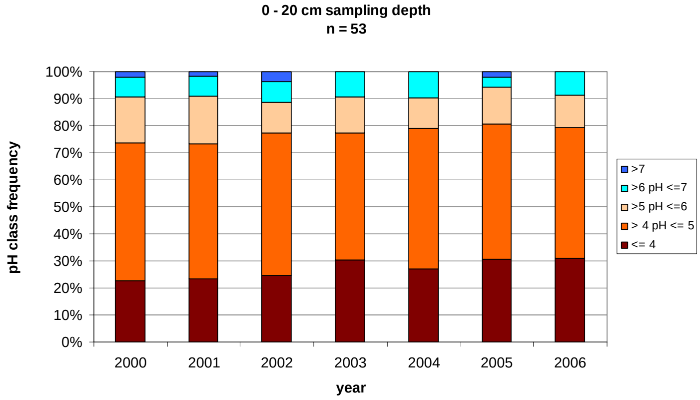


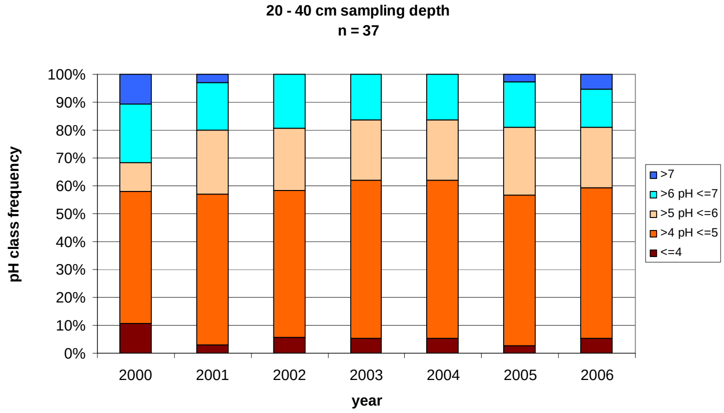


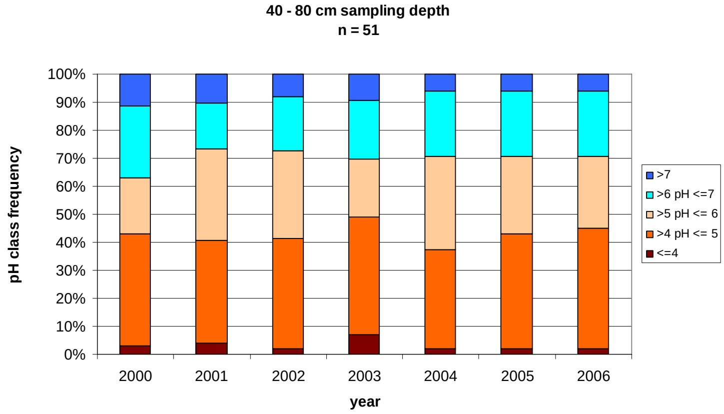


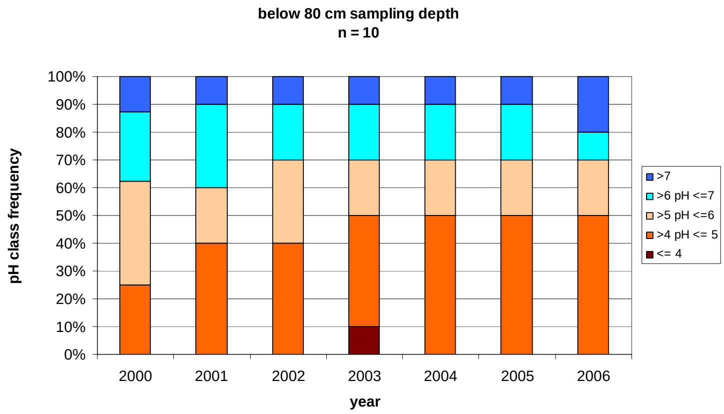


Figures: 3.3.3.3-9 – 3.3.3.3-12: BC/Al ratio class frequencies 2000 – 2006 in four sampling depth classes.









Figures 3.3.3.3-12 – 3.3.3.3-15: pH class frequencies 2000 – 2006 in four sampling depth classes.

3.3.4 Conclusions and Outlook

The improved quality of the soil solution data base allowed for a first comprehensive, descriptive analysis of the submitted transnational data. The presented results underline that acidified soils still are a phytotoxic risk for plants role across Europe, as at about half of the presented plots critical limits for BC/Al ratio are exceeded. For 40.2% of the samplers the critical limit was exceeded in more than 5% of the measurements. The situation appears stable as consistent, significant trends neither towards improvement nor deterioration were detected for BC/Al ratio nor pH. A process of increasing or decreasing soil acidification would be indicated by a change in pH and/ or BC/Al ratios. However, this study showed that these parameters remained mainly unchanged, indicating that soil acidification was not "visible" on this time scale.

It has to be taken into account that plot selection in the countries follows national preferences and the selection of plots for this study was solely driven by data availability. Therefore this study summarizes a number of case studies and is not representative for Europe.

As soil solution chemistry is the product of a variety of processes like weathering, deposition, plant nutrient uptake, lateral and vertical soil water movement and leaching it is highly variable in time and space. However, for the assessment of the risk regarding chemical stress for roots and hinderances of nutrient uptake it is the most feasible indicator. The fact that in more than one third of the samplers the critical limit is exceeded in more than 5% of the measurements is still a matter of concern.

Future evaluations of the available soil solution data will focus on relations between element concentrations and effect parameters. Soil chemical properties will need to be related to soil solution chemistry. Within ICP Forests soil solution element concentrations can be used for nutrient budget and flux calculation after the establishment of water flux models for Level II plots.

Decisive for the critical loads is the definition of the chemical threshold for the used indicator “root”. Critical loads for acidity use the BC/Al ratio according to Sverdrup and Warfvinge (1993), which has a close relation to the root functioning and nutrient uptake. The BC/Al ratio refers to the total concentrations of aluminum in the soil solution, were it occurs partly in low-toxic organic complexes, esp. in the upper soil layer. Thus the concentration of inorganic Al is better suited to estimate Al-toxicity in the soil water compared to total Al. Consequently, submission of inorganic Al data, which is an optional variable in the ICP Forests manual would certainly allow for a better estimation of Al-toxicity on Level II Plots.

For a number of plots soil solution data still needs further quality assessment in order to include more data and parameters in future data evaluation. For the monitoring year 2007, improved data quality and availability can be expected as consultation with submitting countries and data quality assessment during 2009 has in part contributed to the development of a new data submission module.

3.3.5 References

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3.4 Ground vegetation on intensive monitoring plots and its relation to nitrogen deposition

3.4.1 Introduction

This evaluation pertains to the database as obtained by Alterra from vTI in August 2009. The database contains vegetation data from 776 plots divided over 28 countries (Table 3.4.1-1). From each plot, between one and eight relevés made at different points in time are available. Table 3.4.1-2 gives the frequency distribution of the numbers of relevés per plot. Slightly more than half of the plots have been visited more than once, at intervals between one and eleven years (Table 3.4.1-3). There are two aims in this study: (1) determination of the relation between the ground vegetation and environmental variables at a single point in time, and (2) evaluation of the temporal changes at the plots where more than one relevé is available. The temporal changes have been assessed at three levels:

- the individual species;
- the complete vegetation, using multivariate statistics;
- the complete vegetation, using Ellenberg indicator values.

It was attempted to relate the vegetation and its changes to the environmental variables that were measured in the plots. For deposition, model-based estimates from the EMEP network were used in addition to the bulk and throughfall deposition that were measured at a subset of the plots.

Table 3.4.1-1: Number of plots with vegetation data per country

Country	Number of plots
Austria	20
Belgium	21
Bulgaria	3
Cyprus	4
Czech Republic	15
Denmark	22
Estonia	9
Finland	33
France	100
Germany	85
Greece	4
Hungary	16
Ireland	9
Italy	31
Latvia	3
Lithuania	9
Luxembourg	2
Netherlands	14
Norway	13
Poland	148
Portugal	12
Romania	7
Slovak Republic	8

Country	Number of plots
Slovenia	11
Spain	53
Sweden	98
Switzerland	16
United Kingdom	10
SUM	**776**

Table 3.4.1-2: Number of relevés per plot

Number of relevés	Number of plots
1	378
2	159
3	150
4	37
5	13
6	11
7	17
8	11
SUM	**776**

Table 3.4.1-3: Interval between the first and last relevé per plot

Interval (years)	Number of plots
0	378
1	24
2	10
3	20
4	33
5	104
6	24
7	50
8	5
9	5
10	94
11	29
SUM	**776**

3.4.2 Material and Methods

Species

All species were used as given in the database with the following exceptions:

- 'extra' species added by the individual countries were removed;
- all *Rubus* species with the exception of *R. idaeus, R. caesius, R. saxatilis, R. chamaemorus* and *R. arcticus* were taken together as *R. fruticosus;*
- all *Alchemilla* species except *A. alpina* were taken together as *A. vulgaris*.

The numerical codes used in the database were converted into eight-digit codes following the Dutch 'Biobase' database (Van Duuren et al. 2003) as far as possible. New codes were generated for species not in Biobase and manually adapted if necessary to achieve unicity. The correspondence of the Ellenberg database (Ellenberg 1991) and the ICP database was checked on the level of the full species names; codes were adapted if necessary. Annex 3.4.1 gives a full list of all species and their codes used in this project.

Relevés

The analysis was based on a single relevé for each combination of plot and year. If there were data from more than one subplot (called 'survey' in the database) at a given date, the subplots were combined by taking the average cover per species. If there were data from more than one date within a given year, these were combined by taking the maximum cover per species over all these dates. Relevés taken in fenced plots were not used. The tree layer was not considered as a part of the spontaneous vegetation and not used in the analysis. The moss and lichen layer was left out of consideration because it was not recorded by all countries. For technical reasons species with cover percentages < 0.005% (possibly after averaging over subplots) were left out of consideration. Relevés without any species (possibly after the above operations) were also left out of consideration for technical reasons. For the multivariate analyses cover percentages were ln(X+1) transformed.

Soil data

The database contains a wide range of chemical data from a wide range of horizons. Missing values occur for some variables. In principle, chemical values have been computed as the average over the complete organic layer, and as the average over 0 - 20 cm depth in the mineral layer. The following soil chemical variables were used:

- in the organic layer: pH($CaCl_2$); extractable (mostly by extraction with 0.1 M $BaCl_2$) Ca, K, Mg, P; and C-total, N-total;
- in the mineral layer: pH($CaCl_2$), CEC, base saturation, C-total, N-total.

If there were data from more than one year of a given plot, only the last year was used. pH values were averaged after exponentiation. N/C ratios were computed as (N-total) / (C-total) for both the organic and the mineral layer. Missing values have been treated as follows:

- records with missing values for pH($CaCl_2$) in either the mineral or the organic layer were not used;
- records with missing values for more than one variable were not used;
- occasional missing values in other variables were estimated on the basis of their correlation with a single other variable (see Table 3.4.2-4 for details).

The chemical data were checked for normality and outliers. Normality was achieved by logarithmisation, occasional outliers were corrected to their nearest value (max. one per variable). Details are given in Table 3.4.2-4A.

Table 3.4.2-4A: Treatment of soil data.
Logarithmisation is achieved by transforming X = ln (X - MIN(X) +1)
Skewness is computed as
$(M_3 - 3M_1M_2 + 2M_1^3) / (M_2 - M_1^2)^{3/2}$ with $M_i = \sum x^i / N$
Number of plots with usable soil data: 619

Variable	Layer	Number of missing values	Missing estimated on the basis of	Logaritmised	Outlier corrected	Skewness after correction
pH($CaCl_2$)	organic	0		no	no	1,131
N/C	organic	0		no	no	1,038
Ca	organic	44	pH	yes	yes	-1,398
K	organic	3	Mg	yes	no	-0,354
Mg	organic	0		yes	yes	-0,072
P	organic	51	N/C	no	no	0,046
pH($CaCl_2$)	mineral	0		no	no	2,419
N/C	mineral	9	base sat	yes	yes	2,424
CEC	mineral	0		yes	no	0,562
base sat	mineral	0		no	no	1,426

Table 3.4.2-4B: Treatment of deposition data.
Logarithmisation is achieved by transforming X = ln (X - MIN(X) +1)
Skewness is computed as
$(M_3 - 3M_1M_2 + 2M_1^3) / (M_2 - M_1^2)^{3/2}$ with $M_i = \sum x^i / N$
Number of records given in the table.

Element	source	Number of plots	Logarit-mised?	Outlier corrected?	Skewness after correction
NH4 1995	EMEP estimate	616	no	no	1,899
NH4 2000	EMEP estimate	616	no	no	1,699
NO3 1995	EMEP estimate	616	no	no	-0,306
NO3 2000	EMEP estimate	616	no	no	-0,129
N total 1995	NH4+NO3 1995	616	no	no	0,873
N total 2000	NH4+NO4 2000	616	no	no	0,947
SO4 1995	EMEP estimate	616	no	no	0,922
SO4 2000	EMEP estimate	616	no	no	1,755
Quantity	bulk deposition	414	no	yes	1,147
Ca	bulk deposition	414	yes	no	-0,51
Mg	bulk deposition	414	yes	no	-0,091
K	bulk deposition	413	yes	no	-0,562
Na	bulk deposition	414	yes	no	-0,514
Cl	bulk deposition	414	yes	no	-0,549
NH4	bulk deposition	414	no	no	1,132
NO3	bulk deposition	414	yes	no	-2,34
SO4	bulk deposition	414	yes	no	-1,759
Ntot	NH4 + NO3	414	no	no	0,663
Quantity	throughfall	278	no	yes	1,352
Ca	throughfall	278	no	no	1,279
Mg	throughfall	278	yes	no	-0,956
K	throughfall	278	no	no	1,741

Element	source	Number of plots	Logarit-mised?	Outlier corrected?	Skewness after correction
Na	throughfall	278	yes	no	-0,502
Cl	throughfall	278	yes	no	-0,665
NH4	throughfall	278	yes	no	-0,869
NO3	throughfall	278	no	no	1,199
SO4	throughfall	278	no	no	1,61
Ntot	throughfall	278	no	no	1,36
NH4	calculated	265	no	no	1,623
NO3	calculated	265	no	no	1,454
Ntot	NH4+NO3 (calc.)	265	no	no	1,51

Deposition data

Deposition was calculated as the product of rainfall or throughfall quantity per two- or four-week period and the concentration per element over that period, and recalculated to yearly averages. Deposition per plot was determined as the average of the years where sufficient data were available. Only those years were included that had data for at least 80% of that year. In many cases, there were missing values for individual elements, specifically for NH_4, and this led to many missing years. Among the 619 plots with both vegetation and soil data, there are 414 with bulk deposition data, 278 with throughfall data, and 265 with both. An overview of the numbers of plots with either bulk or throughfall data, and their pre-treatment, is given in Table 3.4.2-4B. These plots have deposition measured over periods that differ in length and position in time, but as trends in N deposition were not significant, we assumed that the years for which deposition data are available are a good estimate for the deposition over the period where vegetation data are available.

Because measured deposition was available for only a subset of all plots, deposition estimates for NH_4, NO_3 and SO_4 for 1995, 2000 and 2010 were also derived by overlaying the plot locations with results of the Eulerian atmospheric transport model of EMEP/MSC-W at a 50 km x 50 km grid cell size (Tarrasón et al., 2007). Annex 3.4.2 gives the correlation coefficients between EMEP deposition estimates for 2000 and measured bulk and throughfall deposition. Correlations coefficients are in the order $R \approx 0.6$ for both N and S. For both EMEP estimates and bulk and throughfall deposition, N-total was calculated as the sum of NH_4 + NO_3. In addition, dry deposition of NH_4 and NO_3 was estimated on the basis of the difference between bulk and throughfall deposition, assuming a conservative behaviour of Na; this is referred to as 'calculated' deposition.

Other data

Climatic zones were assigned to each plot on the basis of its geographical position according to De Vries et al (2002). Moreover the following data were taken from the database:
- country;
- latitude and longitude;
- stand age (classes recalculated to 'real' age as code * 20, code 8 ('irregular stands') replaced by 70);
- altitude (classes recalculated to 'real' altitude as code * 50 and logarithmised to correct for skewness);
- tree species: these were clustered as presented in Table 3.4.2-1. For *Quercus*, the temperate and mediterranean species were taken together. *Pinus sylvestris* and *P. nigra* were taken together. *Fagus sylvatica* and *Picea excelsa* were used as such. All other species were lumped to 'coniferous' and 'deciduous'.

The nominal variables (country, tree species and climate zone) were transformed to dummy variables (one for each class with value 1 if a record is in that class, otherwise 0).

Table 3.4.2-1: Classification of plots according to main tree species

Tree species	Number of plots	Tree Group
Pinus sylvestris	230	Pins
Picea abies (P. excelsa)	181	Pice
Fagus sylvatica	114	Fags
Quercus robur (Q. pedunculata)	57	Qurp
Quercus petraea	41	Qurp
Quercus ilex	17	QurM
Pseudotsuga menziesii	14	conf
Abies alba	14	conf
Pinus pinaster	13	conf
Picea sitchensis	11	conf
Pinus nigra	10	Pins
Quercus cerris	9	QurM
Quercus pyrenaica (Q. toza)	5	QurM
Quercus suber	5	QurM
Betula pendula	4	deci
Pinus halepensis	4	conf
Larix decidua	4	conf
Quercus frainetto (Q. conferta)	3	QurM
Pinus brutia	3	conf
Pinus pinea	3	conf
Eucalyptus sp.	3	deci
Pinus contorta	3	conf
Carpinus betulus	2	deci
Fraxinus excelsior	2	deci
Quercus faginea	2	QurM
Castanea sativa (C. vesca)	2	deci
Populus canescens	1	deci
Fagus moesiaca	1	deci
Populus hybrides	1	deci
Quercus rotundifolia	1	QurM
Alnus glutinosa	1	deci
Other broadleaves	1	deci
Other conifers	1	conf
Abies borisii-regis	1	conf
Juniperus oxycedrus	1	conf
Juniperus thurifera	1	conf
Pinus canariensis	1	conf
Pinus cembra	1	conf
Pinus mugo (P. montana)	1	conf
Pinus radiata (P.insignis)	1	conf
Pinus uncinata	1	conf
Erica arborea	1	deci

Missing values and correspondence between vegetation and abiotic data
After the exclusion of records with deficient soil data, there are three records without coordinates (and hence, without climate zone and EMEP deposition estimates). These were also excluded from the analysis. After these exclusions and the replacement of missing soil data by estimates, 616 usable records remain with soil, 'other', and EMEP deposition data, and 265 with soil, 'other', bulk and throughfall deposition data.

Annex 3.4.3 gives the correlation matrix of all variables used in the CCA analysis of last relevé per plot using EMEP deposition estimates. Other analyses have been carried out on different subsets of the data and therefore have slightly different correlation matrices; for the correlation between the EMEP estimates and measured bulk and throughfall deposition see Annex 3.4.2.

On the vegetation side, species with less than three occurrences and relevés with less than three species were excluded from the multivariate analysis of the last relevé per plot, to avoid a very heterogeneous data set. This resulted in 598 usable records, of which 477 had usable abiotic data (excl. bulk and throughfall deposition). These 477 relevés had 170 species (after the exclusion of very rare ones). A separate analysis was done with the bulk and throughfall deposition data instead of the EMEP estimates; for this analysis there were 181 usable records containing 114 species. For the analysis of the vegetation change the first and the last relevé of each plot were used if the interval between them was seven years or more; this yielded 161 plots, of which 138 had usable abiotic data, and 60 bulk deposition and throughfall data. In this operation rare species or species-poor relevés were not excluded because the linear statistical methods used here are less sensitive to heterogeneity.

3.4.3 Statistical methods

The statistical methods used are similar to those used in 2002 (De Vries et al. 2002). The effect of the environmental variables on the vegetation of the last relevé of each plot was assessed by canonical correspondence analysis (CCA). The exclusion of very rare species (< 3 occurrences) and downweighting of rare species resulted in a gradient length GL_1 = 7.5 and explained variance λ_1 / $\Sigma\lambda$ = 4.6% for the first axis at 477 samples and 170 species which was judged acceptable. The change in the vegetation was determined as (%cover in last relevé) minus (%cover in first relevé) per species. The significance of this change was determined by ordinary linear statistics. The relation between the change in the vegetation and the environmental variables was analysed for all species together using RDA (= the linear form of CCA = the canonical form of PCA). Ellenberg values were determined as the unweighted mean over all species (incl. the rare species but excl. relevés with < 3 species with a known Ellenberg value). The relation between the change in Ellenberg values and environmental variables was assessed using multiple regression. All multivariate operations were carried out by the program CANOCO v 4.53, all univariate operation by the program GENSTAT v 12.1.

3.4.4 Results

CCA analysis of last relevé per plot
Possible observer effects were assessed by determining the unique contributions ('TMVs') of the countries and the 'real' environmental variables (Table 3.4.4-1). Out of a total of 25% variance that can be explained anyway, 5% is uniquely due to the countries. As both the geographical coordinates and climate zones are among the environmental variables this 'county effect' is most probably caused by methodological differences. Estonia, France, the Netherlands, Ireland and Italy are the most deviant countries (in that order) and their effect is significant even after accounting for the effect of all environmental variables. Therefore the countries were used as covariables in the subsequent analysis. Table 3.4.4-2 gives the result of the forward selection. Like in De Vries at el. (2002), the variables were included in the model stepwise, at each step

the one that leads to the highest increase in explained variance with the constraint that variables with a correlation |R| > 0.5 with variables already in the model are skipped. Variable selection was stopped when none remained that could significantly (P < 0.05) improve the fit of the model. The resulting 'minimal' model explains 12.5% variance which is quite usual in this type of ecological data. pH is the most important explanatory variable, which is also usual in this type of data. There is a small, but highly significant effect of deposition quantified as the EMEP-estimated NO_3 deposition for 2000. The model is summarised in Table 3.4.4-3. The results strongly agree with those of De Vries at al. (2002) with the traditional factors (in the order: tree layer, soil, climate) as the most important explanatory variables, and c. 5% of the variance in the fitted values explained by deposition. However, in contrast to the 2002 analysis this effect of deposition is solely due to N-deposition and not partly to e.g. seawater ions.

Table 3.4.4-1: Percentage explained variance due to countries and 'real' environmental variables

source	TMV
uniquely due to countries	5,0%
uniquely due to environmental variables	14,1%
undetermined	6,3%
total variance explained	**25,4%**

Table 3.4.4-2: Result of forward selection of environmental variables to explain the vegetation of the last relevé of each plot, using EMEP estimates to quantify deposition and using the countries as covariables. Eigenvalues: λ_1 = 0.259, λ_2 = 0.24, λ_3 = 0.188, λ_4 = 0.125, $\Sigma\lambda$ = 11.739, Number of plots = 477, number of species = 170. Rare species are downweighted. F = (regression mean square with this term - regression mean square without this term) / error mean square; P = probability of this, or a higher F-value under the null hypothesis as determined on the basis of 999 bootstrap samples.

Variable	compart-ment	F	P	percentage explained variance
pH	organic	8,1	0,001	1,70%
mediterr. oak	tree	6,79	0,001	1,45%
temperate oak	tree	5,95	0,001	1,28%
Pinus sylv+nigra	tree	4,83	0,001	1,02%
Fagus	tree	4,42	0,001	0,94%
CEC	mineral	2,84	0,001	0,60%
N/C	organic	2,46	0,005	0,51%
Latitude	climate	2,44	0,001	0,43%
NO3 (2000)	deposition	2,36	0,001	0,51%
Longitude	climate	2,28	0,001	0,51%
coniferous 'other'	tree	2,23	0,003	0,43%
deciduous 'other'	tree	2,13	0,061	0,43%
Ca	organic	2,1	0,002	0,43%
Atlantic South	climate	1,96	0,008	0,43%
Age	tree	1,89	0,003	0,34%
Atlantic North	climate	1,85	0,005	0,34%
K	organic	1,87	0,011	0,43%
Boreal	climate	1,72	0,012	0,34%
P	organic	1,7	0,007	0,34%
Altitude		1,36	0,092	0,26%
N_C_min		1,23	0,173	0,26%
(further terms not given)				
SUM if P < 0.05				**12,44%**

Table 3.4.4-3: Summary of the model of Table 3.4.4-2. % expl. fit = percetage explained variance in the fitted values

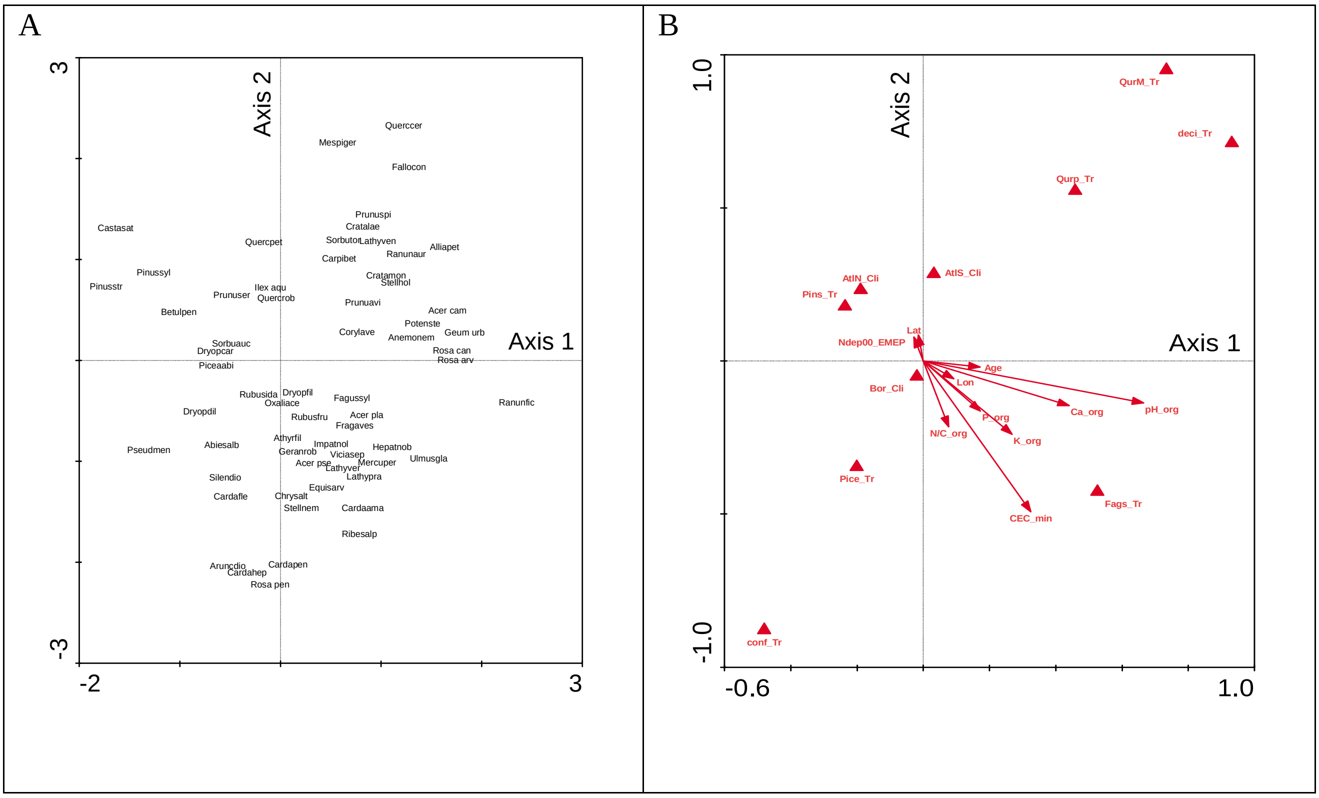
Compartment	% expl. var.	% expl. fit
tree layer	5,9%	47,3%
soil organic layer	3,4%	27,4%
soil mineral layer	0,6%	4,8%
climate	2,0%	16,4%
deposition	0,5%	4,1%
SUM	**12,4%**	**100,0%**

The same analysis was also carried out on a subset of the plots where bulk and throughfall deposition data were available, including terms for both measured and EMEP deposition in the selection procedure. The result is given in Table 3.4.4-4, which shows that -like in the previous analysis- there is a significant effect of EMEP NO_3 deposition, and also a weakly significant (P = 0.07) effect of NO_3 in bulk deposition. Moreover there are significant effects of Na and K in throughfall. However the latter effects may be spurious because especially Na is a strong indicator for distance to the coast and consequently, for climatic effects. The higher overall percentage explained variance (19 vs. 12%) may be due to the lower number of plots (181 vs. 477).

Table 3.4.4-4: Result of forward selection of environmental variables to explain the variation of the last relevé of each plot, using both bulk and throughfall precipitation and EMEP model output to quantify deposition. Eigenvalues: $\lambda_1 = 0.389$, $\lambda_2 = 0.322$, $\lambda_3 = 0.252$, $\lambda_4 = 0.220$, $\Sigma\lambda = 9.723$, Number of plots = 181, number of species = 114. Rare species are downweighted. F = (regression mean square with this term - regression mean square without this term) / error mean square; P = probability of this, or a higher F-value under the null hypothesis as determined on the basis of 999 bootstrap samples.

Variable	compartment	F	P	percentage explained variance
mediterr. oak	tree	4,44	0,001	2,67%
Pinus sylv+nigra	tree	3,85	0,001	2,26%
Fagus	tree	3,57	0,001	2,06%
temperate oak	tree	3,67	0,001	2,06%
pH	mineral	3,02	0,001	1,75%
deciduous 'other'	tree	2,65	0,04	1,44%
Atlantic South	climate	2,42	0,029	1,34%
K	throughfall	2	0,016	1,03%
Lon	climate	1,77	0,004	1,03%
Mg	organic	1,74	0,017	0,93%
N/C	mineral	1,6	0,027	0,82%
NO3 (00)	EMEP	1,67	0,01	0,93%
Na	throughfall	1,72	0,031	0,93%
Altitude	climate	1,57	0,056	0,82%
coniferous 'other'	tree	1,56	0,062	0,82%
CEC	mineral	1,54	0,03	0,82%
N/C	organic	1,43	0,077	0,82%
Ca	organic	1,49	0,058	0,72%
NO3	bulk depo	1,41	0,066	0,72%
Lat	climate	1,38	0,096	0,72%
Ntot	throughfall	1,4	0,082	0,72%
K	bulk depo	1,33	0,097	0,72%
Atlantic North	climate	1,29	0,134	0,72%
SUM if P < 0.05				**19,23%**

Figure 3.4.4-1 is the biplot of the model of Table 3.4.4-2. There seem to be two main gradients: one that is determined by soil chemistry and runs from acid and nutrient-poor to neutral and nutrient-rich; and an other that is determined by tree species, mainly the contrast coniferous vs. deciduous. These ecological gradients are at an angle of c. 45^{o} with the CCA axes (which is usual if the two gradients are more or less equally important). The third and fourth axis mainly seem to separate the mediterranean plots from all other plots. There is no single axis that clearly represents the effect of N deposition; this is also apparent from the canonical coefficients and their t-values (not shown). Therefore an extra analysis was run where the effect of N deposition was forced through the first axis. This is achieved by declaring N deposition as the only environmental variable and moving all other variables with a significant effect in Table 3.4.4-2 to the covariables. The resulting biplot is difficult to interpret and not shown, however the sample scores on this axis are just significantly correlated with the mean Ellenberg N values (R = 0.19, N = 111, P = 0.045). The effect of N deposition in the model of Table 3.4.4-2 is therefore not considered as a spurious effect but most probably represents a real ecological effect.



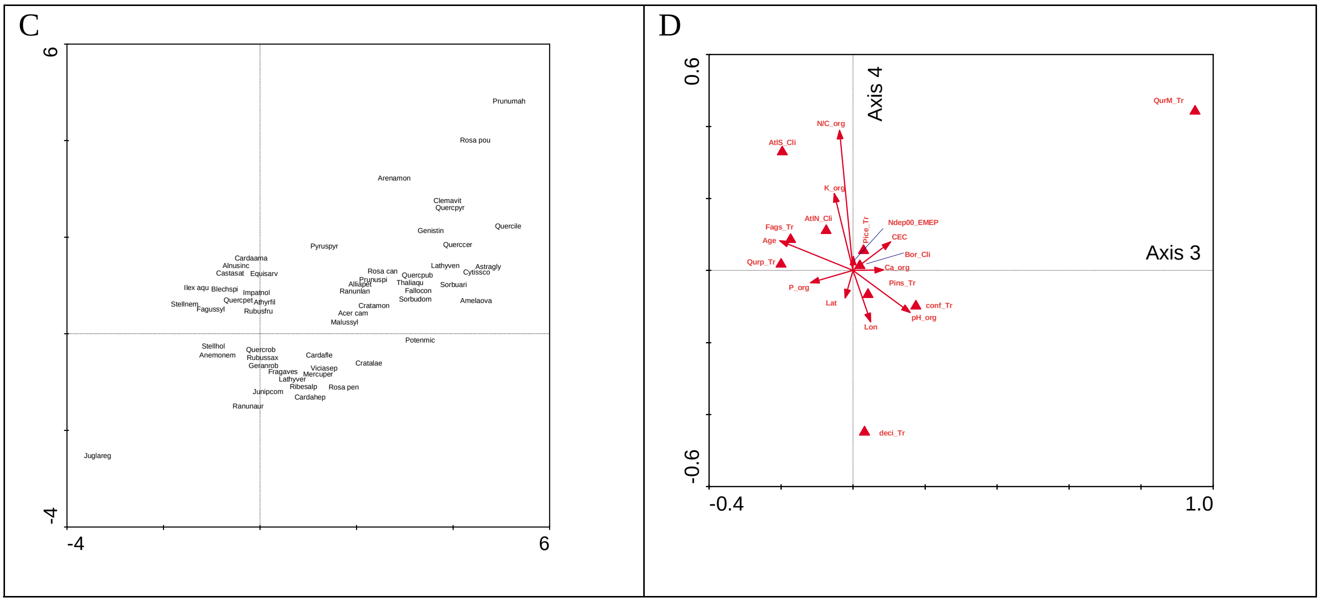


Figure 3.4.4-1: Biplot of the model of Table 3.4.4-2. See caption of Table 3.4.4-2 for details. Explanation of species codes in Annex 3.4.1, explanation of environmental codes: _min = mineral layer, _org = organic layer, _Tr = tree layer, _Cli = climate (Atl = atlantic, Bor = boreal). Only species are given for which the model explains > 2% variance. A: axis 1 vs. axis 2, species; B: axis 1 vs. axis 2, environmental variables; C: axis 3 vs. axis 4, species; D: axis 3 vs. axis 4, environmental variables

Temporal change per species

Table 3.4.4-5 gives the mean change in cover percentage per species for those species where this change was significant at P < 0.1. This appears to be the case for only 13 out of 546 species (note that at this number of species and P < 0.05 one would expect a false significance for 27 species). Moreover the absolute mean change is > 1% for only two species. Apparently the changes have been small. There is no apparent pattern in the ecology of the species that most strongly changed. The three species that declined most strongly (*Rosa pendulina, Ranunculus platanifolius* and *Ribes alpinum*) and the species that increased one-but-most strongly (*Athyrium distentifolium*) are typical mountain species. The strongest changes may be due to methodological problems (*Ranunculus platanifolius* and *Athyrium distentifolium* by being confused with *R. aconitifolius* and *A. filix-femina*, respectively, and *Anemone nemorosa* because of differences in observation date).

