United Nations Economic Commission for Europe
Convention on Long-Range Transboundary Air Pollution

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

Forest Condition in Europe

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PREFACE

In the year 2005, the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) celebrates its 20th anniversary. Established in 1985 under the Convention on Long-range Transboundary Air Pollution (CLRTAP) under the United Nations Economic Commission for Europe (UNECE), it has been monitoring forest condition in Europe since 1986. In close cooperation with the European Union (EU) and with 40 countries including Canada and the United States of America participating, the programme has over the last 20 years grown up into one of the largest biomonitoring networks of the world. ICP Forests aims to provide CLRTAP with scientific information on the effects of air pollution on forests. It provides a periodic overview of the spatial and temporal variation in forest condition in relation to natural and anthropogenic stress factors, in particular air pollution. This is achieved by means of a large-scale, low-intensity monitoring on a systematic network of more than 6 100 plots across Europe, referred to as “Level I”. In addition, the programme contributes to a better understanding of the relationships between stress factors, in particular air pollution, and the condition of forest ecosystems. For this purpose, intensive monitoring at the ecosystem scale is conducted on more than 860 plots selected in the most important forest ecosystems of the participating countries, referred to as “Level II”. This required the development and international harmonization of methods and standards for the implementation of data management and data quality control as well as for scientific evaluations of the monitoring data and for continuous reporting of results.

The results published by ICP Forests within two decades provide a realistic picture of the extent and development of forest damage and contribute to the enlightenment of the complex causes and effects involved. They constitute a part of the scientific basis of the legally binding protocols on air pollution abatement policies of the countries of UNECE under CLRTAP. Besides fulfilling its obligations under CLRTAP, ICP Forests will use its well established infrastructure, its multidisciplinary monitoring approach and its comprehensive data base to also contribute to other processes of international environmental policies. Already now, the programme pursues the objectives of several Resolutions and provides information on several indicators for sustainable forest management of the Ministerial Conference on the Protection of Forests in Europe (MCPFE). Moreover, it will contribute urgently needed information on species diversity and carbon sequestration to the United Nations Framework Conventions on Climate Change and on Biological Diversity. The recent summer heat and drought events across large parts of Europe and the reactions of forests to them underline the need for monitoring and evaluation of the impact of climate change on forests.

The monitoring results of each year are summarized in annual Executive Reports. The methodological background and detailed results of the individual surveys are described in Technical Reports. The present Technical Report on Forest Condition in Europe refers to the results of the large-scale transnational survey of the year 2004 and presents results of individual studies of the intensive monitoring data made available by the year 2002.

SUMMARY

In 2004, the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) and the European Commission (EC) continued to assess forest condition in Europe in the nineteenth survey year. Of the participating 40 countries, 32 assessed crown condition of 325 550 sample trees on 16 763 sample plots of the different national grids. Results on the European scale were derived from a subsample of 133 372 trees on 6 133 plots in 34 countries. These plots are part of the 16 x 16 km transnational grid covering 38 countries. The transnational survey of 2004 revealed a mean defoliation of 20.5%. Of the main species, *Quercus robur* and *Q. petraea* had by far the highest mean defoliation (26.6%), followed by *Fagus sylvatica* (22.3%), *Picea abies* (20.3%) and *Pinus sylvestris* (18.4%).

For the calculation of the long-term and medium-term development of defoliation, two fixed groups of countries had been defined in the Technical Report of 2004 in order to avoid distortions of the results due to the inclusion of newly participating countries in the course of time. The countries of one group were selected according to their uninterrupted participation in crown condition assessment in order to yield as long a time series as possible (1990-2004). The other group yields a shorter time series (1997-2004), but comprises as large a number of countries as possible. During the period 1990-2004 the largest increase in mean defoliation occurred on *Quercus ilex* and *Quercus rotundifolia* (from 13.8% to 20.3%), followed by *Fagus sylvatica* (from 17.9% to 24.2%). A similar increase occurred on *Quercus robur* and *Quercus petraea* (from 21.0% to 26.5%) and on *Pinus pinaster* (from 13.2% to 18.6%). *Picea abies* showed the lowest increase in defoliation (from 22.4% to 25.3%). In contrast, *Pinus sylvestris* showed a recovery since the mid 1990s particularly in Belarus, Poland and parts of the Baltic States. This yielded a better crown condition of *Pinus sylvestris* in 2003 than at the beginning of the time series.

All of the main tree species, except *Pinus sylvestris* and *Quercus ilex* and *Q. rotundifolia* show a marked increase in defoliation in the last year of the time series. This recent deterioration is particularly frequent in southern Finland, southernmost Sweden, central and southern Germany, some parts of France and total Bulgaria. In most of these regions, increased defoliation is attributed largely to the severe heat and drought in summer 2003. First reactions on this extreme weather situation had already been described in the 2004 Executive Report, and further deterioration of crown condition had been predicted.

The spatial and temporal variation of bulk deposition and throughfall was evaluated for sulphate, nitrate, ammonium, calcium, sodium and chlorine. Depending on data availability, between 179 and 411 intensive monitoring plots were involved in the study. Mean annual sulphate deposition decreased by about 40% to 9.5 kg ha^{-1} y^{-1} over the period of observation. High deposition in coastal areas is correlated with high sodium deposition, indicating sea salt as an origin. The decrease in deposition was much less pronounced for ammonium and nitrate. A positive correlation between precipitation and deposition was shown in many regions. Also on intensive monitoring plots, nitrogen deposition was shown to be positively correlated with nitrogen leaching especially on nitrogen enriched soils. At sites with a lower nitrogen status, mean annual temperature is an important factor.

Another study describes an approach for the dynamic modelling of air pollution effects. This approach will be further developed and later be used for scenario analyses of the development of forest ecosystems under those air pollution loads to be expected as a result of clean air policies und CLRTAP.

1. INTRODUCTION

The present report describes the results of the large-scale transnational survey of the year 2004 and of individual evaluations of the intensive monitoring data. The report is outlined as follows:

Chapter 2 refers to the large-scale crown condition survey. The basic methods of the sampling, assessment and evaluation are described. Moreover results of recent data quality control exercises are provided. The last subchapter presents the results of the crown condition assessment of the year 2004. Emphasis is laid upon the current status and the development of crown condition with respect to species and regions.

Chapter 3 presents three studies conducted on intensive monitoring plots. The first study analyses deposition and its trends. The second study describes an approach for the dynamic modelling of air pollution effects, which will be further developed and later be used for scenario analyses of the development of forest ecosystems under air pollution loads to be expected in future. The third study evaluates nitrogen retention and release of forest ecosystems.

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

2. LARGE-SCALE CROWN CONDITION SURVEYS

2.1 Methods of the surveys in 2004

2.1.1 Background

The complete methods of the transnational survey are laid down in the "Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests" (LORENZ et al., 2004) and in Commission Regulation (EEC) No. 1996/87 and its amendments. In the following sections, the selection of sample plots, the assessment of stand and site characteristics and the assessment of crown condition are described. The sections also refer to measures and results of data quality assurance as well as to the evaluation and presentation of the survey results.

2.1.2 Selection of sample plots

2.1.2.1 The transnational survey

The aim of the transnational survey is information on the spatial development of forest condition at the European level. This aim is achieved by means of large-scale monitoring on a 16 x 16 km transnational grid of sample plots. In several countries, the plots of the transnational grid are a subsample of a denser national grid (Chapter 2.1.2.2). The coordinates of the transnational grid were calculated and provided to the participating countries by EC. If a country had already established plots, the existing ones were accepted, provided that the mean plot density resembled that of a 16 x 16 km grid, and that the assessment methods corresponded to those of the ICP Forests Manual and the relevant Commission Regulations. The fact that the grid is less dense in parts of the boreal forests can be shown to be of negligible influence due to the homogeneity of these forests.

With 6 133 plots assessed in 31 countries, the transnational survey of the year 2004 was the most comprehensive ever. The number of plots increased especially in Finland, where the grid was extended into peatlands. In Hungary, the grid was extended into the Great Hungarian Plane. Serbia and Montenegro extended its grid in the course of the current establishment of the ICP Forests monitoring system. Also the grid of Norway was completed, and Andorra was included for the first time. The number of plots in each participating country is presented in Table 2.1.2.1-1 for the last 13 years. In addition, 13 plots were assessed on the Canary Islands, but excluded from the transnational evaluation as they are not located in those geoclimatic regions to which all other plots were assigned (Annex I-1). They are, however, shown in the respective maps. The figures in Table 2.1.2.1-1 are not necessarily identical to those published in previous reports. Consistency checks and subsequent data corrections as well as new data submitted by countries may have caused rearward changes in the data base. For example, the Czech Republic reduced from 1998 onwards the number of its plots in order to avoid an overrepresentation of its results in the transnational data base. In 2000 Belarus submitted new data which dated back to 1997. Italy and Spain completed their plot sample by establishing additional plots.

The spatial distribution of the plots assessed in 2004 is shown in Figure 2.1.2.1-1. The plot sample is stratified according to geoclimatic regions adapted from those by WALTER et al. (1975), and WALTER and LIETH (1967). For an explanation of these regions see Annex I–1. Percentages of plots in the 10 different regions are given in Table 2.1.2.1-2.

Table 2.1.2.1-1: Number of sample plots from 1992 to 2004 according to the current database.

Country	Number of sample plots												
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Austria	77	76	76	76	130	130	130	130	130	130	133	131	136
Belgium	29	29	29	29	29	29	29	30	29	29	29	29	29
Cyprus										15	15	15	15
Czech Republic	156	178	205	199	196	196	116	139	139	139	140	140	140
Denmark	25	25	25	24	23	22	23	23	21	21	20	20	20
Estonia		86	90	90	91	91	91	91	90	89	92	93	92
Finland	413	405	382	455	455	460	459	457	453	454	457	453	594
France	505	506	534	543	540	540	537	544	516	519	518	515	511
Germany	414	412	417	417	420	421	421	433	444	446	447	447	451
Greece	98	96	96	95	95	94	93	93	93	92	91	-	-
Hungary	65	65	62	63	60	58	59	62	63	63	62	62	73
Ireland	22	22	21	21	21	21	21	20	20	20	20	19	19
Italy	202	212	209	207	207	181	177	239	255	265	258	247	255
Latvia	100	101	94	94	99	96	97	98	94	97	97	95	95
Lithuania	73	74	73	73	67	67	67	67	67	66	66	64	63
Luxembourg	4	4	4	4	4	4	4	4	4	-	4	4	4
The Netherlands	14	13	13	13	12	11	11	11	11	11	11	11	11
Poland	476	476	441	432	431	431	431	431	431	431	433	433	433
Portugal	149	143	147	141	142	144	143	143	143	144	145	136	133
Slovak Republic	111	111	111	111	110	110	109	110	111	110	110	108	108
Slovenia		34	34	42	42	42	41	41	41	41	39	41	42
Spain	462	460	444	454	447	449	452	598	607	607	607	607	607
Sweden	67	59	340	726	766	758	764	764	769	770	769	776	775
United Kingdom	72	69	66	63	79	82	88	85	89	86	86	86	85
EU	3534	3656	3913	4372	4466	4437	4363	4613	4620	4645	4649	4532	4691
Andorra													3
Belarus						416	416	408	408	408	407	406	406
Bulgaria			109	120	120	120	135	115	108	109	99	106	103
Croatia		84	88	82	83	86	89	84	83	81	80	78	84
Moldova		12	12	11	10	10	10	10	10	10	-	-	-
Norway	387	390	384	386	387	386	386	381	382	408	414	411	442
Romania	215	167	199	241	224	237	235	238	235	232	231	231	226
Russian Fed.			7	134									
Serbia and Monten.												103	130
Switzerland	45	45	45	47	49	49	49	49	49	49	49	48	48
Total Europe	4181	4354	4757	5393	5339	5741	5683	5898	5895	5942	5929	5915	6133

Table 2.1.2.1-2: Distribution of the 2004 sample plots over the climatic regions.

Climatic region	Number of plots	Percentage of plots
Boreal	1146	18.7
Boreal (Temperate)	940	15.3
Atlantic (North)	340	5.5
Atlantic (South)	283	4.6
Sub-atlantic	1125	18.3
Continental	328	5.4
Mountainous (North)	291	4.8
Mountainous (South)	742	12.1
Mediterranean (Higher)	363	5.9
Mediterranean (Lower)	575	9.4
All regions	6133	100.0

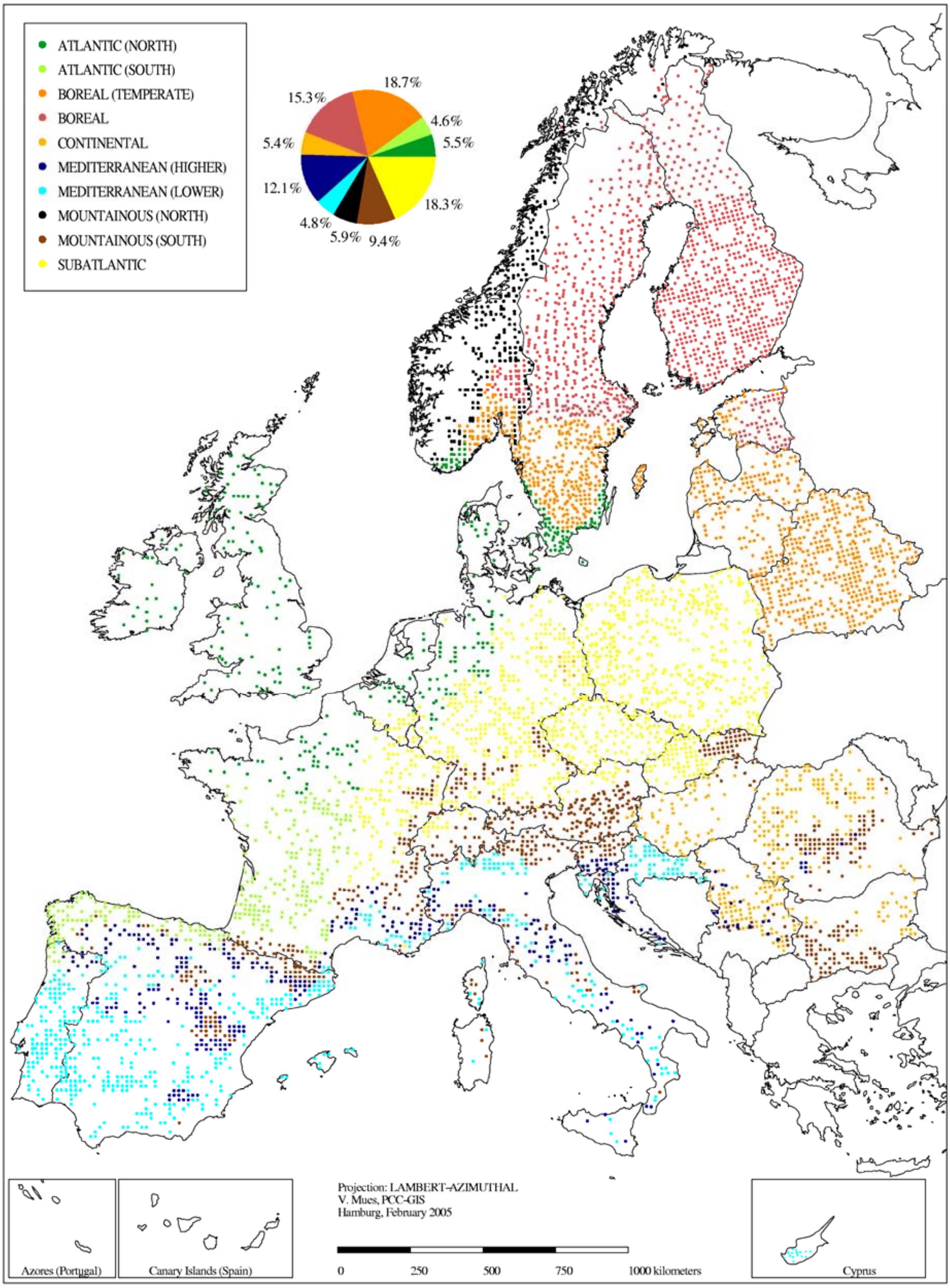


Figure 2.1.2.1-1: Plots according to climatic regions (2004).

2.1.2.2 National surveys

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

2.1.3 Assessment parameters

2.1.3.1 Stand and site characteristics

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

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

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

Nearly all countries submitted data on water availability, humus type, altitude, aspect, and mean age. The numbers of plots for which these site parameters were reported increased distinctively in recent years (Table 2.1.3.1-2). The data set is now almost complete for the EU-Member States. One EU-Member State did not report soil type.

Table 2.1.3.1-2: Number of sample plots and plots per site parameter.

Country	Number of plots	Number of plots per site parameter					
		Water	Humus	Altitude	Aspect	Age	Soil
Austria	136	136	130	136	136	136	130
Belgium	29	29	29	29	29	29	28
Cyprus	15	15	15	15	15	15	0
Czech Republic	140	140	59	140	140	140	59
Denmark	20	20	20	20	20	20	20
Estonia	92	92	92	92	92	92	92
Finland	594	594	594	594	594	594	594
France	511	511	511	511	511	511	511
Germany	451	451	451	451	451	451	420
Hungary	73	61	41	61	61	73	61
Ireland	19	19	19	19	19	19	19
Greece							
Italy	255	255	255	255	255	255	0
Latvia	95	95	95	95	95	95	95
Lithuania	63	63	63	63	63	63	63
Luxembourg	4	4	4	4	4	4	4
The Netherlands	11	11	11	11	11	11	11
Poland	433	433	426	433	433	433	38
Portugal	133	133	133	133	133	133	126
Slovak Republic	108	0	108	108	108	108	108
Slovenia	42	42	42	42	42	42	42
Spain	607	607	607	607	607	607	431
Sweden	775	775	765	775	775	775	580
United Kingdom	85	85	85	85	85	85	85
EU	4691	4571	4555	4679	4679	4691	3517
Percent of EU plot sample		97.4	97.1	99.7	99.7	100.0	75.0
Andorra	3	3	3	3	3	2	3
Belarus	406	406	375	404	406	406	374
Bulgaria	103	103	103	103	103	103	103
Croatia	84	84	84	84	84	84	68
Rep. of Moldova							
Norway	442	0	411	442	442	442	372
Romania	226	226	226	226	226	226	219
Serbia and Monten.	130	130	42	130	129	130	109
Switzerland	48	45	45	48	48	48	45
Total Europe	6133	5568	5844	6119	6120	6132	4810
Percent of total plot sample		90.8	95.3	99.8	99.8	99.9	78.4

2.1.3.2 Defoliation

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

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

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

In principle, the transnational survey results for defoliation are assessed in 5% steps. The assessment down to the nearest 5 or 10% permits studies of the annual variation of defoliation with far greater accuracy than using the traditional system of only 5 classes of uneven width (Chapter 2.1.5). Discolouration is reported both in the transnational and in the national surveys using the traditional classification.

The total numbers of trees assessed from 1992 to 2003 in each country are shown in Table 2.1.3.2-1. The figures are not necessarily identical to those published in previous reports for the same reasons explained in Chapter 2.1.2.1.

Of the 2004 tree sample 105 species were reported. 63.5% of the plots were dominated by conifers, 36.5% by broadleaves (Annex I-2). Plots in mixed stands were assigned to the species group which comprised the majority of the sample trees. Most abundant were *Pinus sylvestris* with 27.4%, followed by *Picea abies* with 20.0%, *Fagus sylvatica* with 8.6%, and *Quercus robur* with 3.7% of the total tree sample (Annex I-3).

Table 2.1.3.2-1: Number of sample trees from 1992 to 2004 according to the current database.

Country	Number of sample trees												
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Austria	2167	2121	2107	2101	3670	3604	3577	3535	3506	3451	3503	3470	3586
Belgium	673	685	684	678	684	683	692	696	686	682	684	684	681
Cyprus										360	360	360	360
Czech Rep	3882	4423	5087	4933	4853	4844	2899	3475	3475	3475	3500	3500	3500
Denmark	600	600	600	576	552	528	552	552	504	504	480	480	480
Estonia		2064	2159	2160	2184	2184	2184	2184	2160	2136	2169	2228	2201
Finland	4545	4427	4261	8754	8732	8788	8758	8662	8576	8579	8593	8482	11210
France	10093	10118	10672	10851	10800	10800	10740	10883	10317	10373	10355	10298	10219
Germany	10767	10729	10866	10907	10980	10990	13178	13466	13722	13478	13534	13572	13741
Greece	2320	2272	2272	2248	2248	2224	2204	2192	2192	2168	2144	-	-
Hungary	1348	1361	1322	1342	1298	1257	1383	1470	1488	1469	1446	1446	1710
Ireland	460	462	441	441	441	441	441	417	420	420	424	403	400
Italy	5643	5884	5791	5703	5836	4873	4939	6710	7128	7350	7165	6866	7109
Latvia	2396	2420	2257	2262	2368	2297	2326	2348	2256	2325	2340	2293	2290
Lithuania	1768	1843	1760	1776	1643	1634	1616	1613	1609	1597	1583	1560	1487
Luxembourg	95	95	93	96	96	96	96	96	96	-	96	96	96
The Netherlands	280	260	260	257	237	220	220	225	218	231	232	231	232
Poland	9520	9520	8820	8640	8620	8620	8620	8620	8620	8620	8660	8660	8660
Portugal	4508	4308	4414	4230	4260	4319	4290	4290	4290	4320	4350	4080	3990
Slovak Rep.	5251	5144	5115	5091	5018	5033	5094	5063	5157	5054	5076	5116	5058
Slovenia		816	816	1008	1008	1008	984	984	984	984	936	983	1006
Spain	11088	11040	10656	10896	10728	10776	10848	14352	14568	14568	14568	14568	14568
Sweden	300	311	3989	10310	10925	10910	11044	11135	11361	11283	11278	11321	11255
United Kingdom	1728	1656	1584	1512	1896	1968	2112	2039	2136	2064	2064	2064	2040
EU	79432	82559	86026	96772	99077	98097	98797	105007	105469	105491	105540	102761	105879
Andorra													72
Belarus						9974	9896	9745	9763	9761	9723	9716	9682
Bulgaria			4370	4812	4789	4788	5389	4379	4197	4209	3753	3870	3629
Croatia		2016	2150	1970	1974	2030	2066	2015	1991	1941	1910	1869	2009
Moldova		288	288	263	236	253	234	259	234	234	-	-	-
Norway	4001	4016	3942	3905	3948	4028	4069	4052	4051	4304	4444	4547	5014
Romania	5155	4004	4776	5688	5375	5687	5637	5712	5640	5568	5544	5544	5424
Russian Fed.			183	3180									
Serbia and Mont.												2274	2915
Switzerland	488	500	509	824	854	880	868	857	855	834	827	806	748
Total Europe	89076	93383	102244	117414	116253	125737	126956	132026	132200	132342	131741	131387	135372

2.1.4 Quality Assurance

Since 2001 the basic quality assurance (QA) instrument within ICP Forests, International Cross-comparison Courses (ICCs), have been conducted as field exercises on specific test ranges where periodically every 4 to 5 years National Reference Teams (NRTs) assess the same trees using their national methods in order to

- document the relative position of individual NRTs within the international context,
- monitor the consistency of NRTs' position through time,

- improve the traceability of the data by establishing a direct connection with the data collected at national level. This will help also explaining anomalous year-by-year fluctuations, and
- explore the relationships between the performance of the various NRTs and the major site and stand characteristics.