Table 3.4.4-5: Change in species cover between the first and last relevé. Only relevés made at intervals of more than six years were used. N = number of occurrences (i.e., number of plots with this species in either one or both years), Diff = MEAN [(%cover in last relevé) - (%cover in first relevé)], T = t-value of difference, P = P-value of difference. The species given are those for which N > 2 and P < 0.1.

species	N	Diff	T	P
Rosa pendulina	8	-1,17	-2,47	0,043
Ranunculus platanifolius	3	-0,83	-5,00	0,038
Ribes alpinum	12	-0,72	-1,91	0,083
Prunus avium	54	-0,57	-1,99	0,052
Crataegus monogyna	11	-0,54	-2,21	0,052
Potentilla erecta	20	-0,52	-2,21	0,040
Lathyrus montanus	13	-0,46	-3,25	0,007
Gymnocarpium dryopteris	13	-0,43	-2,11	0,056
Hippocrepis comosa	3	-0,41	-8,66	0,013
Dryopteris carthusiana	74	-0,37	-1,71	0,091
Polypodium vulgare	8	-0,21	-2,34	0,052
Athyrium distentifolium	5	0,28	3,33	0,029
Anemone nemorosa	47	6,75	2,82	0,007

Temporal change in the vegetation

To form a picture of the general vegetation change over time and its relation with the environmental variables, the analysis of Table 3.4.4-2 was repeated after replacing the cover per species with the change in cover per species. These differences were used without applying transformations and without down-weighting of rare species. The analysis was carried out in RDA instead of CCA. Table 3.4.4-6 gives the result of the forward selection based on EMEP deposition estimates, and Figure 3.4.4-2 is the biplot of the model of Table 3.4.4-6. There is a significant effect of the EMEP estimated total N deposition. However the biplot does not yield a clear ecological picture of what happened in the plots, although some of the notoriously nitrophytic species have a positive correlation with the N deposition (e.g., *Urtica dioica*, *Geranium robertianum*). However, note that *Rubus fruticosus* is weakly negatively correlated with N deposition. These same analysis was repeated with bulk and throughfall as indicators for deposition (and consequently, with a lower number of plots). However the results of this analysis were very comparable to the previous one, with a significant effect of EMEP estimated total N deposition, and no significant effects of bulk and throughfall deposition (except Na in bulk). Therefore the results of this analysis are not shown. An analysis of the Ellenberg values was not attempted in this case as a direct analysis of the change in Ellenberg values seemed more appropriate.

Table 3.4.4-6: Result of forward selection of environmental variables to explain the variation of the change in vegetation per plot, using both bulk and throughfall precipitation and EMEP estimates to quantify deposition. Change is determined as the difference last - first relevé of each species in each plot where the time lag between the first and last relevé is > 6 years. Eigenvalues: $\lambda_1 = 0.056$, $\lambda_2 = 0.036$, $\lambda_3 = 0.016$, $\lambda_4 = 0.007$, $\Sigma\lambda$ standardised to unity, number of plots = 138, number of species = 110. Further explanation see Table 3.4.4-2. Note that bulk and throughfall precipitation do not appear in the table because their effect was not significant.

Variable	compart-ment	F	P	percentage explained variance
pH	organic	3	0,002	2,00%
Latitude	climate	3,46	0,009	3,00%
N-total (95)	EMEP	2,69	0,024	1,00%
Subtlantic	climate	2,51	0,006	2,00%
Atlantic North	climate	1,86	0,059	1,00%
temperate oak	tree	1,72	0,06	2,00%
Base saturation	mineral	1,42	0,157	1,00%
SUM if P < 0.05				8,00%

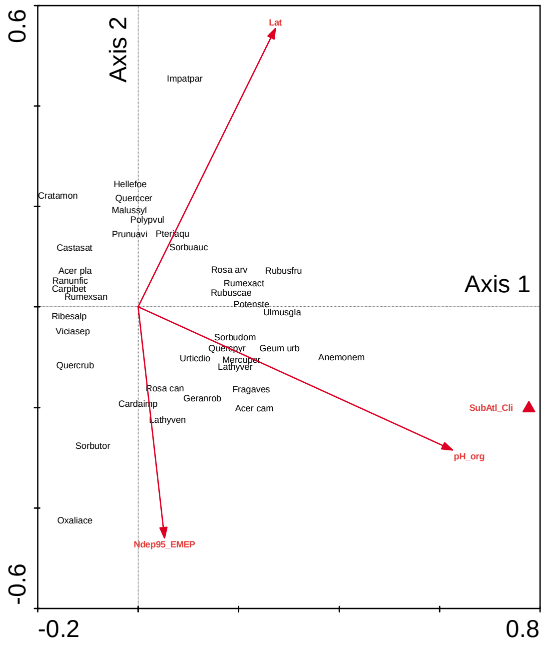


Figure 3.4.4-2: Biplot of the model of Table 3.4.4-6. See caption of Table 3.4.4-6 for details. Explanation of species codes in Annex 3.4.1, explanation of environmental codes as in Figure 3.4.4-1 (SubAtl_Cli = subatlantic). Species are selected for which > 2% variance is explained by the model.

Temporal change in the Ellenberg values and number of species

Table 3.4.4-7 gives the change in Ellenberg values and their significance. The indicator for nutrient availability (N) is the only one that significantly changed (increase, $P = 0.01$). Besides, the number of species per relevé highly significantly increased by 1.4 species ($P < 0.001$). Multiple regression was used to find the relation between the environmental variables and the change in those indicators that significantly changed (Ellenberg N and number of species). A minimal model was derived by backward selection, i.e. stepwise removal of non-significant terms from a full model containing all environmental variables, until only variables with a significant effect remained. Also terms with a correlation of $|R| > 0.5$ with other terms in the model were removed, starting with the one with the lowest T-value. Again this was done with ($N = 99$) and without ($N = 42$) bulk and throughfall deposition (in this case the number of usable records is even lower than in the multivariate analysis because at both points in time (first and last relevé) there should be at least three species with a known Ellenberg value). Table 3.4.4-8 gives the result when only EMEP deposition estimates are included, and Table 3.4.4-9 when both bulk, throughfall en EMEP deposition are included. In both cases there is a significant effect of N deposition, even for both EMEP and throughfall when they are included together (in this selection their R is just < 0.5). Both terms influence the change in Ellenberg N in the expected direction i.e. an increase. Note that the large negative value for the 'undetermined' fit is due to interaction effects which have not been explored in this project. Therefore the models (especially of Table 3.4.4-9) should be viewed with some caution. Table 3.4.4-10 gives the analysis for the change in number of species; the EMEP deposition does not significantly contribute to this change.

Table 3.4.4-7: Change in mean Ellenberg indicator value (+ number of species) between the first and last relevé. Only relevés made at intervals of > 6 years were used. Mean = mean value over both observation dates, N = number of observations (i.e., number of plots with Ellenberg value present in both years), Diff = MEAN [(Ellenberg value in last relevé) - (Ellenberg value in first relevé)], T = t-value of difference, P = P-value of difference.

Indicator	Mean	N	Diff	T	P
light (L)	5,0	152	0,016	0,489	0,63
temperature (T)	5,3	113	0,000	0,002	1,00
continentality (K)	3,4	141	-0,023	-0,972	0,33
humidity (F)	5,2	128	0,046	1,648	0,10
acidity (R)	5,5	112	-0,013	-0,287	0,77
nutrients (N)	5,2	122	0,107	2,569	0,01
number of species	11,8	161	1,410	4,742	0,00

Table 3.4.4-8: 'Minimal' model to explain the change in Ellenberg's N using EMEP deposition estimates in the initial 'full' model. TMV = Top Marginal Variance = the drop in explain variance when omitting this term from the model. Significance: the sign is the sign of the regression coefficient, absolute value: 1 = P < 0.05, 2 = P < 0.01, 3 = P < 0.001. N = 99. The negative 'unexplained' variance is due to interaction effects.

Variable	Compart-ment	TMV	signifi-cance
Latitude	climate	7,80%	-2
Fagus	tree	4,19%	-1
mediterr. oak	tree	6,01%	-2
NO3 (1995)	EMEP	8,65%	2
undetermined		-14,50%	
total expl. var.		**12,14%**	

Table 3.4.4-9: 'Minimal' model to explain the change in Ellenberg's N, using throughfall, bulk, calculated and EMEP estimated deposition as terms in the initial 'full' model. Explanation see Table 3.4.4-8. N = 42.

Variable	Compart-ment	TMV	signifi-cance
Ca	organic	7,22	1
N/C	mineral	13,09	-2
Fagus	tree	17,29	-2
mediterr. oak	tree	15,22	-2
Latitude	climate	29,29	-3
NO3	throughfall	12,87	2
NO3 (1995)	EMEP	7,41	1
undetermined		-64,37	
total expl. var.		**38,03**	

Table 3.4.4-10: 'Minimal' model to explain the change in the number of species. EMEP deposition estimates were included in the 'full' model however removed in the selection process because their effect was not significant. N = 133. Further explanation see Table 3.4.4-8.

Variable	Compart-ment	TMV	signifi-cance
K	organic	10,34	3
CEC	mineral	13,14	3
Mediterranean	climate	6,77	-2
undetermined		-9,05	
total expl. var.		**21,2**	

3.4.5 Discussion

In contrast to the previous analysis of De Vries at el. (2002), where the effect of N-deposition was only just significant, there are now clearly significant (sometimes even highly significant) effects of N-deposition. These effects are found both when using EMEP model output and when using measured throughfall (and sometimes bulk deposition) as estimates for deposition. Significant effects of the 'calculated' deposition were not found. Although the effect of deposition on the individual species cannot be clearly defined, the effect on the vegetation as a whole is a shift towards nitrophytic species, which is found irrespective of the estimator for N deposition (modelled or measured). In most cases the effect is due to the deposition of NO_3; effects of NH_4 deposition were not found. This agrees with the analysis of De Vries et al. (2002) who also reported an effect of NO_3. On the basis of the present analysis it is not possible to determine whether bulk or throughfall measurements or the EMEP model yields the 'best' estimates for the 'true' deposition. On average, EMEP estimates seem to be a slightly better predictor for the vegetation than measured deposition, however the difference appears to be small and a real comparison is hampered by the far larger number of plots that have EMEP deposition estimates compared to bulk and throughfall measurements. Also, being a better predictor for the vegetation is not a guarantee for being a better estimator for the true value of the deposition. The present analysis is solely based on a comparison of the spatial patterns of deposition and vegetation, and the absolute values are irrelevant in this type of statistical evaluation.

The conclusion that the composition of the ground vegetation mainly depends upon the traditional factors soil, climate and dominant tree species is not different from the conclusion of De Vries et al. (2002). However, the present study yields clear indications for a small but significant effect of NO_3 deposition. This effect of N deposition is even larger when the change in vegetation is considered instead of the vegetation at a single point in time. It is not possible to determine whether the change in the vegetation coincides with a change in the N deposition itself because the period over which the change was considered is different per plot both in starting point and in length. This is true for both the vegetation data and the measured deposition data, and their periods do not necessarily coincide. Moreover, EMEP simulations were used at only two points in time (1995 and 2000), and the deposition significantly decreased ($P < 0.001$) between these points in time for both N-total, NH_4, NO_3 and SO_4. However, there is no significant trend in measured deposition. The vegetation in the last relevé per plot is best explained by the EMEP simulation for 2000, while the change is better explained by the simulation for 1995 (but note that a better fit for a certain date is caused by differences in the spatial pattern at the two dates and not by the absolute amount of deposition).

It is difficult to indicate the exact nature of the vegetation change induced by N deposition. There were no large changes in single species, but rather small changes occurring over a wide range of species. Therefore the change is only apparent for generalised measures viz. those derived from multivariate statistics, or indicator values. The change is in agreement with the expected change at increasing N availability (increasing Ellenberg-N, increase in some individual nitrophytic species). National studies from France and Switzerland indicate that a shift towards more nitrophilic species is partly due to changes in the forest canopy, induced by storms. Less dense canopies support mineralization processes in the forest soils and thus can increase nitrogen availability.

There is no apparent explanation for the strong increase of the number of species per plot. Possible explanations are (1) N deposition, (2) climate change, and (3) methodological causes. It should be noted that an increase in the number of species is often found in re-evaluations of permanent plots. In this case, N-deposition is rather improbable as a cause because no significant relation with deposition was found. Also climate change is rather improbable as a cause because Ellenberg's temperature indicator did not change at all. The simplest explanation is that in a second visit to the plot the observer has a better knowledge of the species which increases the probability to find extra species. This is particularly true if a list of species that were found previously is taken into the field. However, this explanation fails to explain the significant positive correlation with fertile soil and negative correlation with the Mediterranean.

3.4.6 References

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Annex 3.4.1: List of species and their codes

code	species name
Abiesalb	Abies alba
Abiescep	Abies cephalonica
Abiesgra	Abies grandis
Abiesneb	Abies nebrodensis
Abiespro	Abies procera
Abiessib	Abies sibirica
Acacidea	Acacia dealbata
Acer cam	Acer campestre
Acer mon	Acer monspessulanum
Acer neg	Acer negundo
Acer obt	Acer obtusatum
Acer opa	Acer opalus
Acer pla	Acer platanoides
Acer pse	Acer pseudoplatanus
Acer tat	Acer tataricum
Acer lob	Acer lobelii
Aconilyc	Aconitum lycoctonum
Aconinap	Aconitum napellus
Actaespi	Actaea spicata
Adenocom	Adenocarpus complicatus
Agrimeup	Agrimonia eupatoria
Agrimpro	Agrimonia procera
Ailanalt	Ailanthus altissima
Alchevul	Alchemilla acutiloba
Alchealp	Alchemilla alpina
Alchevul	Alchemilla coriacea
Alchevul	Alchemilla glabra
Alchevul	Alchemilla glaucescens
Alchevul	Alchemilla plicatula
Alchevul	Alchemilla saxatilis
Alchevul	Alchemilla xanthochlora
Alliapet	Alliaria petiolata
Alnuscor	Alnus cordata
Alnusglu	Alnus glutinosa
Alnusinc	Alnus incana
Alnusvir	Alnus viridis
Alyssaly	Alyssum alyssoides
Alyssmin	Alyssum minutum
Alyssmis	Alyssum minus
Alyssser	Alyssum serpyllifolium
Amelalam	Amelanchier grandiflora
Amelaova	Amelanchier ovalis
Amorpfru	Amorpha fruticosa
Anemoape	Anemone apennina
Anemonem	Anemone nemorosa
Anemopal	Anemone palmata
Anemoran	Anemone ranunculoides
Anemotri	Anemone trifolia
Anogrlep	Anogramma leptophylla
Anthycyt	Anthyllis cytisoides
Anthyher	Anthyllis hermanniae
Anthylot	Anthyllis lotoides
Anthytet	Anthyllis tetraphylla
Anthyvul	Anthyllis vulneraria
Aphanmic	Aphanes microcarpa
Aquilalp	Aquilegia alpina
Aquilatr	Aquilegia atrata
Aquilvul	Aquilegia vulgaris
Arabibra	Arabis brassica
Arabicil	Arabis ciliata
Arabicol	Arabis collina
Arabigla	Arabis glabra
Arabihir	Arabis hirsuta
Arabitha	Arabidopsis thaliana
Arabitur	Arabis turrita
Arabiver	Arabis verna
Arceuoxy	Arceuthobium oxycedri
Aremoagr	Aremonia agrimonoides
Arenamon	Arenaria montana
Arenaser	Arenaria serpyllifolia
Argyrzan	Argyrolobium zanonii
Aristbae	Aristolochia baetica
Aristcle	Aristolochia clematitis
Aristelo	Aristolochia elongata
Aristlut	Aristolochia lutea
Aristpal	Aristolochia pallida
Aristpau	Aristolochia paucinervis
Aristpis	Aristolochia pistolochia
Aristrot	Aristolochia rotunda
Aruncdio	Aruncus dioicus
Asarueur	Asarum europaeum
Aspleadi	Asplenium adiantum-nigrum
Asplecet	Asplenium ceterach
Asplefis	Asplenium fissum
Asplefon	Asplenium fontanum
Aspleobo	Asplenium obovatum
Aspleono	Asplenium onopteris
Asplerut	Asplenium ruta-muraria
Asplesco	Asplenium scolopendrium
Asplesep	Asplenium septentrionale
Aspletri	Asplenium trichomanes
Aspletrr	Asplenium trichomanes-ramosum
Astraalp	Astragalus alpinus
Astracic	Astragalus cicer
Astragly	Astragalus glycyphyllos
Astrahis	Astragalus hispanicus
Astrainc	Astragalus incanus
Astralus	Astragalus lusitanicus
Astramon	Astragalus monspessulanus
Astraono	Astragalus onobrychis
Athyrdis	Athyrium distentifolium
Athyrfil	Athyrium filix-femina
Berbecre	Berberis cretica
Berbevul	Berberis vulgaris
Berteinc	Berteroa incana
Betulnan	Betula nana
Betulpen	Betula pendula
Betulpub	Betula pubescens
Biscuaur	Biscutella auriculata
Biscudid	Biscutella didyma
Bisculae	Biscutella laevigata
Bisculyr	Biscutella lyrata
Biscuval	Biscutella valentina
Biserpel	Biserrula pelecinus
Blechspi	Blechnum spicant
Botrylun	Botrychium lunaria
Brassbar	Brassica barrelieri
Bufonper	Bufonia perennis
Calicspi	Calicotome spinosa
Calthpal	Caltha palustris
Cannasat	Cannabis sativa
Cappaspi	Capparis spinosa
Capsebur	Capsella bursa-pastoris
Cardaama	Cardamine amara
Cardaare	Cardaminopsis arenosa
Cardabul	Cardamine bulbifera
Cardache	Cardamine chelidonia
Cardadra	Cardaria draba
Cardaenn	Cardamine enneaphyllos
Cardafle	Cardamine flexuosa
Cardagla	Cardamine glanduligera
Cardagra	Cardamine graeca
Cardahal	Cardaminopsis halleri
Cardahep	Cardamine heptaphylla
Cardahir	Cardamine hirsuta
Cardaimp	Cardamine impatiens
Cardakit	Cardamine kitaibelii
Cardamon	Cardamine monteluccii
Cardapen	Cardamine pentaphyllos
Cardapra	Cardamine pratensis
Cardatri	Cardamine trifolia
Carpibet	Carpinus betulus
Castasat	Castanea sativa
Cerasarv	Cerastium arvense
Cerasbra	Cerastium brachypetalum
Cerascer	Cerastium cerastoides
Cerasfon	Cerastium fontanum
Cerasglo	Cerastium glomeratum
Cerasgra	Cerastium gracile
Cerasill	Cerastium illyricum
Ceraspum	Cerastium pumilum

Cerassyl	Cerastium sylvaticum
Ceratcla	Ceratocapnos claviculata
Cercisil	Cercis siliquastrum
Chamaaus	Chamaecytisus austriacus
Chamacil	Chamaecytisus ciliatus
Chamahir	Chamaecytisus hirsutus
Chamalaw	Chamaecyparis lawsoniana
Chamarat	Chamaecytisus ratisbonensis
Chamasag	Chamaespartium sagittale
Chamasup	Chamaecytisus supinus
Chamatri	Chamaespartium tridentatum
Cheilmad	Cheilanthes maderensis
Chelimaj	Chelidonium majus
Chenoalb	Chenopodium album
Chenobon	Chenopodium bonus-henricus
Chenoche	Chenopodium chenopodioides
Chenohyb	Chenopodium hybridum
Chrysalt	Chrysosplenium alternifolium
Chrysopp	Chrysosplenium oppositifolium
Clemaalp	Clematis alpina
Clemafla	Clematis flammula
Clemarec	Clematis recta
Clemavit	Clematis vitalba
Clemavtc	Clematis viticella
Clypejon	Clypeola jonthlaspi
Cneortri	Cneorum tricoccon
Coincmon	Coincya monensis
Colutarb	Colutea arborescens
Coroneme	Coronilla emerus
Coronmin	Coronilla minima
Coronrep	Coronilla repanda
Coronsco	Coronilla scorpioides
Coronval	Coronilla valentina
Coronvar	Coronilla varia
Corrilit	Corrigiola litoralis
Corydcav	Corydalis cava
Corydsol	Corydalis solida
Corylave	Corylus avellana
Cotonhor	Cotoneaster horizontalis
Cotonint	Cotoneaster integerrimus
Cotonneb	Cotoneaster nebrodensis
Cotonnig	Cotoneaster niger
Cratacal	Crataegus calycina
Cratalae	Crataegus laevigata
Cratamac	Crataegus macrocarpa
Cratamon	Crataegus monogyna
Crataucr	Crataegus ucrainica
Cryptcri	Cryptogramma crispa
Cucubbac	Cucubalus baccifer
Cystofra	Cystopteris fragilis
Cystomon	Cystopteris montana
Cytinhyp	Cytinus hypocistis
Cytiscan	Cytisus cantabricus
Cytisgra	Cytisus grandiflorus
Cytismal	Cytisus malacitanus
Cytismul	Cytisus multiflorus
Cytispur	Cytisus purgans
Cytisrev	Cytisus reverchonii
Cytissco	Cytisus scoparius
Cytisses	Cytisus sessilifolius
Cytisstr	Cytisus striatus
Cytisvil	Cytisus villosus
Diantare	Dianthus arenarius
Diantarm	Dianthus armeria
Diantcar	Dianthus carthusianorum
Diantmon	Dianthus monspessulanus
Dictaalb	Dictamnus albus
Diphacom	Diphasiastrum complanatum
Diplocat	Diplotaxis catholica
Dorychir	Dorycnium hirsutum
Dorycpen	Dorycnium pentaphyllum
Drabamur	Draba muralis
Droserot	Drosera rotundifolia
Dryopaff	Dryopteris affinis
Dryopcar	Dryopteris carthusiana
Dryopcri	Dryopteris cristata
Dryopdil	Dryopteris dilatata
Dryopexp	Dryopteris expansa
Dryopfil	Dryopteris filix-mas
Dryoprem	Dryopteris remota
Ephedfra	Ephedra fragilis
Equisarv	Equisetum arvense
Equispal	Equisetum palustre
Equispra	Equisetum pratense
Equisram	Equisetum ramosissimum
Equissyl	Equisetum sylvaticum
Equistel	Equisetum telmateia
Erinaant	Erinacea anthyllis
Erodicic	Erodium cicutarium
Erophver	Erophila verna
Erucanas	Erucastrum nasturtiifolium
Erysidif	Erysimum diffusum
Erysinev	Erysimum nevadense
Euphoamy	Euphorbia amygdaloides
Euphocar	Euphorbia carniolica
Euphocha	Euphorbia characias
Euphocor	Euphorbia corallioides
Euphocyp	Euphorbia cyparissias
Euphodul	Euphorbia dulcis
Euphoesu	Euphorbia esula
Euphoexi	Euphorbia exigua
Euphohel	Euphorbia helioscopia
Euphohyb	Euphorbia hyberna
Euphonic	Euphorbia nicaeensis
Euphopep	Euphorbia peplus
Euphopla	Euphorbia platyphyllos
Euphopol	Euphorbia polygalifolia
Euphoser	Euphorbia serrulata
Fagussyl	Fagus sylvatica
Fallocon	Fallopia convolvulus
Fallodum	Fallopia dumetorum
Filipulm	Filipendula ulmaria
Filipvul	Filipendula vulgaris
Fragamos	Fragaria moschata
Fragaves	Fragaria vesca
Fragavir	Fragaria viridis
Fumaroff	Fumaria officinalis
Fumarsch	Fumaria schleicheri
Genisang	Genista anglica
Genisfal	Genista falcata
Genisflo	Genista florida
Genisger	Genista germanica
Genishir	Genista hirsuta
Genishis	Genista hispanica
Genispil	Genista pilosa
Genissco	Genista scorpius
Genistin	Genista tinctoria
Genistou	Genista tournefortii
Genistri	Genista triacanthos
Genisumb	Genista umbellata
Gerancol	Geranium columbinum
Gerandis	Geranium dissectum
Geranluc	Geranium lucidum
Geranmol	Geranium molle
Gerannod	Geranium nodosum
Geranpha	Geranium phaeum
Geranpur	Geranium purpureum
Geranrob	Geranium robertianum
Geransan	Geranium sanguineum
Geransyl	Geranium sylvaticum
Gerantub	Geranium tuberosum
Geranver	Geranium versicolor
Geum mon	Geum montanum
Geum riv	Geum rivale
Geum syl	Geum sylvaticum
Geum urb	Geum urbanum
Gleditri	Gleditsia triacanthos
Gymnodry	Gymnocarpium dryopteris
Gymnorob	Gymnocarpium robertianum
Gypsofas	Gypsophila fastigiata
Gypsorep	Gypsophila repens

Helleboc	Helleborus bocconei	Lenserv	Lens ervoides	Moehrtri	Moehringia trinervia
Hellefoe	Helleborus foetidus	Lepidcar	Lepidium cardamines	Moencere	Moenchia erecta
Hellemul	Helleborus multifidus	Lepidhet	Lepidium heterophyllum	Morusalb	Morus alba
Hellenig	Helleborus niger	Lepidhir	Lepidium hirtum	Myosoaqu	Myosoton aquaticum
Helleodo	Helleborus odorus	Linumbie	Linum bienne	Myricfay	Myrica faya
Hellevir	Helleborus viridis	Linumcat	Linum catharticum	Neototor	Neotorularia torulosa
Hepatnob	Hepatica nobilis	Linumnar	Linum narbonense	Ononifru	Ononis fruticosa
Hernihir	Herniaria hirsuta	Linumsuf	Linum suffruticosum	Ononinat	Ononis natrix
Hernilus	Herniaria lusitanica	Linumtri	Linum trigynum	Ononipus	Ononis pusilla
Hespemat	Hesperis matronalis	Loeflbae	Loeflingia baetica	Ononirec	Ononis reclinata
Hippocil	Hippocrepis ciliata	Lotusalp	Lotus alpinus	Ononispi	Ononis spinosa
Hippocom	Hippocrepis comosa	Lotusang	Lotus angustissimus	Oreoplim	Oreopteris limbosperma
Holosumb	Holosteum umbellatum	Lotuscon	Lotus conimbricensis	Ornitcom	Ornithopus compressus
Hornupet	Hornungia petraea	Lotuscor	Lotus corniculatus	Ornitper	Ornithopus perpusillus
Humullup	Humulus lupulus	Lotusdel	Lotus delortii	Ornitpin	Ornithopus pinnatus
Hupersel	Huperzia selago	Lotusgla	Lotus glareosus	Osmunreg	Osmunda regalis
Hymencir	Hymenocarpos circinnatus	Lotusped	Lotus pedunculatus	Ostrycar	Ostrya carpinifolia
Ibericil	Iberis ciliata	Lotussub	Lotus subbiflorus	Osyrialb	Osyris alba
Ilex aqu	Ilex aquifolium	Lotusuli	Lotus uliginosus	Oxaliace	Oxalis acetosella
Impatgla	Impatiens glandulifera	Lunarred	Lunaria rediviva	Paeonbro	Paeonia broteroi
Impatnol	Impatiens noli-tangere	Lupinang	Lupinus angustifolius	Paeonmas	Paeonia mascula
Impatpar	Impatiens parviflora	Lupinlut	Lupinus luteus	Paeonoff	Paeonia officinalis
Isopytha	Isopyrum thalictroides	Lupinpol	Lupinus polyphyllus	Pariejud	Parietaria judaica
Juglareg	Juglans regia	Lychncor	Lychnis coronaria	Parnapal	Parnassia palustris
Junipcom	Juniperus communis	Lychnflj	Lychnis flos-jovis	Paroncym	Paronychia cymosa
Junipnav	Juniperus navicularis	Lychnflo	Lychnis flos-cuculi	Perseind	Persea indica
Junipoxy	Juniperus oxycedrus	Lychnvis	Lychnis viscaria	Petronan	Petrorhagia nanteuilii
Junippho	Juniperus phoenicea	Lycopann	Lycopodium annotinum	Petrovel	Petrorhagia velutina
Junipsab	Juniperus sabina	Lycopcla	Lycopodium clavatum	Phegocon	Phegopteris connectilis
Junipthu	Juniperus thurifera	Lygossph	Lygos sphaerocarpa	Philacor	Philadelphus coronarius
Kalidfol	Kalidium foliatum	Mahonaqu	Mahonia aquifolium	Phytoame	Phytolacca americana
Laburalp	Laburnum alpinum	Malcolac	Malcolmia lacera	Piceaabi	Picea abies
Laburana	Laburnum anagyroides	Malusdom	Malus domestica	Piceaori	Picea orientalis
Larixdec	Larix decidua	Malussyl	Malus sylvestris	Piceapun	Picea pungens
Larixkae	Larix kaempferi	Mattestr	Matteuccia struthiopteris	Piceasit	Picea sitchensis
Lathyang	Lathyrus angulatus	Mediclup	Medicago lupulina	Pinuscan	Pinus canariensis
Lathyann	Lathyrus annuus	Medicmin	Medicago minima	Pinuscem	Pinus cembra
Lathyaph	Lathyrus aphaca	Medicpol	Medicago polymorpha	Pinuscon	Pinus contorta
Lathylax	Lathyrus laxiflorus	Medicpra	Medicago praecox	Pinushal	Pinus halepensis
Lathymon	Lathyrus montanus	Medicsuf	Medicago suffruticosa	Pinusmug	Pinus mugo
Lathynig	Lathyrus niger	Meliloff	Melilotus officinalis	Pinusnig	Pinus nigra
Lathypal	Lathyrus palustris	Mercuann	Mercurialis annua	Pinuspea	Pinus pinea
Lathypra	Lathyrus pratensis	Mercuova	Mercurialis ovata	Pinuspin	Pinus pinaster
Lathysph	Lathyrus sphaericus	Mercuper	Mercurialis perennis	Pinusrad	Pinus radiata
Lathysyl	Lathyrus sylvestris	Mespiger	Mespilus germanica	Pinusstr	Pinus strobus
Lathytub	Lathyrus tuberosus	Minuahir	Minuartia hirsuta	Pinussyl	Pinus sylvestris
Lathyven	Lathyrus venetus	Minuahyb	Minuartia hybrida	Pinusunc	Pinus uncinata
Lathyver	Lathyrus vernus	Minualar	Minuartia laricifolia	Pistalen	Pistacia lentiscus
Lauruazo	Laurus azorica	Minuaver	Minuartia verna	Pistater	Pistacia terebinthus
Laurunob	Laurus nobilis	Moehrmus	Moehringia muscosa	Polyctet	Polycarpon tetraphyllum
Lembonig	Lembotropis nigricans	Moehrpen	Moehringia pentandra	Polygalp	Polygala alpestris

Polygavi	Polygonum aviculare
Polygbis	Polygonum bistorta
Polygcal	Polygala calcarea
Polygcha	Polygala chamaebuxus
Polyghyd	Polygonum hydropiper
Polyglon	Polygonum longipes
Polygmic	Polygala microphylla
Polygmin	Polygonum minus
Polygmit	Polygonum mite
Polygper	Polygonum persicaria
Polygrup	Polygala rupestris
Polygsco	Polygonum scoparium
Polygser	Polygala serpyllifolia
Polygviv	Polygonum viviparum
Polygvul	Polygala vulgaris
Polypcam	Polypodium cambricum
Polypint	Polypodium interjectum
Polypmac	Polypodium macaronesicum
Polypvul	Polypodium vulgare
Polysacu	Polystichum aculeatum
Polysbra	Polystichum braunii
Polyslon	Polystichum lonchitis
Polysset	Polystichum setiferum
Populalb	Populus alba
Populnig	Populus nigra
Popultre	Populus tremula
Populxcc	Populus x canadensis
Populxcd	Populus x canescens
Potenalb	Potentilla alba
Potenang	Potentilla anglica
Potenarg	Potentilla argentea
Potenaur	Potentilla aurea
Potencin	Potentilla cinerea
Potencra	Potentilla crantzii
Potenere	Potentilla erecta
Potengra	Potentilla grandiflora
Potenmic	Potentilla micrantha
Potenmon	Potentilla montana
Potenpal	Potentilla palustris
Potenrec	Potentilla recta
Potenrep	Potentilla reptans
Potenste	Potentilla sterilis
Potentab	Potentilla tabernaemontani
Prunuavi	Prunus avium
Prunucer	Prunus cerasus
Prunucrf	Prunus cerasifera
Prunudul	Prunus dulcis
Prunufru	Prunus fruticosa
Prunulau	Prunus laurocerasus
Prunumah	Prunus mahaleb
Prunupad	Prunus padus
Prunuser	Prunus serotina
Prunuspi	Prunus spinosa
Pseudeur	Pseudostellaria europaea
Pseudmen	Pseudotsuga menziesii
Psorabit	Psoralea bituminosa
Pteriaqu	Pteridium aquilinum
Pulsaalp	Pulsatilla alpina
Pulsamon	Pulsatilla montana
Pulsapra	Pulsatilla pratensis
Pulsaver	Pulsatilla vernalis
Pyraccoc	Pyracantha coccinea
Pyrusamy	Pyrus amygdaliformis
Pyrusbou	Pyrus bourgaeana
Pyruscom	Pyrus communis
Pyruscor	Pyrus cordata
Pyruspyr	Pyrus pyraster
Querccer	Quercus cerris
Quercoc	Quercus coccifera
Quercdal	Quercus dalechampii
Quercfag	Quercus faginea
Quercfra	Quercus frainetto
Quercile	Quercus ilex
Querclus	Quercus lusitanica
Quercpal	Quercus palustris
Quercped	Quercus pedunculiflora
Quercpet	Quercus petraea
Quercpub	Quercus pubescens
Quercpyr	Quercus pyrenaica
Quercrob	Quercus robur
Quercrub	Quercus rubra
Quercsub	Quercus suber
Ranunaco	Ranunculus aconitifolius
Ranunacr	Ranunculus acris
Ranunadu	Ranunculus aduncus
Ranunaur	Ranunculus auricomus
Ranunbul	Ranunculus bulbosus
Ranuncas	Ranunculus cassubicus
Ranunfic	Ranunculus ficaria
Ranungra	Ranunculus gramineus
Ranungre	Ranunculus gregarius
Ranunlan	Ranunculus lanuginosus
Ranunlin	Ranunculus lingua
Ranunmil	Ranunculus millefoliatus
Ranunmon	Ranunculus montanus
Ranunnig	Ranunculus nigrescens
Ranunoll	Ranunculus ollissiponensis
Ranunpal	Ranunculus paludosus
Ranunpla	Ranunculus platanifolius
Ranunpol	Ranunculus polyanthemos
Ranunpyr	Ranunculus pyrenaeus
Ranunrep	Ranunculus repens
Ranunrpt	Ranunculus reptans
Ranunser	Ranunculus serpens
Ranunspr	Ranunculus sprunerianus
Rapharap	Raphanus raphanistrum
Rhodiros	Rhodiola rosea
Ribesalp	Ribes alpinum
Ribesnig	Ribes nigrum
Ribespet	Ribes petraeum
Ribesrub	Ribes rubrum
Ribesspi	Ribes spicatum
Ribesuva	Ribes uva-crispa
Robinpse	Robinia pseudacacia
Rosa agr	Rosa agrestis
Rosa arv	Rosa arvensis
Rosa can	Rosa canina
Rosa ell	Rosa elliptica
Rosa mic	Rosa micrantha
Rosa pen	Rosa pendulina
Rosa pim	Rosa pimpinellifolia
Rosa pou	Rosa pouzinii
Rosa rub	Rosa rubiginosa
Rosa sem	Rosa sempervirens
Rosa sty	Rosa stylosa
Rosa vil	Rosa villosa
Rosamon	Rosa montana
Rubusarc	Rubus arcticus
Rubusfru	Rubus bifrons
Rubuscae	Rubus caesius
Rubusfru	Rubus canescens
Rubuscha	Rubus chamaemorus
Rubusfru	Rubus divaricatus
Rubusfru	Rubus glandulosus
Rubusfru	Rubus hirtus
Rubusida	Rubus idaeus
Rubusfru	Rubus nessensis
Rubuspho	Rubus phoenicolasius
Rubusfru	Rubus plicatus
Rubussax	Rubus saxatilis
Rubusfru	Rubus silvaticus
Rubusfru	Rubus sulcatus
Rubusfru	Rubus ulmifolius
Rumexace	Rumex acetosa
Rumexact	Rumex acetosella
Rumexalp	Rumex alpinus
Rumexals	Rumex alpestris
Rumexbuc	Rumex bucephalophorus
Rumexcon	Rumex conglomeratus
Rumexhyd	Rumex hydrolapathum
Rumexobt	Rumex obtusifolius
Rumexpul	Rumex pulcher
Rumexsan	Rumex sanguineus

Rumexscu	Rumex scutatus
Salixalb	Salix alba
Salixapp	Salix appendiculata
Salixatr	Salix atrocinerea
Salixaur	Salix aurita
Salixcap	Salix caprea
Salixcin	Salix cinerea
Salixmyr	Salix myrsinifolia
Salixphy	Salix phylicifolia
Salixrep	Salix repens
Salixsta	Salix starkeana
Salsokal	Salsola kali
Sangumin	Sanguisorba minor
Sanguoff	Sanguisorba officinalis
Saponocy	Saponaria ocymoides
Saponoff	Saponaria officinalis
Saxifcar	Saxifraga carpetana
Saxifcun	Saxifraga cuneifolia
Saxifexa	Saxifraga exarata
Saxifgra	Saxifraga granulata
Saxifpan	Saxifraga paniculata
Saxifrot	Saxifraga rotundifolia
Saxifste	Saxifraga stellaris
Sclerann	Scleranthus annuus
Scorpmur	Scorpiurus muricatus
Scorpver	Scorpiurus vermiculatus
Sedumalb	Sedum album
Sedumamp	Sedum amplexicaule
Sedumana	Sedum anacampseros
Sedumand	Sedum andegavense
Sedumann	Sedum annuum
Sedumare	Sedum arenarium
Sedumcep	Sedum cepaea
Sedumhis	Sedum hispanicum
Sedummon	Sedum montanum
Sedumsed	Sedum sediforme
Sedumtel	Sedum telephium
Selagden	Selaginella denticulata
Selagsel	Selaginella selaginoides
Sempemon	Sempervivum montanum
Sempetec	Sempervivum tectorum
Sequosem	Sequoia sempervirens
Sesampur	Sesamoides purpurascens
Silenalp	Silene alpestris
Silencol	Silene colorata
Silencon	Silene conica
Silendio	Silene dioica
Silengal	Silene gallica
Silenita	Silene italica
Silenlat	Silene latifolia
Silenmul	Silene multicaulis
Silennut	Silene nutans
Silenoti	Silene otites
Silenpor	Silene portensis
Silenrup	Silene rupestris
Silensca	Silene scabriflora
Silenvir	Silene viridiflora
Silenvis	Silene viscosa
Silenvul	Silene vulgaris
Sisymiri	Sisymbrium irio
Sisymori	Sisymbrium orientale
Sorbuari	Sorbus aria
Sorbuauc	Sorbus aucuparia
Sorbucha	Sorbus chamaemespilus
Sorbudom	Sorbus domestica
Sorbuint	Sorbus intermedia
Sorbumou	Sorbus mougeotii
Sorbutor	Sorbus torminalis
Spiracha	Spiraea chamaedryfolia
Spirahyp	Spiraea hypericifolia
Staurgen	Stauracanthus genistoides
Stellgra	Stellaria graminea
Stellhol	Stellaria holostea
Stelllnf	Stellaria longifolia
Stelllnp	Stellaria longipes
Stellmed	Stellaria media
Stellneg	Stellaria neglecta
Stellnem	Stellaria nemorum
Stellpal	Stellaria palustris
Stelluli	Stellaria uliginosa
Taxusbac	Taxus baccata
Teesdcor	Teesdalia coronopifolia
Teesdnud	Teesdalia nudicaulis
Thaliaqu	Thalictrum aquilegiifolium
Thalical	Thalictrum calabricum
Thalifoe	Thalictrum foetidum
Thaliluc	Thalictrum lucidum
Thalimin	Thalictrum minus
Thalitub	Thalictrum tuberosum
Thesialp	Thesium alpinum
Thesihum	Thesium humifusum
Thlasarv	Thlaspi arvense
Thlasper	Thlaspi perfoliatum
Tributer	Tribulus terrestris
Trifoalp	Trifolium alpinum
Trifoang	Trifolium angustifolium
Trifoaps	Trifolium alpestre
Trifoarv	Trifolium arvense
Trifoaur	Trifolium aureum
Trifobad	Trifolium badium
Trifoboc	Trifolium bocconei
Trifocam	Trifolium campestre
Trifoche	Trifolium cherleri
Trifogem	Trifolium gemellum
Trifoglo	Trifolium glomeratum
Trifohir	Trifolium hirtum
Trifohyb	Trifolium hybridum
Trifoleu	Trifolium leucanthum
Trifolig	Trifolium ligusticum
Trifomed	Trifolium medium
Trifomon	Trifolium montanum
Trifooch	Trifolium ochroleucon
Trifopra	Trifolium pratense
Triforep	Trifolium repens
Triforub	Trifolium rubens
Trifosca	Trifolium scabrum
Trifoste	Trifolium stellatum
Trifosub	Trifolium subterraneum
Trifosuf	Trifolium suffocatum
Trifotom	Trifolium tomentosum
Trolleur	Trollius europaeus
Tsugahet	Tsuga heterophylla
Ulex gal	Ulex gallii
Ulex min	Ulex minor
Ulex par	Ulex parviflorus
Ulmuscan	Ulmus canescens
Ulmusgla	Ulmus glabra
Ulmuslae	Ulmus laevis
Ulmusmin	Ulmus minor
Ulmuspro	Ulmus procera
Umbilhor	Umbilicus horizontalis
Umbilrup	Umbilicus rupestris
Urticdio	Urtica dioica
Urticure	Urtica urens
Viciacas	Vicia cassubica
Viciacra	Vicia cracca
Viciacre	Vicia cretica
Viciadis	Vicia disperma
Viciadum	Vicia dumetorum
Viciaerv	Vicia ervilia
Viciahir	Vicia hirsuta
Viciainc	Vicia incana
Vicialat	Vicia lathyroides
Vicialut	Vicia lutea
Viciaono	Vicia onobrychioides
Viciaord	Vicia oroboides
Viciaoro	Vicia orobus
Viciaper	Vicia peregrina
Viciapis	Vicia pisiformis
Viciapyr	Vicia pyrenaica
Viciasat	Vicia sativa
Viciasep	Vicia sepium
Viciasyl	Vicia sylvatica

Viciaten	Vicia tenuifolia
Viciatet	Vicia tetrasperma
Viscualb	Viscum album

Annex 3.4.2: Correlation coefficients for measured and modelled deposition

Coefficiants between EMEP deposition estimates for 1995 and measured bulk and throughfall deposition and (N = 265). Corresponding ions are in bold.

element	source	NH4	NO3	N-total	S
NH4	bulk	**0.59**	0.62	0.64	0.61
NO3	bulk	0.46	**0.66**	0.57	0.42
Ntot	bulk	0.53	0.62	**0.60**	0.53
SO4	bulk	0.36	0.60	0.48	**0.54**
NH4	throughfall	**0.74**	0.83	0.82	0.63
NO3	throughfall	0.49	**0.61**	0.57	0.38
Ntot	throughfall	0.70	0.73	**0.76**	0.56
SO4	throughfall	0.39	0.55	0.47	**0.59**
NH4	calculated	**0.62**	0.66	0.68	0.51
NO3	calculated	0.45	**0.61**	0.54	0.33
Ntot	calculated	0.57	0.67	**0.64**	0.45

Annex 3.4.3: Full correlation matrix

Matrix for the explanatory variables used in the CCA analysis of the last relevé per plot, after accounting for the effect of the countries. Values > 0.5 are in bold. N = 477

		soil organic layer					
		pH	N/C	Ca	K	Mg	P
soil organic layer	pH	**1.00**					
	N/C	-0.02	**1.00**				
	Ca	**0.56**	0.05	**1.00**			
	K	0.35	0.20	0.28	**1.00**		
	Mg	0.47	0.10	0.45	**0.61**	**1.00**	
	P	0.14	0.18	0.20	0.38	0.30	**1.00**
soil mineral layer	pH	**0.61**	-0.16	0.41	0.10	0.26	-0.07
	N/C	0.30	0.15	0.30	0.40	0.36	0.19
	CEC	0.35	0.18	0.31	0.40	0.49	0.20
	Bsat	**0.69**	-0.06	0.48	0.17	0.34	-0.03
	Age	0.06	0.01	0.04	0.10	0.09	0.18
	Altitude	0.06	0.07	0.03	0.29	0.09	0.22
	Lat	-0.11	-0.23	-0.14	-0.22	-0.14	-0.05
	Lon	0.28	-0.14	0.06	0.17	0.05	0.06
EMEP deposition estimates	N-tot(95)	-0.15	0.07	-0.06	-0.10	-0.10	-0.03
	N-tot(00)	-0.19	0.08	-0.06	-0.14	-0.10	-0.04
	NH4(95)	-0.16	0.03	-0.08	-0.08	-0.06	-0.04
	HH4(00)	-0.19	0.04	-0.08	-0.12	-0.07	-0.04
	NO3(95)	-0.05	0.12	0.01	-0.07	-0.13	-0.01
	NO3(00)	-0.10	0.13	0.01	-0.10	-0.11	-0.02
Tree layer	conf	-0.05	0.02	0.00	0.04	0.10	0.07
	deci	0.12	0.13	0.13	0.03	0.02	0.06
	Fagus	0.28	0.02	0.19	0.13	0.18	0.16
	Picea	-0.18	0.04	-0.04	0.12	0.12	0.08
	Pinus	-0.26	-0.15	-0.27	-0.37	-0.47	-0.42
	QurcMed	0.23	0.01	0.12	0.05	0.04	-0.11
	QurcTem	0.12	0.06	0.10	0.13	0.16	0.23
Climate zones	AN	-0.14	0.11	-0.14	-0.17	-0.14	-0.10
	AS	-0.08	0.00	0.02	-0.07	-0.02	-0.06
	B	0.03	-0.05	0.03	0.06	0.01	0.02
	BT	0.00	-0.02	-0.01	-0.03	0.03	-0.03
	M	0.03	0.03	0.04	0.12	0.20	0.03
	SA	0.15	-0.10	0.07	0.09	-0.04	0.11
		pH_org	N_C_org	Ca_org	K_org	Mg_org	P_org

		soil mineral layer				other			
		pH	N/C	CEC	Bsat	Age	Altitude	Lat	Lon
soil organic layer	pH								
	N/C								
	Ca								
	K								
	Mg								
	P								
soil mineral layer	pH	**1.00**							
	N/C	0.18	**1.00**						
	CEC	0.40	0.35	**1.00**					
	Bsat	**0.78**	0.31	0.50	**1.00**				
	Age	-0.04	0.01	0.07	-0.05	**1.00**			
	Altitude	0.01	0.09	0.26	-0.01	0.12	**1.00**		
	Lat	-0.02	-0.23	-0.24	-0.12	0.01	-0.38	**1.00**	
	Lon	0.27	0.05	0.10	0.29	0.01	0.34	-0.02	**1.00**
EMEP deposition estimates	N-tot (95)	-0.17	-0.04	-0.05	-0.21	-0.03	-0.21	0.08	-0.33
	N-tot (00)	-0.21	-0.09	-0.10	-0.26	-0.04	-0.27	0.08	-0.44
	NH4 (95)	-0.17	-0.01	-0.04	-0.19	-0.09	-0.15	0.04	-0.27
	HH4 (00)	-0.20	-0.05	-0.08	-0.23	-0.09	-0.19	0.05	-0.36
	NO3 (95)	-0.09	-0.07	-0.04	-0.14	0.09	-0.20	0.10	-0.27
	NO3 (00)	-0.13	-0.12	-0.09	-0.19	0.09	-0.30	0.09	-0.38
Tree layer	conf	-0.01	0.00	0.09	0.04	-0.13	0.15	-0.16	0.06
	deci	0.08	0.10	0.03	0.14	-0.08	-0.16	0.04	0.02
	Fagus	0.25	0.08	0.25	0.15	0.24	0.08	0.05	-0.05
	Picea	-0.10	0.08	0.24	-0.08	-0.02	0.25	-0.12	0.03
	Pinus	0.01	-0.21	-0.37	-0.05	-0.28	-0.20	0.12	0.08
	Qurc Med	0.14	0.05	0.00	0.11	-0.12	0.01	-0.08	0.02
	Qurc Tem	-0.21	0.05	-0.10	-0.10	0.25	-0.14	0.05	-0.12
Climate zones	AN	-0.22	-0.12	-0.21	-0.25	-0.01	-0.31	0.19	-0.31
	AS	-0.15	0.04	-0.12	-0.13	-0.07	-0.06	-0.24	-0.24
	B	0.04	0.04	0.01	0.06	0.02	-0.02	0.27	0.12
	BT	-0.02	-0.03	0.00	-0.02	-0.07	0.03	-0.13	-0.05
	M	0.13	0.03	0.17	0.17	0.04	0.20	-0.29	0.12
	SA	0.19	0.05	0.14	0.16	0.04	0.16	0.17	0.32
		pH_min	N_C_min	CEC	Bsat	Age	Altitude	Lat	Lon

		EMEP Deposition					
		N-tot (95)	N-tot (00)	NH4 (95)	HH4 (00)	NO3 (95)	NO3 (00)
soil organic layer	pH						
	N/C						
	Ca						
	K						
	Mg						
	P						
soil mineral layer	pH						
	N/C						
	CEC						
	Bsat						
	Age						
	Altitude						
	Lat						
	Lon						
EMEP deposition estimates	N-tot (95)	**1.00**					
	N-tot(00)	**0.96**	**1.00**				
	NH4(95)	**0.91**	**0.88**	**1.00**			
	HH4(00)	**0.90**	**0.92**	**0.98**	**1.00**		
	NO3(95)	**0.62**	**0.58**	0.24	0.26	**1.00**	
	NO3 (00)	**0.61**	**0.65**	0.25	0.31	**0.94**	**1.00**
Tree layer	conf	-0.15	-0.12	-0.08	-0.08	-0.19	-0.15
	deci	0.00	0.01	-0.01	0.01	0.00	0.01
	Fagus	-0.01	0.00	-0.06	-0.05	0.09	0.10
	Picea	-0.06	-0.10	-0.01	-0.05	-0.13	-0.16
	Pinus	0.05	0.05	0.09	0.09	-0.05	-0.04
	Qurc Med	-0.01	-0.04	-0.08	-0.09	0.13	0.08
	Qurc Tem	0.11	0.13	0.05	0.07	0.17	0.18
Climate zones	AN	0.48	**0.51**	0.38	0.41	0.41	0.45
	AS	-0.17	-0.05	-0.07	0.00	-0.27	-0.12
	B	-0.19	-0.20	-0.09	-0.10	-0.28	-0.31
	BT	0.06	0.06	0.03	0.03	0.08	0.09
	M	-0.21	-0.20	-0.12	-0.13	-0.26	-0.24
	SA	-0.10	-0.20	-0.18	-0.23	0.11	-0.03
		Ndep95	Ndep00	NH4dep95	NH4dep00	NO3dep95	NO3dep00

		Tree layer						
		conf	deci	Fagus	Picea	Pinus	Qurc Med	Qurc Tem
soil organic layer	pH							
	N/C							
	Ca							
	K							
	Mg							
	P							
soil mineral layer	pH							
	N/C							
	CEC							
	Bsat							
	Age							
	Altitude							
	Lat							
	Lon							
EMEP deposition estimates	N-tot (95)							
	N-tot (00)							
	NH4 (95)							
	HH4 (00)							
	NO3 (95)							
	NO3 (00)							
Tree layer	conf	**1.00**						
	deci	0.00	**1.00**					
	Fagus	-0.15	-0.06	**1.00**				
	Picea	-0.09	-0.13	-0.21	**1.00**			
	Pinus	-0.10	0.00	-0.30	-0.42	**1.00**		
	Qurc Med	-0.06	-0.10	-0.11	-0.12	-0.02	**1.00**	
	Qurc Tem	-0.29	-0.01	-0.24	-0.15	-0.38	-0.05	**1.00**
Climate zones	AN	-0.14	0.00	0.04	-0.16	0.09	0.00	0.09
	AS	-0.03	0.00	-0.03	-0.02	-0.04	-0.05	0.13
	B	0.00	0.00	-0.03	0.08	0.00	0.00	-0.04
	BT	0.00	0.00	-0.03	0.00	0.03	0.00	0.00
	M	0.22	0.00	-0.13	0.16	0.01	0.05	-0.19
	SA	-0.03	0.00	0.11	0.00	-0.07	0.00	0.00
		Boo_conf	Boo_deci	Boo_Fags	Boo_Pice	Boo_Pins	Boo_QurM	Boo_Qurp

		Climate zones					
		AN	AS	B	BT	M	SA
soil organic layer	pH						
	N/C						
	Ca						
	K						
	Mg						
	P						
soil mineral layer	pH						
	N/C						
	CEC						
	Bsat						
	Age						
	Altitude						
	Lat						
	Lon						
EMEP deposition estimates	N-tot (95)						
	N-tot (00)						
	NH4 (95)						
	HH4 (00)						
	NO3 (95)						
	NO3 (00)						
Tree layer	conf						
	deci						
	Fagus						
	Picea						
	Pinus						
	Qurc Med						
	Qurc Tem						
Climate zones	AN	**1.00**					
	AS	-0.19	**1.00**				
	B	-0.17	0.00	**1.00**			
	BT	-0.15	0.00	**-0.65**	**1.00**		
	M	-0.18	-0.30	0.00	0.00	**1.00**	
	SA	-0.49	-0.30	0.00	0.00	-0.43	**1.00**
		Kli_AN	Kli_AS	Kli_B	Kli_BT	Kli_M	

4. National Survey Reports in 2009

4.1 Andorra

The 2009 crown condition survey in Andorra was conducted on 3 plots of the Level I 16 x 16 km transnational grid. This was the 5th survey undertaken in Andorra which included 73 trees, 43 *Pinus sylvestris* and 30 *Pinus uncinata*.

Results obtained in 2009 show a slight improving tendency in forest condition as already noticed in 2008. The majority of trees are classified in defoliation and discolouration classes 0 and 1.

Related to defoliation, an important increase of not defoliated trees was registered from 29.2% in 2008 to 60.3% in 2009. The number of slightly defoliated trees decreased (from 55.6% in 2008 to 32.9% in 2009). The share of moderately defoliated trees decreased to 5.5%. One dead tree was identified.

Results for discolouration show a significant increase in discolouration class 0 from 16.7% in 2008 to 67.1% in 2009, mainly caused by an important decrease in the slight discolouration class. The number of moderately and severely discoloured trees also decreased and achieved only the 2.7% of the trees.

In 2009, the assessment of damage causes showed, as in previous surveys, that the main causal agent was the fungus *Cronartium flaccidum* which affected 8% of the sample trees and which caused the death of one tree.

4.2 Belarus

The assessment of crown condition in Belarus in 2009 included 9 764 trees on 410 plots of the transnational network. 72.5% of the trees were coniferous species and 27.5% were broadleaves.

According to the results of the observation hardly any change in defoliation was noted in comparison to 2008. The share of trees without any defoliation increased by 0.3 percent points to 27.7%, the share of trees in defoliation classes 2 to 4 increased by 0.4 percent points to 8.4%. Average defoliation of all species remained at the level of 2008 (17.7%). From all tree species *Alnus glutinosa* remained the species with lowest defoliation (15.0%).

As in previous years, *Fraxinus excelsior* and *Quercus robur* had the highest average defoliation: 35.6% and 21.0%, respectively. These species had the highest share of trees in defoliation classes 2 to 4, namely 45.4% and 12.7 %, and also the smallest share of trees without any defoliation, namely 9.1% and 14.4%. A substantial deterioration of condition of *Fraxinus excelsior* has been observed during the last years.

The share of trees in defoliation classes 2 to 4 and the average percentage of defoliation of *Quercus robur* decreased slightly in comparison to 2008: by 0.3 and 0.8 percent points, respectively. However, compared to 2005 when the share of trees in classes 2 to 4 had reached 35.4% and average defoliation was 31.9%, an improvement in tree crown condition is obvious.

Damage due to various factors was observed at 14.2% of the sample trees. 1.5% of the trees died. Most frequent damage was recorded at Fraxinus excelsior (at 45.4% of the trees), Populus tremula (37.3%) and Quercus robur (32.7%), and more rarely on Pinus sylvestris (9.8% of the observed trees).

The most frequently observed causes of damage were fungi (4.5%), direct influence of men (3.4%), and abiotic factors (1.7% of the observed trees). The greatest share of trees with signs of damage by fungi was noted at *Fraxinus excelsior* (38.6%, by *Armillaria* spp.), *Populus tremula* (22.8%, mostly by *Phellinus tremulae*) and *Quercus robur* (11.6%, mostly by *Phellinus robustus*). Mechanical and abiotic damage types were assessed on *Picea abies* (5.6% and 3.0%) and on *Betula pendula* (4.8% and 3.2% of the observed trees).

Unfavourable weather conditions in June were caused by frequent thunderstorms. In some cases they were accompanied by hail and high wind speeds. On 12th and 13th of June wind speed reached 110 km/hour in some areas in the eastern part of the Republic. About 4.5 thousand hectares of wood were thrown by strong winds. Two Level I plots were lost and one was badly damaged.

4.3 Belgium

Flanders

The large scale survey was conducted on the plots of the former Level I 4 x 4 km grid. On 72 plots, a total of 1 730 sample trees were assessed.

The mean defoliation in the survey was 19.9% and the share of damaged trees was 15.1%.
19.5% of the trees were considered as healthy and the mortality rate was 0.1%. Discolouration was observed on 8.8% of the sample trees. Broad-leaved trees showed a higher defoliation than conifers. In broadleaves, average defoliation level was 20.5% with 17.8% of the trees in defoliation classes 2 to 4. Conifers revealed a better condition, with a mean defoliation of 18.7% and 9.7% of the trees being damaged.

Populus spp. and *Quercus robur* were the main broad-leaved species with the highest defoliation. Mean defoliation was 26.8% in poplar stands and 21.7% in *Quercus robur*. The share of damaged trees was 36.7% and 20.2%, respectively. As in previous surveys, defoliation was lower in *Fagus sylvatica* and *Quercus rubra*. Mean defoliation was 15.7% in *Fagus sylvatica* and 17.0% in *Quercus rubra*. Less than 10% of the trees were in defoliation classes 2 to 4 (7.7% and 5.5%). The least affected coniferous species was *Pinus sylvestris* with 6.4% of the trees being damaged and a mean defoliation of 17.4%. Mean defoliation in *Pinus nigra subsp. Laricio* was 23.4%, with 21.7% of the trees showing moderate to severe defoliation.

Some sample trees were replaced after thinning but there were no removals due to storm damage. The dry weather in August and September did not have a negative impact on the crown condition of the most common tree species. Seed production was high in comparison to 2008, especially in *Quercus robur* and *Fagus sylvatica*.

Trees were affected by defoliators in several *Quercus* forests. *Quercus robur* showed an increased level of insect damage, and nests of oak processionary moth (*Thaumetopoea processionea*) were observed in more *Quercus robur* plots. As in 2008 severe infestation of *Populus* spp. by rust (*Melampsora* spp.) was causing discolouration and defoliation.

1 702 common sample trees were assessed in 2008 and 2009. Mean defoliation increased by 0.8 percent points and the share of damaged trees by 1.3 percent points. The deterioration of the crown condition is related to an increasing defoliation in broadleaves. *Pinus sylvestris* is the only species with a decrease in defoliation and a lower share of damaged trees.

Wallonia

The 2009 survey was carried out on 1 128 trees on 50 plots of the regional 8 x 8 km systematic grid, in which 17 plots of the 16 x 16 km European grid are included.

The share of trees with defoliation >=25% shows different long term trends for conifers and for broadleaves: conifers were two times more defoliated in the beginning of the nineties, but they stay now with 15.5% of defoliated trees at a lower rate than broadleaves.

Broadleaves showed an increase in mean defoliation from 10% in 1990 to about 20% in 2005. This increase was mainly due to the degradation of beech (*scolytidae* in 2000-2002, drought in 2003 followed by fruiting in 2004) and of the European oak (drought in 2003). The rate decreased from 2006 to 2008 with 15.2%, but severely increased in 2009 with 32% defoliated trees.

Mean defoliation observed for the four main species increased to about 24% in 2009, after an improvement for beech and European oak since 2006. Sessile oak was in the worst condition since 1993 with 18.7%. Spruce shows a slow but continuing increase of main defoliation, with 13.4% in 2009.

This increase in defoliation is difficult to explain. The causes, which are identified for only about 10% of the trees, are mainly defoliators for beech and oaks, abiotic causes (storm) and big games (*Cervus elaphus*) for spruce, and sometimes human induced damage (forest operation). Sunburn for beech bark was also mentioned.

4.4 Bulgaria

The activities during 2009 were directed to restructure the national large scale plots as part of the pan-European forest monitoring system.

In 2009 the forest condition survey was carried out on 159 sample plots (68 in coniferous and 91 in broad-leaved stands). These so called “FutMon” large scale plots were installed with regard to the implementation of the FutMon project. Some sample plots were selected from the 16 x 16 km grid (ICP Forests, UNECE – LRTAP Convention), but some were newly installed in stands with healthy crowns and selected following the national representative criteria.

A total of 5 560 sample trees was assessed, 2 360 conifers and 3 200 broadleaves. The share of conifers without visible defoliation increased from 9.7% in 2008 to 19.6% in 2009. The percentage of damaged trees (defoliation classes 2 to 4) decreased from 44.6% in 2008 to 33.1% in 2009. For broadleaves, the percentage of damaged trees (defoliation classes 2 to 4) decreased from 17.9% in 2008 to 12.2% in 2009. Some damage on *Pinus nigra* was caused by *Sphaeropsis sapinea* and *Lophodermium pinastri.*

The share of not defoliated *Fagus sylvatica* trees increased from 47.3% in 2008 to 54.6% in 2009. For *Quercus* spp. the increase was from 43.5% in 2008 to 79.0% in 2009. Some damage on *Fagus sylvatica* was caused by *Rhynchaenus fagi*, *Ectoedemia libwerdella, Nectria* spp., and some damage on *Quercus* spp. was caused by *Ceratocystis roboris*.

The share of trees showing discolouration decreased in conifers and broadleaves. Abiotic agents (drought, snow, ice) did not have a negative influence on crown condition of the sample trees.

4.5 Croatia

In the forest condition survey in 2009, 83 sample plots on the 16 x 16 km grid were included. The percentage of trees of all species within defoliation classes 2-4 (26.3%) in 2009 was higher than in 2008 (23.9%). For broadleaves as well, the share of trees in classes 2-4 (20.7%) was higher than in 2008 (19.1%). For conifers, the percentage of trees in defoliation classes 2-4 (66.5%) was higher than in 2008 (59.1%) and 2007 (61.1%) but still lower than in 2006 (71.7%). Although the percentage of moderately to severely defoliated conifers is still high, it does not have a stronger impact on the overall percentage of trees of all species for the same defoliation classes, because of the low representation of coniferous trees in the sample (242 coniferous trees vs. 1 749 broad-leaved trees in 2009).

Abies alba was still the most damaged tree species, the percentage of moderately to severely defoliated trees recorded in 2009 was 72.2%, compared to 69.7% in 2008 and 67.9% in 2007. The lowest value with 36.6% of moderately to severely defoliated 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 defoliated trees in 2003, 86.5% in 2004 and the peak at 88.5 % in 2005.

The lowest percentage of moderately to severely defoliated or dead *Quercus robur* trees 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 defoliated oak trees. In 2006, it was slightly lower at 20.5%, and in 2007 it was again lower at 19.6%, returning to values above 20% in 2008 (22.2%) and in 2009 (22.8%).

Fagus sylvatica remained the least damaged tree species in Croatia. The maximum percentage of moderately to severely defoliated beech trees was recorded in 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, 7.6% in 2007, 7.0% in 2008 and 7.8% in 2009.

Overall, the state of crown defoliation in Croatia remains fairly stable, although the condition of some important and sensitive tree species slightly deteriorated.

4.6 Cyprus

The annual assessment of crown condition was conducted on 15 Level I plots, during the period August - October 2009. The assessment covered the main forest ecosystems of Cyprus, and a total of 362 trees of *Pinus brutia, Pinus nigra* and *Cedrus brevifolia* were assessed. A comparison of the results with those of the previous year shows significant improvement for all species.

A comparison with the results of the previous year 2008 shows a decrease by 0.02 percent points of the trees being in class 0 (not defoliated). An increase by 10.7 percent points was observed in class 1 (moderately defoliated). A decrease was observed in the other two classes, by 11.0 percent points in class 2 (slightly defoliated) and by 0.3 percent points in class 3 (severely defoliated). Two trees were dead and were recorded in class 4 (dead).

A significant decrease in class 2 and an increase in class 1 compared with the assessment of the year 2008 is mainly due to the sufficient rainfall in 2008-2009 compared to the rainless period 2007-2008.

In the case of *Pinus brutia*, 3.3% of the sample trees showed no defoliation, 57.5% were slightly defoliated, 37.2% were moderately defoliated, 1.7% were severely defoliated and 0.3% were dead. Comparing the results with those of 2008, no changes were observed in class 0 (not defoliated). In class 1 and class 4, an increase by 12.8 percent points and 0.3 percent points, respectively, was observed. A decrease by 13.1 percent points was observed in class 2 (slightly defoliated) and by 1.3 percent points in class 3 (severely defoliated). In class 3 (severely defoliated) no changes were detected.

In *Pinus nigra*, 0% of the sample trees showed no defoliation, 69.4% of the sample trees showed slight defoliation while 30.6% were moderately defoliated. Comparing with the previous year's results, a decrease by 2.8 percent points in class 0 (no defoliation) and 5.6 percent points of the trees being in class 1 (slightly defoliated), was observed. An increase by 8.3 percent points was detected in class 2 (moderately defoliated).