As part of those ICCs, photo exercises were conducted during which the participants assessed tree crown photographs of test range trees for defoliation (see “ICC photos”, A_{01} to C_{03} in Figure 2.1.4-1). The photographs enable the documentation of the present crown condition. The re-assessment of the same photographs and of actual photographs from coming ICCs describes the change in defoliation. For the same trees field assessments are made in different years as well as assessments of photographs which document the tree status in different years (Figure 2.1.4-1) and the NRTs’ position through time.

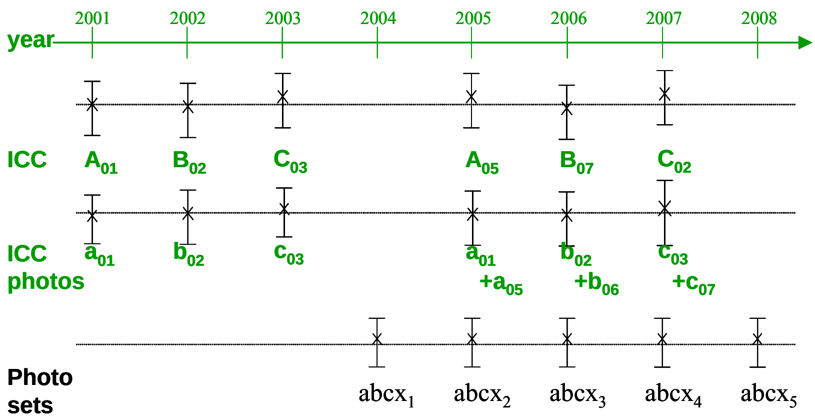


Figure 2.1.4-1: Scheme of ICCs and Photo Exercises since 2001.

In 2004 the assessment of tree crown photographs by a group of experts was tested. This “Photo Exercise 2004” was conducted by the Working Group on Quality Assurance and the PCC of ICP Forests during summer 2004. The main aim of this exercise was to get a starting point for a time series based on assessments of a wide range of experts which will be of high importance in order to describe temporal consistency. Sets of 20 to 26 tree crown photographs were compiled for the six most common tree species in Europe. The sets consist of photographs already used during former ICCs and additional photographs which were made available by national experts.

144 photo sets were printed and sent to 98 experts in 34 countries in November 2004. Due to the circulation of the photo sets among experts in some countries 259 assessments of photo sets were made by 79 experts and five teams representing 31 countries, corresponding to more than 5600 individual photograph assessments. The 259 photograph set assessments comprise the following assessments:

Table 2.1.4-1: Number of assessed sets of photographs during the Photo Exercise 2004.

Photograph set	Tree species	Number of assessments
Scots pine	*Pinus sylvestris*	66
Norway spruce	*Picea abies*	60
Beech	*Fagus sylvatica*	52
European and Sessile oak	*Quercus robur and Qu. petraea*	51
Maritime pine	*Pinus pinaster*	15
Mediterranean oak	*Quercus ilex, Qu. suber and Qu. rotundifolia*	15

From 526 comments which were made on the general exercise as well as on single photographs 201 referred to the quality of tree photographs, most of them (128) on poor image quality. Other comments asked for more information on the single tree position or growing situation as e.g. competition (45).

For each photograph the median of the assessed values for defoliation was calculated (x-axis in Figure 2.1.4-2). The mean of the individual absolute differences to those tree specific median values was used as measure of variability in order to identify which of the photographs were assessed less homogeneously than others. The comments on single photographs in combination with the methodology used by the experts are used for distinguishing between photographs which are probably not useful for such an exercise and those which are scored with high variability due to methodological differences between the experts. The photograph with the highest value of mean absolute deviation from the median was one of the oak photographs with 14.4%. The corresponding comments made by the participants will lead to an exclusion of this specific photograph for coming exercises. Most other photographs were assessed with much lower variability. Only a low number of trees reached values above 10% defoliation for mean absolute deviation from the median. For most of the photos the resulting variation of the assessments was rather low. 96.4% (81.0%) of all assessments were in a range of ±20% (±10%) defoliation around the photo specific median values.

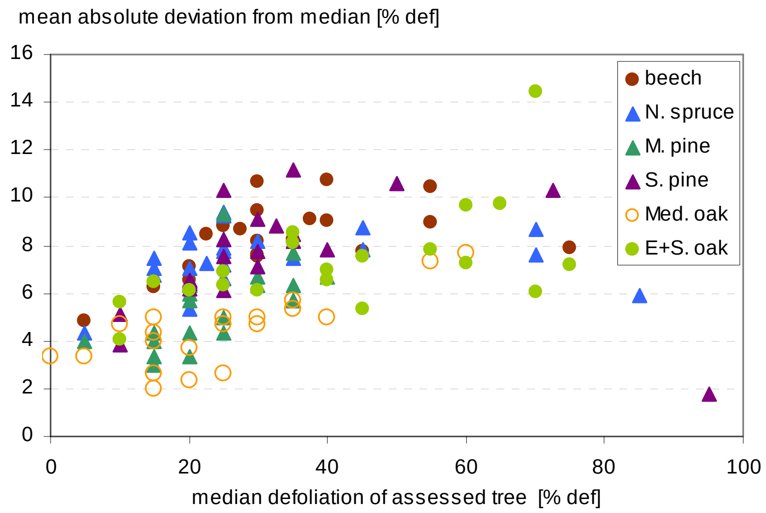


Figure 2.1.4-2: Photograph specific mean absolute differences of expert assessments from the respective median.

The results of the Photo Exercise 2004 as presented in Figure 2.1.4-2 indicate that photographs of very healthy or defoliated trees, respectively, are assessed rather homogenous in contrast to those of trees with medium defoliation, as expected. Some photograph sets in general led to lower variability as e.g. the values for Mediterranean oak are relatively low. This can be explained by a lower number of participating countries which implies a higher homogeneity of the applied methodology but also by a higher comparability of the represented crown types. The photograph sets of tree species with a wider spatial distribution in Europe led to higher variability of the assessed values. More detailed analyses indicate that the diversity of represented types of crown morphology is probably of higher importance than the number of countries from which the participants come.

The most important outcome of the photo exercise in 2004 will be that time series of photograph assessments are started for a huge number of experts all over Europe. The comparison of photograph assessments over the coming years will be an important tool for documentation of temporal consistency. The linkage of photo assessments, the digital scoring system CROCO (DOBBERTIN and MIZOUE, 2000) and field assessments of ICC test ranges by National Reference Teams will be a valuable data base for the documentation of quality assurance.

2.1.5 Evaluation and presentation of the survey results
2.1.5.1 Scientific background

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

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

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

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

Table 2.1.5.2-1: 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

2.1.5.2 Classification of defoliation data

The national survey results are submitted to PCC as country related mean values, classified according to species and age classes. These data sets are accompanied by national reports providing explanations and interpretations. All tree species are referred to by their botanical names, the most frequent of them listed in 11 languages in Annex III.

The results of the evaluations of the crown condition data are preferably presented in terms of mean plot defoliation or the percentages of the trees falling into 5%-defoliation steps. However, in order to ensure comparability with previous presentations of survey results, partly the traditional classification of both defoliation and discolouration has been retained for comparative purposes, although it is considered arbitrary by some countries. This classification (Table 2.1.5.2-1) is a practical convention, as real physiological thresholds cannot be defined.

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

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

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

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

2.1.5.3 Mean defoliation and temporal development

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

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

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

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

For detailed information on the respective calculation method for the change from 2003 to 2004 see Annex IV.

2.2 Results of the transnational survey in 2004

2.2.1 Crown condition in 2004

In the transnational survey of the year 2004, defoliation of 135 372 sample trees was assessed on 6 133 sample plots. 23.3% of these trees had a defoliation of more than 25%, i.e. were classified as “damaged” (Table 2.2.1-1). The share of damaged broadleaves exceeded with 26.3% the share of damaged conifers with 21.3%. The percentages of damaged trees are mapped for each plot in Annex I-4. Mean defoliation in total Europe is 20.4%.

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

	Species type	Percentage of trees in defoliation class							Defoliation		No. of trees
		0-10%	>10-25%	0-25%	>25-60%	>60%	dead	>25%	Mean	Median	
EU	Broadleaves	25.7	46.2	71.9	24.6	2.8	0.7	28.1	22.9	20	40283
	Conifers	35.1	43.1	78.2	19.5	1.6	0.7	21.8	19.7	15	65596
	All species	31.5	44.3	75.8	21.4	2.0	0.7	24.2	20.9	20	105879
Total Europe	*Fagus sylv.*	26.3	45.8	72.1	25.4	2.1	0.4	27.9	22.3	20	11656
	Quercus robur + Q. petraea	16.4	44.3	60.7	35.4	3.2	0.6	39.3	26.6	25	8465
	Broadleaves	29.2	44.5	73.7	23.1	2.5	0.7	26.3	21.9	20	55220
	Picea abies	37.7	34.7	72.4	25.0	2.1	0.5	27.6	20.3	15	27109
	Pinus sylv.	36.0	47.7	83.7	14.6	1.1	0.6	16.3	18.4	15	37104
	Conifers	35.9	42.8	78.7	18.9	1.6	0.8	21.3	19.5	15	80152
	All species	33.2	43.5	76.7	20.6	2.0	0.7	23.3	20.5	15	135372

Because the defoliation classes are of uneven width, the frequency distributions for the 5% classes in which defoliation data are submitted were calculated. These frequency distributions are shown for the broadleaved trees, the coniferous trees and the total of all trees in Figures 2.2.1-1a and 2.2.1-1b for each climatic region as well as for the total of all regions. The number of trees, the mean defoliation and the median are also given. The maps in Figures 2.2.1-2 to 2.2.1-5 show mean plot defoliation for *Pinus sylvestris*, *Picea abies*, *Fagus sylvatica*, and *Quercus robur* and *Q. petraea*. For the two main coniferous species, *Pinus sylvestris* and *Picea abies,* the maps show large and partly well defined regions of both high and low defoliation. In contrast, the main broadleaved species, *Fagus sylvatica* as well as *Quercus robur* and *Quercus petraea,* show highly defoliated plots throughout their habitat. Of these species, the defoliation is highest for *Quercus*. A map of mean plot defoliation of all species is given in Annex I-5.

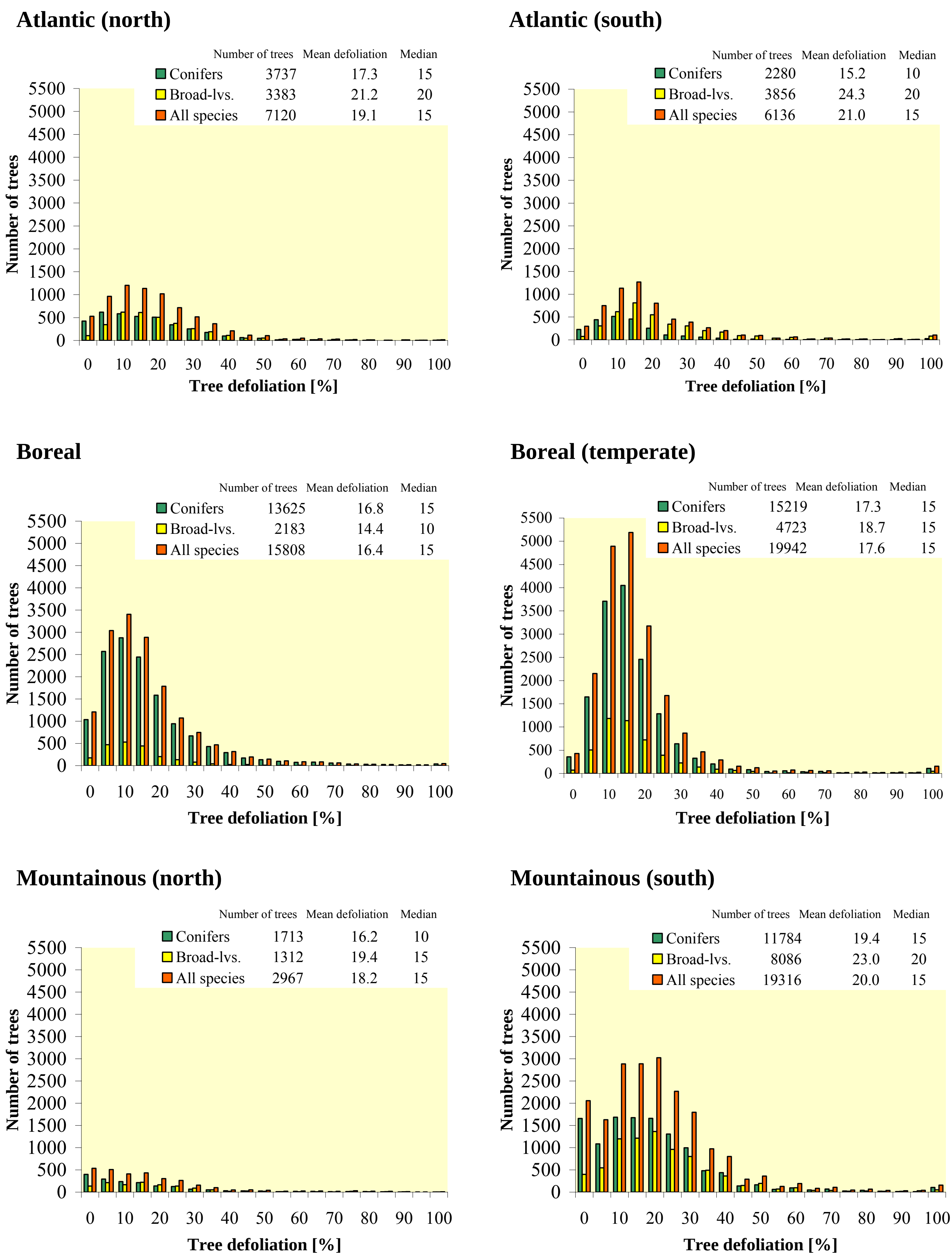


Figure 3.2.1-1a: Frequency distribution of trees in 5%-defoliation steps.

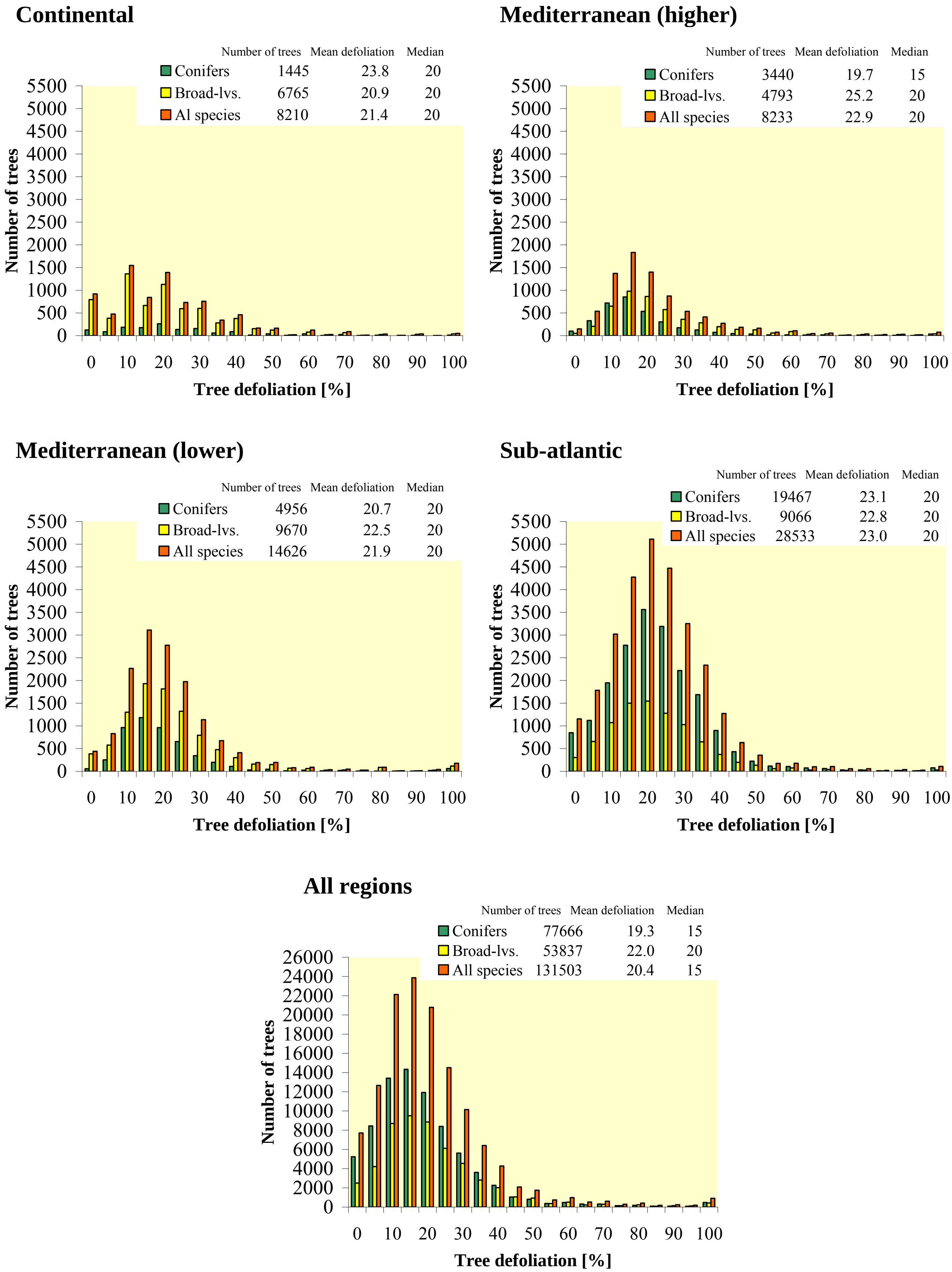


Figure 3.2.1-1b: Frequency distribution of trees in 5%-defoliation steps.