In *Cedrus brevifolia*, 4% of the sample trees showed no defoliation, 88% of them were slightly defoliated, 4% were moderately defoliated and 4% were dead. Compared with the results of the previous year, an increase by 4.0 percent points in class 0 and by 8.8 percent points in class1 (slightly defoliated) was observed. In class 4, an increase by 4.0 percent points was observed as well. A decrease by 8.7 percent points in class 2 and by 4.2 percent points in class 3 was observed.

99.2% of the trees were not discoloured.

From the total number of sample trees surveyed, 65.6% showed signs of insect attack and 9.7% showed signs of attack by "*other agents*" (lichens, dead branches and rat attacks). 18.9% showed signs of both factors (insect attack and other agents). The major abiotic factor causing defoliation during the year 2009 was the adverse climatic condition (drought) prevailing in Cyprus the last years. As a result of the drought, half of the trees were attacked by *Leucaspis* spp., which contributed to the defoliation during the year 2009 as a secondary factor. No damage was attributed to any of the known air pollutants.

4.7 Czech Republic

In 2009 no important change in the development of defoliation for coniferous tree species in older age categories (stands 60 years old and older) was observed when compared with the preceding year. Only a slight improvement of particular species was recorded in this category for *Picea abies* and *Larix decidua* which was manifested by decreasing defoliation of trees in class 2 and an increase in class 1. This trend was reverse for *Pinus sylvestris*, and no change occurred for *Abies alba*.

Distinct improvement showed the younger age categories of coniferous tree species (stands up to 59 years) where the share of trees showing no defoliation (class 0) increased from 35.0% in 2008 to 41.3% in 2009. This decrease in defoliation applied to spruce, larch and fir (*Picea abies, Larix decidua, Abies alba*), whereas when compared to the preceding year, slight increase in defoliation appeared in the younger pine stands (*Pinus sylvestris*).

Younger conifers (up to 59 years) were of lower defoliation within the long-term period than stands with younger broadleaves. In contrast, for older stands (60 years old and older), defoliation of conifers was distinctly higher than in stands of broadleaves. Important increase in defoliation was observed in broad-leaved stands (60 years old and older), the share of broadleaves in class 2 increased from 32.4% in 2008 to 41.0% in 2009. This increase in defoliation was mainly observed in oak stands (*Quercus* spp.), whereas the change in other deciduous tree species was negligible. On the contrary, important improvement occurred in the younger broadleaves (stands up to 59 years); where the percentage in defoliation class 2 dropped from 30.1% in 2008 to 14.6% in 2009. This positive change was found in most of the investigated deciduous tree species of this younger age category, but most distinctly for oak (*Quercus* spp.) where the percentage of trees in class 2 decreased from 47.6% in 2008 to 12.0% in 2009, and at the same time the share of trees in classes 0 and 1 increased to 7.7% and 30.0%, respectively.

During November, at the end of the vegetation period some forest stands in most forest areas were mechanically damaged by wet snow. In several forest areas, mainly in spruce stands, higher occurrence of cambiophagous insects was recorded during the vegetation period. In 2009, average month temperatures were mostly above average in comparison with the long-term standard (mainly in April), and the level of average precipitation was mostly above average mainly in the first half of the year.

In 2009 no important change was recorded for the main pollutants (particulate matters, SO_2, NO_x, CO, VOC, NH_3), total emission of most of these substances, despite a certain fluctuation, has been slightly decreasing for a long time.

4.8 Denmark

The Danish forest condition monitoring in 2009 was carried out in the National Forest Inventory (NFI) and on the remaining Level I and II plots. Monitoring showed that most tree species had satisfactory health status. Exceptions were *Fraxinus excelsior* where the problem with extensive dieback of shoots has continued. Average defoliation was 42% for all monitored ash trees; however, this result was strongly influenced by one monitoring plot, where the trees were dying. But even without those trees, average defoliation was 27%, which is higher than ever recorded before the appearance of ash dieback.

After two years of severe aphid infestations (*Elatobium abietinum*) *Picea sitchensis* recovered in 2009 (13% average defoliation), but this is also due to harvesting of affected stands. Average defoliation score of *Fagus sylvatica* increased slightly in 2009 (9%), but *Quercus* (*robur* and *petraea*) stayed at the same level (14%). *Picea abies* showed very good health with an average defoliation of 6%, and for other trees species the defoliation scores were generally low.

Based on both NFI plots and Level I & II plots, the results of the crown condition survey in 2009 showed that 74% of all coniferous trees and 62% of all deciduous trees were undamaged. 19% of all conifers and 27% of all deciduous trees showed warning signs of damage. The mean defoliation of all conifers was 8% in 2009, and the share of damaged trees was 7%. Mean defoliation of all broadleaves was 14%, and 11% were damaged.

4.9 Estonia

Forest condition in Estonia has been systematically monitored since 1988. In 2009, 2 202 trees were assessed on 92 permanent Level I sample plots from July to October. The survey covered 602 spruces (*Picea abies*), 1483 pines (*Pinus sylvestris*), 92 birches (*Betula pendula*), 12 aspens (*Populus tremula*), and 13 other broadleaves.

Scots pine (*Pinus sylvestris*) has traditionally been the most defoliated tree species in Estonia. In general, defoliation of pines in NW and NE of Estonia is higher than in SW and SE regions. Essential improvement in crown condition of Scots pine was observed in the period 1991–2000. Then a certain decline was registered up to 2003 and since 2004 defoliation has remained on the same level. In 2008-2009 37% of Scots pines (*Pinus sylvestris*) were not defoliated (defoliation class 0). In general, some worsening of crown condition for Scots pine (*Pinus sylvestris*) was noted in 2008, mainly because of the increase in the number of moderately and severely defoliated trees, but in 2009 a certain improvement was observed again.

The increase in defoliation of Norway spruce (*Picea abies*) which started in 1996 stopped in 2003, and remained on the same level up to 2005. In 2006 some worsening in crown condition occurred. In 2007-2009 the level of Norway spruces which were not defoliated (defoliation class 0) remained almost at the same level 54-58%.

Numerous factors determine the condition of forests. Climatic factors, disease and insect damage as well as other natural factors have an impact on tree vitality. 3% of the trees assessed had some kind of insect damage, and 44% identifiable damage symptoms of disease. Needle cast (308 trees damaged) and shoot blight (560 trees damaged) were the most significant reasons of biotic damage of trees, whereby the number of pines, affected by shoot blight was higher than in 2008.

However, the condition of deciduous species was estimated to be better than that of the conifers. In 2009, 61% of birches were not defoliated (defoliation class 0). The highest defoliation amongst deciduous trees was observed for aspens (*Populus tremula*) and ashes (*Fraxinus excelsior*).

4.10 Finland

In Finland the integration between ICP Level I and NFI has been accomplished in 2009 by moving the extensive level (level I) ICP plots to the present NFI network, i.e. to the permanent plots established during the 9th NFI in 1996-2003. The sampling design of the NFI (NFI 11) is a systematic cluster sampling. The distance between clusters, the shape of a cluster, the number of field plots in a cluster and the distance between plots within a cluster vary in different parts of the country according to spatial variation of forests and density of road network. Principally, every fourth cluster is marked as a permanent cluster. The same permanent plots will be assessed in five- year intervals. All tallied dominant and co-dominant Norway spruce, Scots pine and birch trees are assessed, and results from 6 pre-selected permanent plots from each cluster are reported to the ICP and to the EU.

Please note that because Finland is using a completely new plot design from 2009 onwards, the results from 2009 are not directly comparable with the results from previous years.

The 2009 forest condition survey was conducted on 886 permanent sample plots. Of the 7182 trees assessed in 2009, 56.4% of the conifers and 67.2% of the broadleaves were not suffering from defoliation (leaf or needle loss 0-10%). The proportion of slightly defoliated (11- 25%) conifers was 33.6%, and that of moderately defoliated (over 26%) 9.9%. For broadleaves the corresponding proportions were 28.1% and 4.7%, respectively. In general, the average tree-specific degree of defoliation was 11.9% in Scots pine, 18.3% in Norway spruce, and 13.4% in broadleaves (mainly *Betula* spp.).

The proportion of discoloured Scots pine trees (discolouration > 10%) was 1.2%, the corresponding proportion for Norway spruce was 7.3% and for broadleaves 2.4%. Most of the discoloured spruces or pines belonged to the discolouration class 10 to 25%, and moderate or severe discolouration was rare. The most frequent discolouration symptoms on Scots pine was browning of needles of all ages. In Norway spruce the most common symptoms was yellowing and yellow tips and the youngest needles.

Abiotic and biotic damage was also assessed in connection with the large-scale monitoring of forest condition. 33.1% of the Scots pines, 34.5% of the Norway spruces and 25.2% of the broadleaves were reported to have visible/ symptoms attributed to abiotic or biotic damaging agents. *Gremmeniella abietina* (7.4 %), *Neodiprion sertifer* (4.9%) and *Tomicus* spp. (3.5 %) were the most abundant biotic damaging agents in pine, and *Chrysomyxa ledi* (11.2 %) and *Heterobasidion* sp. (2.1%) in spruce. In broadleaves, undetermined defoliating insects (3.6% of the trees) were the most common group of biotic/ abiotic causes.

According to the observations of the Forest Damage Information Service, *Neodiprion sertifer* had vast mass outbreaks in pine forests, mainly in southern Ostrobothia and in mid-Finland. Sporadic damage was also found in the southern parts of the country. The damaged area was estimated to be over 350 000 hectares.

4.11 France

The assessment of crown condition in France in 2009 was based on 9 949 trees on 500 plots of the transnational grid (16 x 16 km). This survey included 66% broad-leaved and 33% coniferous tree species. Compared to the previous year, the overall health condition remained stable.

Pinus pinaster represented 21% of all coniferous trees. *Pinus sylvestris*, A*bies alba*, *Picea abies* and *Pseudoplatanus menziesii* constituted together almost 60% of the conifers assessed. The broad-leaved forests were in majority represented by *Quercus petraea* (19% of observations). *Quercus robur*, *Fagus sylvatica*, *Quercus pubescens*, *Castanea sativa* and *Quercus ilex* represented 60% of the assessed broadleaves. The diversity of species included 42 different broad-leaved species and 15 coniferous species.

The mean defoliation of all species was 23%, the same defoliation as in 2008 (19% for coniferous and 26% for broadleaves). In general, the repartition within the defoliation classes was the same as in the two previous years.

Compared to 2008, the defoliation class repartition slightly moved to higher defoliation (class 3 and 4), but this trend is not significant. The trees were mainly classified in the three first classes (29%, 38% and 30%, respectively) which show a general good forest health. Almost 10% of the trees had no defoliation (26% for coniferous and 3% for broadleaves). Broadleaves stayed at a higher defoliation level than conifers.

In spite of the increasing populations of defoliating insects, the crown condition of *Quercus* species has continued to improve thanks to the good climate conditions during the previous years (the classes 0 and 1 are the most represented).

The highest mean defoliation was recorded for *Quercus ilex* and *Quercus pubescens*. The attacks of *Tortrix viridana* were really important in 2009 for the latter one. *Castanea sativa* remains very sensitive to *Cryphonectria parasitica*: the infections are still often mentioned (43% of known causes). This species recorded the most important broadleaf dead rate but the main health condition is relatively steady.

The storm which broke out in January and the growing bark beetle populations highly affected *Pinus pinaster*. There was severe mechanical damage in the South-East. A total volume of 37 millions m^3 timber was damaged by storm. In the South-East, the particular dried climate conditions during two years increased the discoloration and the defoliation levels. *Pinus pinaster* recorded the most important death rate (3.2%). The defoliation recorded for *Picea abies* and *Abies alba* were very low (more than 80% in class 0). Most of the *Pinus sylvestris* are severely damaged (4.3% in class 3). This effect is particularly due to high snow damage.

The dry and warm summer had consequences to *Fagus sylvatica*: the classes 2 and 3 of discolouration increased. Moreover, *Orchestes fagi* was responsible for a loss in the defoliation class 0 on this species.

In 2009, the most frequently identified damage types were microphylla (54% of mentions), then *Viscum album* (12%), fructifications (5%), and storm damage (3.9%). After windbreak, snow was the most important abiotic damaging factor which appeared very early in 2009, especially in the mountains.

The most frequently mentioned damage referred to *Fagus sylvatica* (microphylla, fructification, and *Orchestes fagi*) and *Quercus robur* (wind, insect damage and *Collybia fusipes*) for broadleaves. Then, followed by *Pinus sylvestris* (*Viscum album*, snow and microphylla) and *Pinus pinaster* (*Thaumetopoea pityocampa* during the winter 2008-2009, *Dioryctria sylvestrella* and wind), which suffered most heavily among conifers.

The climate in 2009 was warm and the rainfalls were relatively low. These conditions were not favourable for vegetation, but the defoliation and discolouration results obtained in 2009 showed a generally good health status: the vegetation has continued to take advantage of the favourable climate conditions during the three last years. The mortality rate was very low (0.26% for conifers and 0.85% for broadleaves).

4.12 Germany

The survey was carried out by the *Laender* on different grid densities ranging from 2 x 2 km to 16 x 16 km. For the calculation of the national results the common 16 x16 km grid was used. The survey 2009 included 10 376 trees on 424 plots.

For all tree species, 27% of the forest area was assessed as damaged (defoliation classes 2 -4), as compared to 26% in 2008. 37% were at the warning stage and 36% were undamaged (2008: 31%). Mean crown defoliation decreased slightly from 20.4% to 19.7%.

The main tree species showed the following development:

- **Spruce** *(Picea abies)***:** 26% of the area assessed was rated as damaged (2008: 30%). Mean crown defoliation decreased from 20.8% in 2008 to 19.4% in 2009.
- **Scots pine** *(Pinus sylvestris)*: 13% of the area assessed was rated as damaged (2008: 18%). Mean crown defoliation decreased from 18.9% in 2008 to 15.8%.
- **Beech** trees *(Fagus sylvatica)* showed a sharp deterioration of their crown condition. The area percentage of damaged trees increased by 20 percent points and reached 50% in 2009. Mean crown defoliation increased from 22.0% to 27.0%. The intense fruiting in 2009 was conducive to this development. Furthermore, premature senescence and fall of leaves during a drought period in August was observed in some regions.
- **Oaks** (*Quercus petraea and Q. robur*) showed a slight improvement compared with the previous year, however, almost half of the trees still show more than 25% crown defoliation. The area percentage of damaged trees amounts to 48% (2008: 52%). The mean crown defoliation decreased from 28.3% in 2008 to 26.5%.

The sharp increase in defoliation in *Fagus sylvatica* was mainly due to the intensive fruiting observed in 2009. Furthermore premature senescence and fall of leaves was observed during a warm and dry period in summer. There is a strong relationship between the intensity of fruiting and defoliation, as can be seen in Figure 3.

Fruiting years of *Fagus sylvatica* were frequent in the past decade. This might be a response to warmer summer temperatures and high availability of nitrogen.

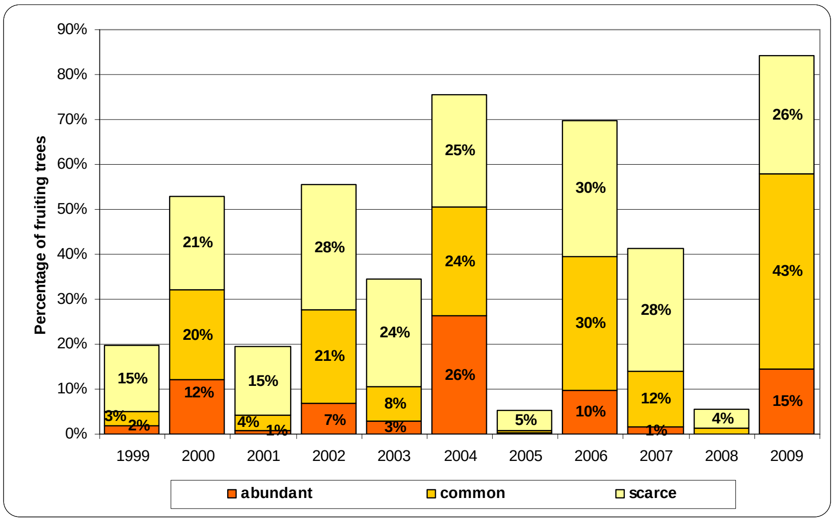

Figure 1: Fruiting of *Fagus sylvatica*: percentage of trees by fruiting intensity classes (trees older than 60 years).

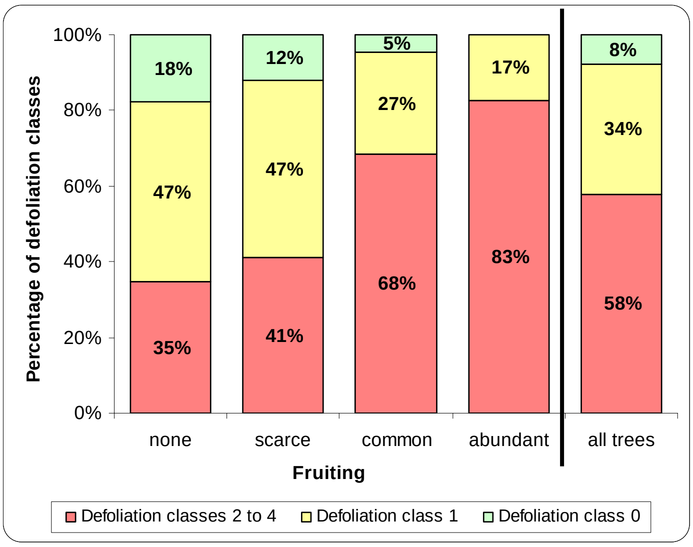

Figure 2: Percentage of defoliation classes for beech trees older than 60 years by fruiting intensity classes in 2009.

4.13 Hungary

In 2009, the forest condition survey based on the 16 x 16 km grid including 1 872 sample trees on 78 permanent plots in Hungary. The assessment was carried out during the period of July – August. 86.3% of all assessed trees were broadleaves, 13.7% were conifers.

The overall health condition of the Hungarian forests improved compared to 2007, when the assessment method was the same one. The share of trees without visible damage increased from 51.8% to 54.8%. The mean defoliation of all species was 19.0%, i. e. by 0.3 percent points slightly lower than in 2007.

The percentage of all tree species in defoliation classes 2-4 (moderately damaged, severely damaged and dead) was in 2009 lower than in 2007 (18.4% and 20.7%, respectively). The ICP

Forests defoliation class 4 was divided into two classes. Whereas in class 4 trees were included that died in the current year, trees were included in class 5 which died in previous years. In class 5 were 0.3% of the sample trees in 2007, while this amount increased to 1.4% in 2009.

In the classes 2-4 the most damaged species was *Robinia pseudoacacia,* with 26.7% of the trees in these defoliation classes, followed by *Quercus robur* (14.2%) and *Quercus petraea* (14.0%). *Fagus sylvatica* had the lowest defoliation (8.0%) in classes 2-4.

Discolouration rarely occurred in Hungarian forests, 95.7% of the sample trees did not show any discolouration.

Following the classification defined in the ICP manual on crown condition assessment, it can be ascertained that damage caused by defoliating insects was assessed on 28.2% of all trees. Mainly *Quercus robur* (50.9% of the assessed trees), *Quercus petraea* (49.2%) and *Quercus cerris* (49.0%) were damaged. Mean defoliation of the assessed trees was 6.22%.

Damage attributed to fungi was assessed on 40.3% trees. Fungal damage on leaves was assessed on 10.5%, on branch and on stem together on 29.8% of all assessed trees. The mean damage attributed to fungi was 18.1%. Abiotic damage was recorded on 19.4% of the sample trees. Among abiotic agents 35% were caused by drought and 29.2% by frost.

4.14 Ireland

The annual assessment of crown condition was conducted on the Level I plots in Ireland between June 25th and September 28th 2009. Overall mean defoliation and discolouration recorded for 2009 was 9.6% and 7.4% respectively. These results indicate that overall mean defoliation remained unchanged and mean discolouration levels showed a slight dis-improvement of 0.7% since the 2008 survey.

Defoliation levels recorded in 2009 were significantly below the respective long term 21 year average of 14.3% whilst discolouration levels were slightly below the long term average of 7.7%.

In terms of species, defoliation decreased in the order of lodgepole pine (*Pinus contorta*) (15.8%)> Norway spruce (*Picea abies*) (8.0%)> Sitka spruce (*Picea sitchensis*) (6.9%), while the trend in discolouration was in the order of lodgepole pine (*Pinus contorta*) (16.8%)> Norway spruce (*Picea abies*) (2.2%)>Sitka spruce (*Picea sitchensis*) (1.8%).

Traditionally, Norway spruce (*Picea abies*) exhibited the greatest defoliation of the three species in this survey. However, following the 2008 survey, sample trees of Norway spruce (*Picea abies*) were felled as part of normal forest operations. Hence the apparent improvement in condition of Norway spruce (*Picea abies*) in 2009 is directly attributable to a change in the number of sample trees rather than an overall improvement in condition.

Exposure continued to be the greatest single cause of damage to the sample trees in 2009. Other damage types (aphid, shoot die-back, top dying and nutritional problems) accounted for damage in a smaller percentage of trees. No instances of damage attributable to atmospheric deposition were recorded in the 2009 survey.

4.15 Italy

The 2009 Level I survey in Italy was based on 6 966 trees on 257 permanent plots. 31.8% of the conifers and 21.3% of the broadleaves were without any defoliation (class 0). 31.6% of the conifers and 31.6% of the broadleaves were in defoliation classes 2 to 4. Among the young conifers (<60 years), *Pinus sylvestris* and *Larix decidua* had 35.1% and 33.3% respectively of trees in classes 2 to 4, followed by *Picea abies* (26.9%), *Pinus nigra* (11.4%) and *Pinus halepensis* (7.3%). Among the old conifers (60 years), the highest defoliation was recorded for *Pinus nigra* (45.5%) and *Picea abies* (41.7%), followed by *Larix decidua* (35.2%) of the trees in classes 2 to 4.

Among the young broadleaves (<60 years), 54.3% *Castanea sativa* and 50.5% *Quercus pubescens* were assigned to classes 2 to 4, followed by *Fagus sylvatica* (33.3%), *Ostrya carpinifolia* (26.3%) and *Quercus cerris* (23.0%). Among the old broadleaves (60 years), 80.6% *Quercus pubescens*, 67.5% *Castanea sativa* and 10.7% *Fagus sylvatica* were in defoliation classes 2-4. *Quercus ilex* showed the lowest level of defoliation with 10.0% of the trees in classes 2-4.

94.8% of conifers and 94.3% of broadleaves did not show discolouration, only for young *Pinus sylvestris* stands 12.4% of the trees were assessed in discoloration classes 2 to 4.

Starting from 2005, a new methodology for a deeper assessment of damage factors (biotic and abiotic) was introduced. The main results are as follows: Most of the observed symptoms were attributed to insects (20.6%), subdivided into defoliators (15.1%), wood borers (2.2%), aphids (0.7%), and needle miners (0.5%). Abiotic agents made up for 6.4% of the sample, fungi for 8.2%.

4.16 Latvia

The forest condition survey in 2009 comprised 8 036 sample trees on 340 permanent sample plots on the national grid (8 x 8 km), including 92 plots on the transnational grid (16 x 16 km). *Pinus sylvestris* accounted for 50.2% of all trees assessed, *Picea abies* for 22.0%, *Betula* spp. for 21.8%, and other species for 6.0%.

The changes in mean defoliation are insignificant for both conifers and broadleaves. The distribution of all tree species in defoliation classes is very close to that of the 2008 survey. In 2009, 17.0% of all trees showed no defoliation, 69.2% were assessed as slightly defoliated and 13.8% moderately to severely defoliated or dead.

Mean defoliation of the most common coniferous species, *Pinus sylvestris* and *Picea abies*, was 21.5% and 20.3%, respectively, and the share of moderately damaged to dead trees constituted 15.1% and 14.1%, respectively. The changes in mean defoliation of both species did not exceed 1.3-1.4 percent points during the period of the last 5 years. The defoliation of the most common deciduous species in the sample plots - *Betula* spp., remained almost at the same level as in 2008 (18.5% in 2009, 18.8% in 2008). No significant changes were observed in *Betula* spp. distribution in defoliation classes as well compared to 2008. The worst crown condition showed *Fraxinus excelsior* with a mean defoliation of 31.5%, and a share of 44.4% in defoliation classes 2-4.

Visible damage symptoms were observed for 16.1% of the assessed trees (18.8% in 2008). Similarly to the previous years most frequently recorded damage was caused by insects (29.6% of all cases), followed by others – direct action by man (12.5%), abiotic factors (mostly wind) (12.1%), fungi (10.6%). The proportion of damaged trees of the most common tree species was quite similar and constituted 14.1-16.5% of the assessed trees. No serious and extensive attacks of biotic agents were recorded in 2009. *Pinus sylvestris* stands in western regions were still slightly damaged by *Neodiprion sertifer* and the crowns had not fully recovered from the attacks of the previous years as well. A local outbreak of *Lymantria dispar* has continued for the second year in south-western Latvia. A decline of *Alnus* was observed in different regions of Latvia, but the causing agent has not yet been ascertained.

4.17 Lithuania

The national forest inventory and the regional forest health monitoring grids (4 × 4 km) in Lithuania were combined since 2008. The transnational Level I grid (16 × 16 km) was kept. In 2009 the forest condition survey was carried out on 983 sample plots from which 72 plots were on the transnational Level I grid and 911 plots on the national forest inventory grid. In total 5 961 sample trees representing 19 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.*

In general, the mean defoliation of all trees species has slightly increased since 2007. However, mean defoliation of all tree species has varied inconsiderably from 1997 to 2009 and the condition of Lithuanian forests can be defined as relatively stable.

The mean defoliation of all tree species slightly increased up to 21.3% in 2009 (20.5% in 2008). 18.6% of all sample trees were not defoliated (class 0), 63.7% were slightly defoliated and 17.7% were assessed as moderately defoliated, severely defoliated and dead (defoliation classes 2–4). Mean defoliation of conifers was 20.8% (20.3% in 2008) and for broadleaves 22.1% (20.8% in 2008).

Mean defoliation of *Pinus sylvestris* was 20.8% (20.4% in 2008). Starting from 1998 mean defoliation of *Pinus sylvestris* has not exceeded 22.0%. The number of trees in defoliation classes 2-4 decreased to 14.9% (16.4% in 2008). Mean defoliation of *Picea abies* was only 0.3 percent points higher than in 2008 (20.3%) and the share of trees in defoliation classes 2-4 decreased to 20.9% (24.5% in 2008).

Populus tremula had the lowest mean defoliation and the lowest share of trees in defoliation classes 2-4. Mean defoliation of *Populus tremula* was 17.8% (16.3% in 2008) and the proportion of trees in defoliation classes 2-4 was 9.3% (10.3% in 2007). Mean defoliation of *Alnus glutinosa* increased up to 25.1% (18.5% in 2008) and the share of trees in defoliation classes 2-4 up to 27.9% (16.5% in 2008). It was the worst condition of *Alnus glutinosa* in the whole assessment period (1989 – 2009). Mean defoliation of *Alnus incana* was 1.2 percent points lower than in 2008 (24.4%). The share of trees in defoliation classes 2-4 decreased to 19.6% (28.9% in 2008). Mean defoliation of *Betula* spp. Slightly increased to 19.8% (19.1% in 2008) and the share of trees in defoliation classes 2-4 decreased to 13.8% (16.5% in 2008).

The condition of *Fraxinus excelsior* remained the worst. This tree species had the highest defoliation since 2000. Mean defoliation of *Fraxinus excelsior* has been gradually decreasing in the last few years, but increased again in 2009. Mean defoliation was 39.8% (36.5% in 2008).

The share of trees in defoliation classes 2-4 decreased to 48.4% (50.7% in 2008). Mean defoliation of *Quercus robur* was 0.9 percent points higher than in 2008 (21.3%), and the number of trees in defoliation classes 2-4 decreased to 16.8% (23.0% in 2008).

17.1% of all sample trees had some kind of identifiable damage symptoms. The most frequent damage was caused by direct action of man (4.8%), abiotic agents (3.3%), and fungi (2.6%). The highest share of damage symptoms was assessed for *Fraxinus excelsior* (46.2%) and for *Populus tremula* (30.5%), the least for *Alnus glutinosa* (10.1%).

4.18 Republic of Moldova

The climate conditions at the beginning of the vegetation period were favorable for tree growth and development, whereas in the second half of the vegetation period drought events were observed nearly in the whole country. This had adverse impact on the health condition of forests. However, in general, the health condition of the assessed trees did not show distinct changes in comparison with the previous year.

In 2009, 13 676 broad-leaved trees on 622 plots of the national 2 x 2 km grid net were assessed. Trees without any sign of damage (defoliation class 0) constituted 43.1% against 42.8% in 2008. The percentage of trees in defoliation classes 1 – 4 remained approximately at the same level and accounted for 56.9% against 57.2% in 2008.

In 2009, a decrease of trees in discolouration classes 2-4 was observed, and they accounted for 7.6% of all assessed trees against 12.6% in 2008.

A significant decrease in the share of trees in defoliation classes 2-4 was observed in *Robinia pseudoacacia* stands with 41.5% in 2009 against 58.0% in 2008. 28.4% of *Quercus robur* were assessed in defoliation classes 2-4. In *Fraxinus* plantations a decrease of trees in defoliation classes 2-4 was observed with 28.2% of trees in these classes. Overall, the slight improvement of health condition of trees in 2009 seems to stop the process of degradation.

The number of trees with identified types of damage constituted 1 899 trees, or 13.8% of the whole sample. The most common type of injury was damage caused by insects, which constituted 79.1% of all infected trees.

4.19 Norway

The results for 2009 show a small decrease in crown defoliation for all tree species compared to the year before. The mean defoliation for *Picea abies* was 15.5%, for *Pinus sylvestris* 15.2%, and for *Betula* spp. 22.2%. After a peak with low defoliation for both Norway spruce and Scots pine in 2004, the last years represent deterioration in defoliation. *Betula* spp. had the lowest defoliation in 2001. Since then, defoliation has increased.

Of all the coniferous trees, 48.5% were rated as not defoliated in 2009, which is a small increase by about 1.4 percent points compared to the year before. Only 39.9% of the *Pinus sylvestris* trees were rated as not defoliated, while 54.3% of all *Picea abies* trees were not defoliated. For *Betula* spp. 25.6% of the trees were observed in the class not defoliated, representing about the same percentage compared to the year before. The percentage of moderately and severely defoliated *Betula* spp. trees was 30.8%, representing a decrease compared to the year before. *Betula* spp. and *Picea abies* had the same percentage of trees with severe defoliation in 2009 with about 4.1%, while only 0.8% of *Pinus sylvestris* had severe defoliation.

In crown discolouration there has been observed a slight improvement for *Picea abies* from 2008 to 2009 with only 9.6% of the trees showing signs of discolouration. For *Pinus sylvestris*, only 2.7% of the assessed trees were discoloured, reflecting a continuous improvement from 2001 when discolouration was as high as 11.3%. For *Betula* spp., about the same discolouration was observed in 2009 as in 2008 with 95.3% of the trees having no signs of discolouration.

The mean mortality rate for all species was 0.2% in 2009. The mortality rate was 0.3%, 0.1% and 0.2% for *Picea abies, Pinus sylvestris* and *Betula* spp., respectively. The mortality rate of *Betula* spp. was more normal in 2009 and was heavily reduced from the high level of 1-1.8% which occurred in the tree year period 2006-2008. 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 2009 was regarded as relatively warm. The mean temperature for the whole country was 0.8°C above normal, and the precipitation was 110% of the normal for these months. There are of course large climatic variations between regions in Norway.

4.20 Poland

In 2009 the survey was carried out on 1 923 plots. Forest condition was almost at the same level as in the previous year. 24.1 % of all sample trees were without any symptoms of defoliation, indicating a decrease by 0.3 percent points compared to 2008. The proportion of defoliated trees (classes 2-4) decreased by 0.3 percent points to the current level of 17.7% for all trees. The share of trees defoliated more than 25% decreased by 0.2 percent points for conifers and by 0.5 percent points for broadleaves.

22.6% of conifers were not suffering from defoliation. For 17.2% 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 and indicated a slight worsening especially in older stands. A share of 22.6% (22.3% in 2008) of spruce trees up to 59 years old and 32.3% (28.5% in 2008) of spruce trees 60 years old and older was in defoliation classes 2-4.

27.3% of the assessed broadleaved trees were not defoliated. The proportion of trees with more than 25% defoliation (classes 2-4) amounted to 18.6%. As in the previous survey the highest defoliation amongst broadleaved trees was observed in stands of *Quercus* spp. and indicated a slight worsening in older stands. In 2009, a share of 17.4% (17.7% in 2008) of oak trees up to 59 years old and 37.1% (34.9% in 2008) of oak trees 60 years old and older was in defoliation classes 2-4.

In 2009, discolouration (classes 1-4) was observed on 0.8 %of the conifers and 1.1% of the broadleaves.

4.21 Romania

In 2009, the assessment of forest condition at Level I plots in Romania was carried out on the 16 x 16 km transnational grid net. 5 448 sample trees were assessed on 227 permanent plots. From the total number of trees, 1 115 were conifers and 4 333 broadleaves. Trees on 4 plots were harvested in the course of the last year and several other plots were not accessible due to natural causes such as windfall and floods.

For all species, 44.1% of the trees were rated as healthy, 37.0% as slightly defoliated, 17.6% as moderately defoliated, 0.9% as severely defoliated, and 0.4% were dead. The percentage of damaged trees (defoliation classes 2-4) was 18.9%.

For conifers 21.7% of the trees were classified as damaged (classes 2-4) and 78.3% were in defoliation classes 0-1. *Picea abies* was the least affected coniferous species with 20.3% of the trees damaged (defoliation classes 2-4). For broadleaves 18.1% of the trees were assessed as damaged or dead (classes 2-4) and 81.9% as healthy and slightly defoliated (classes 0-1). From all broad-leaved species, *Fagus sylvatica* was the healthiest one with 13.5% of the assessed trees in defoliation classes 2-4 and the most affected species was *Robinia pseudoaccacia* with a share of 26.9% damaged or dead trees (classes 2-4). For *Quercus* spp. a share of 25.8% trees was rated as damaged or dead.

Compared to 2007, the overall percentage of damaged trees (classes 2-4) decreased by 4.3 percent points. Forest health status was directly influenced, mainly for broadleaves, by the relatively favourable weather conditions in the beginning of the vegetation season.

Regarding the assessment of biotic and abiotic damage factors, most of the observed symptoms were attributed to insects (13%), abiotic factors (10%), and fungi (4%), but the largest part of the sample trees did not reveal any visible symptoms (68%).

4.22 Serbia

In the Republic of Serbia, the 16 x 16 km grid consists of 103 sampling plots and 27 newly added plots on a 4 x 4 grid. In 2009 the monitoring was performed only on 122 plots as some plots were clear cut. Monitoring was not performed in the autonomous provinces Kosovo and Metohija.

The total number of trees assessed on all sample plots was 2 765 trees, of which were 331 conifers and a considerably higher number of 2 434 broadleaves. The assessed coniferous tree species were *Abies alba*, *Picea abies*, *Pinus nigra*, and *Pinus sylvestris*, and the most represented broad-leaved tree species were *Carpinus betulus, Fagus moesiaca, Quercus cerris, Quercus frainetto,* and *Quercus petraea.*

For conifers, the share of trees with no defoliation was 64.7%, with slight defoliation 22.7%, with moderate and severe defoliation 10.2% and 2.4%, respectively. For broadleaves, 68.6% were not defoliated, 21.5% slightly, 8.6% moderately and 0.7% severely defoliated, 0.6% of the broadleaves were dead.

Discolouration was not detected on 90.6% of the conifers and slight discolouration on 9.4%. The degree of discolouration calculated for all broad-leaved species was as follows: no discolouration 95.9%, slight 3.0%, moderate 0.6%, severe discolouration 0.5% trees and dead 0.0% trees.

No visible damage symptoms were observed on 84.3% of the conifers, 8.5% showed slight damage, 6.0% conifers were moderately and 1.2% were severely damaged. As for broad-leaved tree species, the proportions of trees with visible damage symptoms were as follows: no damage on 88.7%, 8.2% with slight damage, 2.0% moderately damaged trees, 0.6% trees with severe damage and 0.5% trees were dead.

4.23 Slovak Republic

The 2009 national crown condition survey was carried out on 108 Level I plots on the 16 x 16 km grid net. The assessment covered 4 944 trees, 4 049 of which being assessed as dominant or co-dominant trees. Of the 4 049 assessed trees, 32.1% were damaged (defoliation classes 2-4). The respective figures were 42.7% for conifers and 24.5% for broadleaved trees. Compared to 2008, the share of trees defoliated more than 25% increased by 2.9 percent points. Mean defoliation for all tree species together was 24.6%, with 28.0% for conifers and 22.2% for broadleaves. Results show that crown condition in Slovak Republic is worse when compared to the European average. This is mainly due to the condition of coniferous species.

Compared to the 2008 survey, worsening of average defoliation was observed in *Fagus sylvatica, Quercus* spp., *Picea excelsa* and *Abies alba*. Improvements were observed in *Carpinus betulus.*

Since 1987, the lowest damage was observed for *Fagus sylvatica* and *Carpinus betulus*, with exception of fructification years. The most severely damaged species were *Abies alba*, *Picea abies* and *Robinia pseudoacacia*.

From the beginning of the forest condition monitoring in 1987 until 1996 results show a significant decrease in defoliation and in 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 the crown condition survey, damage types were assessed. 31.9% of all sample trees (4 944) had some kind of damage symptoms. The most frequent damage was caused by insects (14.0%) and fungi (12.7%) at tree stems. Additional damage causes were logging activities (11.1%), and abiotic agents (3.7%). Epiphytes had the most important influence on defoliation. 63% of trees damaged by epiphytes revealed defoliation above 25%. In addition, abiotic agents had a direct influence on defoliation.

4.24 Slovenia

In 2009 the Slovenian national forest health inventory was carried out on 44 systematically arranged sample plots (16 x 16 km net). The assessment encompassed 1 056 trees, 407 coniferous and 649 broad-leaved trees. The sampling scheme and the assessment method was the same as in the previous years.

The mean defoliation of all tree species was estimated to 26.5%. In comparison to the results of 2008 when the mean defoliation was 25.7%, the change is 0.4%. The mean defoliation for coniferous trees was 26.4% and for broadleaves 25.9% in 2009.

In 2009 the share of trees with more than 25% of unexplained defoliation (damaged trees) reached 35.4%. In comparison to the results of 2008, when the share of trees with more than 25% of unexplained defoliation was 36.9%, the value decreased by 1.5 percent points. Also obvious is the decrease in defoliation for broadleaves where the share of damaged trees dropped from 34.6% in 2008 to 33.3% in 2009.

Like in the previous years conifers are still more damaged than broadleaves. While their mean defoliation and the share of damaged trees were assessed to 26.4% and 39.1% respectively (in 2008 26.0% and 40.7%) the values of the both indicators for broadleaves were assessed to 25.9% and 32.8% (in 2008 25.4% and 34.6%). However, the health condition of coniferous sample trees was better than in 2008.

4.25 Spain

Results obtained in the 2009 inventory show a certain decline process when compared to previous years. 82.3% of the surveyed trees were healthy (compared to 84.4% in the previous year). 15.7% of the trees were included in defoliation classes 2 and 3, indicating defoliation levels higher than 25%, with a clear deterioration, whereas in 2008 this percentage was 14.2%. The number of damaged trees increased slightly and the number of dead ones increased to a larger extent. This general worsening was slightly less noticeable in conifers, with a percentage of 85.1% healthy trees (87.1% in the previous year), than in broadleaves (79.3% in 2009 and 81.6% in 2008).

The mortality of trees (2.0% dead trees of the total sample, compared to 1.4% in 2008) was due to decline processes related to drought and felling operations (frequently sanitary cuts). Apart from water shortages, the causal agents most frequently quoted were spring defoliators on broadleaves, the continuous increase in the occurrence of the pine processionary caterpillar, followed by bark beetles (*Escolitidae*), broadleaves borers, insects present in Eucalyptus stands (*Gonypterus, Ophelimus, Glycapsis*…), as well as defoliating fungi infestations in Eucalyptus stands; moreover, there were decline processes in *Pinus radiata* stands near the Cantabrian coasts and the general presence of chestnut blight and chestnut ink disease in chestnut stands. Mistletoe infestations are continuously relevant in certain areas affecting pines and juniper trees, as well as a new decline process of a still unknown origin that seems to affect alder forest stands near the Cantabrian coasts. Last but not least a punctual decline process can be observed in fir stands in the Pyrenees. There is not a noticeable increment in damage due to drought symptoms in Holm and cork oak stands.

The importance of atmospheric pollution in 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, in combination with other agents it can contribute to the degradation processes of forests.

4.26 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, 7 097 trees on 3 217 sample plots were assessed. The Swedish NFI is carried out on permanent as well as on temporary sample plots. The permanent sample plots, which are two thirds of the total sample, are remeasured every 5th year.

The proportion of trees with more than 25% defoliation was in Norway spruce (*Picea abies)* 25.0% (26.2% in 2008) and in Scots pine (*Pinus sylvestris)* 7.1% (9.7% in 2008). The improvement compared to previous years is mainly due to the development of forest condition in northern Sweden. The share of discoloured *Picea abies* trees has decreased and was 5.7%. In *Pinus sylvestris* discolouration was rare, 1.1%.

The outbreak of the European spruce bark beetle (*Ips typographus*) in southern Sweden has declined. The volume of *Picea abies* killed by the European spruce bark beetle in 2009 is estimated to 200 000 m^3. This is clearly less than previous years and there are also indications on decreasing populations of the bark beetles. However, the weather is crucial and new storms and long hot summers could easily change the situation. A changing climate towards longer and warmer summers increases the risk of damage by insects. In northern Sweden an outbreak of chrysomyxa rust of spruce (*Chrysomyxa ledi)* was noticed. The fungi were not only found on younger *Picea abies* trees but also on older trees and in some areas it changed the colour of the forest. An increasing decline in *Fraxinus excelsior* has been observed during the last years in southern Sweden. The decline is caused by a fungus (*Chalara fraxinea*). A special tailored inventory on *Fraxinus excelsior* was in 2009 carried out in southern Sweden showing that about 25% of the trees were severely damaged or dead. Although tree species as *Fraxinus excelsior* and *Ulmus* spp. cover less than 1% of the total standing volume in Sweden, they are significant in the landscape of the agricultural areas. Both these species have been affected during the last years by fungi and the number of trees decreases rapidly.

4.27 Switzerland

In 2009 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.
Crown condition in 2009 remained the same as in 2008. In 2009, 18.3 % of the trees had more than 25% unexplained defoliation (i.e. subtracting the known causes such as insect damage, or frost damage; 2008: 19.0 %) and 24.6 % of the trees had more than 25 % total defoliation (2008: 26.4%). Annual mortality rates were again average (4 out of 1000 trees died).
The relative low defoliation was somehow surprising as 2009 was an extremely high seed mast year which followed a year without seeds. High seed production was found for almost all tree species. For *Fagus sylvatica* on Level I plots in 2009 64% of all trees were recorded with seeds as compared to only 2% in 2008, for *Picea abies* 63% had fresh cones in 2009 as compared to only 14% in 2008. Usually, high seed production in *Fagus sylvatica* coincides with higher crown transparency due to less and smaller leaves in the upper tree crown. On the other hand,

low rates of insect defoliation or pathogens were observed for most tree species in 2009. Also, bark beetle infestation reached one of the lowest level since the storm in 1999. This can be attributed to the relative wet conditions in the last 3 years. In young *Fraxinus excelsior*, branch die-back and wilting of twigs during the summer has spread dramatically in northern Switzerland in 2009. In old trees branch-dieback has been observed since 2007, but no wilting symptoms have yet been reported and crown defoliation has not been affected in many trees yet.

4.28 Turkey

In 2009, defoliation was assessed on 563 plots including 12 290 trees. In 2009, the mean defoliation for conifers was 18.9%, and 21.5% for broadleaves. On 18.7% of the monitored trees, defoliation was more than 25%. *Pinus brutia* had the highest defoliation among conifers and *Quercus pubescens* the highest defoliation among the broadleaves.

In 2009, an improvement in forest health was identified. Improvement in the health status of trees may be ascribed to better weather conditions in 2009 (more humid and temperate) as compared to 2008. The most damaged regions both in 2009 and 2008 are the Black Sea coast of Thrace and the Black Sea Regions (excluding the province of Kastamonu in 2009). The Thrace Region is thought to be affected by transboundary air pollution from İstanbul and its neighbourhood. It has been observed that high defoliation rates in Western, Central and Eastern Black Sea Regions were caused by biotic factors. Furthermore in the plots close to industrial zones, for example Iskenderun Iron and Steel Factory, Muğla-Yatağan Coal-fired Power Plant Industrial Zone, the defoliation rate was found high.

In 2008 and 2009 in the Central Mediterranean region, forests appeared to be healthy. Plots of the ICP Forests Level I Programme are planned to be linked to the network of the National Forest Inventory.

Assessments of ground vegetation, biodiversity and crown condition are carried out on Level II plots on a regular basis. The number of 15 Level II plots was kept stable. The installation of the necessary laboratory facilities is still ongoing. Phenological observations were carried out on 7 Level II plots in 2009. On a number of plots, rain gauges, snow samplers and stem flow measurement equipment installations were completed for deposition assessments. Litterfall traps were placed and sample trees for leaf chemistry studies were selected. Ozone damage assessments were made on 4 Level II plots, but no ozone damage was identified.

4.29 Ukraine

In 2009, 35 065 sample trees were assessed on 1 483 forest monitoring plots in all of the administrative regions of Ukraine. Mean defoliation of conifers was 10.5% and of broadleaved trees 11.7%.

For the total sample insignificant changes were observed comparing to the previous year. In 2009, the percentage of healthy trees remained at the same level (66.4% against 66.5%). At the same time, the share of slightly and moderately defoliated trees increased from 30.1% to 32.9%. These changes may be considered, however, as being related to the change of the sample size.

For the sample of common sample trees (CSTs) (33 649 trees) an insignificant improvement was observed. Mean defoliation slightly decreased in 2009 (11.2%), compared to 2008 (11.8%). Changes are characterised by increasing shares of trees in defoliation classes 0 and 1 (0.2% and 1.2%) and decreases in all other classes. Some improvement of tree condition was registered for CST of European oak (*Quercus robur*). Statistically significant change was observed in class 0 (increase to 3.3%) and decreasing in class 1 to 2%. Among CSTs of Scots pine (*Pinus sylvestris*) an increase in class 1 (on 1.4%) was observed with an insignificant decrease in all other classes. Some improvement of tree condition may be explained by more favourable weather conditions during the vegetation period in 2009 compared to 2008 and a decreasing impact of defoliating insects.

4.30 United States of America

America's forests provide many benefits and services, including clean water, recreation, wildlife habitat, carbon sequestration, and a variety of forest products. Most of the US forests appear healthy and green; however, they face many threats to forest health and long-term sustainability. In the American West, outbreaks of native pests have killed trees on millions of acres, fires are burning larger areas than in the past, and severe droughts have led to additional stress on forest ecosystems. In the East, invasive forest pests have changed the structure and composition of some forests and, in numerous locations, increasing human development has led to forest fragmentation. Many of these threats may be exacerbated by a changing climate.

A 10-year trend for tree mortality indicates a large increase in tree mortality - from about 2 million acres (0.8 million hectares) in 1998 to 9.5 million acres (3.8 million hectares) in 2008. This increase was largely due to increased bark beetle activity in the West, much of it following severe regional drought in the recent years. Much of the large increase in tree mortality that occurred in 2003 and 2004 was attributed to outbreaks of *Ips* bark beetles in pines in the South-western States of Utah, Colorado, Arizona, and New Mexico. Severe drought conditions in this area from 2000 to 2003 predisposed pinion and ponderosa pines to attacks by *Ips* and other bark beetles. Mortality included trees of all ages and sizes. Stand level mortality rates ranged from 40 to 80 percent of trees larger than seedlings. Native bark beetles also caused extremely high levels of mortality in southern California during 2003 and 2004, following an extended drought period. Western pine beetle (*Dendroctonus brevicomis*), Jeffrey pine beetle (*Dendroctonus jeffreyi*), and mountain pine beetle (*Dendroctonus ponderosae*) killed large numbers of pine trees on the San Bernardino and Cleveland National Forests and adjacent lands. Air pollution, specifically elevated levels of ground-level ozone and wet and dry deposition of nitrogenous compounds contribute to increased forest susceptibility to drought and bark beetle attacks. Massive wildfires driven by Santa Ana winds burned thousands of hectares of these beetle-killed forests in 2003 and 2007.

Fire is a major disturbance agent in many forests of North America. Many forest ecosystems are adapted to particular fire frequencies and intensities. The annual amount of forest area burned varies depending on weather conditions, fuel loading, and forest stand conditions. Many years of fire exclusion have resulted in increased fuel loads and dense forests, leading to increased risks of uncharacteristic wildfires. The recent increase in number, size, and severity of fires in the Western United States has also been linked to recent climatic changes. In addition, large bark beetle outbreaks in the West have also increased fuel loading in many forests. Large fire frequency and total area burned have increased markedly since the mid-1980s in strong association with increased spring and summer temperatures and an earlier spring snowmelt. The total area burned in the United States in 2006 was the largest fire-affected acreage recorded since 1916 and amounted to 6.5 million acres (2.6 million hectares).

References:

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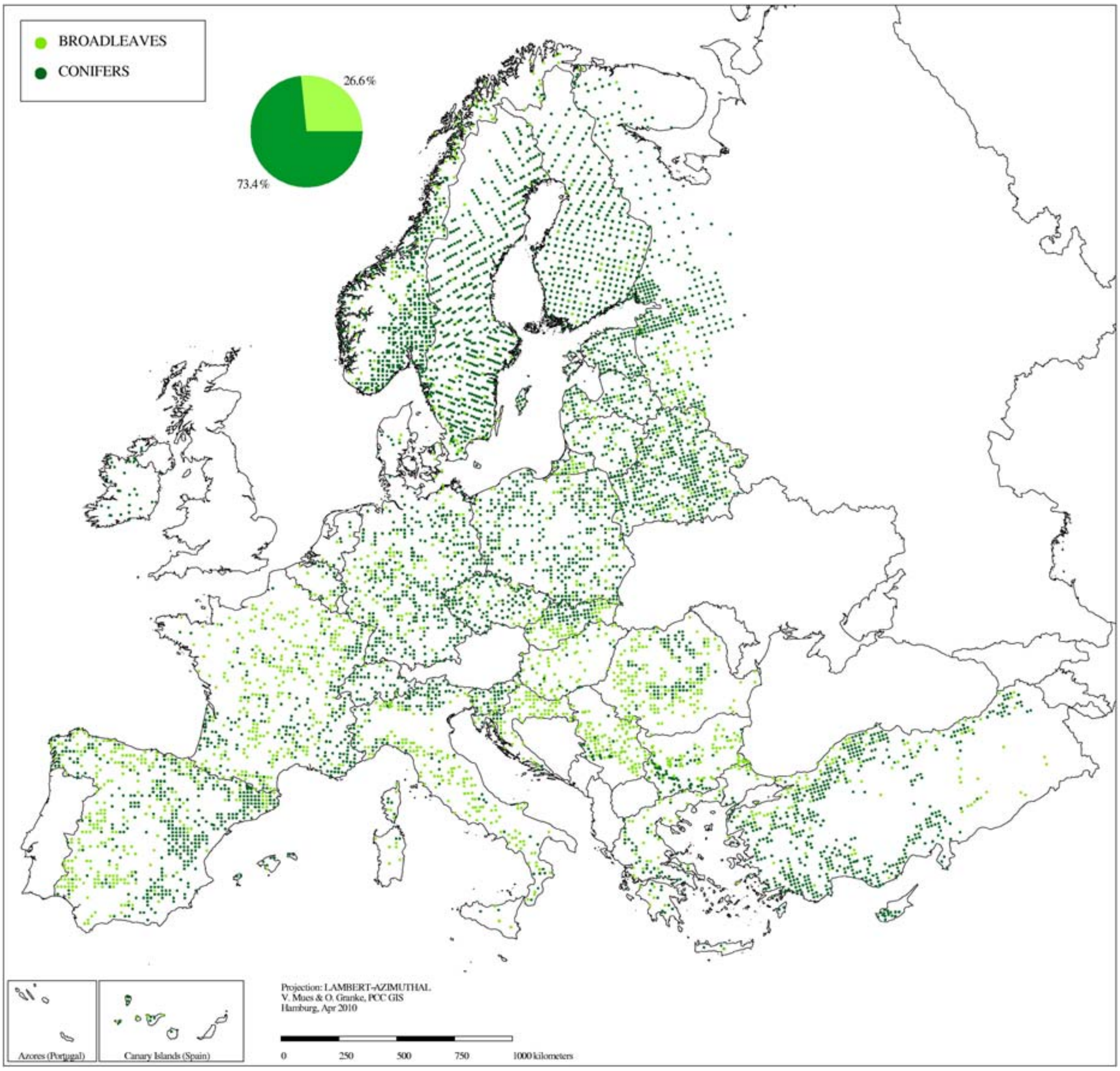
Grulke, N. E., et al. 2009. Air pollution increases forest susceptibility to wildfires: a case study in the San Bernardino Mountains in southern California. In: A. Bytnerowicz, M. Arbaugh, A. Riebau, C. Andersen (eds.) Wildland Fires and Air Pollution, Elsevier, Amsterdam, Developments in Environmental Science, vol. 8, 365-403.

Annex I

Transnational Surveys

Annex I-1
Broadleaves and conifers (2009)



Annex I-2
Species assessed (2009)

	Observed trees		Observed plots	
Species	**Number**	**%**	**Number**	**%**
*Pinus sylvestris**	33325	24.29	2950	20.84
*Picea abies (P. excelsa)**	19716	14.37	2122	14.99
*Fagus sylvatica**	11492	8.38	812	5.74
*Betula pendula**	6650	4.85	1007	7.11
*Pinus nigra**	5385	3.92	314	2.22
*Quercus robur (Q. pedunculata)**	4653	3.39	551	3.89
*Quercus petraea**	4554	3.32	445	3.14
*Quercus ilex**	3925	2.86	237	1.67
*Pinus brutia**	3672	2.68	189	1.33
*Betula pubescens**	3381	2.46	734	5.18
*Quercus cerris**	3021	2.20	271	1.91
*Pinus halepensis**	2629	1.92	135	0.95
*Quercus pubescens**	2310	1.68	193	1.36
*Pinus pinaster**	2210	1.61	139	0.98
*Carpinus betulus**	2054	1.50	300	2.12
*Abies alba**	2046	1.49	233	1.65
*Alnus glutinosa**	1904	1.39	213	1.50
*Populus tremula**	1713	1.25	334	2.36
*Castanea sativa (C. vesca)**	1327	0.97	156	1.10
*Quercus frainetto (Q. conferta)**	1308	0.95	84	0.59
*Fraxinus excelsior**	1138	0.83	234	1.65
*Larix decidua**	1085	0.79	165	1.17
*Fagus moesiaca**	928	0.68	53	0.37
Fagus orientalis	913	0.67	74	0.52
Eucalyptus sp.*	869	0.63	43	0.30
*Quercus pyrenaica (Q. toza)**	868	0.63	51	0.36
*Robinia pseudoacacia**	813	0.59	78	0.55
Juniperus excelsa	751	0.55	69	0.49
*Acer pseudoplatanus**	691	0.50	199	1.41
Other broadleaves	589	0.43	91	0.64
*Pinus pinea**	559	0.41	36	0.25
*Pseudotsuga menziesii**	548	0.40	49	0.35
*Picea sitchensis**	492	0.36	27	0.19
*Quercus suber**	489	0.36	42	0.30
Alnus incana	471	0.34	52	0.37
*Populus hybrides**	449	0.33	24	0.17
Other conifers	438	0.32	46	0.32
Tilia cordata	431	0.31	92	0.65
*Ostrya carpinifolia**	370	0.27	61	0.43
*Quercus faginea**	367	0.27	45	0.32
*Pinus radiata (P.insignis)**	324	0.24	16	0.11
*Abies cephalonica**	318	0.23	15	0.11
*Juniperus thurifera**	278	0.20	22	0.16

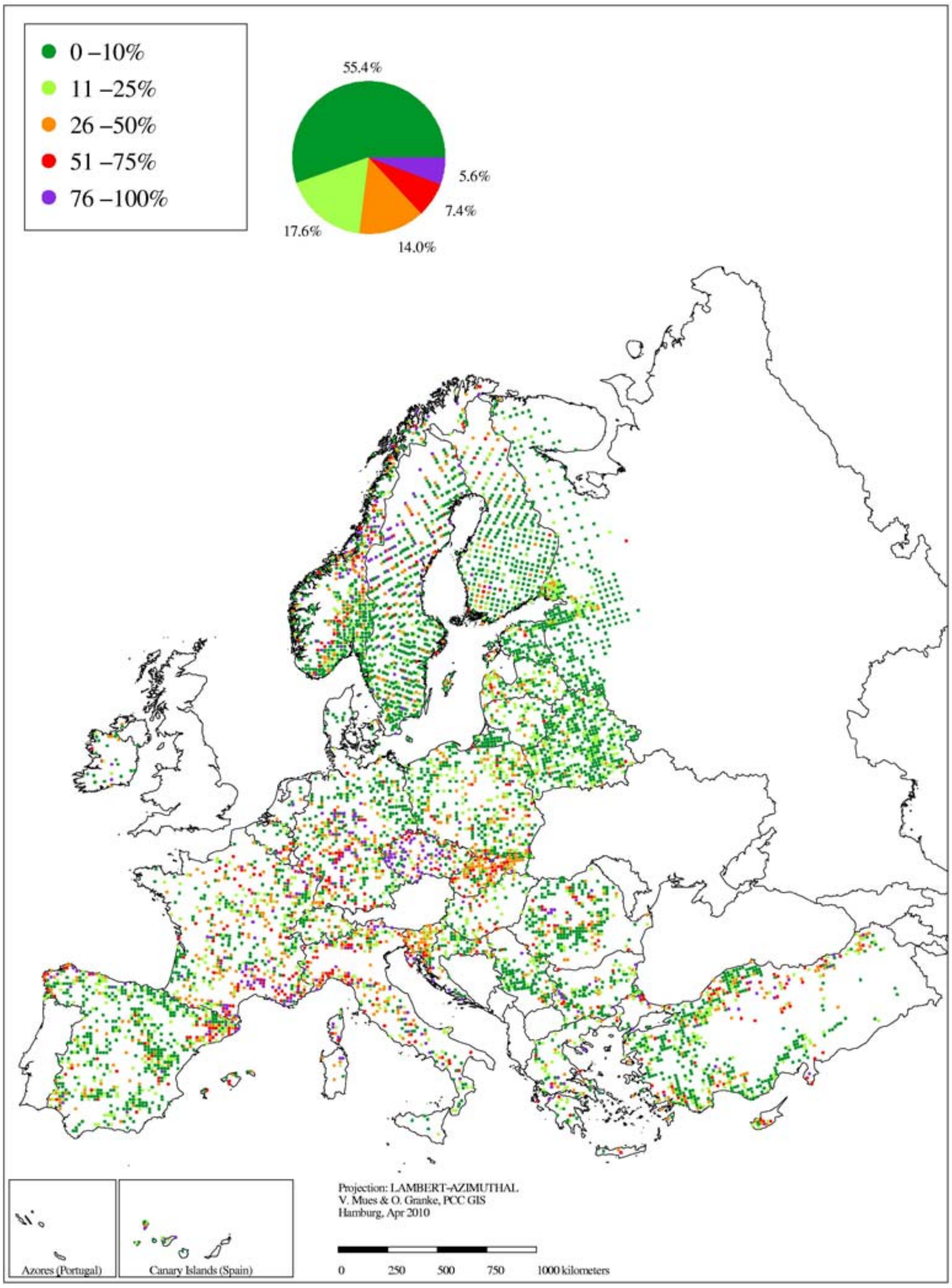
	Observed trees		Observed plots	
Species	**Number**	**%**	**Number**	**%**
Abies nordmanniana	232	0.17	24	0.17
*Pinus contorta**	226	0.16	21	0.15
Tilia platyphyllos	225	0.16	30	0.21
*Prunus avium**	217	0.16	108	0.76
*Quercus coccifera (Q. calliprinos)**	210	0.15	29	0.20
*Fraxinus angustifolia spp. Oxycarpa (F. oxyphylla)**	205	0.15	23	0.16
Pinus canariensis	193	0.14	9	0.06
*Olea europaea**	189	0.14	21	0.15
*Acer campestre**	188	0.14	85	0.60
Cedrus libani	180	0.13	19	0.13
*Pinus uncinata**	177	0.13	16	0.11
*Abies borisii-regis**	177	0.13	9	0.06
Platanus orientalis	174	0.13	13	0.09
Carpinus orientalis	167	0.12	26	0.18
*Quercus rubra**	166	0.12	22	0.16
Acer platanoides	157	0.11	63	0.44
*Fraxinus ornus**	155	0.11	55	0.39
Cupressus sempervirens	128	0.09	10	0.07
*Juniperus oxycedrus**	127	0.09	46	0.32
Central Anatolian oaks	126	0.09	16	0.11
Juniperus communis	117	0.09	24	0.17
*Populus nigra**	114	0.08	16	0.11
Pinus cembra	101	0.07	12	0.08
Larix kaempferi (L.leptolepis)	99	0.07	13	0.09
Abies cilicica	99	0.07	12	0.08
Pinus strobus	98	0.07	12	0.08
Picea orientalis	97	0.07	13	0.09
*Alnus cordata**	86	0.06	4	0.03
Quercus macrolepis (Q. aegilops)	82	0.06	5	0.04
Juniperus foetidissima	80	0.06	9	0.06
Juniperus phoenicea	72	0.05	12	0.08
Salix alba	67	0.05	9	0.06
Sorbus aucuparia	63	0.05	27	0.19
Ulmus glabra (U. scabra, U. scaba, U. montana)	57	0.04	32	0.23
Erica arborea	57	0.04	5	0.04
*Acer monspessulanum**	54	0.04	15	0.11
Sorbus aria	53	0.04	33	0.23
Populus alba	48	0.03	11	0.08
Populus canescens	39	0.03	4	0.03
Phillyrea latifolia	39	0.03	12	0.08
Ulmus minor (U. campestris, U. carpinifolia)	38	0.03	17	0.12
Acer opalus	38	0.03	18	0.13
Salix caprea	36	0.03	21	0.15
Cedrus atlantica	34	0.02	4	0.03

	Observed trees		Observed plots	
Species	**Number**	**%**	**Number**	**%**
Pistacia terebinthus	34	0.02	12	0.08
Sorbus torminalis	33	0.02	27	0.19
Salix sp.	32	0.02	18	0.13
Myrica faya	30	0.02	3	0.02
Cedrus brevifolia	25	0.02	1	0.01
Quercus petraea_or_robur	24	0.02	4	0.03
*Corylus avellana**	23	0.02	10	0.07
Juglans regia	22	0.02	8	0.06
Buxus sempervirens	21	0.02	3	0.02
Pyrus communis	19	0.01	10	0.07
Quercus fruticosa (Q. lusitanica)	19	0.01	1	0.01
Arbutus andrachne	19	0.01	6	0.04
Quercus trojana	19	0.01	2	0.01
Arbutus unedo	15	0.01	6	0.04
Laurus canariensis	13	0.01	3	0.02
Juniperus sabina	13	0.01	1	0.01
Sorbus domestica	9	0.01	8	0.06
Tsuga sp.	9	0.01	1	0.01
Ulmus laevis (U. effusa)	8	0.01	5	0.04
Ilex aquifolium	8	0.01	5	0.04
Crataegus monogyna	8	0.01	4	0.03
Cupressus lusitanica	8	0.01	1	0.01
Phyllyrea angustifolia	7	0.01	2	0.01
Prunus serotina	6	0.00	1	0.01
*Quercus rotundifolia**	5	0.00	4	0.03
Ilex canariensis	5	0.00	3	0.02
Pistacia lentiscus	4	0.00	1	0.01
Malus domestica	4	0.00	3	0.02
Cedrus deodara	4	0.00	1	0.01
Abies grandis	3	0.00	1	0.01
Laurus nobilis	3	0.00	3	0.02
Salix fragilis	3	0.00	3	0.02
Ceratonia siliqua	3	0.00	2	0.01
Erica scoparia	2	0.00	1	0.01
Chamaecyparis lawsonia	2	0.00	1	0.01
Cercis siliquastrum	2	0.00	1	0.01
Erica manipuliflora	1	0.00	1	0.01
Prunus padus	1	0.00	1	0.01
Prunus dulcis (Amygdalus communis)	1	0.00	1	0.01
Salix eleagnos	1	0.00	1	0.01
Total	137209	100.00	14158	100.00

* Multiple counts of plots with several tree species

Annex I-3
Percentage of trees damaged (2009) [1)]

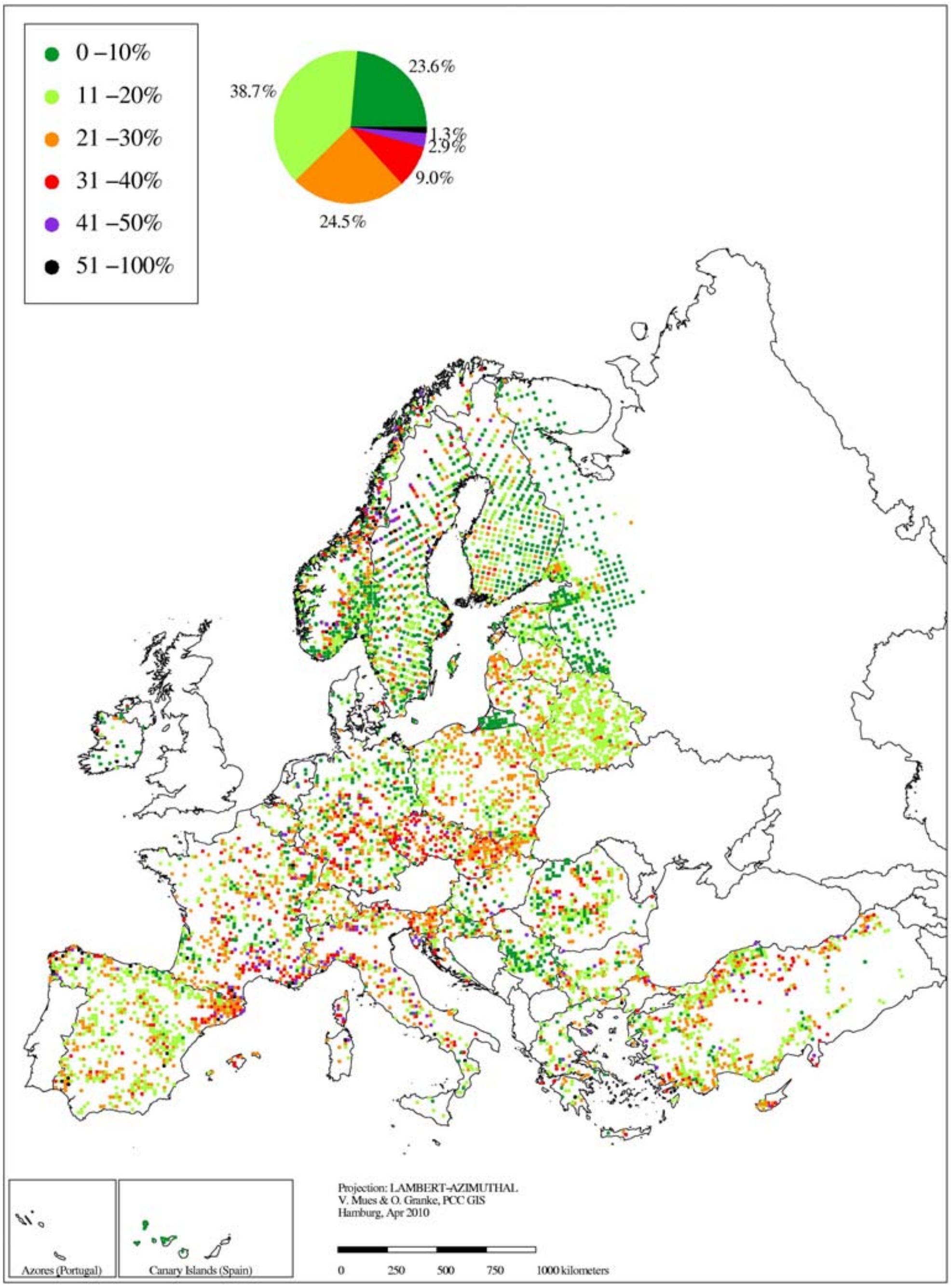
Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction however does not affect the reliability of the trends over time.