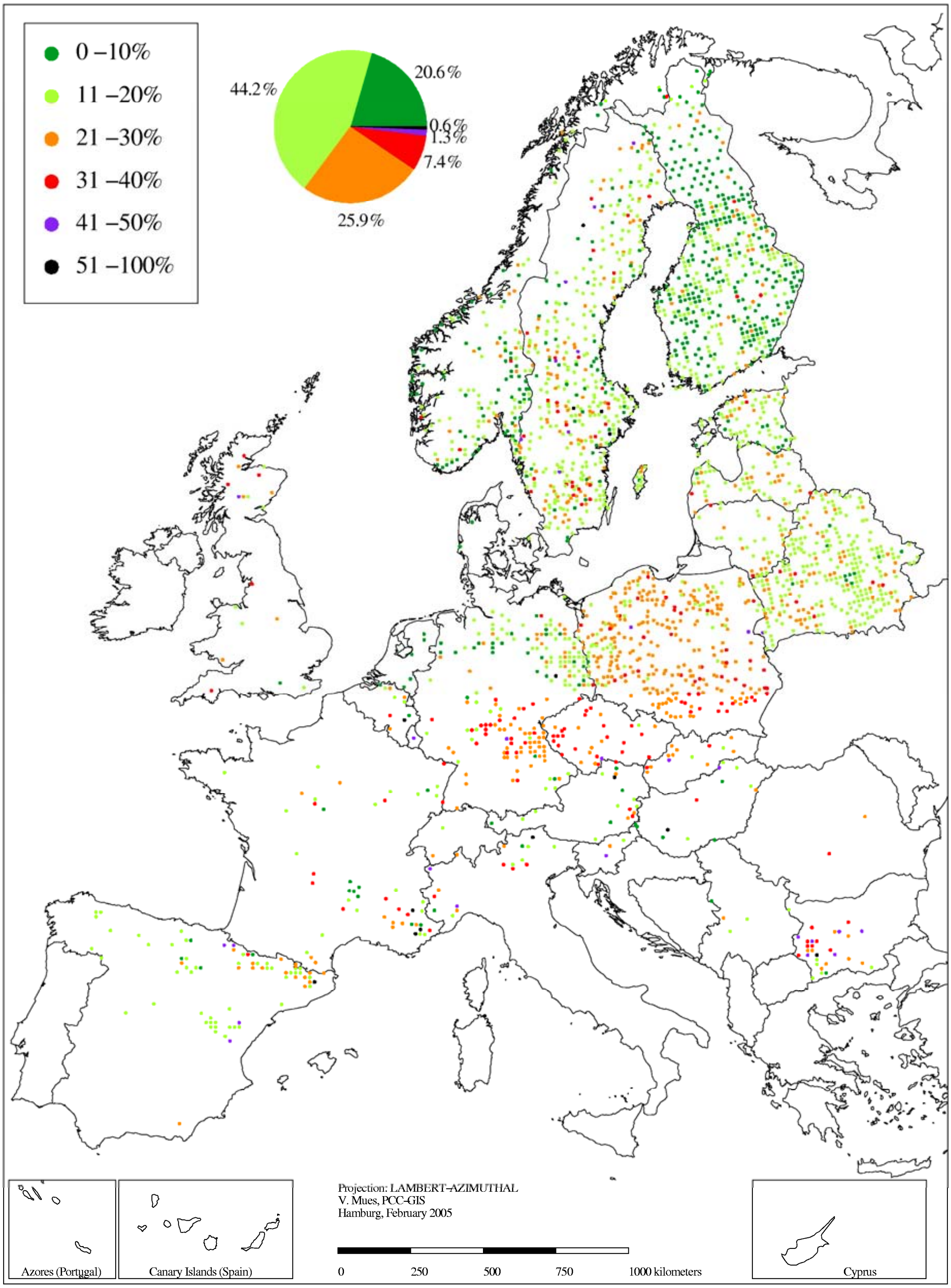


Figure 2.2.1-2: Mean plot defoliation of *Pinus sylvestris*

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

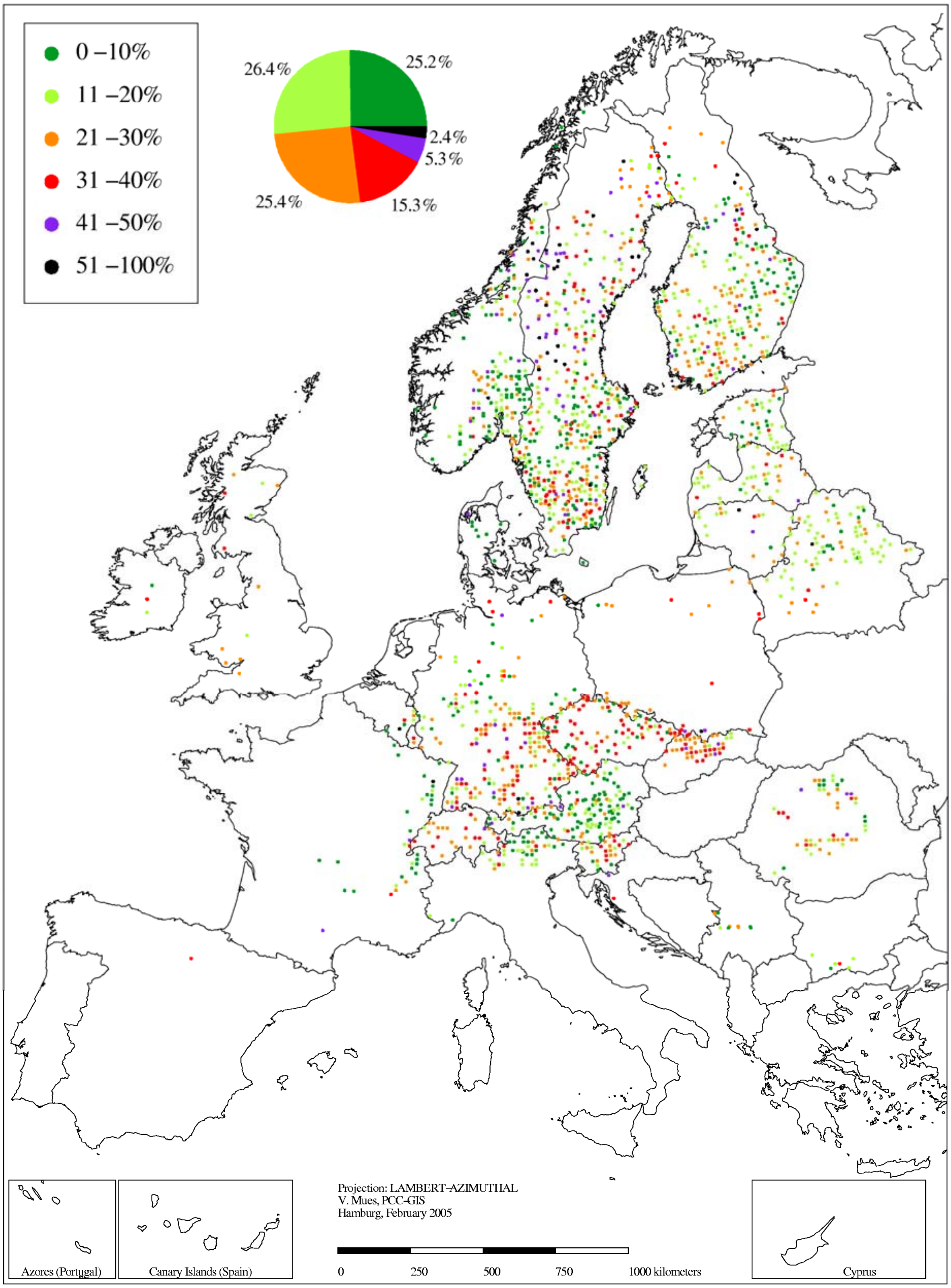


Figure 2.2.1-3: Mean plot defoliation of *Picea abies*

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

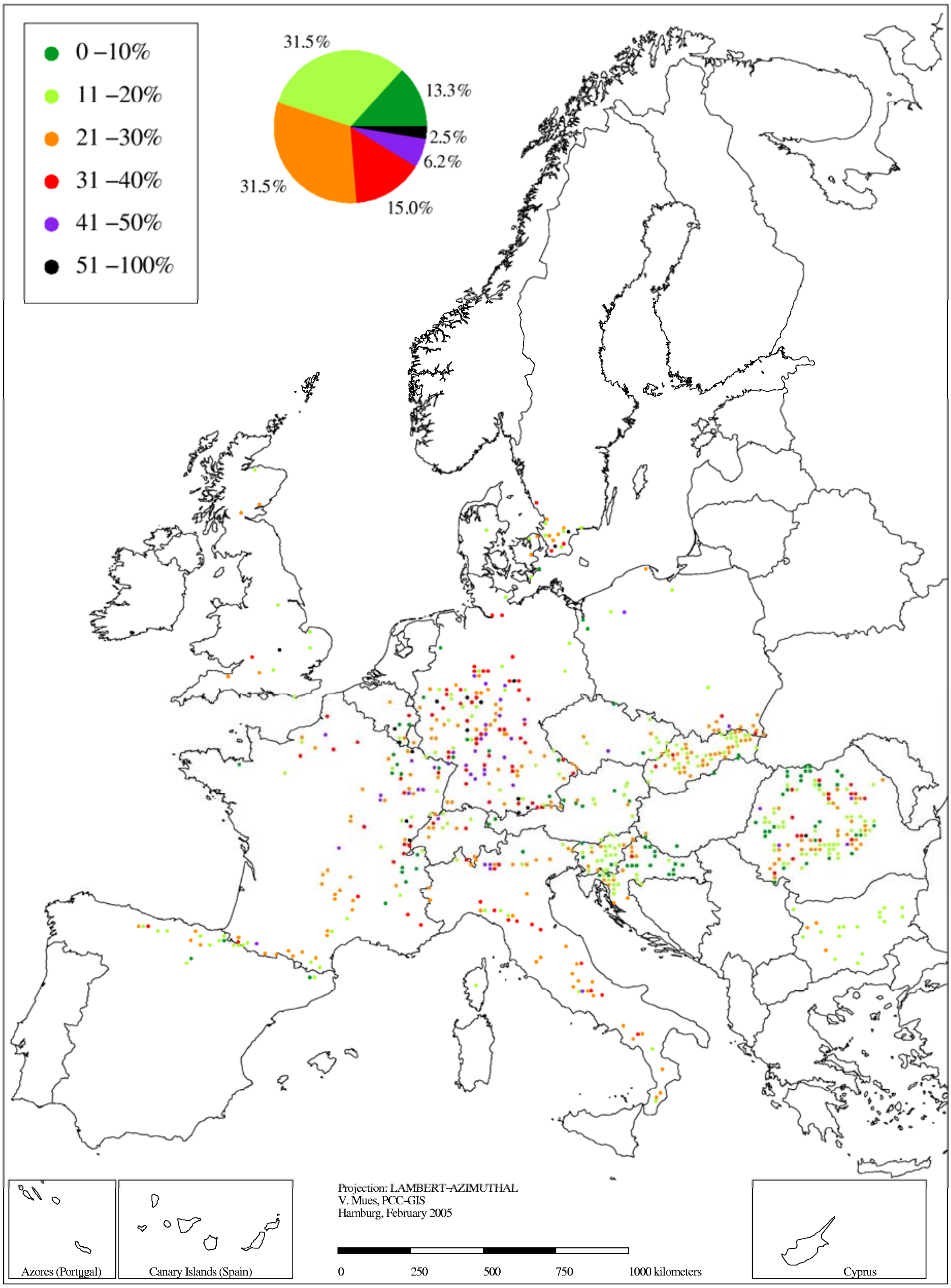


Figure 2.2.1-4: Mean plot defoliation of *Fagus sylvatica*

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

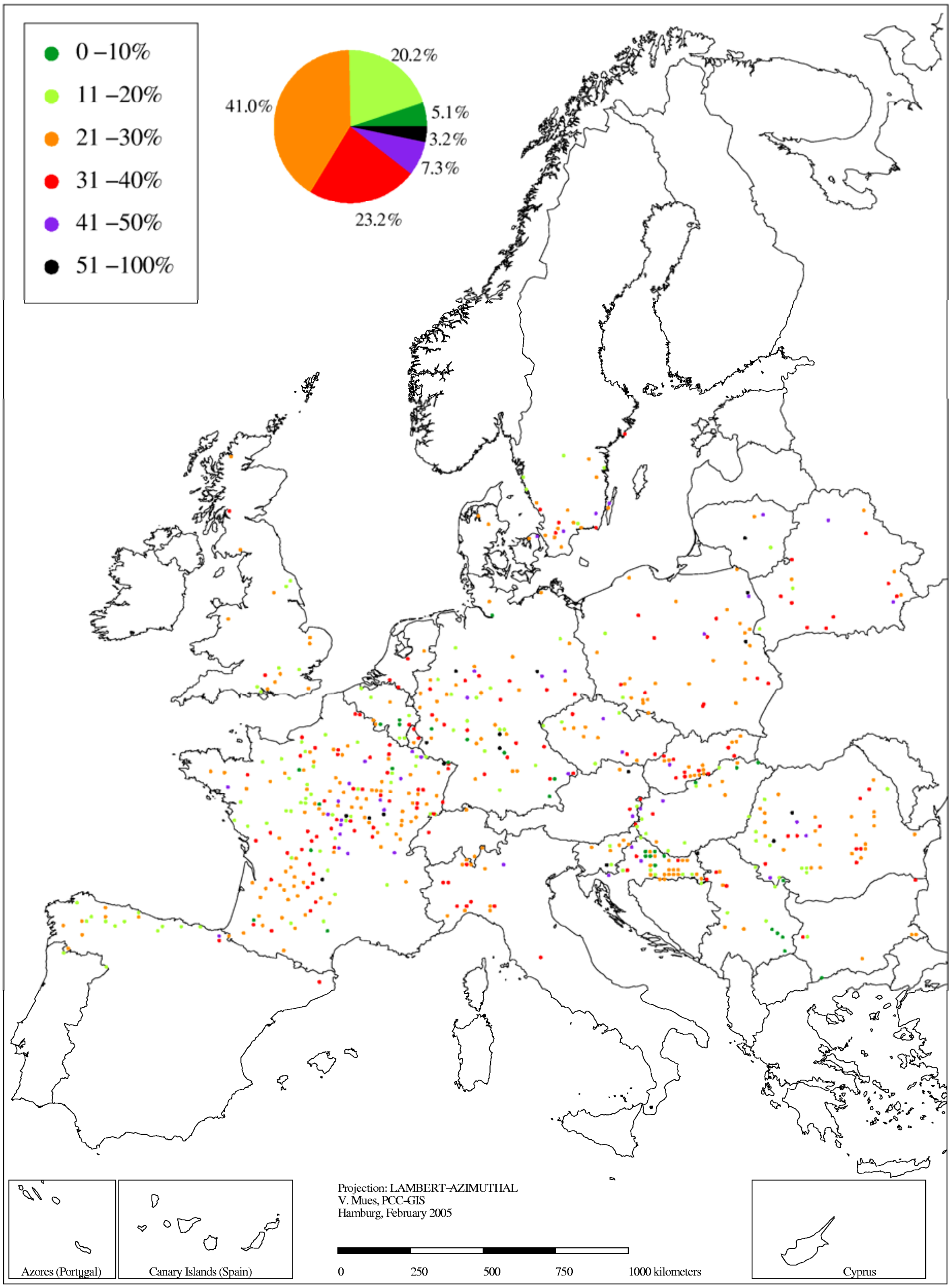


Figure 2.2.1-5: Mean plot defoliation of *Quercus robur* and *Quercus petraea*

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

The share of the discoloured trees (i.e. trees of discolouration greater than 10%) of all species in total Europe was 6.9% (Table 2.2.1-2). Plot discolouration is mapped in Annex I-6.

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

	Species type	Discolouration						No. of trees
		0-10%	>10-25%	>25-60%	>60%	dead	>10%	
EU	Broad-leaves	93.1	4.8	1.2	0.2	0.7	6.9	40283
	Conifers	95.5	3.0	0.8	0.2	0.6	4.5	65596
	All species	94.6	3.6	0.9	0.2	0.6	5.4	105879
Total Europe	Broad-leaves	91.6	6.2	1.5	0.3	0.5	8.4	55220
	Conifers	94.1	4.1	1.0	0.2	0.6	5.9	80152
	All species	93.1	5.0	1.2	0.3	0.5	6.9	135372

2.2.2 Development of defoliation

2.2.2.1 Background

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

- Period 1990-2004:
  Belgium, Denmark, Germany (west), Hungary, Ireland, Latvia, Poland, Portugal, Slovak Republic, Spain, Switzerland, and The Netherlands.

- Period 1997-2004:
  Austria, Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, The Netherlands and United Kingdom.

It must be noted that a seven-year time series (1997-2004) is too short to give evidence of long-term deterioration or improvement. Several countries could not be included in one or both time series because of changes in their tree sample sizes, changes in their assessment methods or missing assessments in certain years.

Development of defoliation is presented either as graphs or in maps. Graphs show the fluctuations of either mean defoliation or shares of trees in defoliation classes over time. Maps indicate trends in mean defoliation calculated as described in Chapter 2.1.5.3. In addition to the development of defoliation during the two above mentioned periods also the change in mean plot defoliation from 2003 to 2004 was mapped. The result of this biannual comparison is presented in Annex I-7. It shows a significant increase in defoliation on 18.4% of the plots, whereas only 8.3% of the plots show a decrease. Although the plots with increased defoliation are scattered all across Europe, they are particularly frequent in southern Finland, southernmost Sweden, central and southern Germany, some parts of France and total Bulgaria. In most of these regions, increased defoliation is attributed largely to the severe heat and drought in summer 2003. First reactions on this extreme weather situation had already been observed in 2003, and further deterioration of crown condition had been predicted (FISCHER et al. 2004).

The increase in defoliation from 2003 to 2004 is reflected largely in the trends in mean defoliation of the trees of the six most frequent species over the periods 1990-2004 and 1997-2004 (Figures 2.2.2.1-1 and 2.2.2.1-2). The numerical basis behind the latter two graphs can be found in Annex I-9. All of the main tree species, except *Pinus sylvestris* and *Quercus ilex* and *Q. rotundifolia* show a marked increase in defoliation in the last year of the time series. Since 1990, the largest increase in defoliation - more than six percent points - occurred on *Quercus ilex* and *Quercus rotundifolia* as well as on *Fagus sylvatica*. For *Pinus pinaster* as well as for *Quercus robur and Quercus petraea* the increase in defoliation over the same period was more than five percent points. The increase was lowest for *Picea abies* with about three percent points. *Pinus sylvestris* is the only species showing no deteriorating crown condition since 1990. Its recovery particularly in Belarus, Poland and parts of the Baltic states since the mid 1990s renders this species in 2004 even in a slightly better condition than at the beginning of the time series. Trends in mean plot defoliation for the period 1997-2003 are mapped in Figure 2.2.2.1-3. The share of plots with distinctly increasing defoliation (18.8%) surmounts the share of plots with decreasing defoliation (12.4%). The latter improving plots are largely *Pinus sylvestris* plots in Belarus and Poland.

Trends in defoliation of each of the six most frequent species are described in greater detail in Chapters 2.2.2.2 to 2.2.2.7. In each chapter the development of defoliation of the respective species is visualised for the total tree sample of all climatic regions in one graph. Additional graphs reflect particular developments selected climatic regions. Each chapter contains also a map indicating trends of mean plot defoliation. Annexes I-8 and I-9 provide for each of the two time series and each of the six species the number of sample trees and their distribution over the defoliation classes for each year. This information is given for the total of all climatic regions and for each region separately. In addition, the same information is provided for three more species, namely *Abies alba*, *Picea sitchensis* and *Quercus suber* because of their ecological and economical importance in some regions.

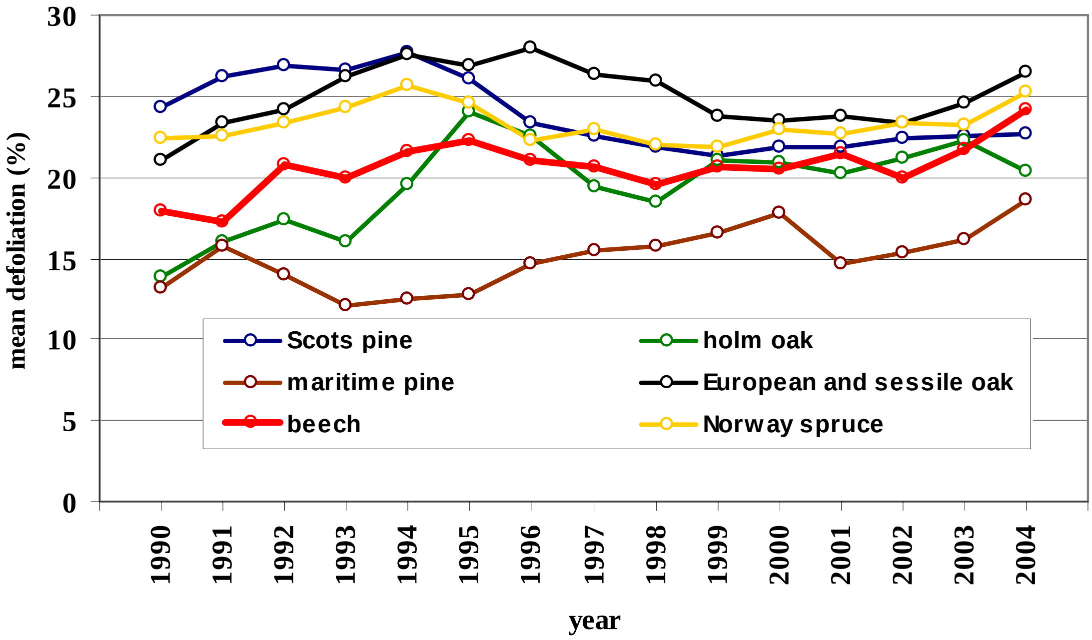


Figure 2.2.2.1-1: Mean defoliation of main species 1990 – 2004.

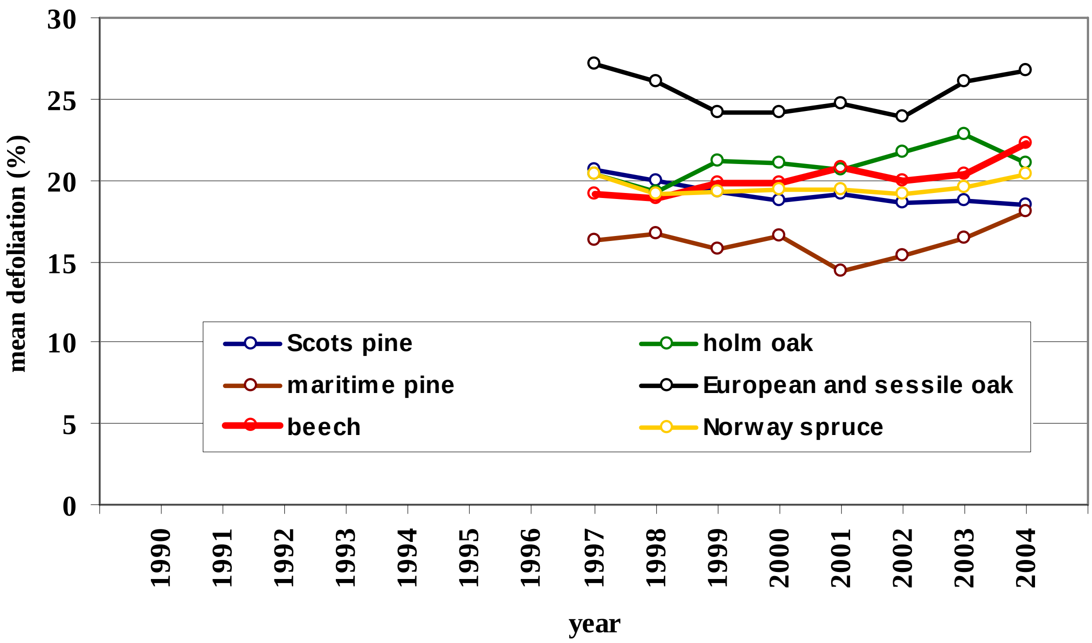


Figure 2.2.2.1-2: Mean defoliation of main species 1997 – 2004.

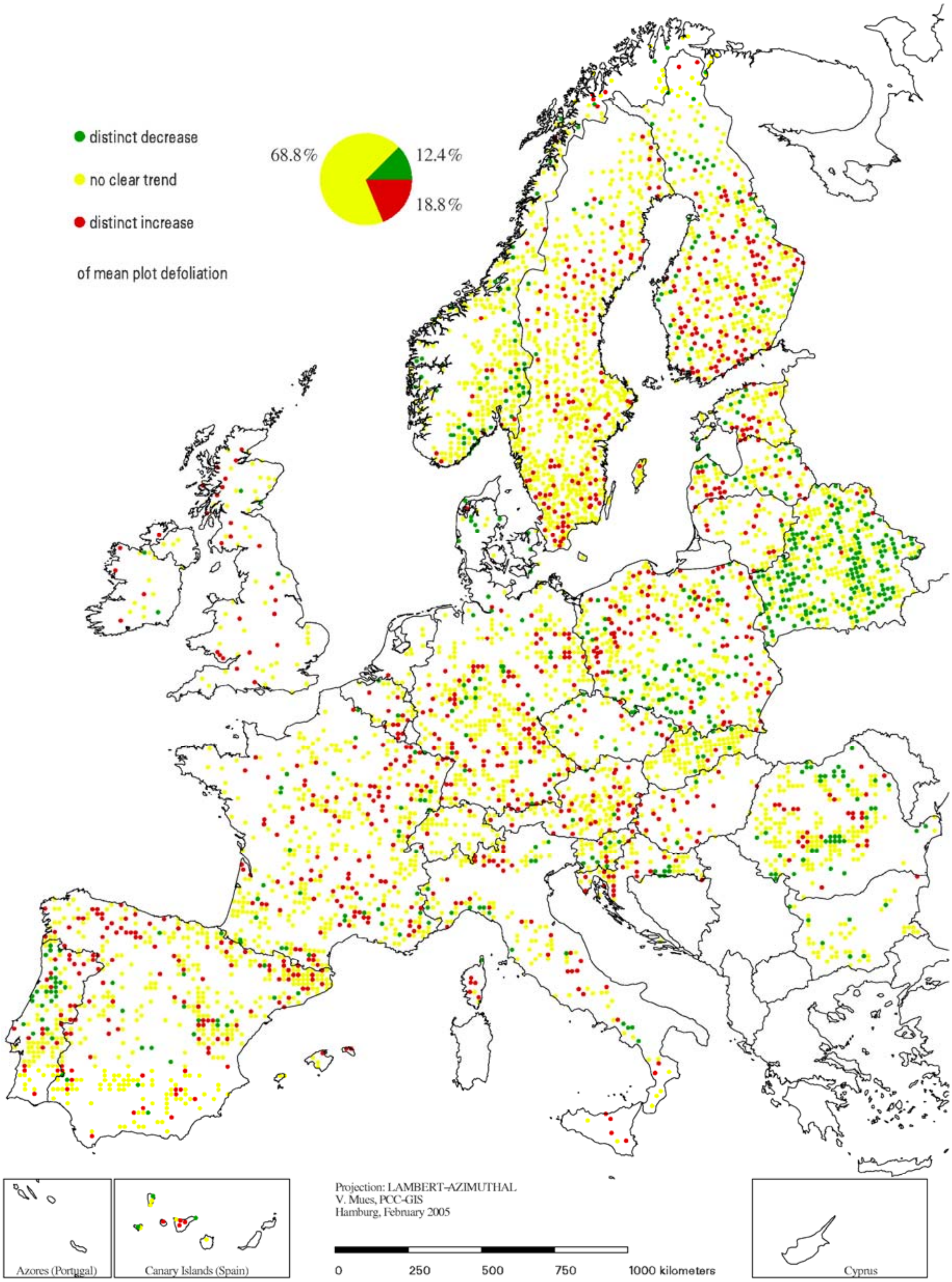


Figure 2.2.2.1-3: Trends of mean plot defoliation of all main species over the years 1997 to 2004.

2.2.2.2 Pinus sylvestris

Pinus sylvestris is the only species represented in all climatic regions. It constitutes the largest portion of sample trees in the two periods of observation, 1990-2004 and 1997-2004. The portion of damaged trees in the total of all regions shows a pronounced decrease from a peak at 46.2% in 1994 to 24.3% in 2004. This reflects mainly the recuperation in the Sub-Atlantic region - which represents by far the largest share of trees – and to a lower extent an extreme decrease in the share of damaged trees after 1992 in Latvia, i.e. in the Boreal (temperate) region. Also into the Boreal (temperate) region, but observed only since 1997, falls a continuous recuperation of *Pinus sylvestris* until 2004. As a result, the share of damaged trees of the observation period 1997-2004 has with 9.4% its so far lowest value. The recuperation of *Pinus sylvestris* is absent or less pronounced in other climatic regions. An example is the Mountainous (south) region which represents another large portion of the *Pinus sylvestris* sample trees (Figure 2.2.2.2-1).

The map (Figure 2.2.2.2-2) shows the high number of recuperating plots after1997 in Belarus. Many recuperating plots are also seen in Poland, Finland, the Baltic states and Germany. Especially Poland and Lithuania have attributed the recuperation largely to reduced air pollution. The pie diagram shows that the share of plots showing a recuperation (16.5%) is larger than that of the plots showing a deterioration (15.2%).

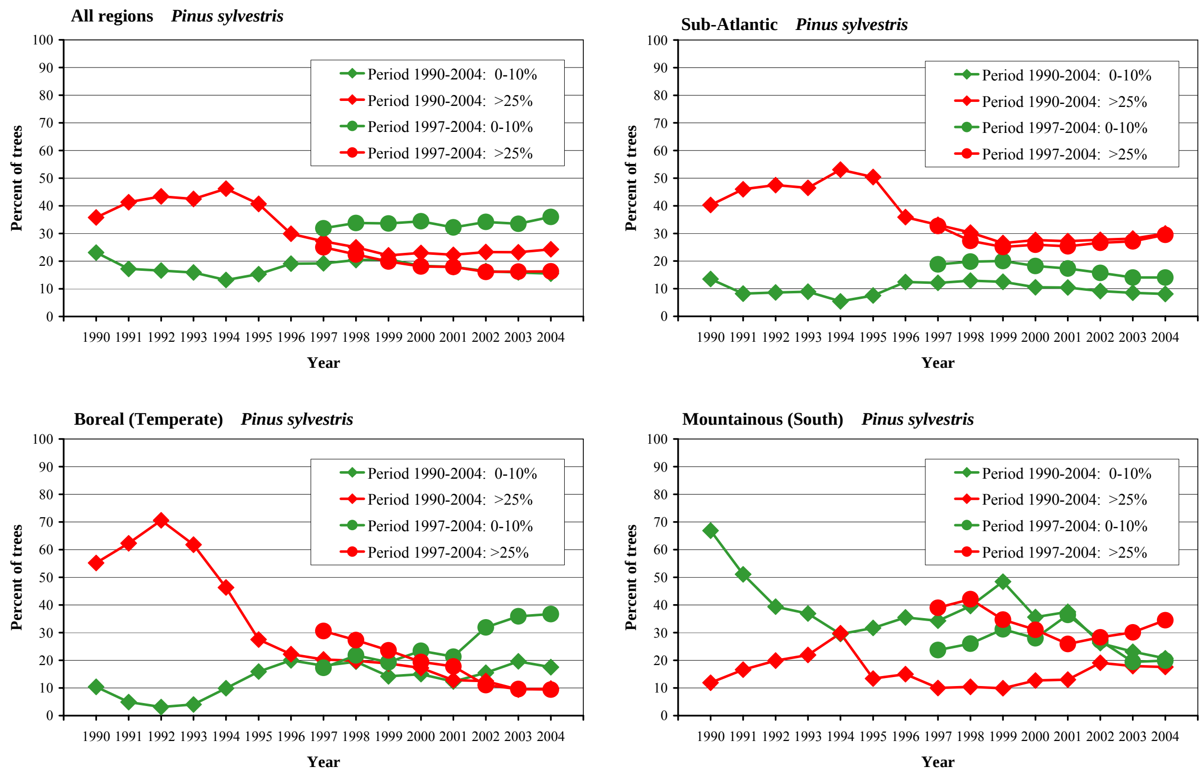


Figure 2.2.2.2-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2004 and 1997-2004).

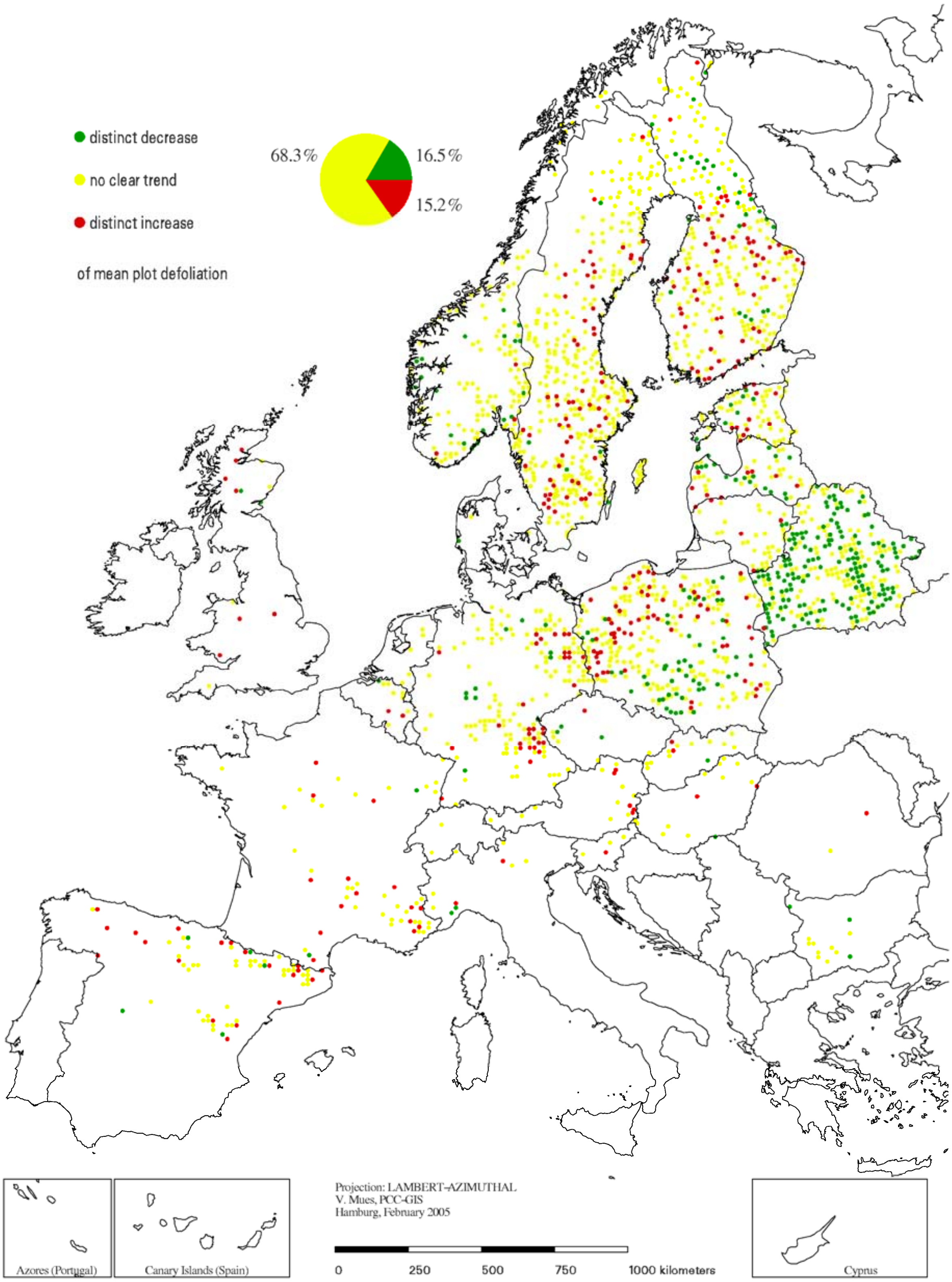


Figure 2.2.2.2-2: Trend of mean plot defoliation (slope of linear regression) of *Pinus sylvestris* over the years 1997 to 2004.

2.2.2.3 Picea abies

Picea abies constitutes the second largest share of trees behind *Pinus sylvestris* in both periods of observations. In the total of all regions the share of damaged trees decreased from its 1994 peak of 38.2% until the late 1990s. After only little changes until 2003, a steep increase in defoliation occurred in 2004. In the 1990-2004 period of observation, the share of damaged trees in 2004 is with 38.0% almost back to its 1994 peak. This reflects largely the development in the Sub-Atlantic and Mountainous (south) regions, which constitute the largest and second largest shares of all *Picea abies* trees, respectively. In the Sub-Atlantic region, the share of damaged trees increased from 34.5% in 2003 to 41.6% in 2004. In the Mountainous (south) region, the respective increase was even larger, namely from 28.7% to 41.0%. This deterioration of crown condition is mainly attributed to the heat and drought of the summer 2003. A similar deterioration is observed in the Boreal (temperate) region, but to a lower extent and starting already in 2003 (Figure 2.2.2.3-1).

The recent deterioration in parts of the Sub-Atlantic, Mountainous (south) and Boreal (temperate) regions is so pronounced that it is discernable in Figure 2.2.2.3-2, although the map shows the trends since already 1997. Of all plots in the map, 18.4% showed a distinct increase in defoliation, whereas only 9.9% of them showed a distinct decrease.

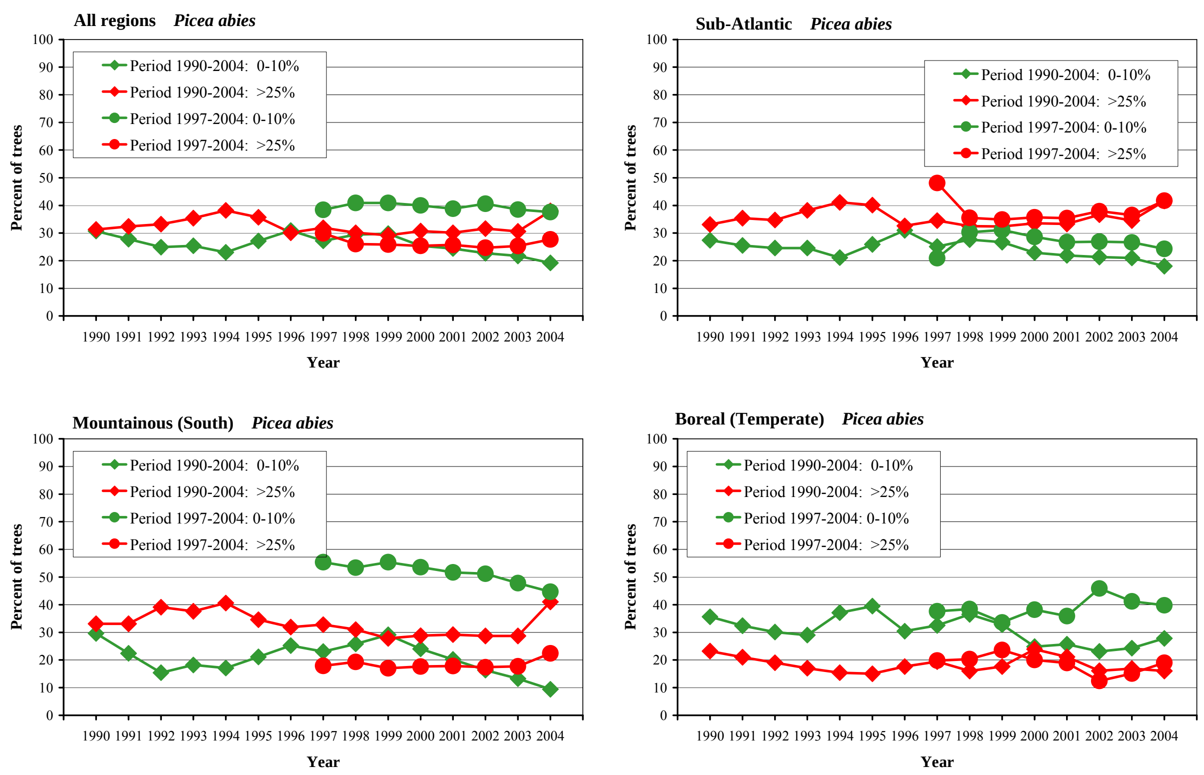


Figure 2.2.2.3-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2004 and 1997-2004)

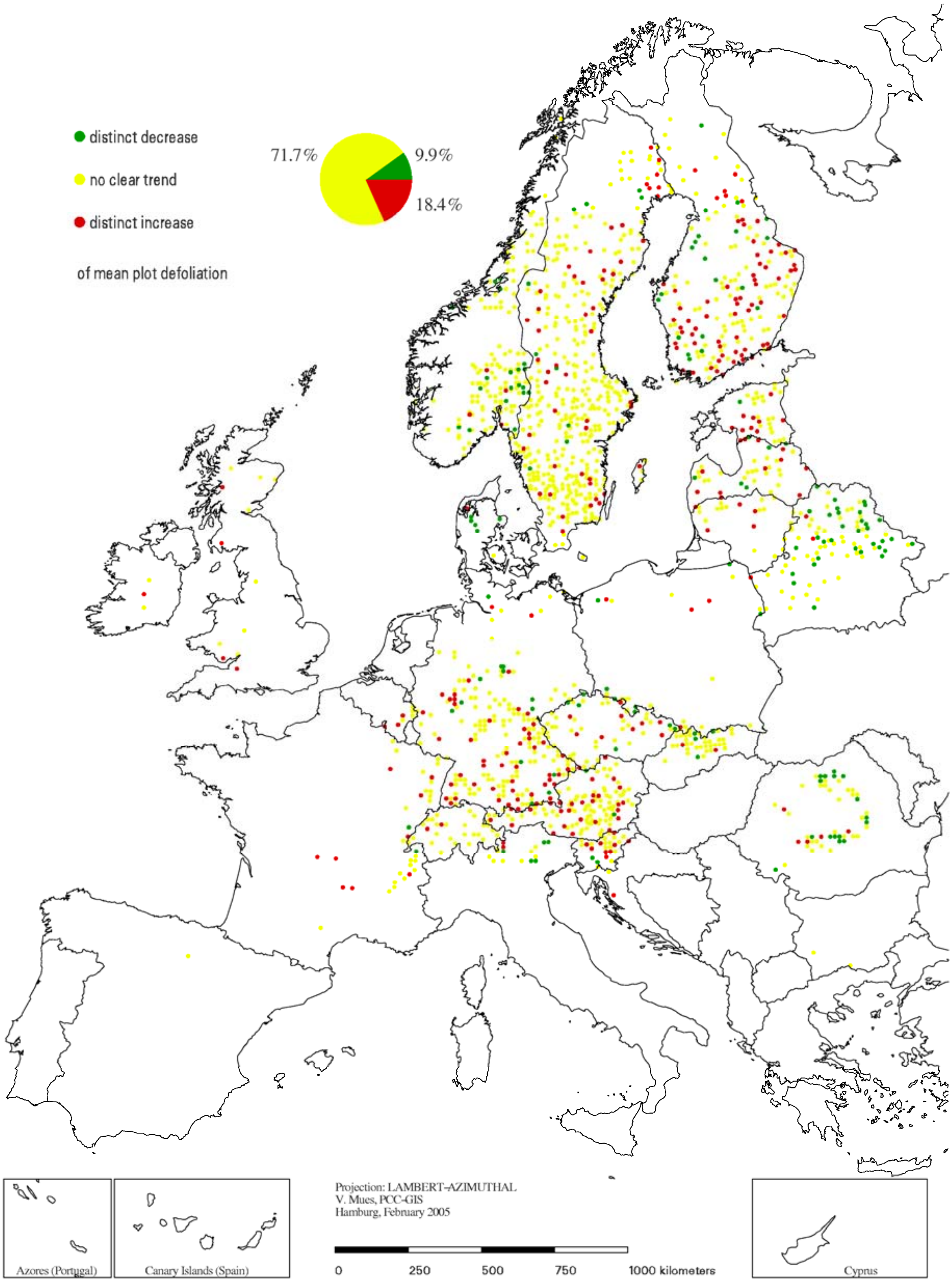


Figure 2.2.2.3-2: Trend of mean plot defoliation (slope of linear regression) of *Picea abies* over the years 1997 to 2004.

2.2.2.4 Fagus sylvatica

Of the broadleaved species, *Fagus sylvatica* represents the largest portion. In the total of all regions and in both periods of observation (1990-2004 and 1997-2004) the share of damaged trees is now with 32.1% and 27.8%, respectively, larger than ever before. This deterioration started in 2003 and reflects the increased defoliation since 2003 especially in the Sub-Atlantic and Mountainous (south) regions which constitute together more than half of the *Fagus sylvatica* trees. A particular increase in defoliation occurred in the 1990-2004 time series in the Mountainous (south) region. There, the share of damaged trees tripled approximately from 11.8% in 2002 to 32.5% in 2003 which reflects largely the high fructification in the eastern Slovak Republic. Another striking increase in defoliation was noted in the Atlantic (north) region. There, the share of damage trees of the time series 1990-2004 increased from 29.2% in 2003 to 45.8% in 2004. This sudden deterioration and the deterioration in the Sub-Atlantic region can be attributed to the hot and dry summer of 2003 (Figure 2.2.2.4-1).

Besides the deterioration of crown condition of *Fagus sylvatica* in 2003 and 2004, an increase in defoliation over the whole period of 1997-2004 was observed particularly in the Atlantic (north), in the Sub-Atlantic and in the Mountainous (south) region. Figure 2.2.2.4-2 shows the spatial distribution of the trends since 1997 across Europe. The share of plots with increasing defoliation is 20.2%. The share of plots showing a decrease in defoliation is 9.0%.

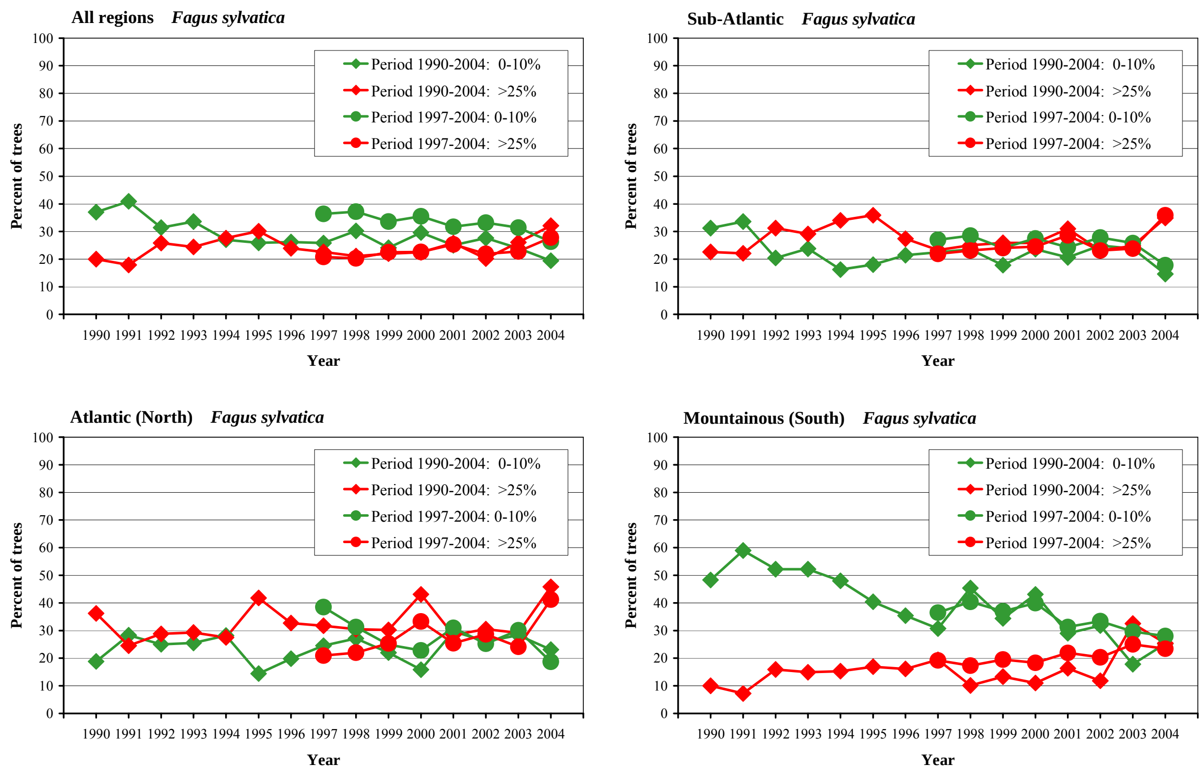


Figure 2.2.2.4-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2004 and 1997-2004).

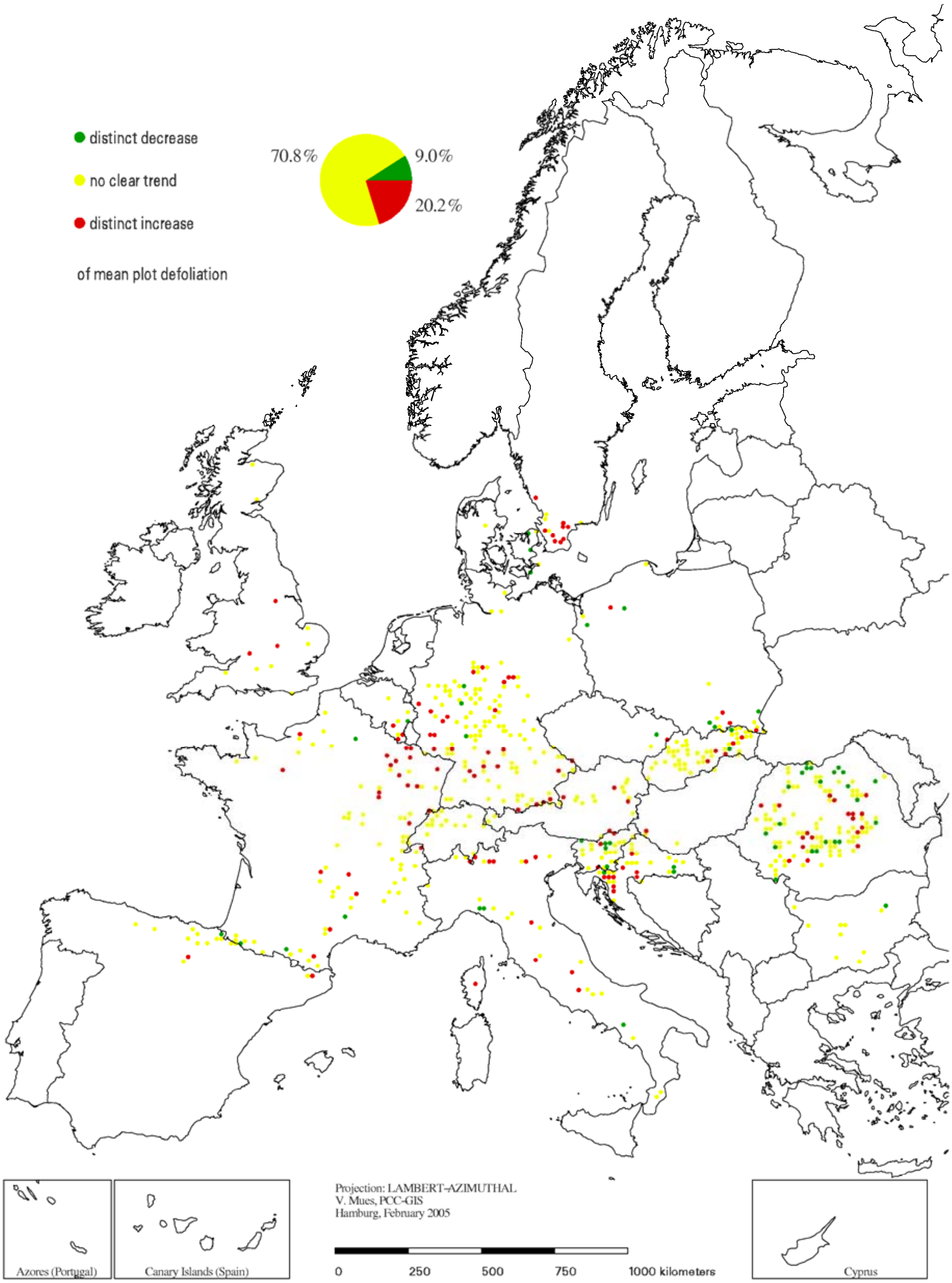


Figure 2.2.2.4-2: Trend of mean plot defoliation (slope of linear regression) of *Fagus sylvatica* over the years 1997 to 2004.