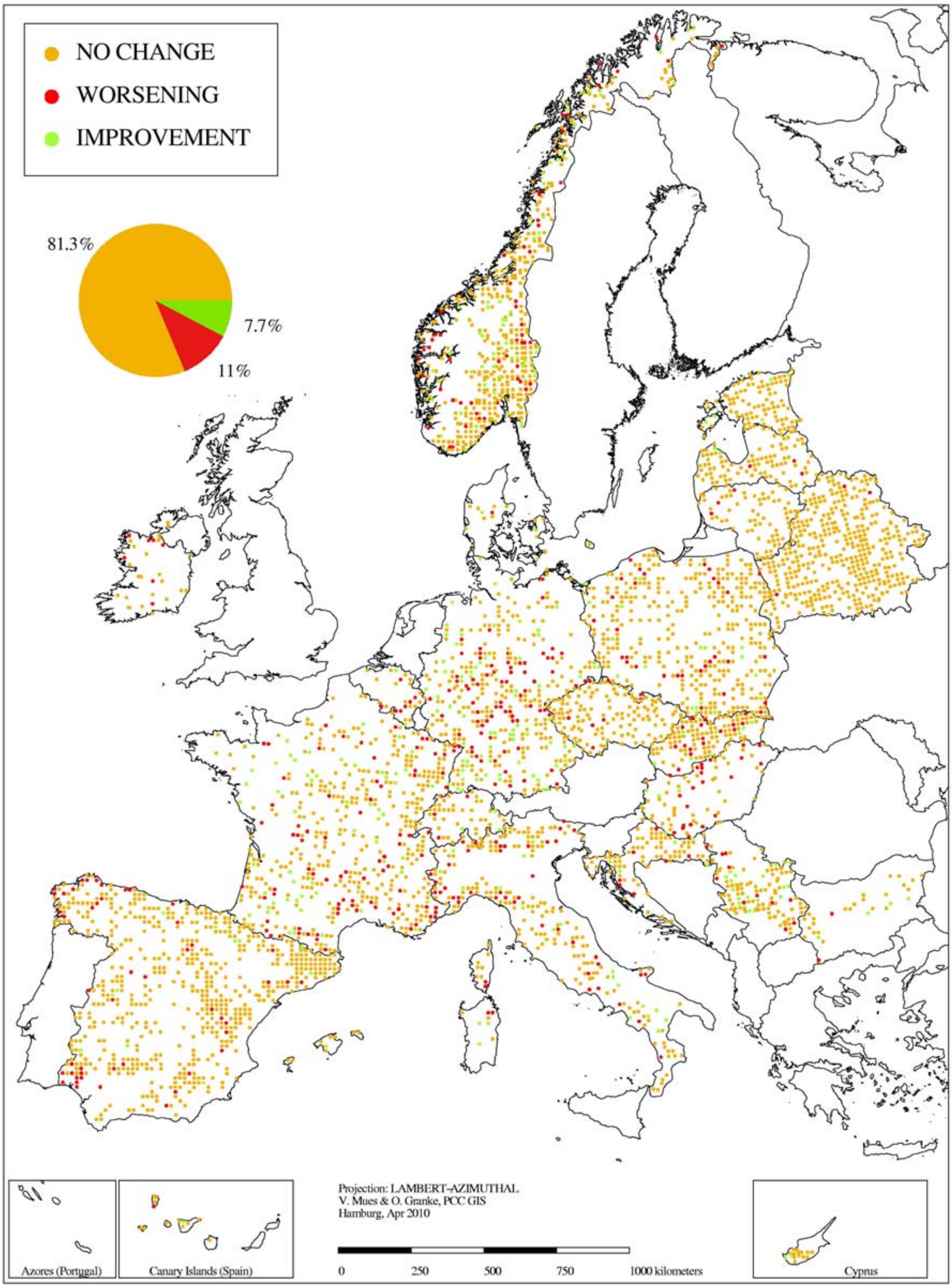
1) trees with defoliation larger than 25%

Annex I-4
Mean plot defoliation of all species (2009)

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



Annex I-5
Changes in mean plot defoliation (2008-2009)



Annex I-6

Development of mean defoliation of most common species for the periods 1991-2009 and 1998-2009.

Period 1998 - 2009

Year	Mean defoliation $\bar{x}$	Standard error $s_{\bar{x}}$ s/ N	Mean defoliation $\bar{x}$	Standard error $s_{\bar{x}}$ s/ N
Pinus sylvestris				
1991	23.5	0.12		
1992	23.3	0.12		
1993	22.9	0.12		
1994	23.6	0.13		
1995	21.0	0.11		
1996	19.8	0.11		
1997	19.2	0.10		
1998	18.4	0.09	21.2	0.09
1999	18.1	0.09	20.0	0.08
2000	18.5	0.09	19.8	0.08
2001	18.6	0.09	19.4	0.08
2002	19.2	0.10	18.8	0.08
2003	19.4	0.09	18.9	0.08
2004	19.0	0.09	18.4	0.08
2005	18.9	0.09	18.5	0.08
2006	17.7	0.09	17.8	0.08
2007	17.9	0.09	17.9	0.08
2008	18.3	0.09	18.2	0.07
2009	18.3	0.10	18.1	0.08
Picea abies				
1991	23.5	0.13		
1992	23.6	0.15		
1993	23.3	0.16		
1994	24.4	0.16		
1995	23.9	0.15		
1996	23.5	0.14		
1997	23.5	0.13		
1998	21.4	0.13	21.1	0.12
1999	21.0	0.13	20.5	0.12
2000	21.5	0.13	20.9	0.12
2001	21.3	0.13	20.6	0.12
2002	21.8	0.13	20.6	0.12
2003	21.7	0.13	20.6	0.12
2004	22.9	0.13	21.1	0.12
2005	21.9	0.13	20.4	0.12
2006	20.5	0.14	18.8	0.12
2007	21.3	0.14	19.4	0.13
2008	21.4	0.15	19.4	0.13
2009	21.6	0.16	19.2	0.13
Quercus robur and ***Q. petraea***				
1991	17.9	0.22		
1992	18.2	0.22		
1993	21.1	0.24		
1994	22.3	0.23		
1995	21.7	0.23		
1996	24.5	0.24		
1997	26.4	0.21		
1998	24.9	0.21	26.1	0.22
1999	23.7	0.19	24.0	0.19
2000	23.3	0.19	24.4	0.19
2001	23.7	0.19	24.3	0.19
2002	23.5	0.19	23.4	0.18
2003	25.8	0.19	25.6	0.19
2004	27.0	0.21	26.6	0.20
2005	27.3	0.20	27.1	0.20
2006	25.3	0.21	24.8	0.20
2007	25.8	0.22	25.1	0.20
2008	25.4	0.20	24.7	0.18
2009	24.7	0.20	23.8	0.18

Period 1998 - 2009

Year	Mean defoliation $\bar{x}$	Standard error $s_{\bar{x}}$ s/ N	Mean defoliation $\bar{x}$	Standard error $s_{\bar{x}}$ s/ N
Fagus sylvatica				
1991	14.9	0.17		
1992	17.3	0.19		
1993	16.7	0.19		
1994	17.5	0.18		
1995	19.7	0.19		
1996	19.4	0.17		
1997	20.6	0.18		
1998	19.5	0.17	19.5	0.17
1999	21.0	0.16	20.2	0.15
2000	20.6	0.17	20.0	0.17
2001	21.5	0.16	21.1	0.16
2002	20.7	0.16	20.4	0.16
2003	21.7	0.16	20.8	0.15
2004	24.9	0.18	23.7	0.17
2005	22.5	0.17	21.7	0.17
2006	22.1	0.17	21.9	0.18
2007	21.9	0.16	21.0	0.15
2008	20.1	0.16	19.4	0.15
2009	22.8	0.17	20.5	0.15
Pinus pinaster				
1991	11.7	0.27		
1992	14.0	0.29		
1993	14.1	0.29		
1994	18.5	0.38		
1995	18.0	0.28		
1996	20.1	0.31		
1997	17.2	0.26		
1998	19.1	0.29	19.0	0.28
1999	17.2	0.22	17.4	0.22
2000	18.2	0.26	18.3	0.25
2001	17.9	0.22	18.1	0.21
2002	18.9	0.21	19.1	0.21
2003	20.0	0.23	20.2	0.23
2004	20.5	0.26	20.7	0.25
2005	22.6	0.24	22.9	0.24
2006	22.3	0.24	22.6	0.24
2007	21.6	0.24	21.8	0.24
2008	20.7	0.21	20.9	0.21
2009	22.6	0.26	22.8	0.26
Quercus ilex and ***Q. rotundifolia***				
1991	12.1	0.16		
1992	14.8	0.22		
1993	14.9	0.18		
1994	19.2	0.31		
1995	23.6	0.30		
1996	23.8	0.28		
1997	21.3	0.27		
1998	19.1	0.23	19.2	0.22
1999	21.3	0.22	21.3	0.22
2000	21.0	0.19	21.1	0.19
2001	20.7	0.20	20.7	0.20
2002	21.8	0.19	21.8	0.19
2003	23.0	0.23	23.0	0.22
2004	21.2	0.19	21.1	0.19
2005	24.1	0.19	24.1	0.19
2006	24.4	0.22	24.4	0.22
2007	23.1	0.21	23.1	0.21
2008	22.4	0.20	22.3	0.20
2009	22.5	0.20	22.4	0.20

Annex I-7
Level II plots

Annex II

National Surveys

Annex II-1

Forests and surveys in European countries (2009).

Participating countries	Total area (1000 ha)	Forest area (1000 ha)	Coniferous forest (1000 ha)	Broadleav. forest (1000 ha)	Area surveyed (1000 ha)	Grid size (km x km)	No. of sample plots	No. of sample trees
Albania	2875	1063	171	600	no survey in 2009			
Andorra	47	18	15	2	18	16 x 16	3	73
Austria	8385	3878	2683	798	no survey in 2009			
Belarus	20760	7921	4741	3180	7921	16 x 16	409	9620
Belgium	3035	700	281	324	700	4^2 / 8^2	122	2858
Bulgaria	11100	3699	1119	2580	3699	$4^2/8^2/16^2$	159	5560
Croatia	5654	2061	321	1740		16 x 16	83	1991
Cyprus	925	298	172	0	172	16x16	15	362
Czech Republic	7886	2647	2014	633	2647	$8^2/16^2$	133	5284
Denmark	4310	527	250	224	474	$7^2/16^2$	16	384
Estonia	4510	2213	1446	1066	2213	16 x 16	92	2202
Finland	30415	20150	17974	1897	19871	16^2 / 24x32	886	7182
France	54883	15840	4041	9884		16 x 16	500	9949
Germany	35702	11076	6490	3857	10347	16^2 / 4^2	424	10376
Greece	12890	2034	954	1080	2034		89	2098
Hungary	9300	1904	226	1678	1904	16 x 16	78	1872
Ireland	7028	680	399	37	436	16 x 16	30	599
Italy	30128	8675	1735	6940		16 x 16	257	6966
Latvia	6459	3162	1452	1710	3162	8 x 8	340	8036
Liechtenstein	16	8	6	2	no survey in 2009			
Lithuania	6530	2150	1153	893		8x8/16x16	983	5961
Luxembourg	259	89	30	54	no survey in 2009			
Rep. of Macedonia					no survey in 2009			
Rep. of Moldova	3376	318	6	312		2x2	622	13676
The Netherlands	3482	334	158	52	no survey in 2009			
Norway	32376	12000	6800	5200	12000	$3^2/9^2$	1622	9332
Poland	31268	9200	6955	2245	9200	16 x 16	1923	38460
Portugal	8893	3234	1081	2153	no survey in 2009			
Romania	23839	6233	1873	4360	6233	16 x 16	227	5448
Russian Fed.	1700075	809090	405809	195769	36173		365	11016
Serbia	8836	2360	179	2181	1868	16 x 16/4 x 4	130	2765
Slovak Republic	4901	1961	815	1069	1961	16 x 16	108	4049
Slovenia	2027	1099	410	688	1099	16 x 16	44	1056
Spain	50471	11588	5910	4056		16 x 16	620	14880
Sweden	41000	28300	19600	900	20600	varying	3217	7097
Switzerland	4129	1186	818	368	1186	16 x 16	48	1040
Turkey	77846	21389	13006	8383	8313	16 x 16	563	12290
Ukraine	60350	9400	2756	3285	6033	16 x 16	1483	34498
United Kingdom	24291	2837	1640	1197	no survey in 2009			
TOTAL	2340257	1011322	515489	271397	160264	varying	15591	236980

Annex II-2

Percent of trees of all species by defoliation classes and class aggregates (2009).

Participating countries	Area surveyed (1000 ha)	No. of sample trees	0 none	1 slight	2 moderate	3+4 severe and dead	2+3+4
Albania			no survey in 2009				
Andorra	18	73	60.3	32.9	5.5	1.3	6.8
Austria			no survey in 2009				
Belarus	7921	9620	27.7	63.9	6.9	1.5	8.4
Belgium	700	2858	30.7	49.1	18.5	1.7	20.2
Bulgaria	3699	5560	29.6	49.3	19.8	1.3	21.1
Croatia		1991	37.2	36.5	22.6	3.7	26.3
Cyprus	172	362	3.0	60.8	34.3	1.9	36.2
Czech Republic	2647	5284	11.7	31.5	54.8	2.0	56.8
Denmark	474	384	69.0	25.5	4.4	1.1	5.5
Estonia	2213	2202	44.3	48.5	6.5	0.7	7.2
Finland	19871	7182	58.2	32.7	8.3	0.8	9.1
France		9949	28.7	37.8	30.2	3.3	33.5
Germany	10347	10376	36.4	37.1	25.2	1.3	26.5
Greece	2034	2098	42.2	33.5	21.1	3.2	24.3
Hungary	1904	1872	54.8	26.8	12.4	6.0	18.4
Ireland	399	599	69.9	17.5	11.5	1.0	12.5
Italy		6966	24.5	39.7	30.2	5.6	35.8
Latvia	3162	8036	17.0	69.2	12.1	1.7	13.8
Liechtenstein			no survey in 2009				
Lithuania		5961	18.6	63.7	15.7	2.1	17.7
Luxembourg			no survey in 2009				
Rep. of Macedonia			no survey in 2009				
Rep. of Moldova		13676	43.1	31.7	22.5	2.7	25.2
The Netherlands			no survey in 2009				
Norway	12000	9332	43.1	35.8	17.7	3.3	21.0
Poland	9200	38460	24.1	58.2	16.9	0.8	17.7
Portugal			no survey in 2009				
Romania		5448	44.1	37.0	17.6	1.3	18.9
Russian Fed.	36173	11016	80.0	13.8	4.8	1.4	6.2
Serbia	1868	2765	68.1	21.6	8.8	1.5	10.3
Slovak Republic	1961	4049	9.3	58.6	30.8	1.3	32.1
Slovenia	1099	1056	18.2	46.4	31.3	4.2	35.5
Spain		14880	17.8	64.4	14.3	3.4	17.7
Sweden	20600	7097	59.9	25.1	12.3	2.8	15.1
Switzerland	1186	1040	32.3	49.4	9.4	8.9	18.3
Turkey	13110	12290	25.1	56.2	16.9	1.9	18.7
Ukraine	6033	34498	66.4	26.8	6.2	0.6	6.8
United Kingdom			no survey in 2009				

Cyprus: Only conifers assessed. *Moldova*: Only broadleaves assessed. *Sweden*: Only conifers assessed.

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

Annex II-3

Percent of conifers by defoliation classes and class aggregates (2009).

Participating countries	Coniferous forest (1000 ha)	No. of sample trees	0 none	1 slight	2 moderate	3+4 severe and dead	2+3+4
Albania			no survey in 2009				
Andorra	15	73	60.3	32.9	5.5	1.3	6.8
Austria			no survey in 2009				
Belarus	4741	6975	26.0	65.7	7.1	1.2	8.3
Belgium		929	32.8	53.6	12.9	0.7	13.6
Bulgaria	1119	2360	19.7	47.3	30.4	2.6	33.0
Croatia	321	242	6.2	27.3	57.0	9.5	66.5
Cyprus	172	362	3.0	60.8	34.3	1.9	36.2
Czech Republic	2014	4189	10.3	26.6	60.7	2.4	63.1
Denmark	250	195	87.2	11.8	1.0	0.0	1.0
Estonia	1146	2085	43.4	49.1	6.8	0.7	7.5
Finland	17974	5991	56.4	33.6	9.1	0.8	9.9
France	4041	3393	44.6	28.6	24.2	2.6	26.8
Germany	6490	6209	39.9	39.8	19.2	1.1	20.3
Greece	954	1113	37.9	35.8	23.7	2.6	26.3
Hungary	226	254	45.3	27.6	16.1	11.0	27.1
Ireland	399	599	69.9	17.5	11.5	1.0	12.5
Italy	1735	2104	31.8	36.6	25.9	5.7	31.6
Latvia	1452	5809	11.4	73.8	13.1	1.7	14.8
Liechtenstein			no survey in 2009				
Lithuania	1153	3515	18.2	64.4	16.1	1.3	1153
Luxembourg			no survey in 2009				
Rep. of Macedonia			no survey in 2009				
Rep. of Moldova			only broadleaves assessed				
The Netherlands			no survey in 2009				
Norway	6800	7111	48.6	33.5	14.9	3.0	17.9
Poland	6955	25505	22.6	60.2	16.5	0.7	17.2
Portugal			no survey in 2009				
Romania	1873	1115	44.1	34.2	19.9	1.8	21.7
Russian Fed.	405809	6854	78.3	14.3	5.5	1.9	7.4
Serbia	179	331	64.7	22.7	10.2	2.4	12.6
Slovak Republic	815	1683	2.1	55.2	40.7	2.0	42.7
Slovenia	410	407	21.9	39.3	34.6	4.2	38.8
Spain	5910	7488	21.5	63.5	11.9	3.0	14.9
Sweden	19600	7097	59.9	25.1	12.3	2.8	15.1
Switzerland	818	741	30.2	51.0	11.2	7.6	18.8
Turkey	13006	7793	26.2	57.7	14.6	1.4	16.0
Ukraine	2756	14615	70.0	23.7	5.9	0.4	6.3
United Kingdom			no survey in 2009				

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

Annex II-4
Percent of broadleaves by defoliation classes and class aggregates (2009).

Participating countries	Broadleav. forest (1000 ha)	No. of sample trees	0 none	1 slight	2 moderate	3+4 severe and dead	2+3+4
Albania			no survey in 2009				
Andorra	2		only conifers assessed				
Austria	798		no survey in 2009				
Belarus	3180	2645	32.3	59.0	6.4	2.3	8.7
Belgium	783	1929	29.7	46.9	21.1	2.3	23.4
Bulgaria	2580	3200	37.0	50.8	12.0	0.2	12.2
Croatia	1740	1749	41.6	37.7	17.8	2.9	20.7
Cyprus			only conifers assessed				
Czech Republic	633	633	17.0	50.1	32.1	0.8	32.9
Denmark	224	189	50.3	39.7	7.9	2.1	10.0
Estonia	1066	117	59.7	36.8	2.6	0.9	3.5
Finland	1897	1185	67.2	28.1	4.3	0.4	4.7
France	9884	6556	20.5	42.5	33.5	3.6	37.1
Germany	3857	4167	31.0	32.9	34.6	1.5	36.1
Greece	1080	985	80.4	14.4	2.9	2.3	5.2
Hungary	1678	1618	56.1	26.8	11.9	5.2	17.1
Ireland	37		only conifers assessed				
Italy		4368	21.3	41.9	31.3	5.5	36.8
Latvia	1710	2227	31.4	57.0	9.5	2.1	11.6
Liechtenstein	2		no survey in 2009				
Lithuania	893	2446	19.1	62.5	15.1	3.3	18.4
Luxembourg	54		no survey in 2009				
Rep. of Macedonia			no survey in 2009				
Rep. of Moldova	312	13676	43.1	31.7	22.5	2.7	25.2
The Netherlands			no survey in 2009				
Norway	5200	2221	25.6	43.3	26.7	4.3	31.0
Poland	2245	12955	27.3	54.2	17.6	0.9	18.5
Portugal	2153		no survey in 2009				
Romania	4360	4333	44.2	37.7	17.0	1.3	18.3
Russian Fed.	195769	4162	82.8	12.8	3.7	0.7	4.4
Serbia	2181	2434	68.6	21.5	8.6	1.3	9.9
Slovak Republic	1069	2366	14.5	61.0	23.8	0.7	24.5
Slovenia	688	649	15.9	50.8	29.1	4.2	33.3
Spain	4056	7392	13.9	65.4	16.8	3.9	20.7
Sweden	900		only conifers assessed				
Switzerland	368	299	36.8	45.8	5.6	11.8	17.4
Turkey	8383	4497	23.0	53.6	20.7	2.7	23.4
Ukraine	3285	19883	63.8	29.0	6.5	0.7	7.2
United Kingdom	1197		no survey in 2009				

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

Annex II-5

Percent of damaged trees of all species (1998-2009).

Participating countries	All species Defoliation classes 2-4												change points 08/09
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Albania	9.8	9.9	10.1	10.2	13.1		12.2		11.1				
Andorra							36.1		23.0	47.2	15.3	6.8	-8.5
Austria	6.7	6.8	8.9	9.7	10.2	11.1	13.1	14.8	15.0				
Belarus	30.5	26.0	24.0	20.7	9.5	11.3	10.0	9.0	7.9	8.1	8.0	8.4	0.4
Belgium	17.0	17.7	19.0	17.9	17.8	17.3	19.4	19.9	17.9	16.4	14.5	20.2	5.7
Bulgaria	60.2	44.2	46.3	33.8	37.1	33.7	39.7	35.0	37.4	29.7	31.9	21.1	-10.8
Croatia	25.6	23.1	23.4	25.0	20.6	22.0	25.2	27.1	24.9	25.1	23.9	26.3	2.4
Cyprus				8.9	2.8	18.4	12.2	10.8	20.8	16.7	47.0	36.2	-10.8
Czech Rep.	48.8	50.4	51.7	52.1	53.4	54.4	57.3	57.1	56.2	57.1	56.7	56.8	0.1
Denmark	22.0	13.2	11.0	7.4	8.7	10.2	11.8	9.4	7.6	6.1	9.1	5.5	-3.6
Estonia	8.7	8.7	7.4	8.5	7.6	7.6	5.3	5.4	6.2	6.8	9.0	7.2	-1.8
Finland	11.8	11.4	11.6	11.0	11.5	10.7	9.8	8.8	9.7	10.5	10.2	9.1	-1.1
France	23.3	19.7	18.3	20.3	21.9	28.4	31.7	34.2	35.6	35.4	32.4	33.5	1.1
Germany	21.0	21.7	23.0	21.9	21.4	22.5	31.4	28.5	27.9	24.8	25.7	26.5	0.8
Greece	21.7	16.6	18.2	21.7	20.9			16.3				24.3	
Hungary	19.0	18.2	20.8	21.2	21.2	22.5	21.5	21.0	19.2	20.7		18.4	
Ireland	16.1	13.0	14.6	17.4	20.7	13.9	17.4	16.2	7.4	6.0	10.0	12.5	2.5
Italy	35.9	35.3	34.4	38.4	37.3	37.6	35.9	32.9	30.5	35.7	32.8	35.8	3.0
Latvia	16.6	18.9	20.7	15.6	13.8	12.5	12.5	13.1	13.4	15.0	15.3	13.8	-1.5
Liechtenstein													
Lithuania	15.7	11.6	13.9	11.7	12.8	14.7	13.9	11.0	12.0	12.3	19.6	17.7	-1.9
Luxembourg	25.3	19.2	23.4										
Rep. of Macedonia													
Rep. of Moldova			29.1	36.9	42.5	42.4	34.0	26.5	27.6	32.5	33.6	25.2	-8.4
The Netherlands	31.0	12.9	21.8	19.9	21.7	18.0	27.5	30.2	19.5				
Norway	30.6	28.6	24.3	27.2	25.5	22.9	20.7	21.6	23.3	26.2	22.7	21.0	-1.7
Poland	34.6	30.6	32.0	30.6	32.7	34.7	34.6	30.7	20.1	20.2	18.0	17.7	-0.3
Portugal	10.2	11.1	10.3	10.1	9.6	13.0	16.6	24.3					
Romania	12.3	12.7	14.3	13.3	13.5	12.6	11.7	8.1	8.6	23.2		18.9	
Russian Fed.				9.8	10.9							6.2	
Serbia	8.4	11.2	8.4	14.0	3.9	22.8	14.3	16.4	11.3	15.4	11.5	10.3	-1.2
Slovak Rep.	32.5	27.8	23.5	31.7	24.8	31.4	26.7	22.9	28.1	25.6	29.3	32.1	2.8
Slovenia	27.6	29.1	24.8	28.9	28.1	27.5	29.3	30.6	29.4	35.8	36.9	35.5	-1.4
Spain	13.6	12.9	13.8	13.0	16.4	16.6	15.0	21.3	21.5	17.6	15.6	17.7	2.1
Sweden	14.2	13.2	13.7	17.5	16.8	19.2	16.5	18.4	19.4	17.9	17.3	15.1	-2.2
Switzerland	19.1	19.0	29.4	18.2	18.6	14.9	29.1	28.1	22.6	22.4	19.0	18.3	-0.7
Turkey										8.1	24.6	18.7	-5.9
Ukraine	51.5	56.2	60.7	39.6	27.7	27.0	29.9	8.7	6.6	7.1	8.2	6.8	-1.4
United Kingdom	21.1	21.4	21.6	21.1	27.3	24.7	26.5	24.8	25.9	26.0			

Andorra: observe the small sample size. *Austria*: From 2003 on. results are based on the 16x16 km transnational grid net and must not be compared with previous years. *Cyprus*: Only conifers assessed. *Moldova*: only broadleaves assessed. *Poland*: Change of grid net since 2006. *Russian Federation:* North-western and Central European parts only. *Ukraine*: Change of gridnet in 2005. *Hungary, Romania*: comparisons not possible due to changing survey designs.

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

Annex II-6

Percent of damaged conifers (1998-2009).

Paticipating countries	Conifers Defoliation classes 2-4												change points 08/09
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Albania	12.0	12.1	12.3	12.4	15.5		14.0		13.6				
Andorra							36.1		23.0	47.2	15.3	6.8	-8.5
Austria	6.3	6.4	9.1	9.6	10.1	11.2	13.1	15.1	14.5				
Belarus	33.9	28.9	26.1	23.4	9.7	9.5	8.9	8.4	7.5	8.1	8.1	8.3	0.2
Belgium	13.5	15.5	19.5	17.5	19.7	18.6	15.6	16.8	15.8	13.9	13.2	13.6	0.4
Bulgaria	69.8	48.9	46.4	39.1	44.0	38.4	47.1	45.4	47.6	37.4	45.6	33.0	-12.6
Croatia	45.8	53.2	53.3	65.1	63.5	77.4	70.6	79.5	71.7	61.1	59.1	66.5	7.4
Cyprus				8.9	2.8	18.4	12.2	10.8	20.8	16.7	46.9	36.2	-10.7
Czech Rep.	54.6	57.4	58.3	58.1	60.1	60.7	62.6	62.7	62.3	62.9	62.8	63.1	0.3
Denmark	17.0	9.9	8.8	6.7	4.5	6.1	5.8	5.5	1.7	3.1	9.9	1.0	-8.9
Estonia	9.0	9.1	7.5	8.8	7.9	7.7	5.3	5.6	6.0	6.7	9.3	7.5	-1.8
Finland	12.2	11.9	12.0	11.4	11.9	11.1	10.1	9.2	9.6	10.4	10.1	9.9	-0.2
France	16.8	14.1	12.0	14.0	15.2	18.9	18.6	20.8	23.6	24.1	25.1	26.8	1.7
Germany	19.0	19.2	19.6	20.0	19.8	20.1	26.3	24.9	22.7	20.2	24.1	20.3	-3.8
Greece	12.9	13.5	16.5	17.2	16.1			15.0				24.3	
Hungary	18.7	17.6	21.5	19.5	22.8	27.6	24.2	22.0	20.8	22.3		27.1	
Ireland	16.1	13.0	14.6	17.4	20.7	13.9	17.4	16.2	7.4	6.2	10.0	12.5	2.5
Italy	25.5	23.1	19.2	19.1	20.5	20.4	21.7	22.8	19.5	22.7	24.0	31.6	7.6
Latvia	18.9	20.6	20.1	15.8	14.3	12.2	11.9	13.2	15.2	16.2	16.7	14.8	-1.9
Liechtenstein													
Lithuania	13.6	11.5	12.0	9.8	9.3	10.7	10.2	9.3	9.5	10.2	19.1	17.4	-1.7
Luxembourg	10.5	8.7	7.0										
Rep. of Macedonia													
Rep. of Moldova						55.4	35.5	38.0	38.6	34.3			
The Netherlands	43.2	14.5	23.5	20.7	17.5	9.4	17.2	17.9	15.3				
Norway	27.5	24.3	21.8	25.1	24.1	21.2	16.7	19.7	20.2	23.0	19.2	17.9	-1.3
Poland	34.6	30.6	32.1	30.3	32.5	33.2	33.4	29.6	21.1	20.9	17.5	17.2	-0.3
Portugal	6.6	6.0	4.3	4.3	3.6	5.3	10.8	17.1					
Romania	9.0	9.1	9.8	9.6	9.9	9.8	7.6	4.7	5.2	21.8		21.7	21.7
Russian Fed.				9.8	10.0							7.3	
Serbia	6.0	9.2	10.0	21.3	7.3	39.6	19.8	21.3	12.6	13.3	13.0	12.6	-0.4
Slovak Rep.	40.3	40.2	37.9	38.7	40.4	39.7	36.2	35.3	42.4	37.5	41.1	42.7	1.6
Slovenia	36.7	38.0	34.5	32.2	31.4	35.3	37.4	33.8	32.1	36.0	40.7	38.8	-1.9
Spain	12.9	9.8	12.0	11.6	15.6	14.1	14.0	19.4	18.7	15.8	12.9	14.9	2.0
Sweden	15.0	13.6	13.5	18.4	17.7	20.4	16.0	19.6	20.1	17.9	17.3	15.1	-2.3
Switzerland	19.7	18.3	33.0	19.1	19.9	13.3	27.4	28.2	22.5	20.7	18.7	18.8	0.1
Turkey										8.1	16.2	16.0	-0.2
Ukraine	64.9	50.0	47.3	16.8	14.6	15.4	11.4	8.1	6.9	7.1	7.1	6.3	-0.8
United Kingdom	19.8	20.1	20.2	20.6	25.1	25.8	23.2	22.2	23.3	16.1			

Andorra: observe the small sample size. *Austria*: From 2003 on. results are based on the 16 x 16 km transnational grid net and must not be compared with previous years. *Moldova*: Only broadleaves assessed. *Poland*: Change of grid net since 2006. *Russian Federation:* North-western and Central European parts only. *Ukraine*: Change of gridnet in 2005. *Hungary, Romania*: Comparisons not possible due to changing survey designs.

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

Annex II-7
Percent of damaged broadleaves (1998-2009).