2.2.2.5 Quercus robur and Q. petraea

The species group *Quercus robur* and *Quercus petraea* shares the regional deterioration of crown condition in 2003 and 2004 which is also observed for other main species (Chapters 2.2.2.2-2.2.2.4). The share of damaged trees of the total of all regions recovered from its peak with 46.5% in 1994. After a steady stated from 1999 onwards, it increased markedly in 2003 because of the summer heat and drought. This reflects mainly the development of crown condition in the Sub-Atlantic region which comprises the largest share of the sample trees of this species group. In the Sub-Atlantic region the share of damaged trees of the time series 1990-2004 increased from 32.6% in 2002 to 36.8% in 2003 and to 42.0% in 2004. This increase is also seen, though to a lower extent, in the Atlantic (south) region, which comprises the second largest share of the *Quercus robur* and *Quercus petraea* trees. However, the development of defoliation in the Atlantic (south) region differed otherwise greatly from that in the Sub-Atlantic region. During the period from 1990 to 2004 the share of not defoliated trees decreased from 66.5% to 20.4%. In the Atlantic (north) region, the share of damaged trees has been increasing already since 2001.

The spatial variation of the trend since 1997 show that nearly half of the trees with increasing defoliation is situated in France. Of all plots of the map, 16.4% show increasing defoliation. On 10.1% of the plots defoliation decreased (Figure 2.2.2.5-2).

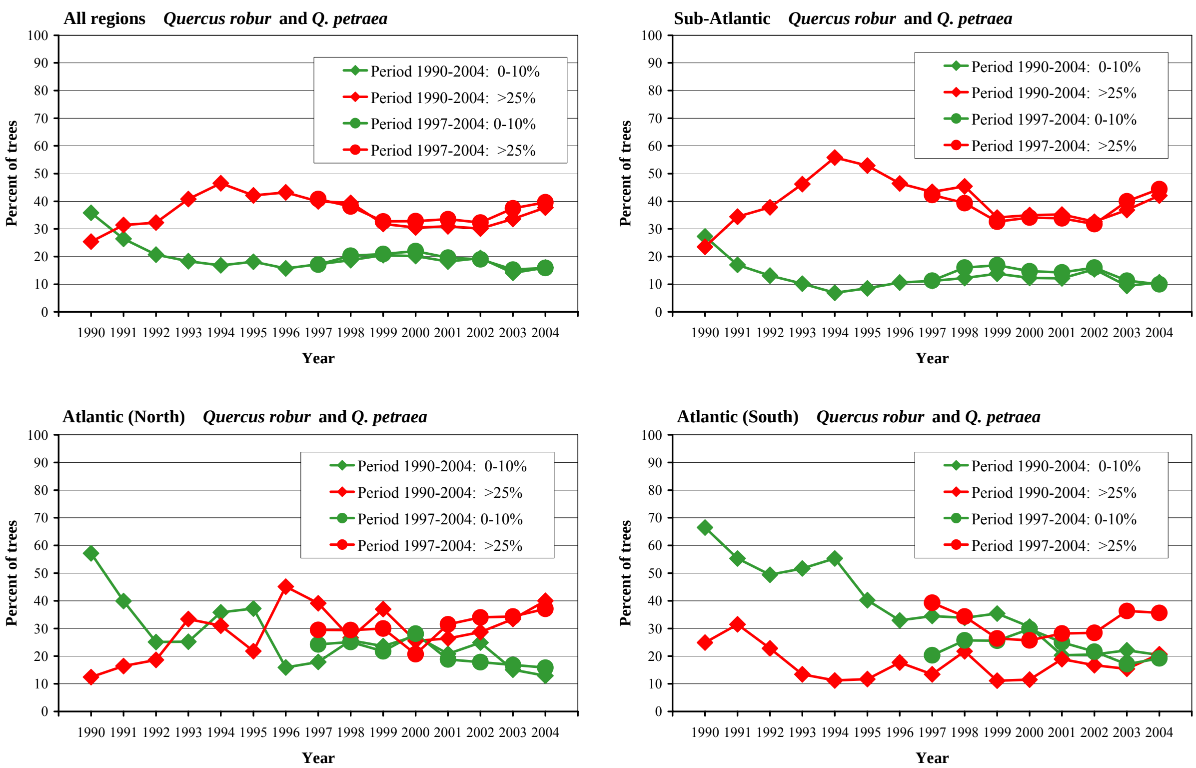


Figure 2.2.2.5-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2004 and 1997-2004).

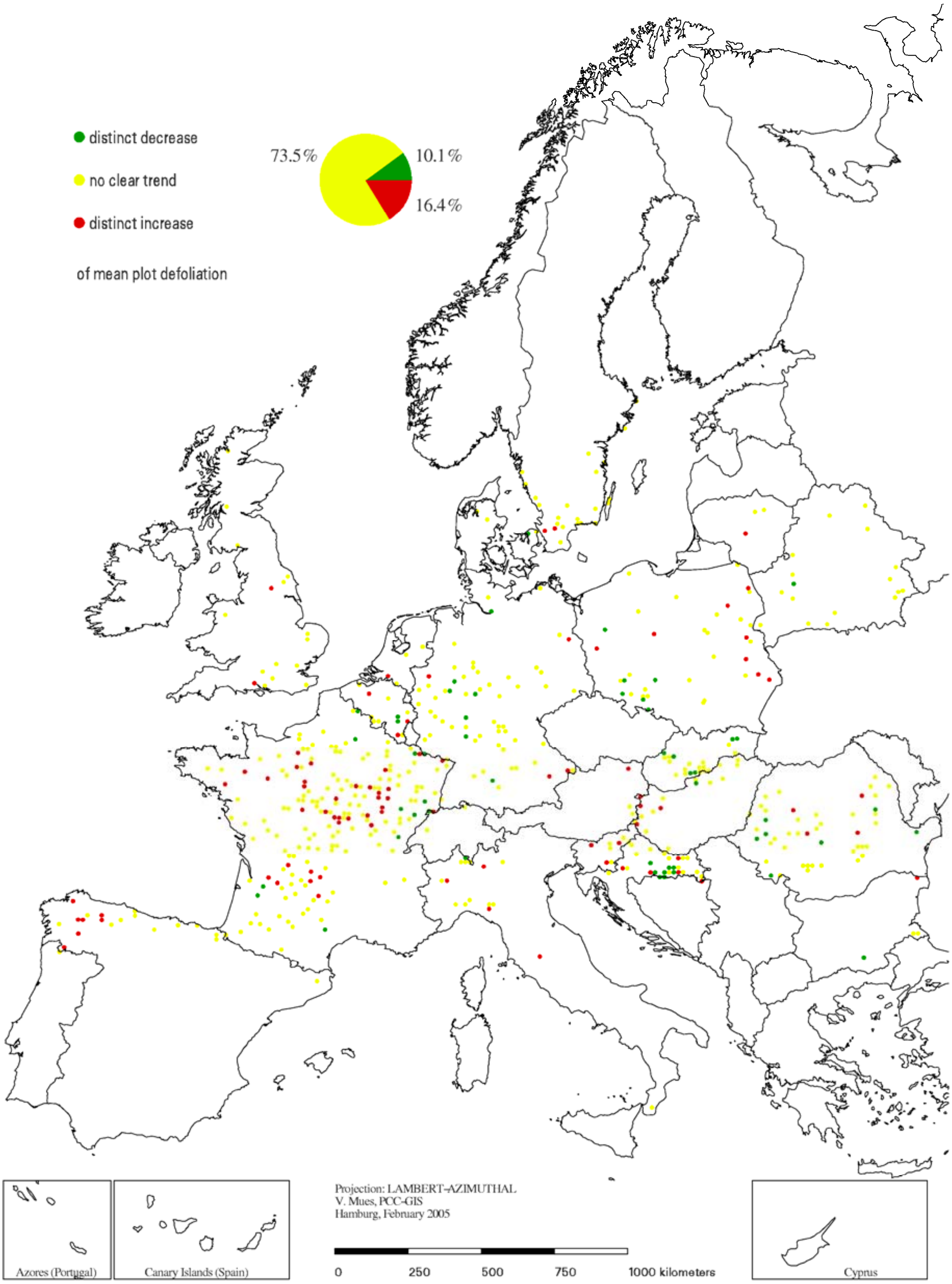


Figure 2.2.2.5-2: Trend of mean plot defoliation (slope of linear regression) of *Quercus robur* and *Quercus petraea* over the years 1997 to 2004.

2.2.2.6 Quercus ilex and Q. rotundifolia

Quercus ilex and *Quercus rotundifolia* shows in the total of all regions an increase in the share of damaged trees from 11.3% in 1990 to a peak of 28.1% in 1995. This deterioration was followed by a clear decrease to 13.4% in 1998. Since then each of the samples of the two time series (1990-2004 and 1997-2004) reveals and increase in its share of damaged trees by about three percent points. The trees are mainly distributed over the Mediterranean (lower) region, which comprises about three quarters of the sample trees of both periods of observation. The development of defoliation in the Mediterranean (higher) region is similar (Fig. 2.2.2.6-1). A comparison of the map in Figure 2.2.2.6-2 with that in Figure 2.1.2.1-1 suggests that defoliation has been increasing most at higher altitudes. Of all plots on the map, 23.9% showed increasing defoliation against only 8.7% of the plots with a decrease.

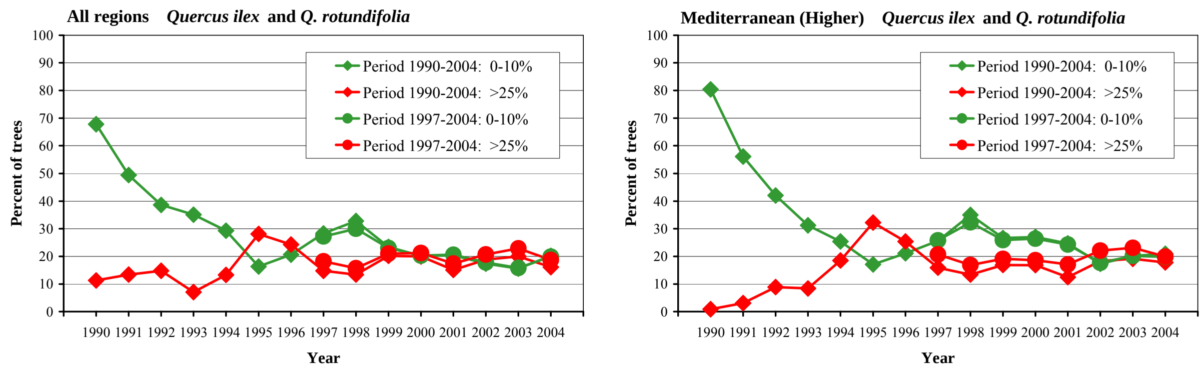


Figure 2.2.2.6-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2004 and 1997-2004).

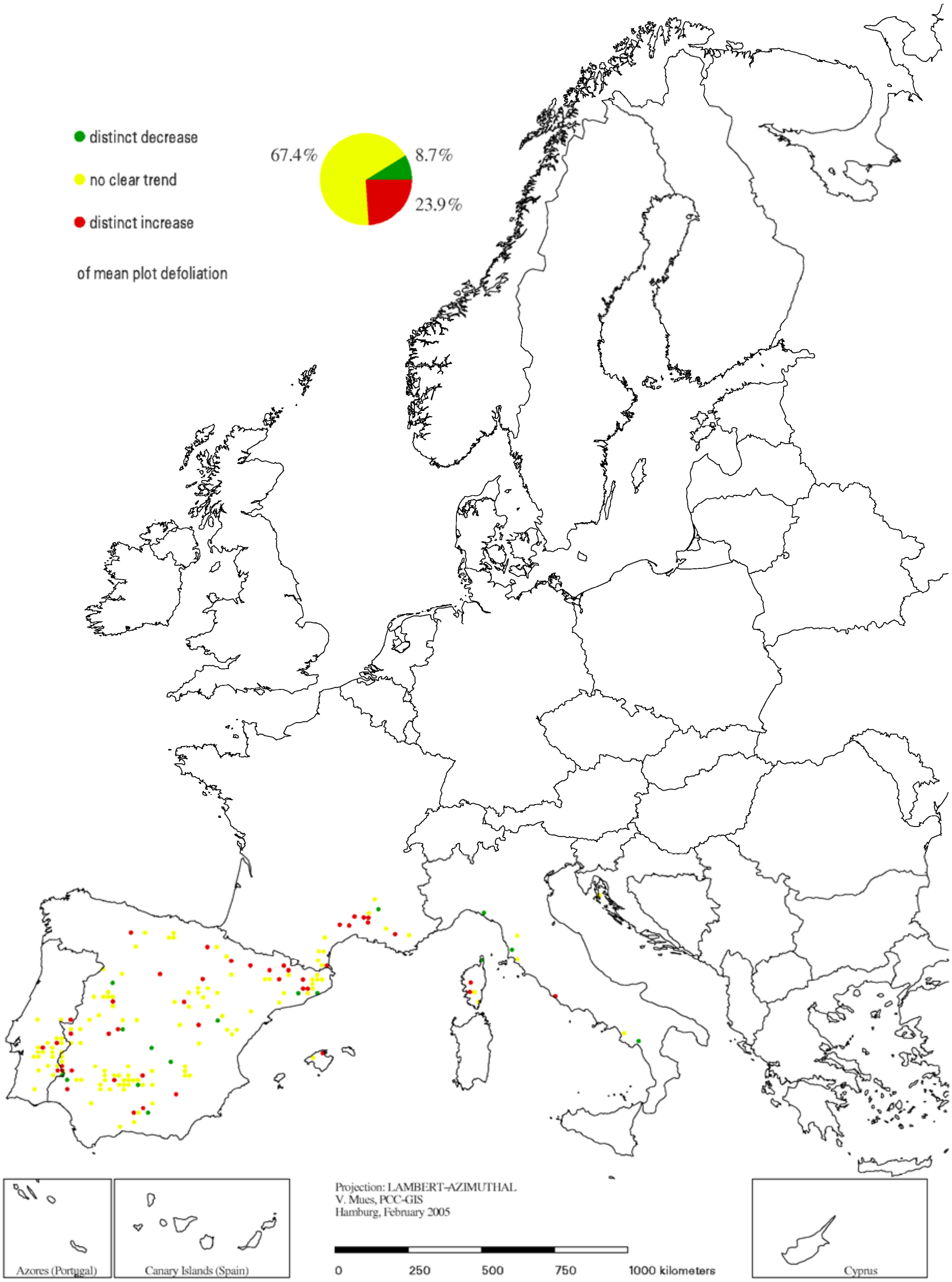


Figure 2.2.2.6-2: Trend of mean plot defoliation (slope of linear regression) of *Quercus ilex* and *Quercus rotundifolia* over the years 1997 to 2004.

2.2.2.7 Pinus pinaster

In the total of all regions, the share of damaged trees of *Pinus pinaster* is today hardly higher than at the beginning of the time series in 1990. Despite this, defoliation of this species increased due to a clear decrease in the share of not defoliated trees (defoliation 0-10%). This share fell from 68.1% in 1990 to 44.1% in 2004. This development reflects largely the one in the Mediterranean (lower) and Mediterranen (higher) regions, in which more than half of the sample trees are situated. The development in the Atlantic (south) region is very different from that. Here, the share of damaged trees decreased from 37.9% in 1990 to a minimum of 4.0% in 1999. Since then, it increased to 14.2% in 2004 (Figure 2.2.2.7-1).

The map in Figure 2.2.2.7-2 shows that the plots with increasing mean defoliation are scattered across the whole habitat, while a number of recuperating plots is concentrated in Portugal. The share of deteriorating plots is with 24.5% clearly larger than the share of improving plots with 16.5%.

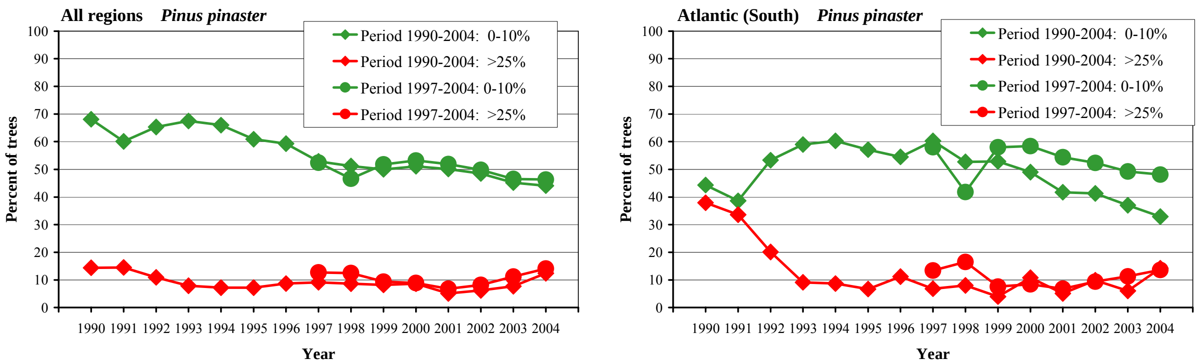


Figure 2.2.2.7-1: Shares of trees of defoliation 0-10% and >25% in two periods (1990-2004 and 1997-2004).

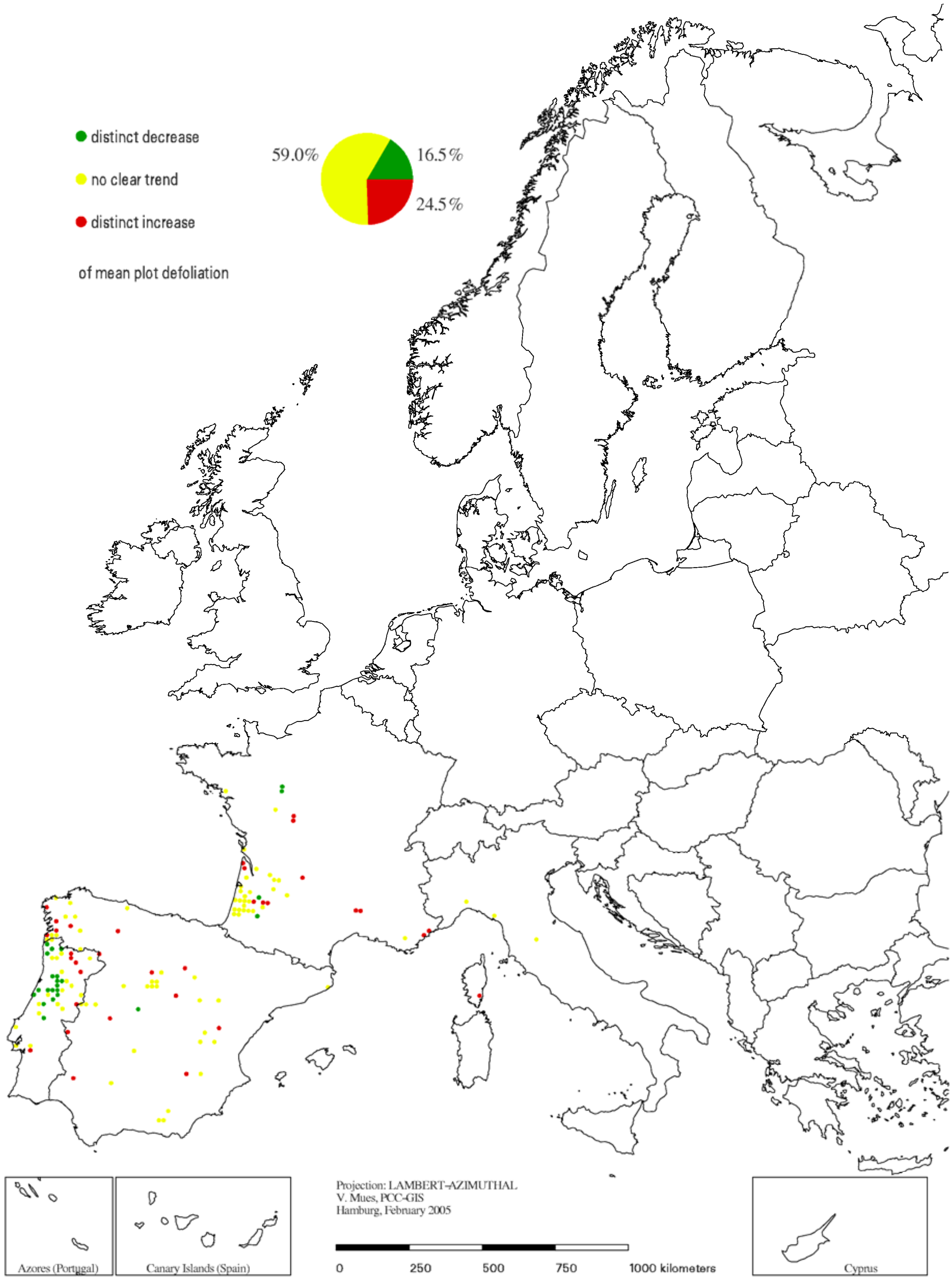


Figure 2.2.2.7-2: Trend of mean plot defoliation (slope of linear regression) of *Pinus pinaster* over the years 1997 to 2004.

3. INTENSIVE MONITORING

3.1 Introduction

The aim of the intensive monitoring is to assess causal relationships on the forest ecosystem scale. This is achieved on more than 860 intensive monitoring (Level II) plots selected in the most important forest ecosystems of 30 participating countries (see Annex I-10). The following surveys are mandatory on all of these plots: Annual assessments of crown condition, assessments of soil condition every ten years as well as bi-annual foliage chemistry surveys and forest growth studies every five years. Ground vegetation is assessed every five years on 715 plots. On 513 plots, atmospheric deposition is assessed continuously. Also continuously assessed are ambient air quality on 170 plots, soil solution chemistry on 242 plots and meteorology on 206 plots. Phenology is assessed several times per year on 64 plots. The complete methods of the intensive monitoring are laid down in the "Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests" (ANONYMOUS, 2004). Results of the intensive monitoring have been presented in annual Technical Reports since 1997 (e.g. DE VRIES et al., 2003).

In the present report, Chapter 3.2 presents results of bulk and throughfall deposition measurements based on the Level II data made available by the countries by 2001. Chapter 3.3 contains results of a study on depositions of nitrogen an carbon. Chapter 3.4 presents a dynamic modelling approach for the future calculation of scenarios of atmospheric depositions and their effect.

3.2 Deposition and its trends

3.2.1 Introduction

The present chapter aims at the description of deposition situations on Level II plots. Element input, element leaching and element budgets for forest soils on Level II plots were described in previous reports (DE VRIES et al., 2001). Results on deposition of nitrogen as well as critical loads and their exceedances were presented by DE VRIES et al. (2002). ULRICH (2003) found linear trends in nitrogen, sulphur, calcium and magnesium concentration between 1992 and 2002 for the French intensive monitoring network "Renecofor". In the Technical Report 2004 mean concentrations of nitrogen and sulphur bulk depositions and their trends were presented.

The present chapter describes a study of temporal development and spatial variability of nitrate ($N\text{-}NO_3$), ammonium ($N\text{-}NH_4$) and sulphate ($S\text{-}SO_4$) deposition on Level II plots from 1996 to 2001. In addition, depositions of calcium (Ca), sodium (Na), and chlorine (Cl) and the amount of precipitation are described and presented when ever needed in order to enable a sound interpretation of the results.

3.2.2 Methods

The Level II data used were collected and analysed according to the ICP Forests Manual (ANONYMOUS, 2004). The data employed for statistical analyses were checked and validated by the Forest Intensive Monitoring Coordinating Institute (FIMCI). Open field deposition is measured in order to reflect the local air pollution situation. For assessments of air pollution effects on forests deposition under canopy throughfall and in some cases stemflow are measured. Deposition under canopy is generally larger than in the open field as wet deposition is additionally polluted by dry deposition which was filtered by the canopy from the air and washed off the foliage. This effect leads to a higher total deposition in forests (wet + higher dry deposition) compared to open field or "bulk" deposition, respectively. Two further processes can be observed during the passage of the deposition through the canopy:

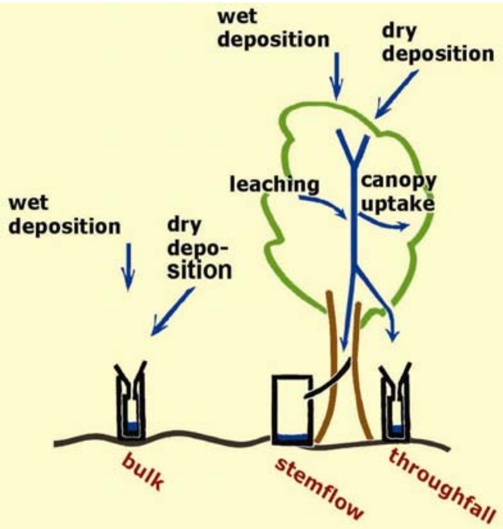


Figure 3.2.2-1: Deposition measurements in forests.

1. Leaching, the solution of an element, mostly of nutrient cations, from the tree crown into the water passing through, which leads to an enrichment of the particular element in the throughfall deposition compared to bulk deposition.

2. Canopy uptake, the absorption of an element, mostly nitrogen compounds, from the water passing through the canopy by the leaves which leads to decreased deposition of the particular element in the throughfall deposition compared to bulk deposition.

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

The study is based on the Level II data on bulk deposition measured in the open field and on throughfall deposition in order to describe the under canopy deposition. Due to the fact that stemflow data were available only for 16 plots continuously from 1996 to 2001 those measurements were not taken into consideration.

The variables subjected to the statistical analyses are bulk and throughfall deposition data expressed in terms of annual deposition in $kg.ha^{-1}.yr^{-1}$. The time span for trend analyses was 1996 to 2001. This is a trade-off between the needs of high numbers of plots in order to cover a wide range of deposition situations and of the length of the time span. In fact, real trend analysis begins to make sense only for periods of at least 10 years and, thus, the present study must be understood as a case of descriptive analyses.

Among the approximately 500 sites on which deposition is measured within ICP Forests, only those sites were selected which have been operational for the whole period 1996-2001, with a maximum of 1 month of missing data per year (s. Table 3.2.2-1). For the eventually missing period the deposition was estimated by the respective average daily deposition of the remaining year.

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

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

In order to give a general overview on the temporal development, in addition to the slope maps, the annual mean depositions were calculated for all examined deposition elements of those 169 plots for which all data were completely available from 1996 to 2001 (Table 3.2.2-1).

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

The plot-wise mean deposition for a three years period (1999 and 2001) was mapped instead of presenting the eventually specific deposition situation in a single year. These maps show a high spatial variability of deposition situations. By selecting measurements from only 3 years a much higher number of plots could be taken into account than in case of a longer time span (Table 3.2.2-1). This relatively high number of plots could be basis also for time series analyses if the extent of the Level II monitoring activities is not reduced significantly. For mapping, in case of mean deposition percentile classes were chosen comprising the whole range of values found.

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

n obs		Na	Cl	Ca	N-NH_4	N-NO_3	S-SO_4
	complete			169			
trend 1996 – 1999	Bulk	295	290	292	294	294	285
	throughfall	188	185	188	188	188	179
mean 1999 – 2001	Bulk	411	409	408	407	409	401
	throughfall	283	283	283	282	283	275

3.2.3 Results

3.2.3.1 Mean Annual Deposition 1999 to 2001

The mean annual deposition in the period 1999 to 2001 was calculated in bulk as well as in throughfall deposition for ammonium, nitrate and sulphur being the most important anions in the acidification process. In addition, calculations for sodium, chlorine and calcium were done in order to enable a sound interpretation of the outcome. Figure 3.2.3.1-1 shows the mean annual sodium (Na) bulk deposition in order to get an impression on which plots sea spray is probably an important source of sodium and sulphate deposition. In fact, most of those plots which are in the class with highest sodium depositions are located close to the coast and seem to be influenced by sea spray effects.

On many of the plots on which high sulphur bulk depositions were measured (Figure 3.2.3.1-2) high depositions of sodium are also observed (Figure 3.2.3.1-1), e.g. on the west coast of the UK, in the south west of Norway and in Italy and Greece. On the other hand there are also plots in Poland, the Slovak Republic, Hungary, the south west of Germany, and the north of Italy where the relatively high sulphur deposition can not be linked to sea spray due to large distances to the coast and surrounding plots with lower sulphur deposition. Thus, the combined interpretation of sodium and sulphur depositions allows an identification of plots with high sulphur depositions of anthropogenic origin.

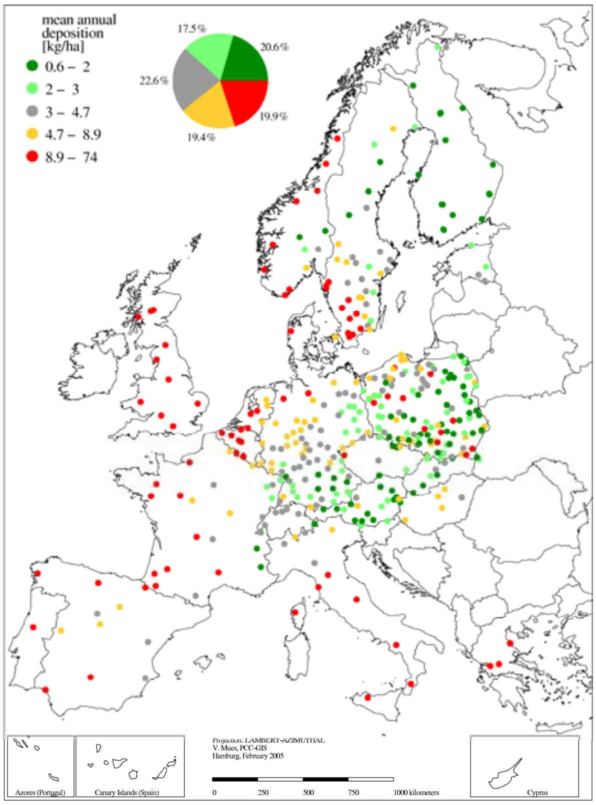


Figure 3.2.3.1-1: Mean annual sodium (Na) bulk deposition 1999 to 2001.

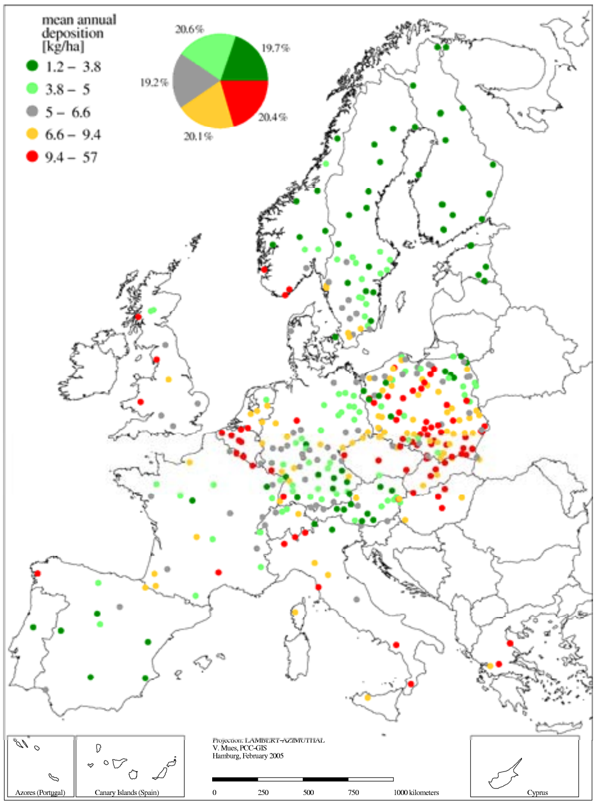


Figure 3.2.3.1-2: Mean annual sulphate (S-SO_4) bulk deposition 1999 to 2001.

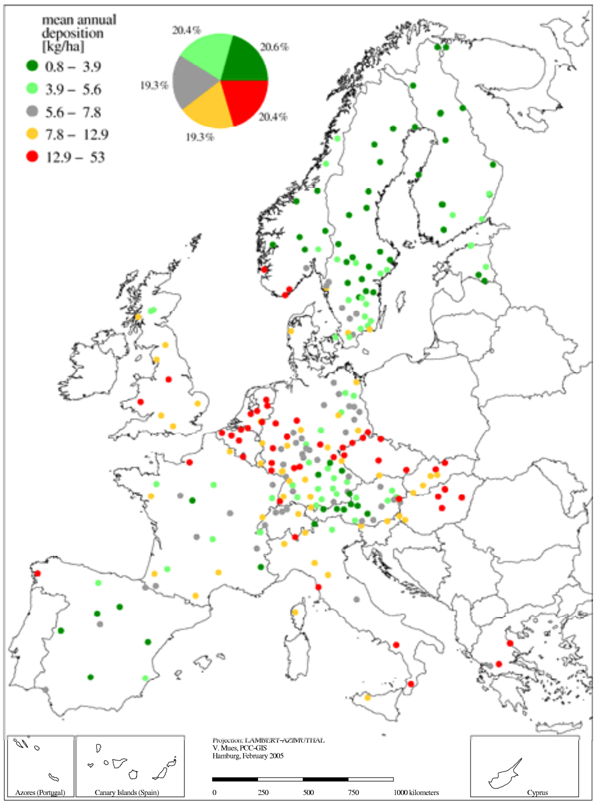


Figure 3.2.3.1-3: Mean annual sulphate (S-SO_4) throughfall deposition 1999 to 2001.

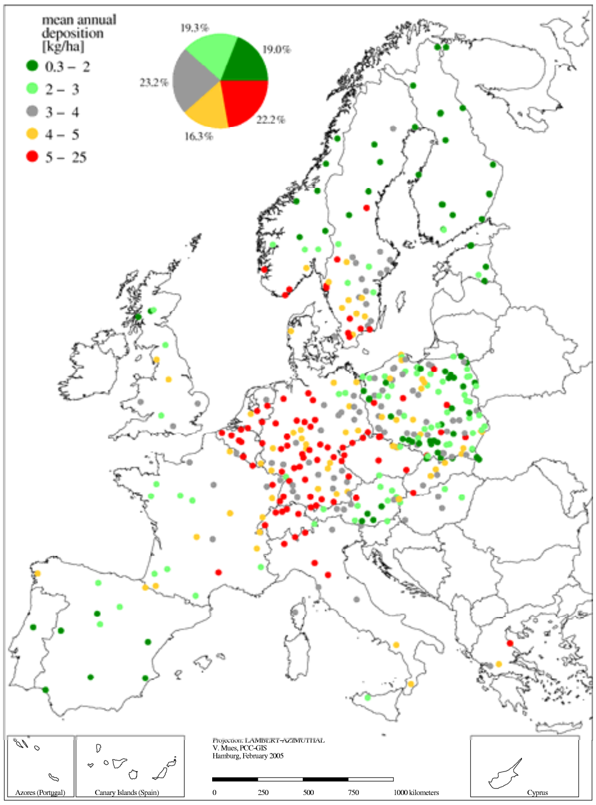


Figure 3.2.3.1-4: Mean annual nitrate (N-NO_3) bulk deposition 1999 to 2001.

For the mean annual throughfall deposition fluxes of sulphate (Figure 3.2.3.1-3) even more plots with high deposition values were observed in Central Europe. In this context it must be mentioned that for the plots in Poland no throughfall measurements were available. As the three highest values for mean annual sulphur bulk deposition from 1999 to 2001 were calculated for plots in Poland (31.1, 40.6, and 56.4 $kg.ha^{-1}.yr^{-1}$, respectively) it must be expected that also throughfall deposition on those plots is comparatively high.

Figure 3.2.3.1-4 shows the mean annual nitrate bulk deposition which is high on plots in Central Europe from the south of Sweden and Norway to the North of Italy and from Belgium to the south east of Germany and the Czech Republic. This finding can be explained by the high amount of vehicular traffic in this region and the fact that vehicles are a major source of nitrate depositions.

Similar to the findings for nitrate the mean annual deposition fluxes of ammonium are high on plots in Central Europe. Again, highest values in bulk deposition were found on plots in Poland with 41.0, 24.1 and 24.0 $kg.ha^{-1}.yr^{-1}$, respectively (Figure 3.2.3.1-5). The highest value for ammonium throughfall deposition (Figure 3.2.3.1-6, no observations from Poland available) was observed on a plot in Belgium with 33.8 $kg.ha^{-1}.yr^{-1}$. For this plot a mean annual bulk deposition of 10.4 $kg.ha^{-1}.yr^{-1}$ ammonium was calculated which indicates a high amount of dry deposition as result of the filtering effect of the crown.

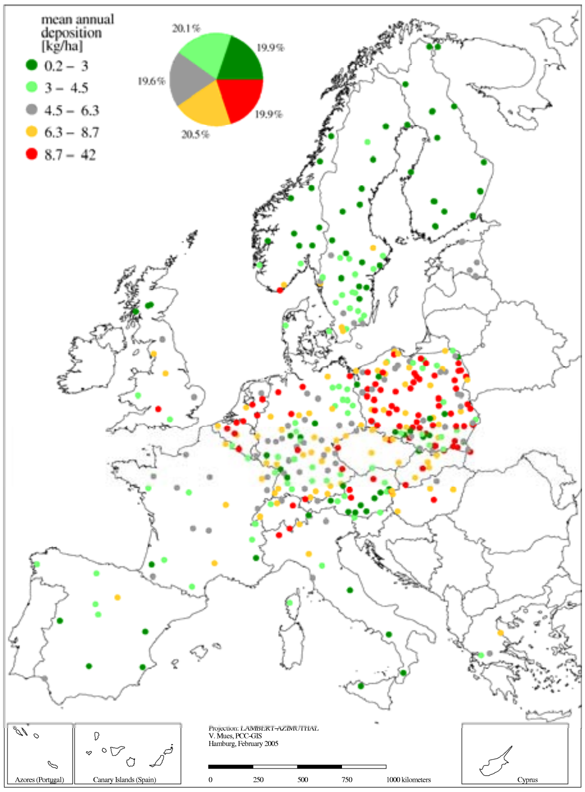


Figure 3.2.3.1-5: Mean annual ammonium ($N-NH_4$) bulk deposition 1999 to 2001.

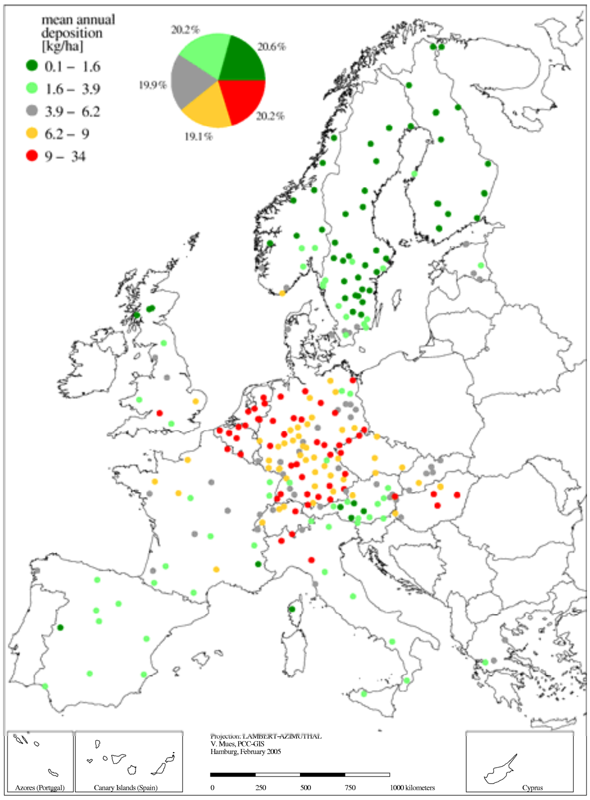


Figure 3.2.3.1-6: Mean annual ammonium ($N-NH_4$) throughfall deposition 1999 to 2001.

3.2.3.2 Trends

Mean annual deposition on 169 plots shows a reduction for sulphate and a less clear development for ammonium and nitrate deposition from 1996 to 2001 (Figure 3.2.3.2-1). The reduction in sulphur deposition is most evident for throughfall deposition which decreases from almost 16.1 kg.ha^{-1}.yr^{-1} in 1996 to 9.5 kg.ha^{-1}.yr^{-1} in 2001. The reduction in bulk deposition from 7.4 to 5.8 kg.ha^{-1}.yr^{-1} is not as impressive and at much lower level. Under the assumption that in case of sulphur the amount of canopy exchange (leaching and canopy uptake) is of low importance this indicates that (i) the amount of dry sulphur deposition is of comparable level to that of wet deposition and that (ii) the reduction of sulphur emissions leads to relatively higher reductions in forests than in open field. Both statements are based on average values. As further results show, the deposition situation is of high variability on the examined Level II plots.

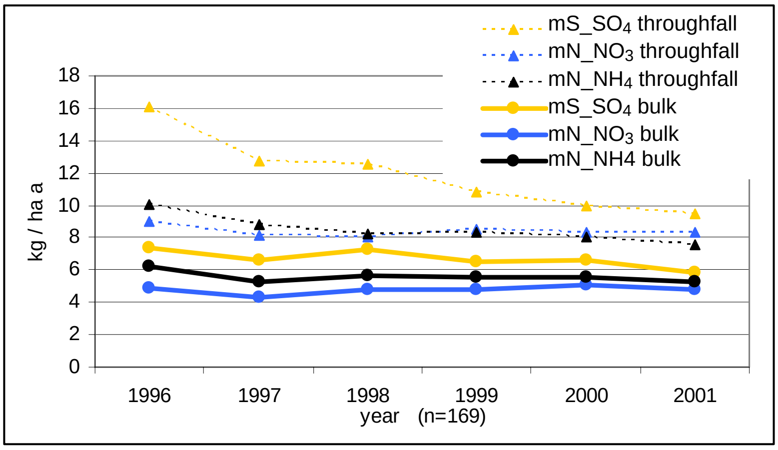


Figure 3.2.3.2-1: Mean annual deposition of sulphate, nitrate, and ammonium at 169 plots in bulk and throughfall deposition.

The deposition of nitrogen compounds especially in bulk deposition shows no clear trend. The mean depositions for all examined plots are of low variability.

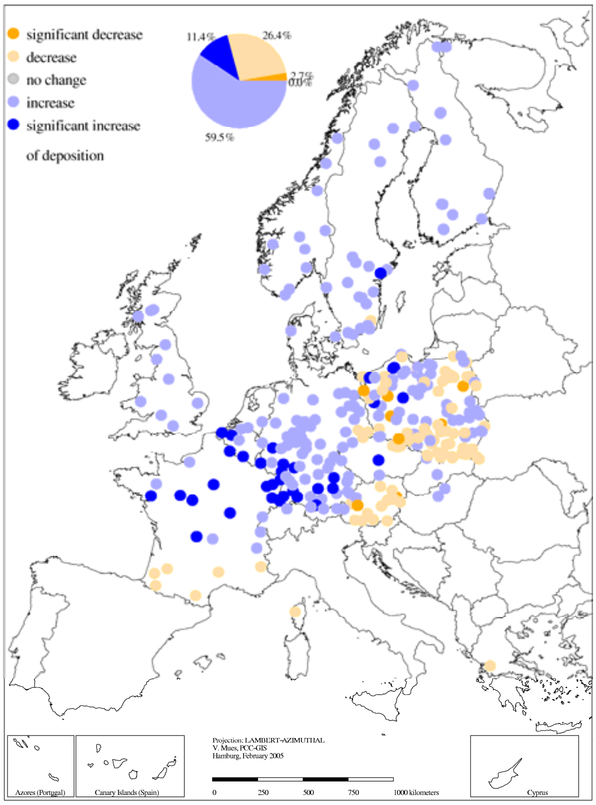


Figure 3.2.3.2-2: Trends of water amount in bulk deposition 1996 to 2001.

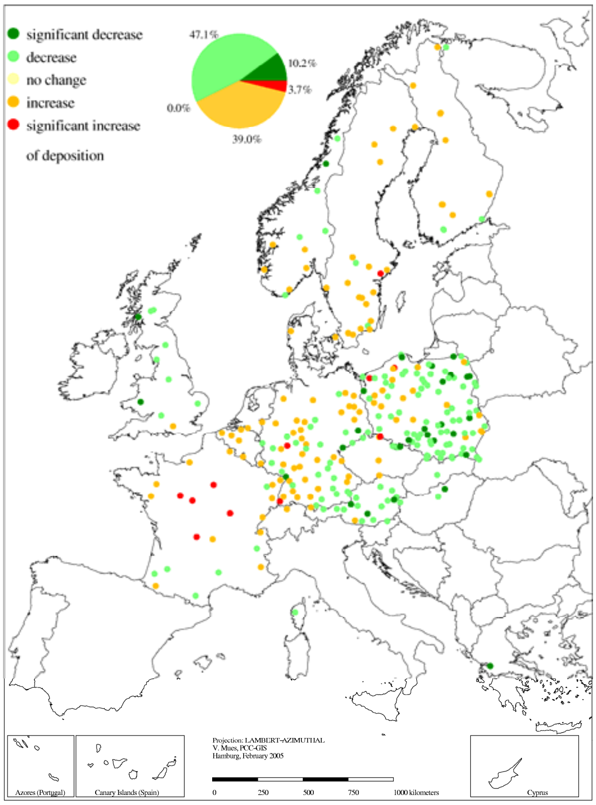


Figure 3.2.3.2-3: Trends of nitrate (N-NO_3) in bulk deposition 1996 to 2001.

Because the amounts of bulk deposition and throughfall deposition are dependent on the amount of wet deposition, the trend of precipitation is important in order to allow a sound interpretation of the development of deposition. The plot specific trends of the amount of water in bulk deposition are presented in Figure 3.2.3.2-2. On more than 70% of the plots precipitation increased during the observation period.