Paticipating countries	Broadleaves Defoliation classes 2-4												change points 08/09
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Albania	8.0	8.1	8.4	8.4	10.7		10.3		8.5				
Andorra							only conifers assessed						
Austria	9.6	9.4	7.6	10.4	11.3	10.2	13.6	12.9	20.1				
Belarus	19.3	17.0	16.9	13.3	9.0	15.8	12.9	10.6	8.9	8.2	7.6	8.7	1.1
Belgium	19.2	19.1	18.8	18.3	17.0	16.6	21.3	21.4	18.8	17.5	15.3	23.4	8.1
Bulgaria	48.4	35.9	45.8	26.0	29.0	27.2	30.1	23.1	36.4	21.1	17.8	12.2	-5.6
Croatia	21.9	16.8	18.3	18.7	14.4	14.3	17.2	19.2	18.2	20.0	19.1	20.7	1.6
Cyprus							only conifers assessed						
Czech Rep.	13.5	17.1	21.4	21.7	19.9	24.4	31.8	32.0	31.2	33.5	32.2	32.9	0.7
Denmark	30.1	18.8	13.9	8.5	15.4	16.6	19.1	14.4	14.8	10.3	8.0	10.0	2.0
Estonia	1.0	1.1	9.5	2.1	2.7	6.7	5.3	3.4	8.6	7.6	3.4	3.5	0.1
Finland	9.4	8.6	9.9	8.8	8.8	8.3	8.4	7.2	10.3	10.9	10.6	4.7	-5.9
France	26.9	22.9	21.6	23.6	25.5	33.5	38.7	41.3	42.0	41.6	36.5	37.1	0.6
Germany	25.2	26.9	29.9	25.4	24.7	27.3	41.5	35.8	37.2	32.8	28.4	36.1	7.7
Greece	31.7	20.2	20.2	26.6	26.5			17.9				5.2	
Hungary	19.0	18.2	20.8	21.5	20.8	22.0	21.0	20.9	19.0	20.6		17.1	
Ireland							only conifers assessed						
Italy	38.9	39.3	40.5	46.3	44.6	45.0	42.0	36.5	35.2	40.4	35.8	36.8	1.0
Latvia	13.6	14.2	22.2	14.8	12.8	13.5	14.3	12.9	8.5	11.8	11.5	11.6	0.1
Liechtenstein													
Lithuania	19.7	11.8	17.7	16.3	19.0	24.6	21.8	15.4	16.6	17.7	20.3	18.4	-1.9
Luxembourg	33.3	25.8	33.5										
Rep. of Macedonia													
Rep. of Moldova		41.4	29.2	36.9	42.5	42.3	33.9	26.4	27.6	7.4	33.6	25.2	-8.4
The Netherlands	14.0	10.0	18.8	18.5	29.6	33.7	46.9	53.1	26.2				
Norway	42.2	44.8	34.0	33.7	30.4	29.0	33.2	27.6	33.2	36.3	33.8	31.0	-2.8
Poland	34.8	31.1	32.0	31.4	33.1	39.6	38.7	34.1	18.0	18.9	19.1	18.5	-0.6
Portugal	12.0	13.7	13.2	12.8	12.6	16.2	19.0	27.0					
Romania	13.3	14.0	15.8	14.7	14.8	13.3	13.0	9.3	9.9	23.5		18.3	18.3
Russian Fed.					16.0							4.4	
Serbia	10.1	13.0	6.7	6.7	0.6	21.5	13.5	15.7	11.0	15.7	11.3	9.9	-1.4
Slovak Rep.	27.0	19.3	13.9	26.9	14.5	25.6	19.9	13.6	17.0	16.6	20.8	24.5	3.7
Slovenia	21.7	23.2	18.4	26.7	25.9	22.6	24.2	28.5	27.6	35.7	34.6	33.3	-1.3
Spain	14.4	16.1	15.7	14.4	17.3	19.1	16.1	23.3	24.4	19.5	18.4	20.7	2.3
Sweden	7.4	8.7	7.5	14.1	9.6	11.1	8.3	9.2	10.8	only conifers assessed			
Switzerland	18.1	20.4	22.1	16.3	16.0	18.1	32.8	27.9	22.6	26.1	19.6	17.4	-2.2
Turkey											38.3	23.4	-14.9
Ukraine	43.2	59.7	69.6	53.3	36.7	35.3	43.2	9.2	6.2	7.1	9.1	7.2	-1.9
United Kingdom	22.9	23.2	23.8	21.9	30.3	23.2	30.6	28.2	29.2	35.3			

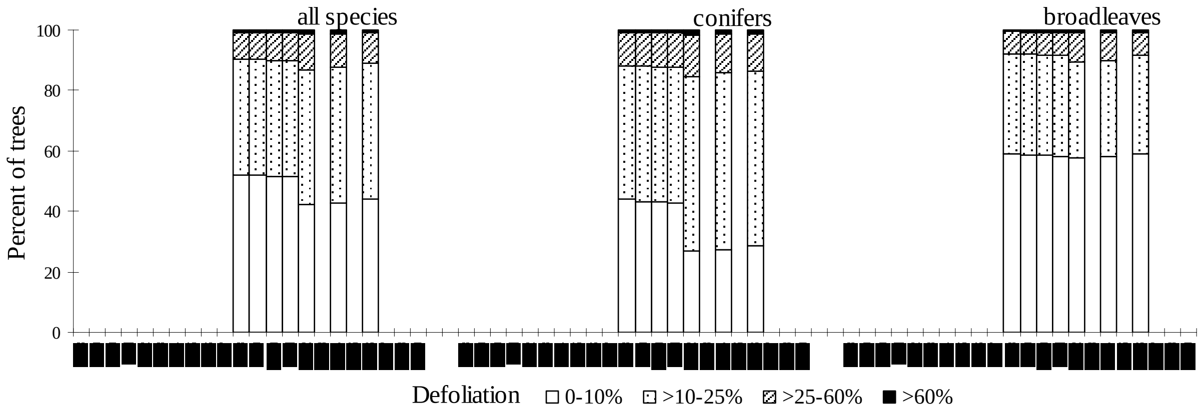
Andorra: observe the small sample size. *Austria*: From 2003 on. results are based on the 16 x 16 km transnational grid net and must not be compared with previous years. *Poland*: Change of grid net since 2006.*Russian Federation:* North-western and Central European parts only. *Ukraine*: Change of gridnet in 2005. *Hungary, Romania*: Comparisons not possible due to changing survey designs.

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

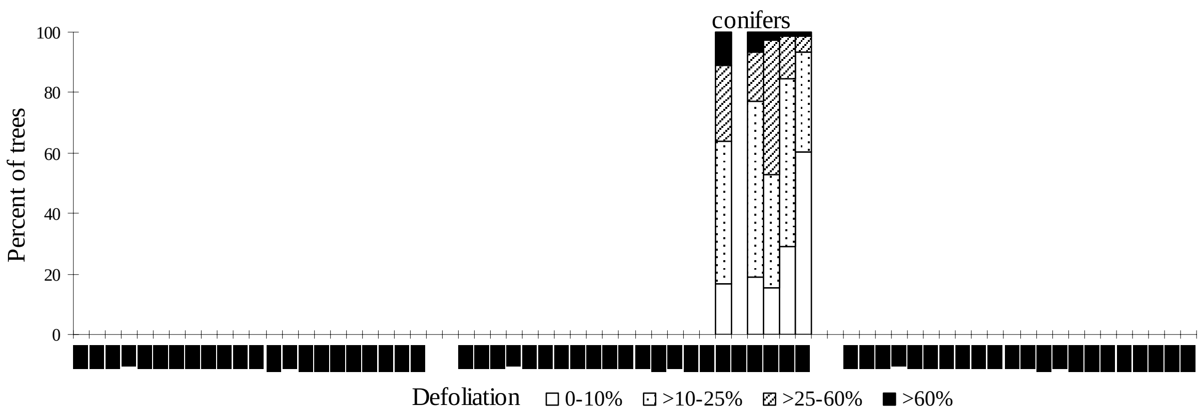
Annex II-8

Changes in defoliation (1988-2009)

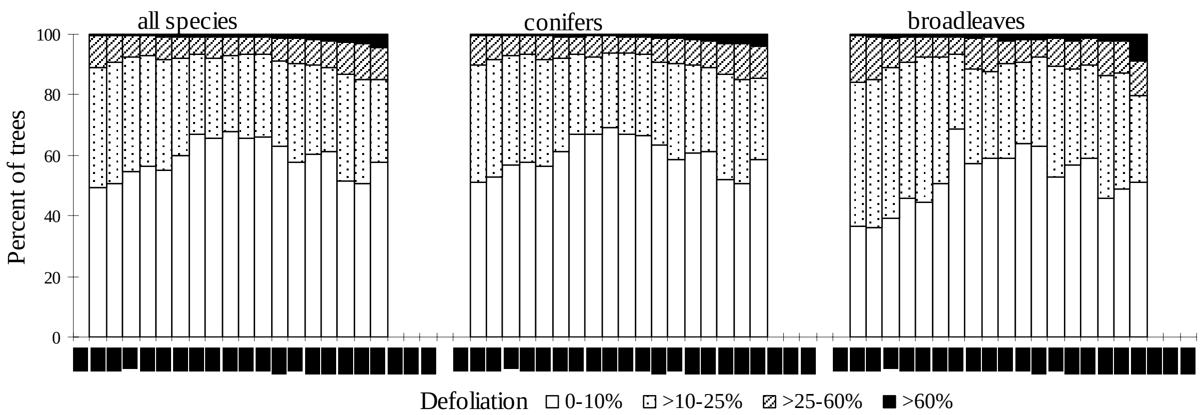
Albania



Andorra

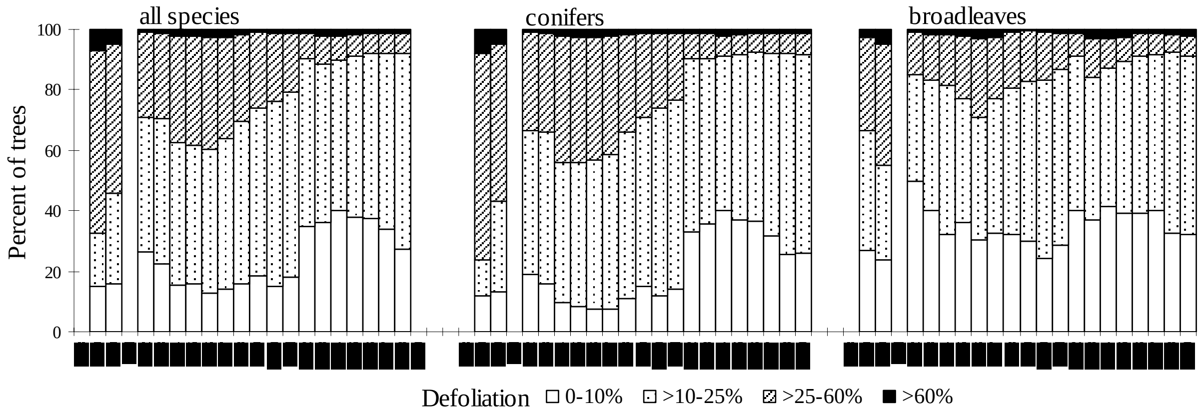


Austria *

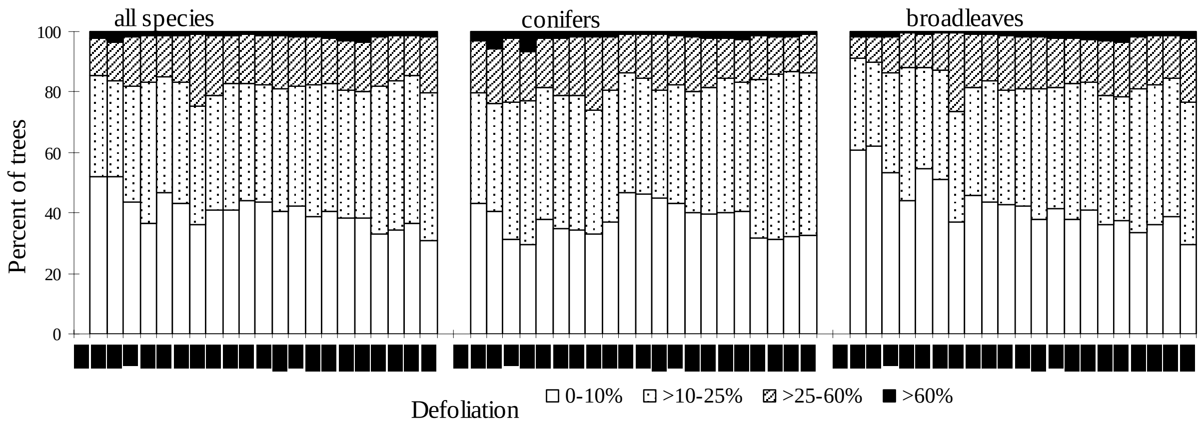


* from 2003 on, results are based on the 16 x 16 km transnational gridnet and must not be compared with previous years.

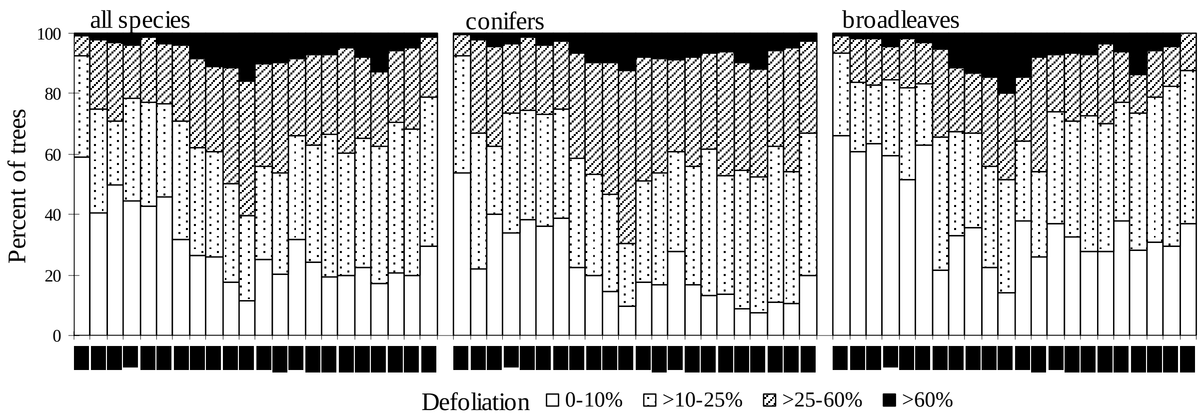
Belarus



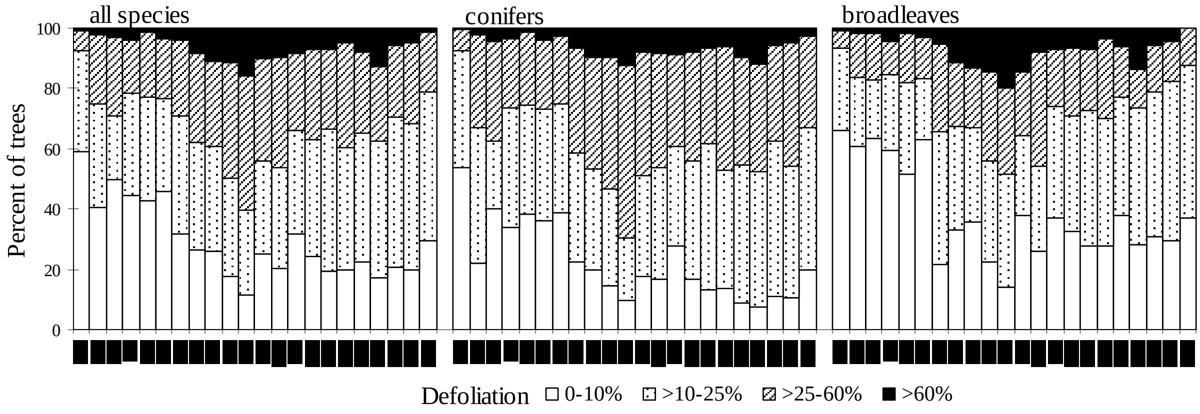
Belgium



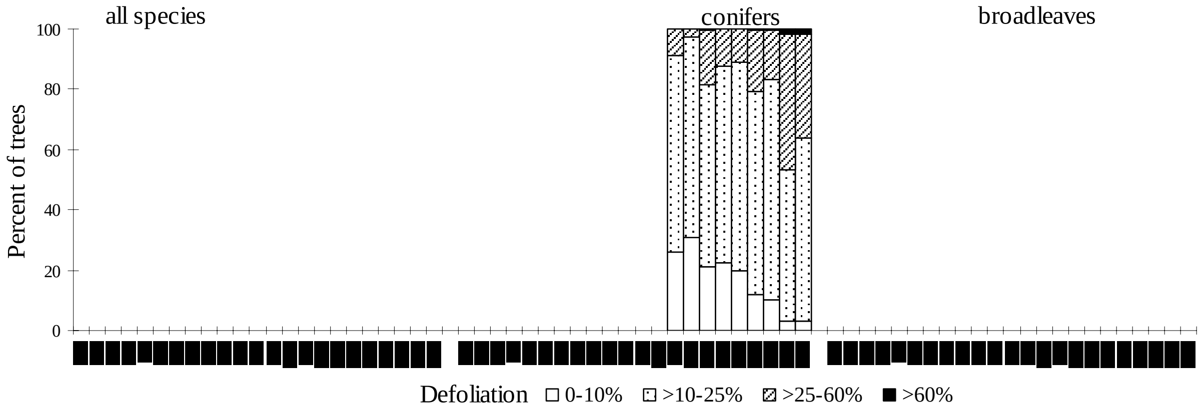
Bulgaria



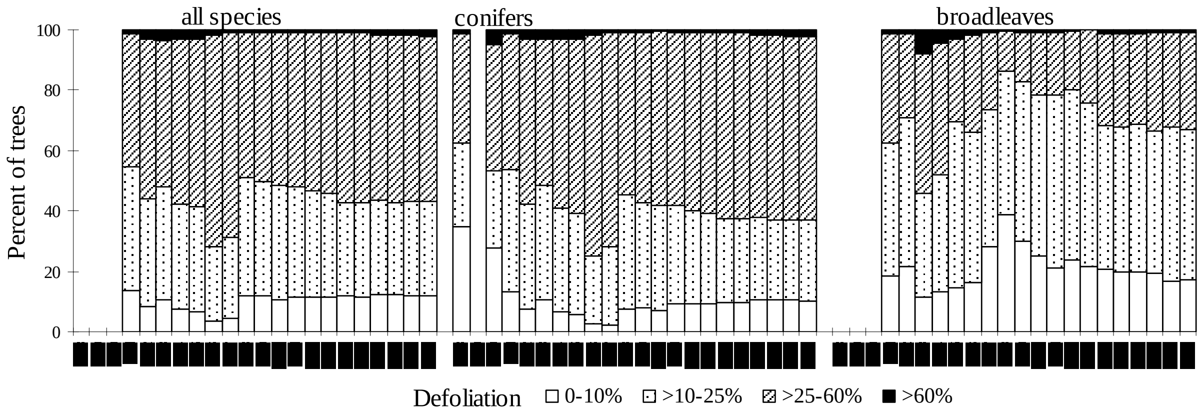
Croatia



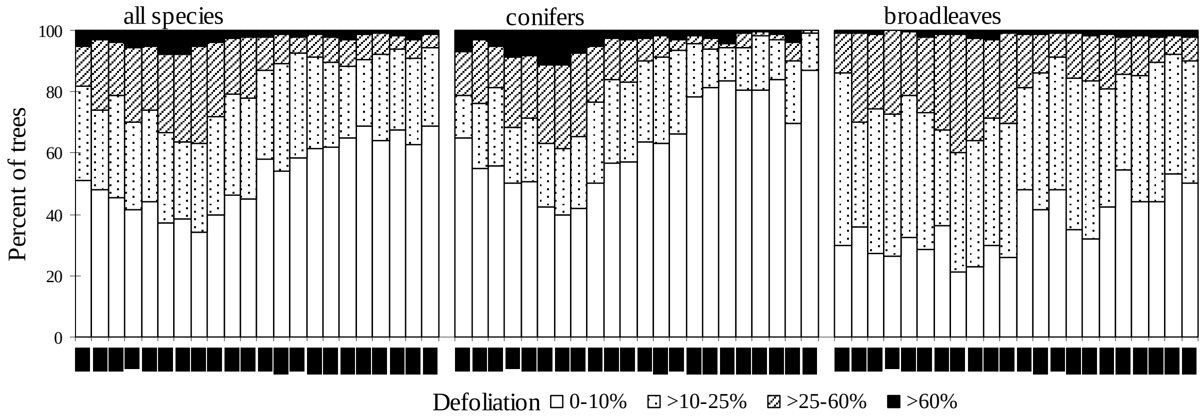
Cyprus



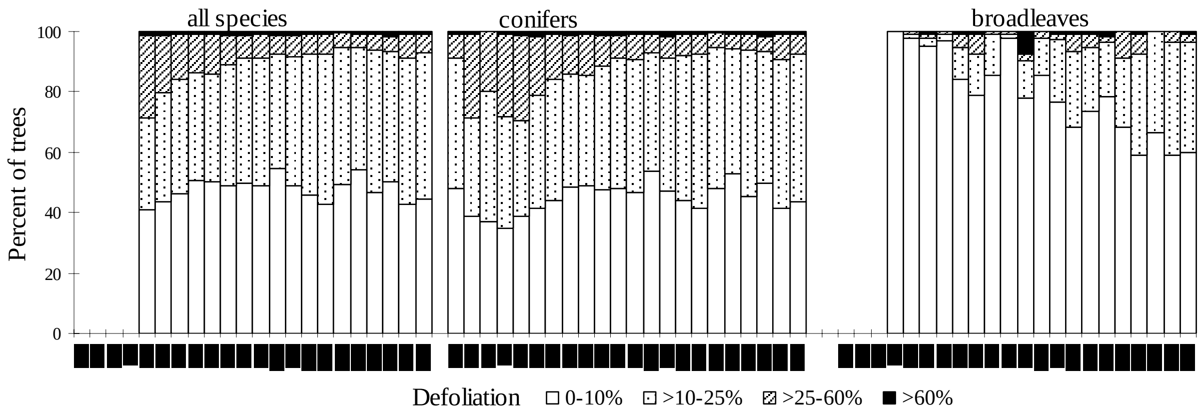
Czech Republic



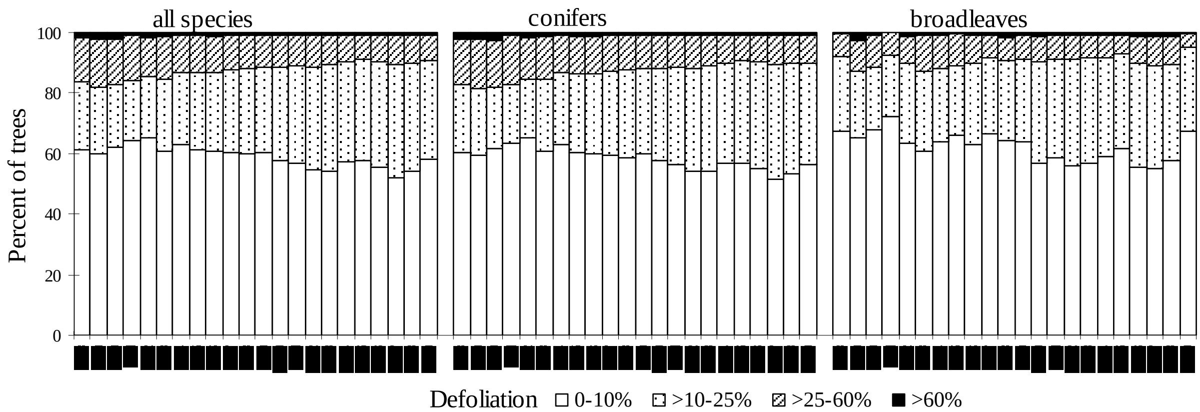
Denmark



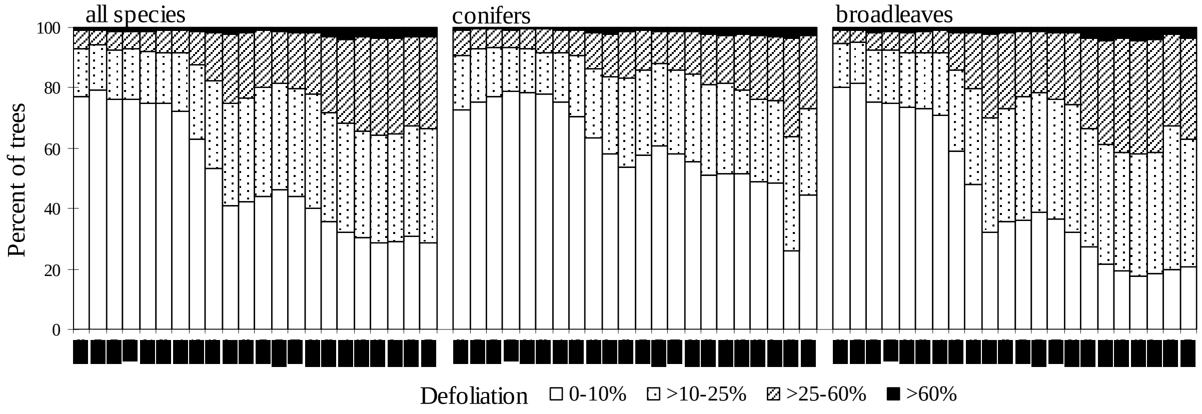
Estonia



Finland

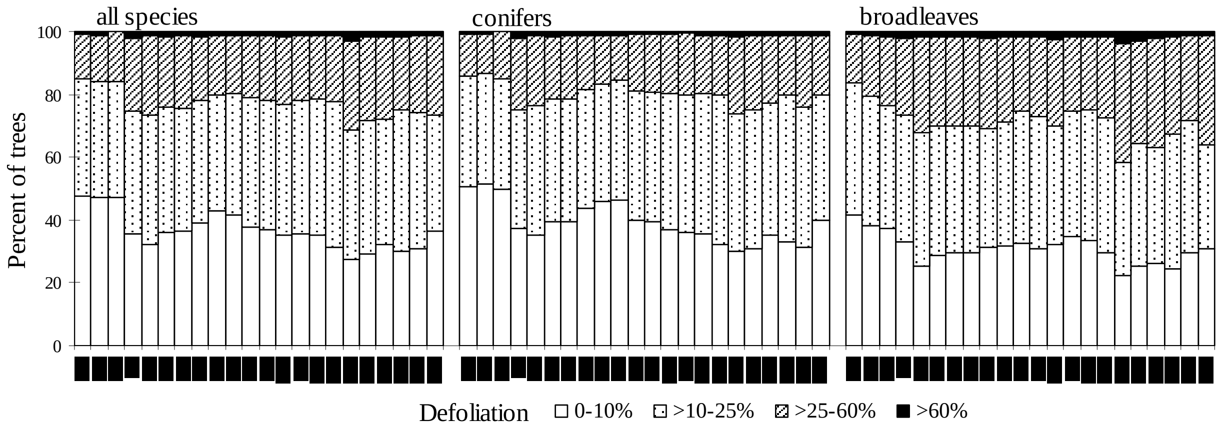


France *



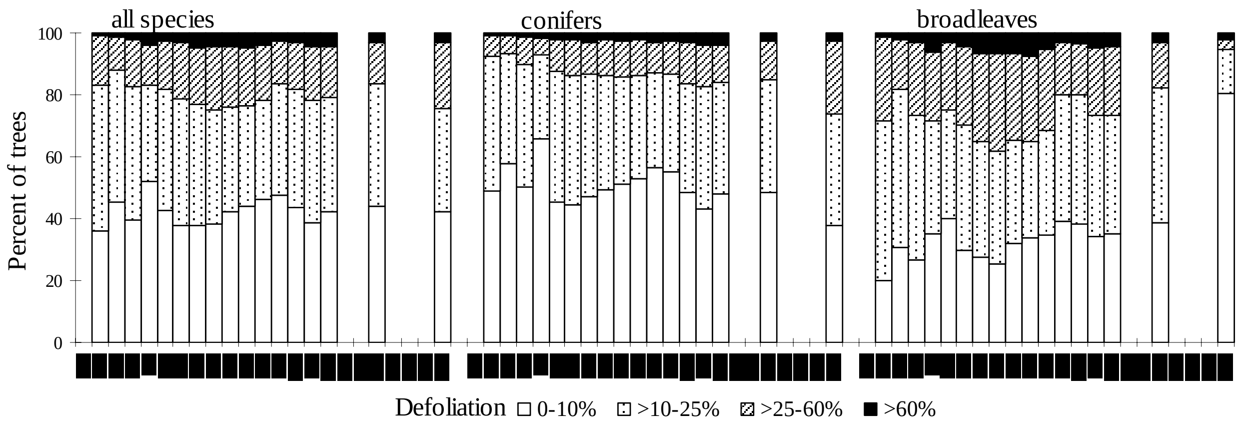
* due to methodological changes, only the time series 1988-94 and 1997-2009 are consistent, but not comparable to each other.