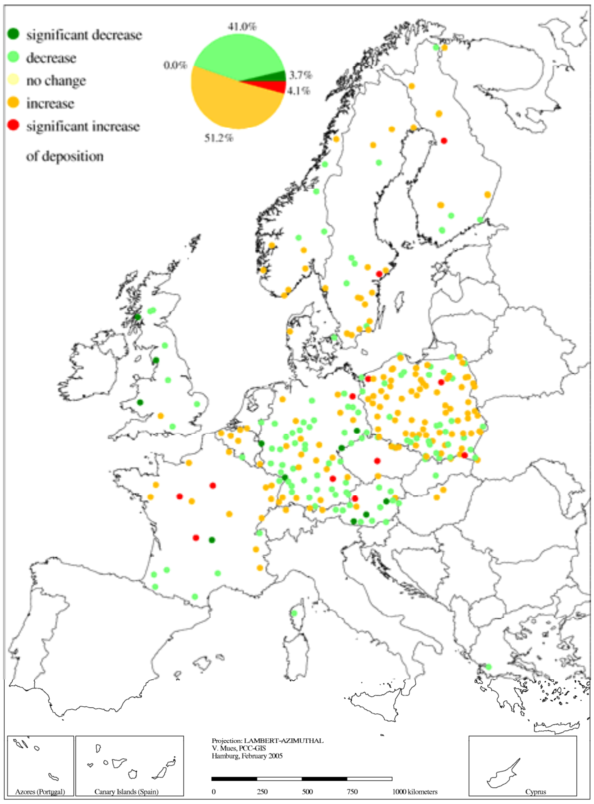


Figure 3.2.3.2-4: Trends of ammonium (N-NH_4) in bulk deposition 1996 to 2001.

It can be stated that on many plots in the northern part of France and in the south-west of Germany, the west of Belgium, and in the north-east of Poland the amount of water in bulk deposition, the precipitation, increased during the observed period. On most plots in the same regions also nitrate bulk deposition increased from 1996 to 2001 (Figure 3.2.3.2-3). In other regions such as south-east Poland, Austria and southern France a decrease in water amount and nitrate deposition is observed. This coincidence – increase in both, water amount and nitrate deposition – is not found in the United Kingdom, in the middle of Norway as well as on some plots the south of Finland, in Hungary, the Slovak Republic, in western Austria, and in southern Germany where nitrate deposition decreased although the amount of precipitation increased. In accordance with this observation, the share of plots with decreasing nitrate bulk deposition is with almost 60% much higher than that of plots with decreasing precipitation.

The coincidence of increasing deposition on plots with increasing precipitation values is not found to be as clear for ammonium (Figure 3.2.3.2-4) and again the share of plots with decreasing deposition fluxes (almost 45%) is higher than that of decreasing precipitation (29.1%). But also for ammonium the increase in bulk deposition seems to be related with an increase in precipitation.

The highest frequency of plots with statistically significant decrease in deposition was found for sulphur throughfall deposition fluxes with 31.8% (Figure 3.2.3.2-5), on 58.1% of the plots the decrease was not significant. For example in southern Germany plots are found with decreased throughfall deposition of sulphur although precipitation increased in the same period (Figure 3.2.3.2-2).

Also in case of sulphur bulk deposition (Figure 3.2.3.2-6) a significant increase in deposition is mostly found on those plots where the precipitation amount also increased significantly. Thus, e.g. on a plot in south eastern Sweden a statistically significant increase in sulphur bulk deposition was observed where the amount of water in bulk deposition increased as well. Nevertheless, there are also some plots with increased deposition and decreased precipitation in southern Poland.

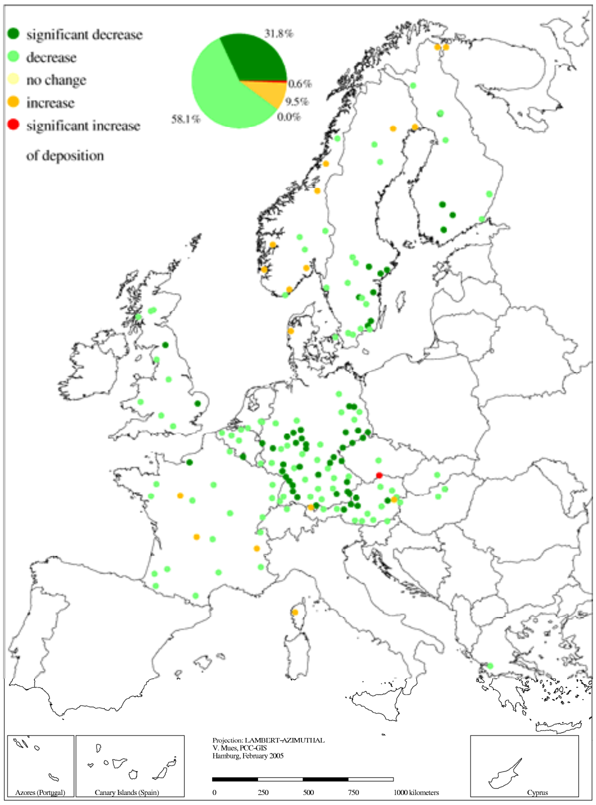


Figure 3.2.3.2-5: Trends of sulphate (S-SO_4) in throughfall deposition 1996 to 2001.

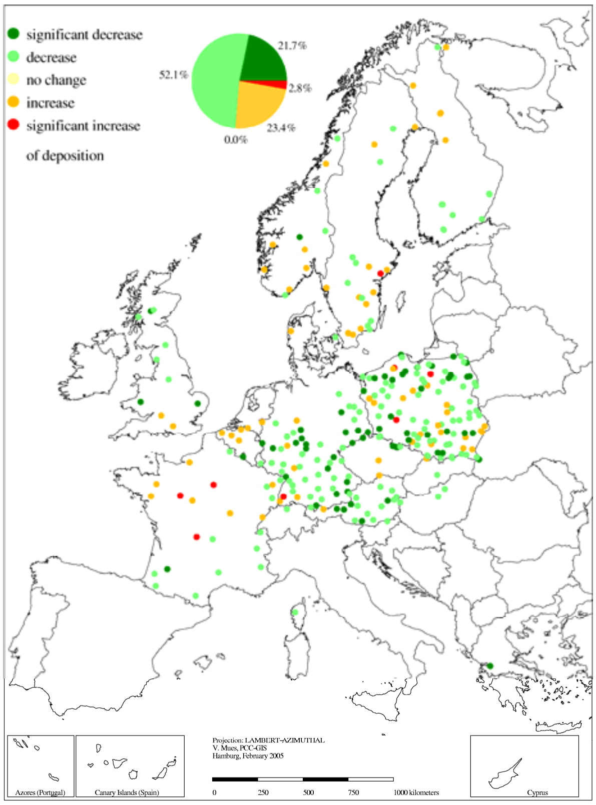


Figure 3.2.3.2-6: Trends of sulphate (S-SO_4) in bulk deposition 1996 to 2001.

3.3 DYNAMIC MODELLING

3.3.1 Introduction

The Convention on Long Range Transboundary Air Pollution (CLRTAP) of the United Nations Economic Commission for Europe (UNECE), which celebrated its 25th anniversary last year, implemented 8 international environmental treaties as important political instruments for emission control and reduction. From 1990 to 2010 emissions of sulphur will be reduced by 63%, nitrogen oxides by 41% and ammonia by 17% (WGE 2004).

Up to now critical loads derived by steady state models have been used in the CLRTAP negotiations. The critical load is defined as "a quantitative estimate of an exposure to deposition of nitrogen as NH_x and/or NO_y below which harmful effects in ecosystem structure and function do not occur according to the present knowledge"; for acidification accordingly „...of acidifying compounds..." (ICP Modelling&Mapping 2004).

If the above quoted emission ceilings will be reached in 2010, time delay aspects between time point of non-exceedance and recovery of abiotic and biotic environment become more important. For this dynamic models have to be applied.

The time delay aspects are shown in Figure 3.3.1-1. If the critical loads are exceeded by deposition (left grey area, red line), the ecosystem is able to compensate the deposition for a more or less time period. The chemical (e.g. pH in soil solution, blue line) and the biological response (brown line) of the ecosystem, which is in line with a decline of ecological indicators, occur with time delay. This is called damage delay time (DDT). Decrease deposition due to emission reduction below critical load (right grey area, red line), theoretically recovery of the abiotic and biotic parts of an ecosystem occurs also with time delay (recovery delay time, RDT).

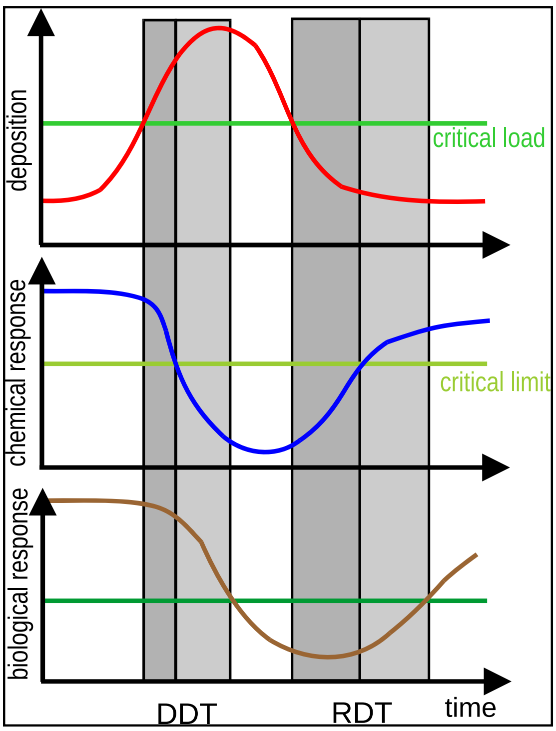


Figure 3.3.1-1: Time aspects in soil and biotic response of an ecosystem due to atmospheric deposition (UBA 2004, adapted).

As shown by actual studies in several countries ecosystem recovery takes decades or centuries in dependency of abiotic and biotic conditions, especially in central Europe where deposition loads were the highest (SVERDRUP et. al 2005, BECKER et al. 2004).

The monitored parameters of ICP Forests Level I and Level II plots build a very good data base for dynamic models. But the measured data cover at best a period of some decades. For a forest ecosystem this time period is very short. Dynamic models could help scientists to broaden their knowledge concerning time aspects and process understanding of forest ecosystem complexity. The future effects of forestry measures like harvest practice or liming could be estimated by using dynamic models.

Dynamic soil models have been and are applied to show the effects of acid deposition on soils and to derive targets for emission reduction in respect to acidification processes. This year dynamic models are available which include acidification **and** eutrophication processes. They build the basis to estimate effects of deposition, climate change and forest measures on soil chemistry and bio diversity.

3.3.2 Methods

3.3.2.1 Dynamic soil models and their concepts

In this year's report results of dynamic models are presented which are developed with the objective to show the effects of acid deposition on soils. These models are well tested and validated. Two models are used for this report and are described below: The Very Simple Dynamic model (VSD) and SAFE (Soil Acidification in Forest Ecosystems).

The next generation of dynamic models is now available for testing. In addition to acidification they estimate effects of eutrophication and climate change on soil chemistry and biodiversity. The next report will handle their methods and first results.

Very Simple Dynamic Model (VSD)

The dynamic model VSD (Very Simple Dynamic) is a simple extension of the steady-state Simple Mass Balance (SMB) which is used to calculate critical loads. It includes cation exchange and time-dependent N immobilisation and is restricted to the ecosystem key processes. VSD takes not into account the nutrient cycles, the dependency of deposition to bio mass, nitrogen fixation, ammonia and sulphur adsorption and complexation of aluminium.

VSD consists of mass balance equations which describe the proportion of element fluxes into the soil to that ones which leaves the soil. Soil solution chemistry depends on

- net fluxes of deposition minus element uptake by harvested vegetation minus immobilisation of nitrogen and
- geochemical processes of soil weathering, CO_2 equilibrium and cation exchange.

The exchange of Al, H and Ca+Mg+K is described by using Gaines Thomas or Gapon equation.

VSD is a simple one layer model – vertical heterogeneity of the soil is neglected. In fact of this it assumes equal conditions for soil and soil solution in the whole rooted soil body. VSD calculates all implemented processes in yearly time steps.

Detailed information on concepts and methods for VSD can be found in POSCH and REINDS (2005).

SAFE (Soil Acidification in Forest Ecosystems) model

SAFE is a dynamic soil chemistry model developed by SVERDRUP and WARFVINGE with the objective to show the effects of acid deposition on soils and ground water although nitrogen processes are included. It based on the steady state model PROFILE (SVERDRUP and WARFVINGE 1992). The soil body can be split up into several, with respect to their chemical and physical properties homogenous soil layers. For each layer detailed soil solution chemistry and cation exchange is calculated by using mass balance equations.

The included key processes in SAFE are:

- soil solution equilibrium reactions including CO2, organic acids and aluminium
- cation exchange
- element movement with horizontal water flow in the multi layer concept
- weathering processes for base cations and aluminium in equilibrium to soil solution based on mineral contents
- nitrification

An overview of the model compartments is given in Figure 3.3.2.1-1.

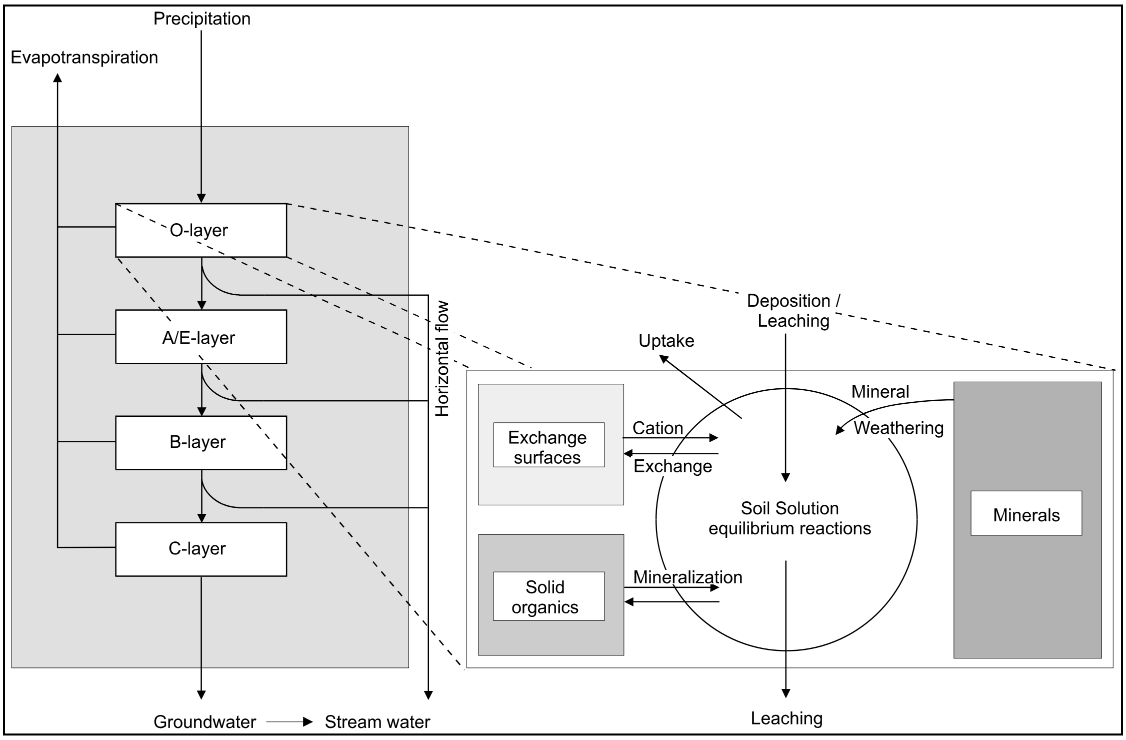


Figure 3.3.2.1-1: Overview of the model compartments of SAFE (ALVETEG 1998 and MARTINSON 2004, adapted)

SAFE needs consistent time series of deposition, nutrient cycle parameters and mineralization which are calculated by MAKEDEP model:

- deposition of base cations, nitrogen, sulphur and chloride in interaction with bio mass
- nutrient cycle of Ca, Mg, K and N
- mineralization of base cations and nitrogen
- detailed implementation of harvesting measures which influences nutrient export, deposition, mineralization and nutrient cycle

InitSAFE calculates the initial conditions of soil chemistry which are input data for SAFE.

The model concept of SAFE includes all important processes to describe soil chemistry of a forest ecosystem. Partly they are simplified. For sulphur exchange processes additional data is needed. Details on SAFE model and the follow-up model ForSAFE can be found in ALVETEG (1998), MARTINSON (2004), WALLMAN (2004) and WALSE (1998).

3.3.2.2 Data need of dynamic modelling

Table 3.3.2.2-1 gives an overview what kind of data is needed to apply the dynamic models SAFE and VSD. Almost all of these parameters are part of the ICP Forests Level II program either mandatory or optional. In principle it is possible for all National Focal Centres (NFCs) of the ICP Forests to apply dynamic models based on their own data. In Germany a successful cooperation of NFC Forests and NFC Modelling & Mapping was developed to bring together all data and knowledge for applying critical load approaches and dynamic models.

Table 3.3.2.2-1: Needed parameters for calculating critical loads and for dynamic modelling

	parameter	**unit**	**model** S = SAFE V = VSD	**optional**
general	latitude	[dec °]	S, V	
	longitude	[dec °]	S, V	
	soil type	[]	V	
	humus description	[]	S, V	
meteo (for different years)	yearly through fall precipitation	[m a^{-1}]	S	
	yearly open field precipitation	[m a^{-1}]	S	
	yearly precipitation surplus	[m a^{-1}]	S, V	
	yearly mean temperature	[° C]	S, V	
trees (for all tree species)	tree species	[]	S, V	
	planting year	[]	S, V	
	harvested biomass per year as mean value over the time from planting to harvesting of the plot	[fm ha^{-1} a^{-1}]	S, V	
	% of tree species area of plot area	[%]	S, V	
	contents of N, Ca, K, Mg in stem, bark, root, branch and canopy	[g kg^{-1}]	S, V	√
	bio mass of stem, bark, root, branch and canopy for a specified year	[fm ha^{-1}]	S	√
depo (for different years)	total deposition of S, NO_y, NH_x, Ca, Mg, K, Na, Cl	[eq ha^{-1} a^{-1}]	S, V	
soil (for all soil layers)	upper and lower depth of soil layer	[m]	S, V	
	clay, silt and sand content	[%]	S, V	
	coarse content	[%]	S, V	
	humus content	[%]	S, V	
	water content (for plants useable water capacity)	[%]	S, V	√
	soil density	[g kg^{-1}]	S, V	
	parent material	[]	V	
	dissolved organic carbon (DOC)	[mg l^{-1}]	S, V	√
	mineral contents	[%]	S	
	cation exchange capacity (CEC)	[µeq g^{-1}]	S, V	
	base saturation	[%]	S, V	
	C/N ratio	[]	S, V	
soil solution	soil solution contents of ph, S, NO_y, NH_x, Ca, Mg, K, Na, Cl, Al for checking		S, V	√

3.3.3 Results

In this chapter the results of the dynamic models SAFE and VSD are presented. The soil solution pH value is chosen as well known and accepted chemical indicator to value the ecosystem conditions for the years 1800 to 2100. VSD results give a mean soil solution pH for the whole soil profile. In contrast pH values for each layer of the soil profile are calculated by SAFE.

To value the modelled pH values they are compared with critical limits which are also shown in the graphs. The critical limits are critical pH values which reflect – simplifying - ecosystem stability regarding buffer capacity, flora and fauna (preservation of bio diversity). To set the critical limit for a plot in the first step the lowest pH in 1800 in that layer is chosen which is below 10 cm soil depth. In the second step the buffer class defined by ULRICH 1985 (Table 3.3.3-1) is selected in which this pH is located. Then the lower border of this class is chosen as critical limit.

Table 3.3.3-1: Buffer systems in soils (ULRICH 1985, adapted)

buffer system	pH class	chemical reactions
carbonate buffer	6.2 – 8.6	leaching of base cations
silicate buffer	5.0 – 6.2	extension of cation exchange capacity
exchange buffer	4.5 – 5.0	reduction of cation exchange capacity
n $[Al(OH)_x^{(3-x)+}]$	4.2 – 4.5	reduction of base saturation
aluminium buffer	3.8 – 4.2	leaching of aluminium
aluminium iron buffer	3.2 – 3.8	organic Fe-complexes
iron buffer	< 3.2	Fe^{3+}

For the plots Blåbärskullen (Sweden), Altdorf and Freising (Germany) the results are elaborated by MARTINSON et al. (2005) and BECKER et al. (2004). They use SAFE for their dynamic model applications. For the Spanish plot Lugar Nuevo the VSD model was applied based on original Level II data. For all plots the historic depositions derived by SCHÖPP et al. (2003) were used. The future deposition based on the Gothenburg protocol, EU CAFE program and other international agreements for emission reduction are estimated by the International Institute for Applied Systems Analysis (IIASA) using the RAINS model.

Lugar Nuevo (26), Spain

The Level II plot Lugar Nuevo is covered by *Quercus ilex*. The soil type is a Dystric Cambisol which was formed from the parent material Quartzite. The long term precipitation is 511 mm a^{-1} and the mean temperature is 15.4° C. In contrast to central European plots the base cation deposition is in relation to sulphur and nitrogen deposition relatively high. This is the reason for a (modelled) pH of 6.7 in the year 1800 (Figure 3.3.3-1). From 1950 to 1998 the pH decreases to 6.0. The emission reductions based on inter alia the Gothenburg protocol will increase the pH up to 6.3 after 2030. For keeping the critical limit of pH 6.5 further emission reductions are necessary.

Altdorf (909) and Freising (919), Germany

The Bavarian Level II plot Altdorf was planted in 1902 with *Pinus sylvestris* trees. They grow on a Haplic Podzol which is based on pleistocenic sands. The precipitation is 790 mm and the mean annual temperature 8.5° C. The depositions of acidifying components are two times higher than deposition of base cations. In the past decades this relation was (much) higher.

At the beginning of the modelling period deposition of acidity is equal to base cation deposition (Figure 3.3.3-2). In fact of higher uptakes of nitrogen in relation to base cations pH values increase in all mineral soil layers. This effect can be observed at poor sites regarding base cation weathering rates because pH is influenced mainly by depositions and uptakes of tree compartments. After 1812 – in the deeper soil layers after 1840 – pH values decrease as a result of an increase of acid deposition and higher base cation uptakes. The clear cut of the former stand in 1901 results in a clear pH peak. After 1988 pH values in all soil layers have increased slightly in fact of emission reduction. The measured and modelled pH values match well except the measures in 30 cm soil depth. In the soil layers of 15 cm to 45 cm soil depth pH is below the critical limit of 3.8. Even if emissions of acidifying components will be reduced additionally to the Gothenburg protocol to reach the critical limit, the site has lost a lot of its buffer capacity and its ecosystem potential caused by acid deposition.