Germany

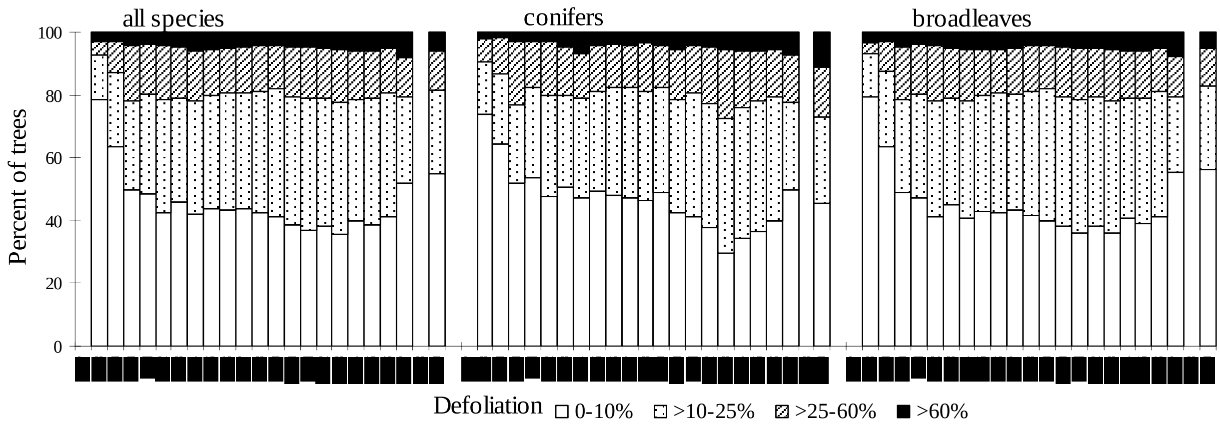


* since 1991 with former GDR

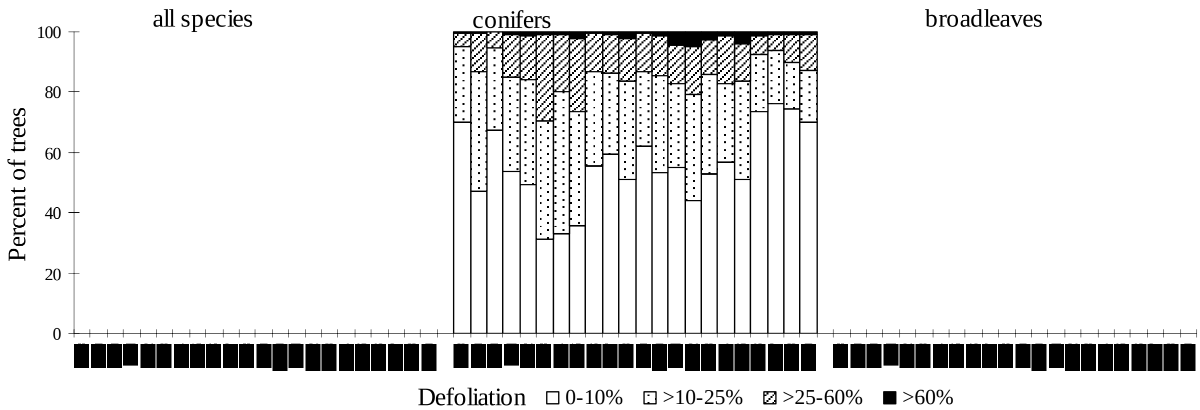
Greece



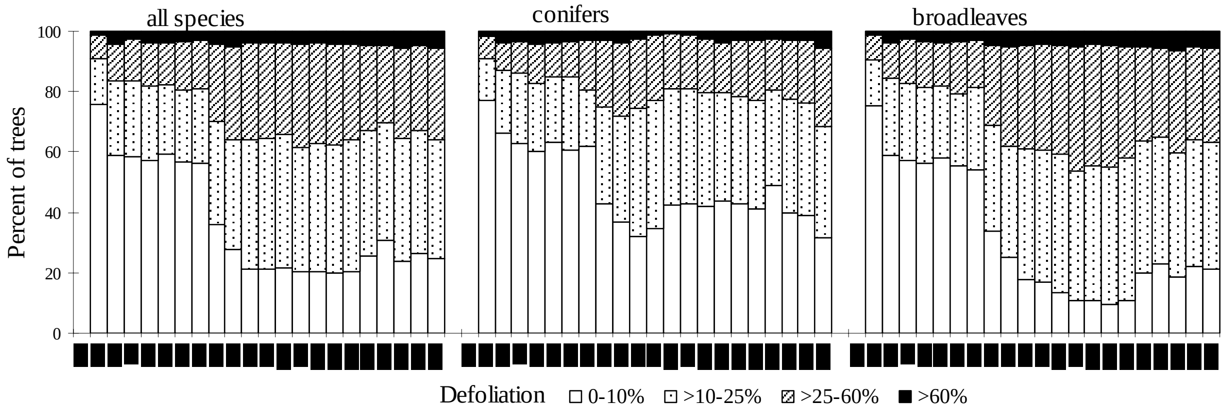
Hungary



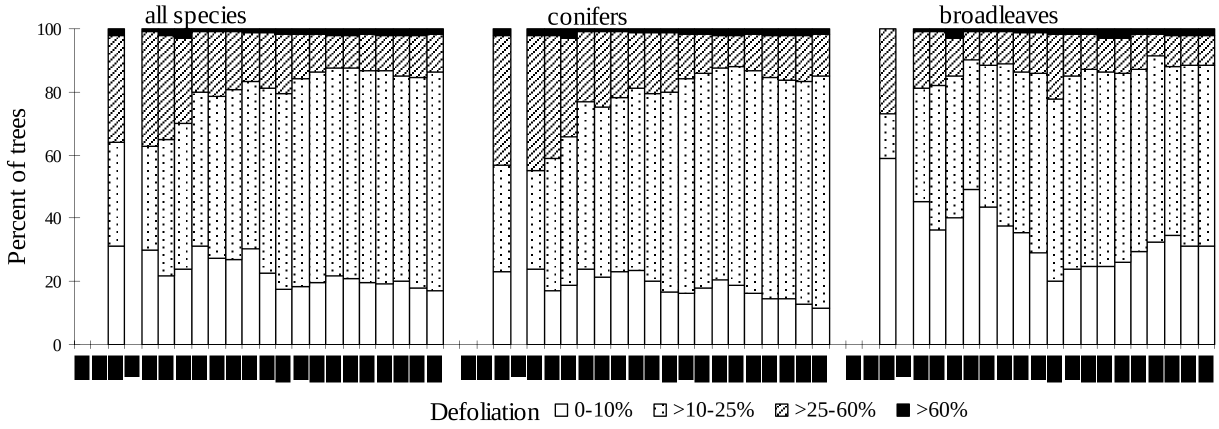
Ireland



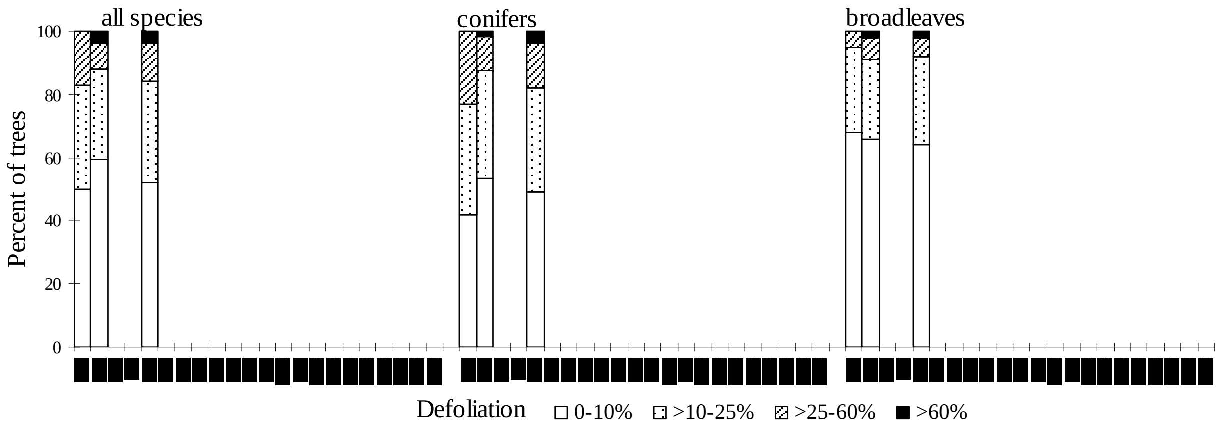
Italy



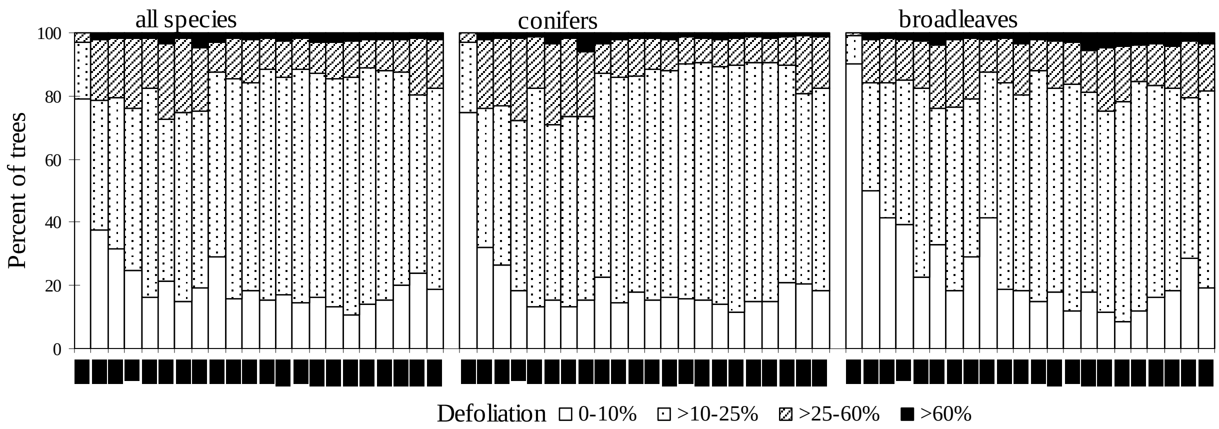
Latvia



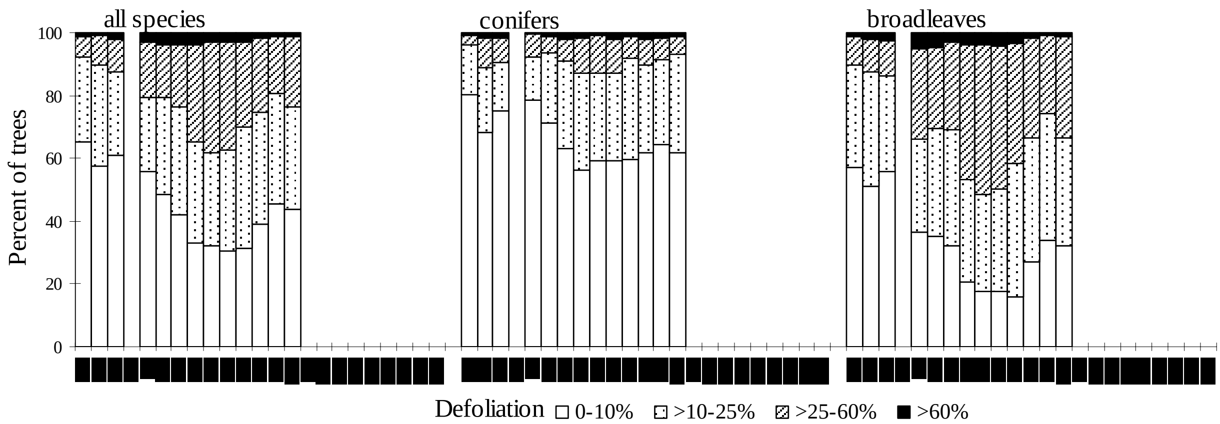
Liechtenstein



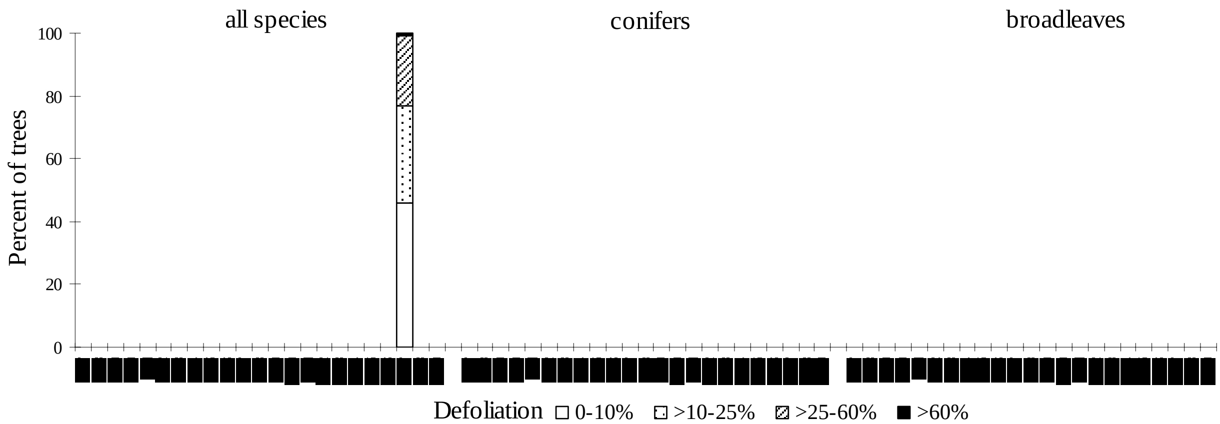
Lithuania



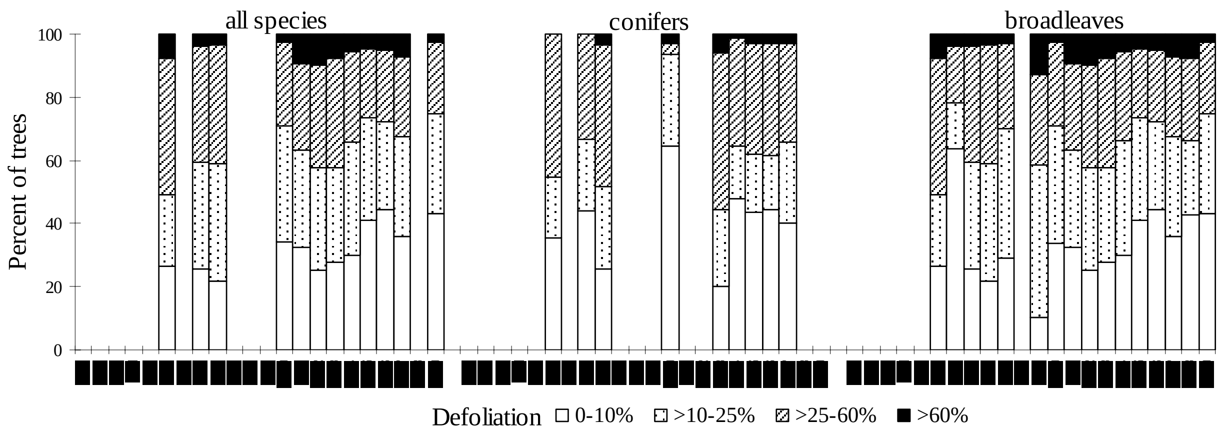
Luxembourg



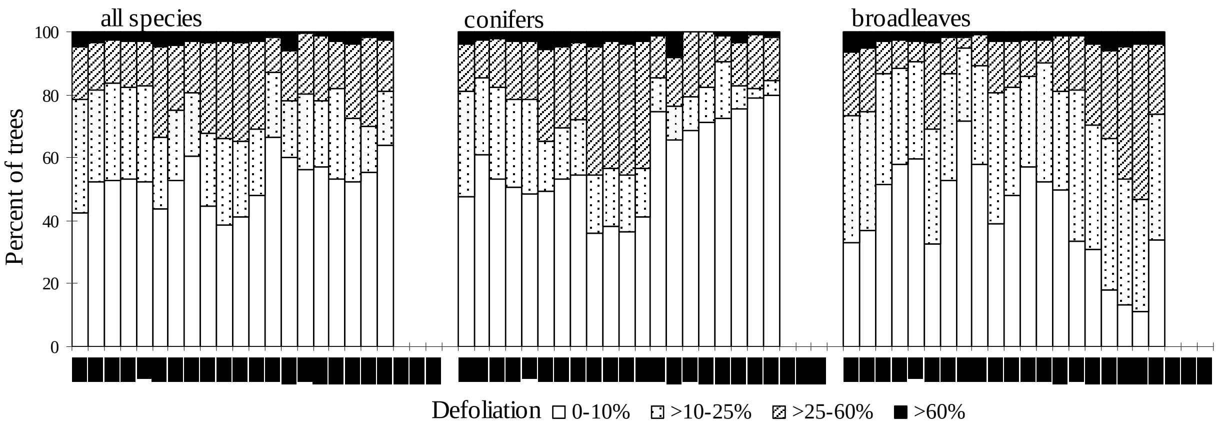
Republic of Macedonia



Republic of Moldova

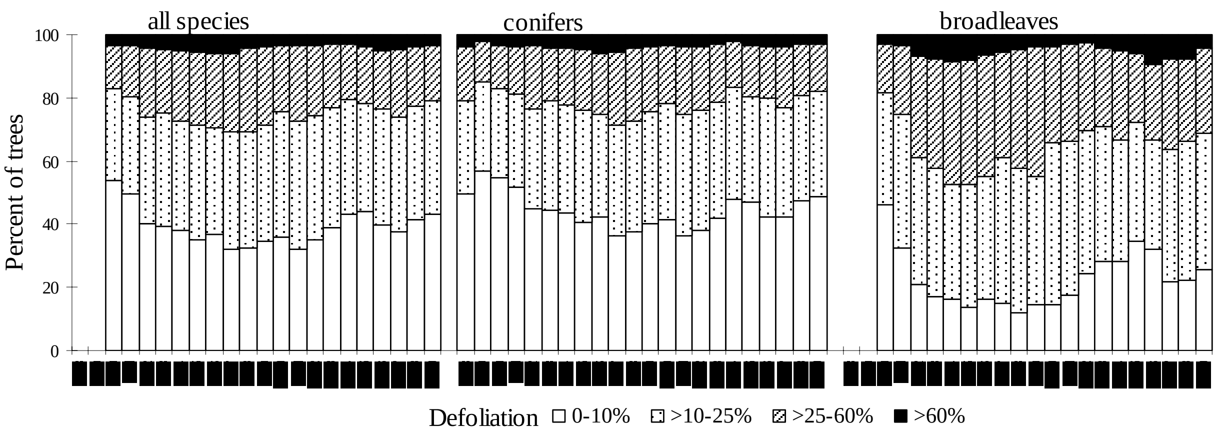


The Netherlands

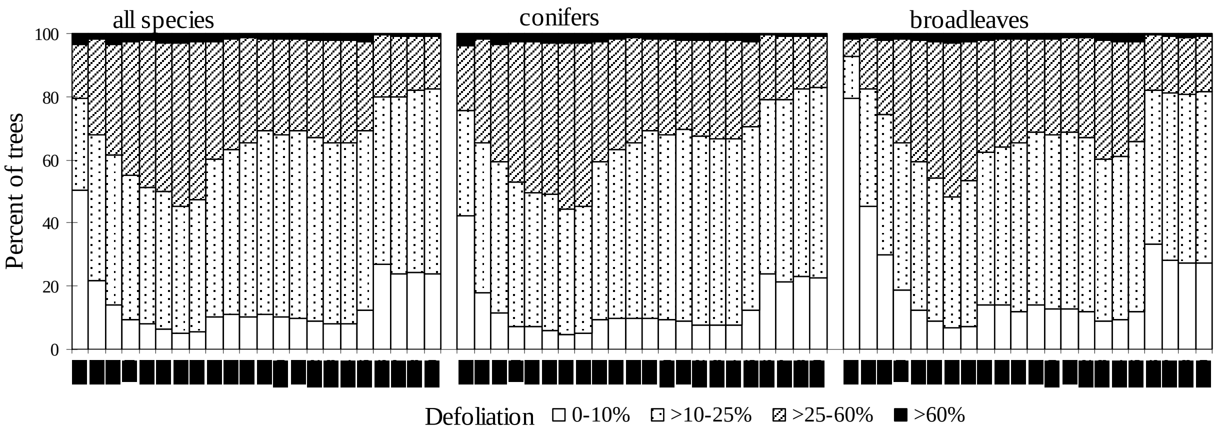


1989-1994: 1500 plots, 1995-1998: 200 plots, since 1999: 11 plots

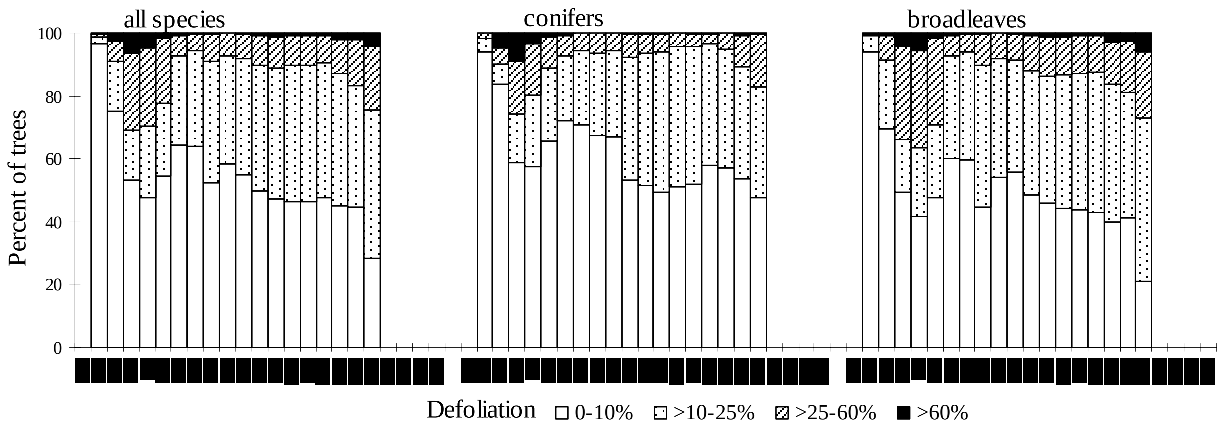
Norway



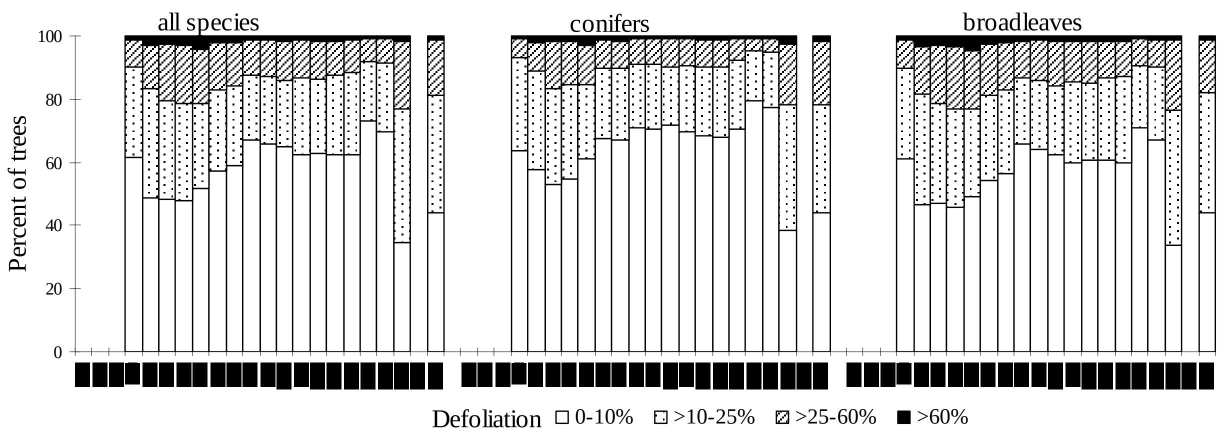
Poland



Portugal

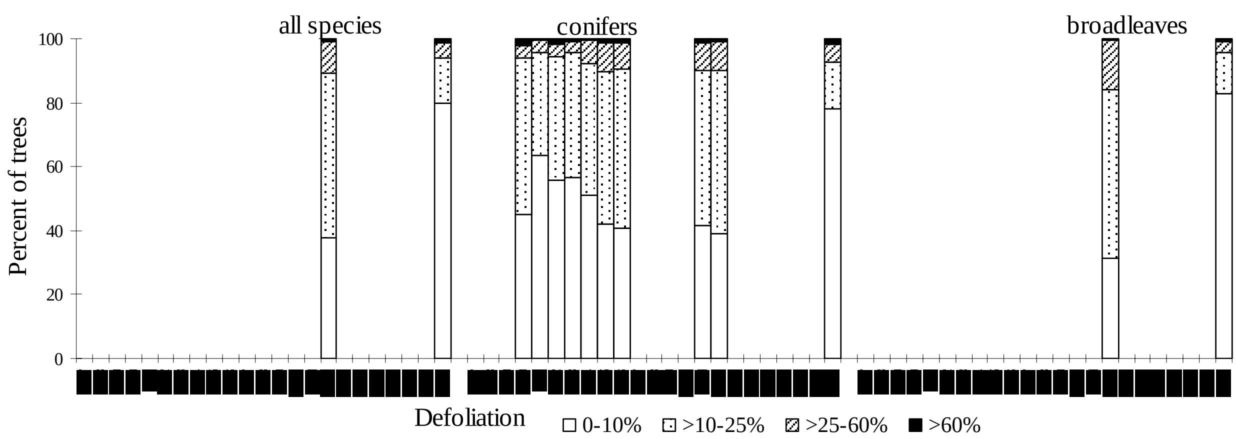


Romania *



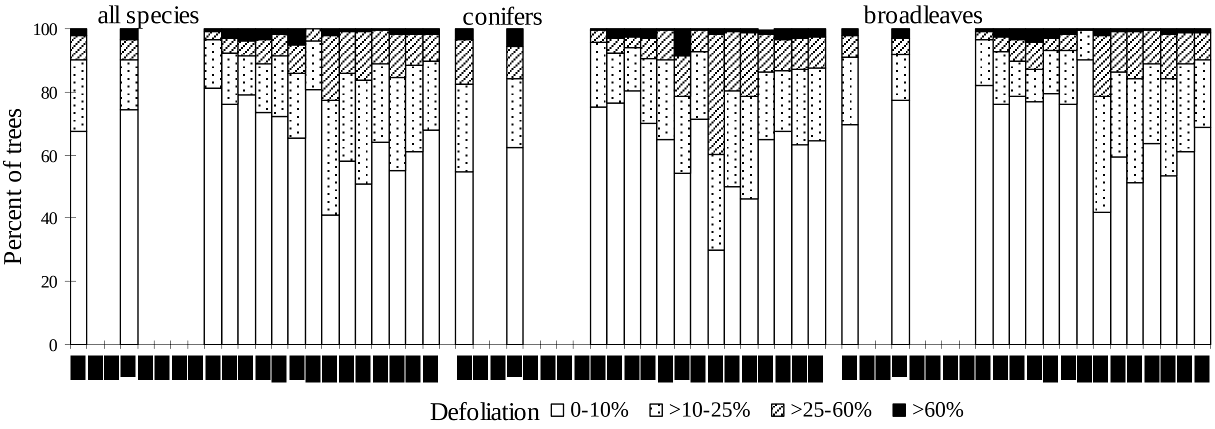
* from 2007 on, results are based on the 16 x 16 km transnational gridnet and must not be compared with previous years.

Russian Federation *

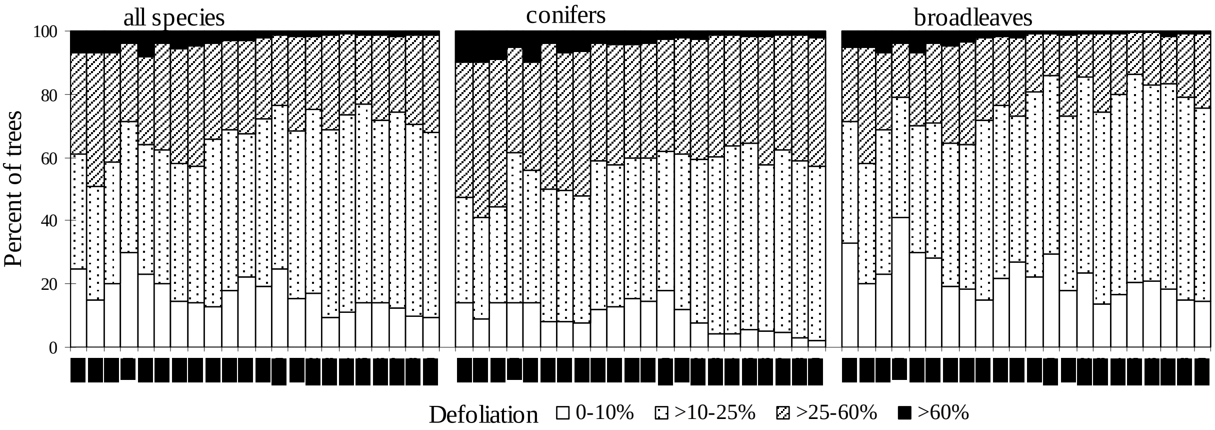


* Only regional surveys in north-western and Central European parts of Russia until 2002.

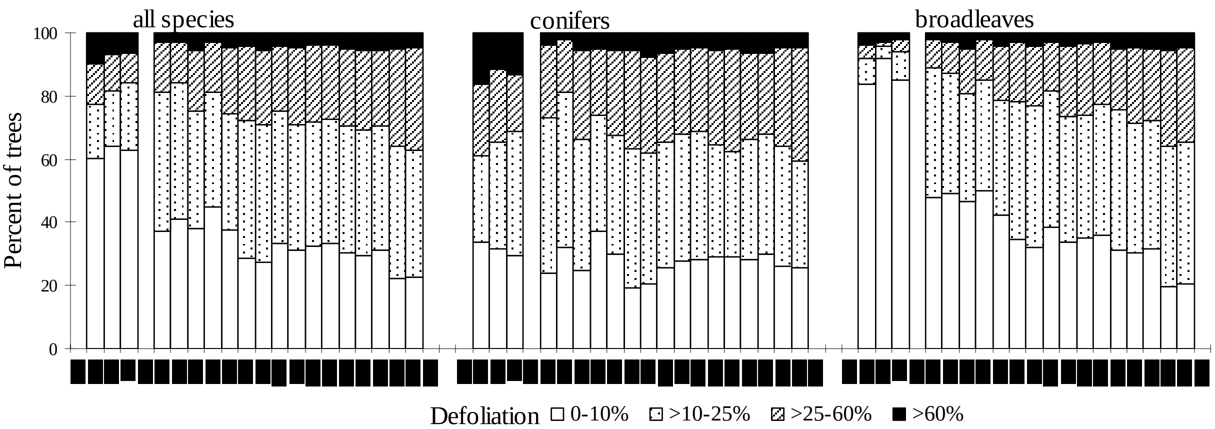
Serbia



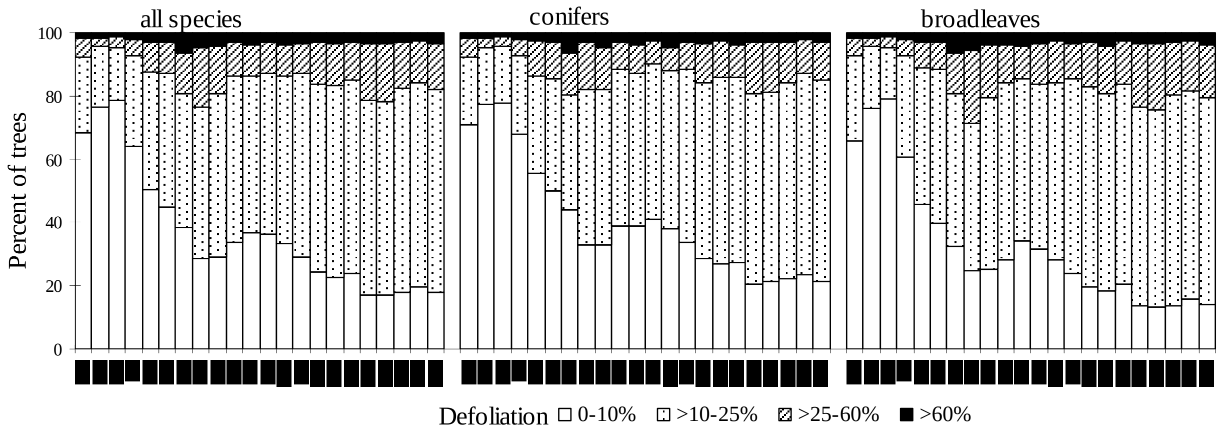
Slovak Republic



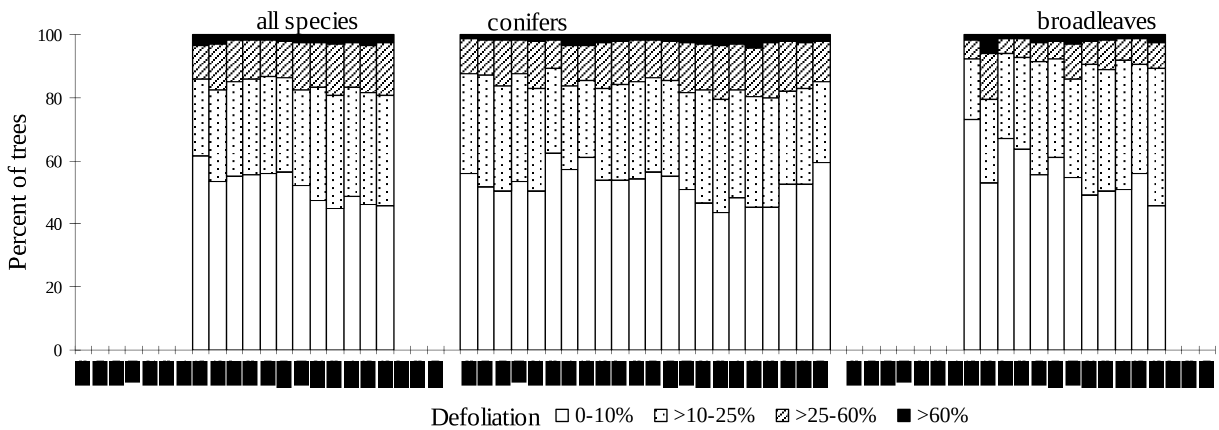
Slovenia



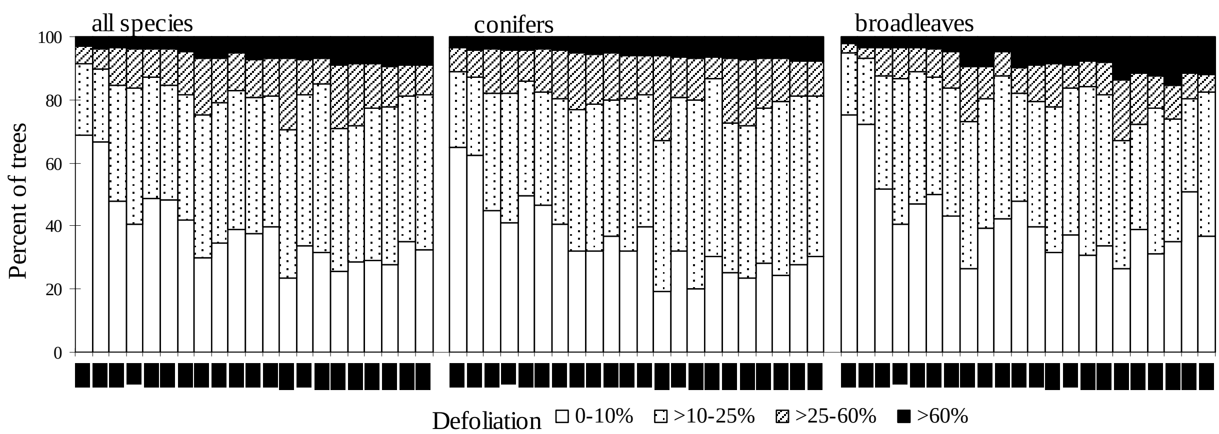
Spain



Sweden

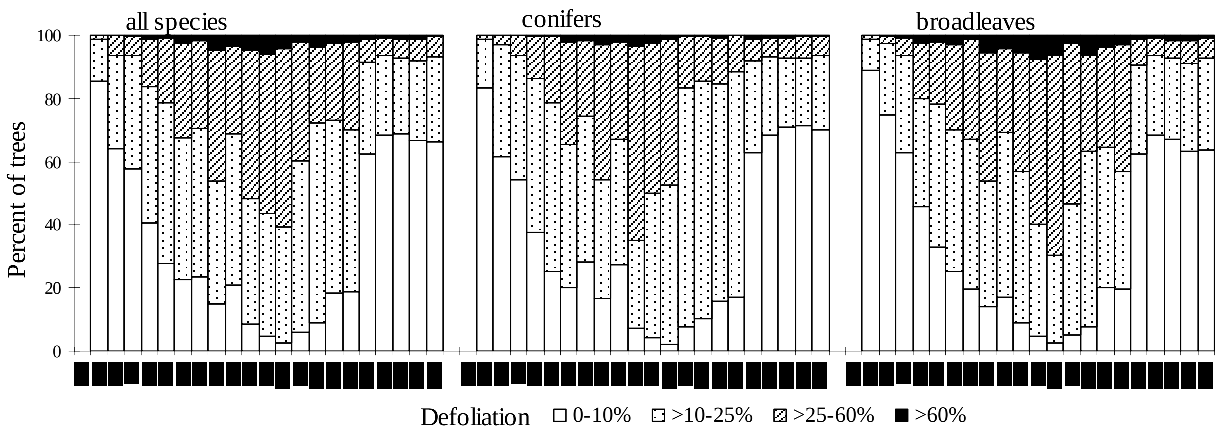


Switzerland



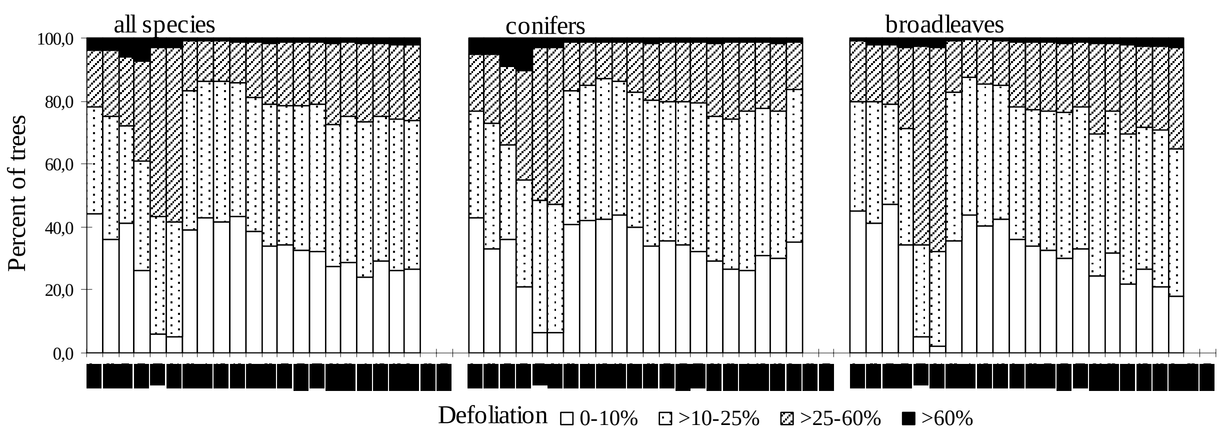
Turkey

Ukraine



since 2005 change of assessment grid

United Kingdom



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

Annex III

Main species referred to in the text

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

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

Annex IV

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

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

$$t = \frac{\left|\bar{x}_{2009} - \bar{x}_{2008}\right|}{\sqrt{\frac{s^2}{n_{2009}} + \frac{s^2}{n_{2008}}}}$$

where $\bar{x}_{2009}$ - $\bar{x}_{2008}$ is the difference in mean plot defoliation between the assessments in 2008 and 2009,

s - the standard deviation of these differences,

n_{2009}, n_{20008} - number of sample trees on plots being tested.

The standard deviation s is calculated as follows

$$s = \sqrt{\frac{(n_{2009} - 1)s_{2009}^2 + (n_{2008} - 1)s_{2008}^2}{n_{2009} + n_{2008} - 2}}$$

with standard deviations s_{2009}, s_{2008} derived from the defoliation scores for the years 2009 and 2008 on the plots investigated.

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

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