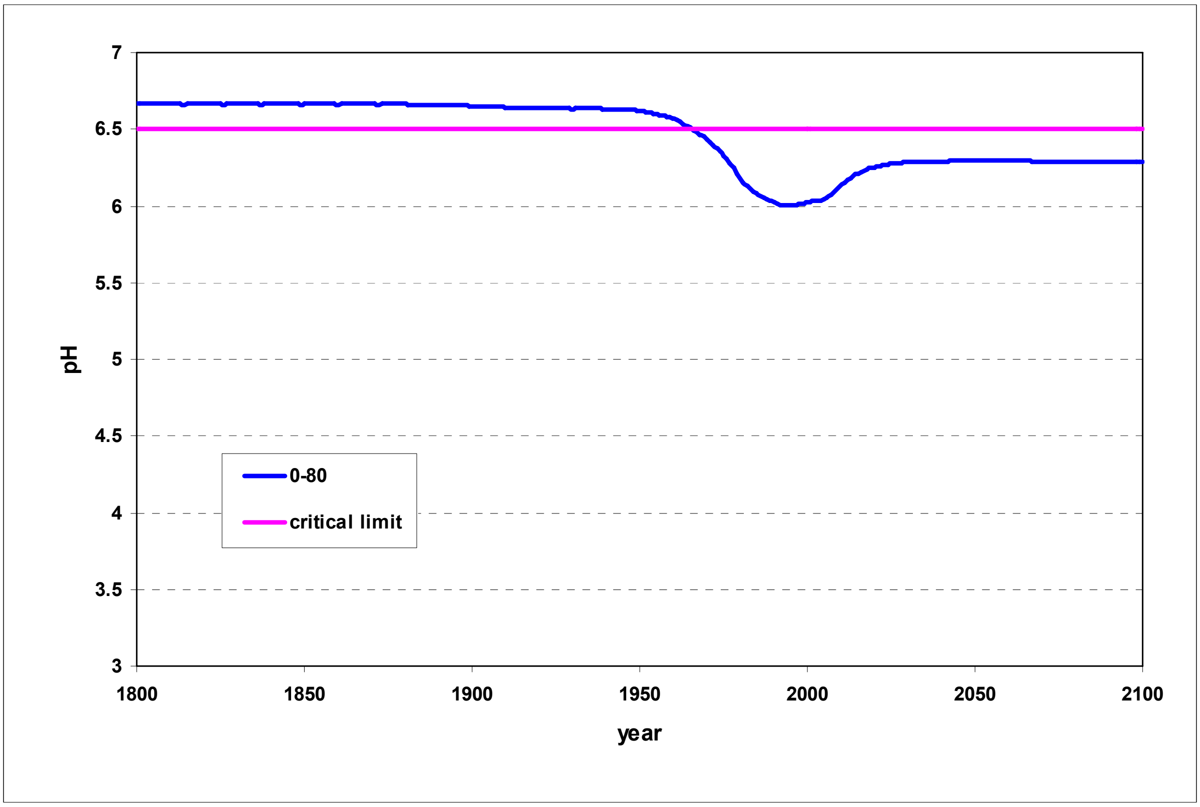


Figure 3.3.3-1: pH at Level II plot Lugar Nuevo (26).

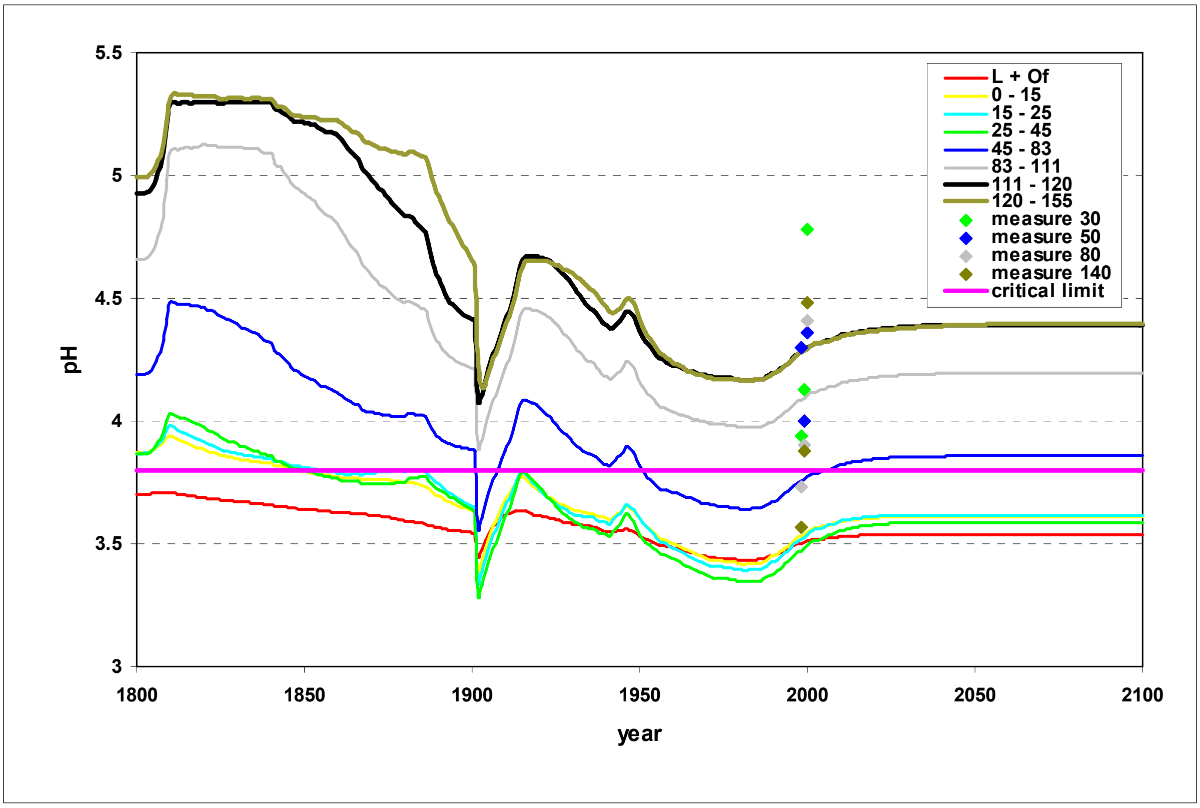


Figure 3.3.3-2: pH at Level II plot Altdorf (BECKER et al. 2004).

The Level II plot Freising is covered with 65% *Fagus sylvatica* planted in 1852 and 35% *Quercus petraea*. The soil type is an Eutric Cambisol and the parent material a weathered Loam. The precipitation is 880 mm and the mean annual temperature 7.7 °C.

The relatively high weathering rate of base cations (3 keq ha^{-1} a^{-1}) results in relatively stable pH values over time in the soil layers below 45 cm soil depth (Figure 3.3.3-3). Only the upper layers are influenced by acid deposition. Especially the soil layer from 25 cm to 45 cm soil depth shows a decreasing pH over the whole modelling period. In this layer emission reductions based on Gothenburg protocol has no influence on the pH of this layer because acid deposition is much higher than buffer ability. In future it could be that the acidification of this layer goes down to the next one if buffer capacity is exhausted. The measured and modelled pH values match very well.

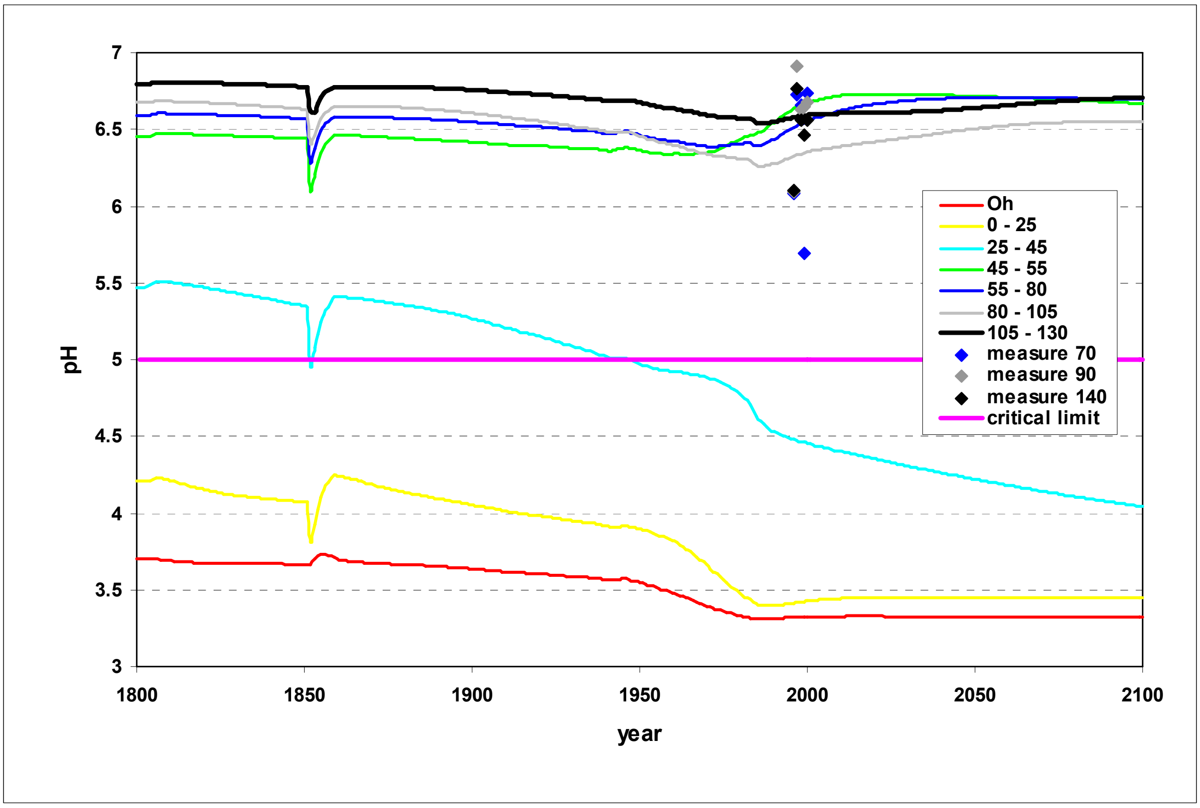


Figure 3.3.3-3: pH at Level II plot Freising (BECKER et al. 2004)

Blåbärskullen, Sweden

Blåbärskullen is covered with *Picea abies*, the soil type is a Cambic Arenosol. The long term precipitation rate is 1040 mm a^{-1} and the mean temperature is 4° C. In the first decades of the modelling period acid deposition is not much higher than the base cation deposition. Because of a good base cation weathering rate (0.96 keq ha^{-1} a^{-1}) the deposited acidity can be buffered in all layers (Figure 3.3.3-4). After 1880 a very slight, and after 1950 a clearly decrease of pH values occur as a result of increasing deposition rates of acidity. The emission reductions based on the Gothenburg protocol result in more or less higher pH values in the soil layers. The recovery is influenced by the effects of a clear cut in 2028, but in all relevant soil layers below 10 cm soil depth the critical limit is kept.

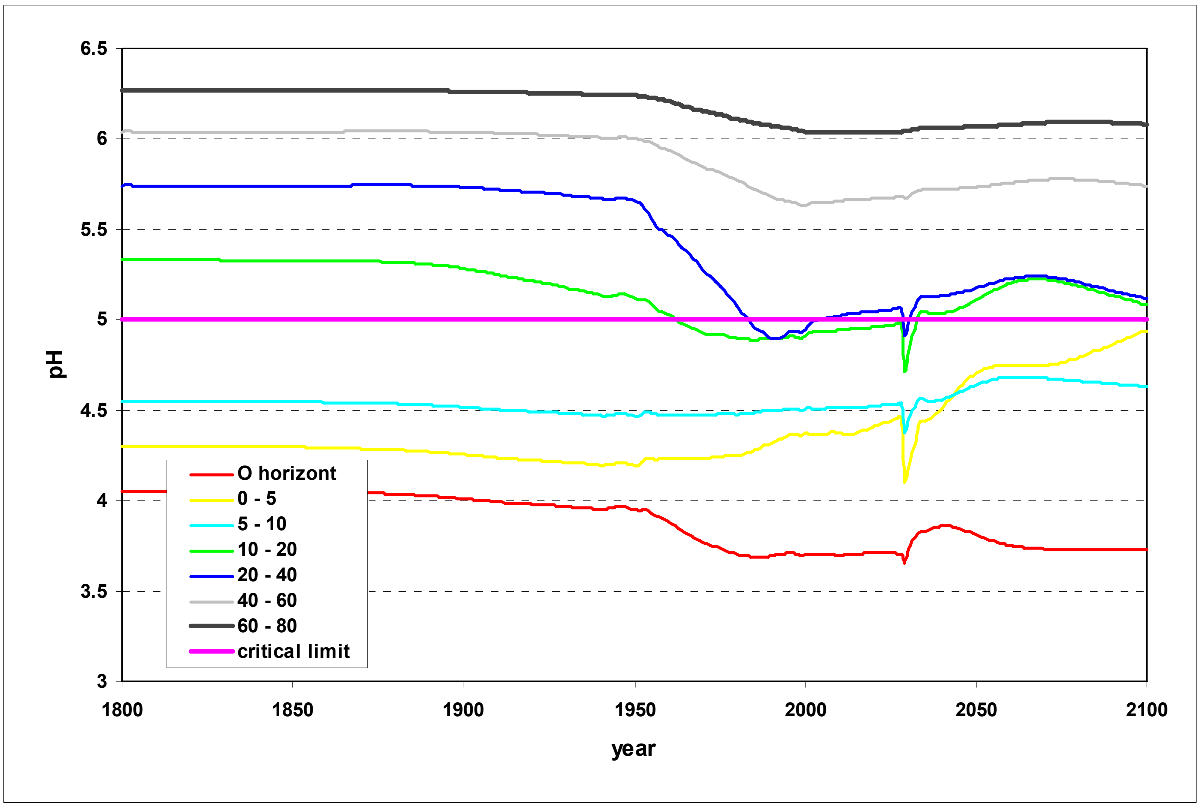


Figure 3.3.3-4: pH at Level II plot Blåbärskullen (MARTINSON et al. 2005)

The above presented Level II plots except Altdorf may result in the conclusion that the potential for recovery in comparison to critical limits for forest sites is relatively good. Results of dynamic model application in many countries – some examples are mentioned below -show that this is a wrong picture.

- Bulgaria: The VSD model was applied at 3 Level II plots which are presented in HETTELINGH et al. 2004.
- Germany: In Germany several studies using VSD and SAFE at Level I and Level II plots are compiled (e.g. BECKER 2002, BECKER 2003, BECKER 2004, BECKER et al. 2000, BECKER et al. 2004). The application of SAFE at 84 Level II plots in Germany predicts that at more than 90% of the investigated plots the critical limits will still be exceeded in 2010 and recovery processes will be very slow. This is in line with investigations at Level I plots.
- Great Britain: Studies using the dynamic models SAFE, VSD and MAGIC were made (e.g. EVANS and REYNOLDS 2003, BROADMEADOW 2004).
- Norway: For Norway a dynamic model application predict that, even with a maximum feasible reduction scenario, base saturation levels in soils will not reach pre-industrial levels in the next 50 years at any of the sites modelled (LARSSEN et al. 2004).
- Poland: At selected Level II sites MILL and SCHLAMA (2002) have applied the SAFE model.
- Sweden: In Sweden many studies using SAFE and the new ForSAFE model at Level I and Level II plots have been published (e.g. ALVETEG 1998, ANDERSSON 2002, MARTINSON et al. 2005, SVERDRUP et al. 2004 and 2005, WALLMAN 2004 and WALSE 1998). For 16 forest sites in Sweden a slow recovery of soil chemistry has been predicted by the models assuming full implementation of the UNECE LRTAP Gothenburg Protocol. In 2100, still 44% of the modelled sites might have soil layers with a base cation/aluminium ratio below the presumed critical value of 1.

- Switzerland: In Switzerland SAVE and VSD applications at Level I and Level II plots have been done. Reports are in preparation.

3.3.4 Summary and outlook

The applications of dynamic models, which are developed with the objective to show the effects of acid deposition on soils, all over Europe show that

- Level I and Level II plots are a good data base for dynamic model application,
- emission reductions based on Gothenburg protocol, EU CAFÉ program and further international agreements result in a more or less recovery of soils, but
- to reach a soil status regarding long term ecosystem stability for the most forest ecosystems further emission reductions are necessary.

In the next year's report results of SAFE and VSD application at all European Level II plots where the data base is sufficient will be presented to get a more detailed picture of forest ecosystem recovery and need of further emission reductions in Europe. To value these emission reductions target loads will be calculated.

In future questions concerning effects of deposition, climate change and forestry measures on soil chemistry and bio diversity come to the front. Dynamic models necessary for these questions are or will be available this year. Two of them are:

- BERN: The BERN-model (**B**ioindication for **E**cosystem **R**egeneration towards **N**atural conditions) allows for the first time to model changes of major plant communities as bio indicators as a result of changes of soil parameters. In combination with existing process-oriented soil chemical models, prognoses on possible changes of ecosystems, the derivation of abatement measures and the evaluation of their effectiveness will be possible (SCHLUTOW and HÜBENER 2004).

- ForSAFE-VEG: The new model ForSAFE-VEG provides simultaneous predictions of climate change, soil acidification and eutrophication with vegetation changes and effects on forest growth influenced by environmental pollution, climate change and landscape changes. ForSAFE is a fully mechanistic nitrogen- and carbon-cycle sub model including predictions of forest growth under production management. It also comprises a biogeochemistry model based on SAFE. (SVERDRUP et al. 2005, WALLMAN 2004).

First results of these two models at selected Level II plots in Europe will be presented in next year's report.

3.4 NITROGEN RETENTION AND RELEASE IN EUROPEAN FORESTS: DERIVING INDICATORS FROM LARGE DATABASES

3.4.1 Introduction

Emission of NH_3 and NO_x by agriculture and fossil fuel combustion results in enhanced deposition of reactive nitrogen. In forests, nitrogen deposition over the last ca 50 years has lead to increased storage of nitrogen in the organic matter and soil, and ultimately to enhanced concentrations of nitrogen in runoff or leachate (DISE et al. 1998a,b). The ICP Integrated Monitoring (ICP IM) sites have been crucial in providing a Europe-wide assessment of the impact of high nitrogen deposition levels on forests. Information on N leaching and storage from these sites, together with other data from the Level II forest plots (DE VRIES et al., 2004), and the IFEF (Indicators of Forest Ecosystem Functioning) database on published literature from forested plots and catchments (MAC DONALD et al. 2002) may be used to derive empirical relationships relating N leaching to stand and site characteristics. These relationships are used both as simple predictors of N leaching across Europe, and for insights into the major processes that control N leaching and soil C sequestration in forests.

3.4.2 Methods

The IFEF database (DISE et al., 1998a,b, MAC DONALD et al. 2002) contains input-output budgets and stand/site characteristics from approximately 280 forested plots and catchments published in scientific papers over the last decade (Figure 3.4.2-1). IFEF has been used to develop pan-European maps and equations describing the major environmental correlates to the leaching of nitrogen (DISE and WRIGHT 1995, DISE et al. 1998a,b, MAC DONALD et al. 2002), aluminium (DISE et al. 2002), magnesium (ARMBRUSTER et al. 2002), and basic cations (LANGUSH et al. 2003). Years and methods differ, but since the number of sites is very large, significant statistical trends usually emerge from this variability.

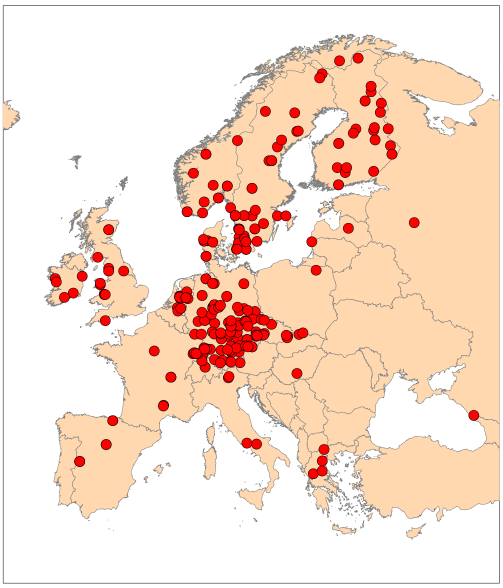


Figure 3.4.2-1: Distribution of sites included in the IFEF database.

The Level II database (DE VRIES et al. 2004) contains input-output budgets derived for 121 ICP Forests intensive monitoring plots for the period 1995-1998 (Figure 3.4.2-2). Leaching fluxes are calculated by multiplying measured soil solution concentrations with simulated water fluxes. Water fluxes are simulated based on daily meteorological data and generic soil physical characteristics using a Richards' model (Van der Salm et al., 2004 and Belmans et al., 1983). The Level II database is an improvement over IFEF in that it covers similar years and employs standard methods with set quality control checks, but it contains fewer sites, a narrower range of variables (e.g. input N, climate), and a more generic water flux calculation than the IFEF forests.

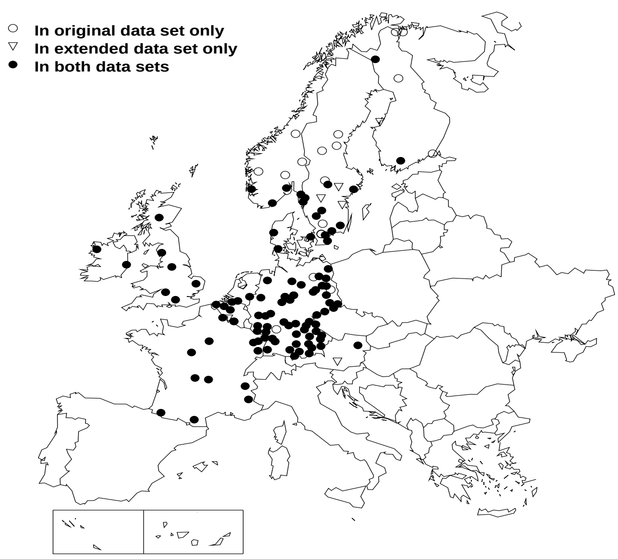


Figure 3.4.2-2: Distribution of sites included in the Level II database.

Broad quality control checks on both databases consisted of tests on the Cl^- balance (if available), with the ratio between Cl^- input and output required to be between 0.5 and 1.5. An additional check was that N leaching should be no more than 10% higher than N in throughfall, with sites exceeding this value indicating a disturbance in the N cycle.

3.4.3 Results and discussion

As with previous analyses, the relationship between the throughfall input of N ('Nin') and the leaching of N ('Nout') showed a general positive trend, with a large number of sites leaching undetectable levels of nitrogen at N input fluxes below around 8 kg N ha^{-1} y^{-1} (Fig. 3.4.3-1). Joining the two databases together also showed that IFEF spanned almost twice the range in N deposition as the Level II sites, with more sites at both the low and high ends of the N deposition range. There are two reasons for this: 1. The IFEF sites cover a geographically larger area than Level II (Fig. 3.4.2-1 and Fig. 3.4.2-2), and 2. flux measurements from the Level II sites are all more recent than 1996, when substantial reductions in N emission and deposition had begun in high-deposition areas such as the Netherlands and Denmark.

The most significant predictor of nitrogen leaching from the joint database is the input flux of nitrogen in throughfall, explaining about 50% of the variability in Nout (Fig. 3.4.3-1). The relationship between Nout and Nin could be further improved by dividing the sites into those with a forest floor that is relatively N- enriched ('high-N status') and those that are relatively N-poor ('low-N status'). A C:N ratio of 22 provided the best discriminant (Fig. 3.4.3-2 and Fig. 3.4.3-3). For the high-N status sites (C:N ≤ 22), N_{in} alone is sufficient to explain most of the variation in N_{out}, and no other variables explained additional variability in a regression model containing N_{in} (Fig. 3.4.3-2). For the low-N status sites, mean annual temperature (MAT) emerges as a second significant predictor variable.

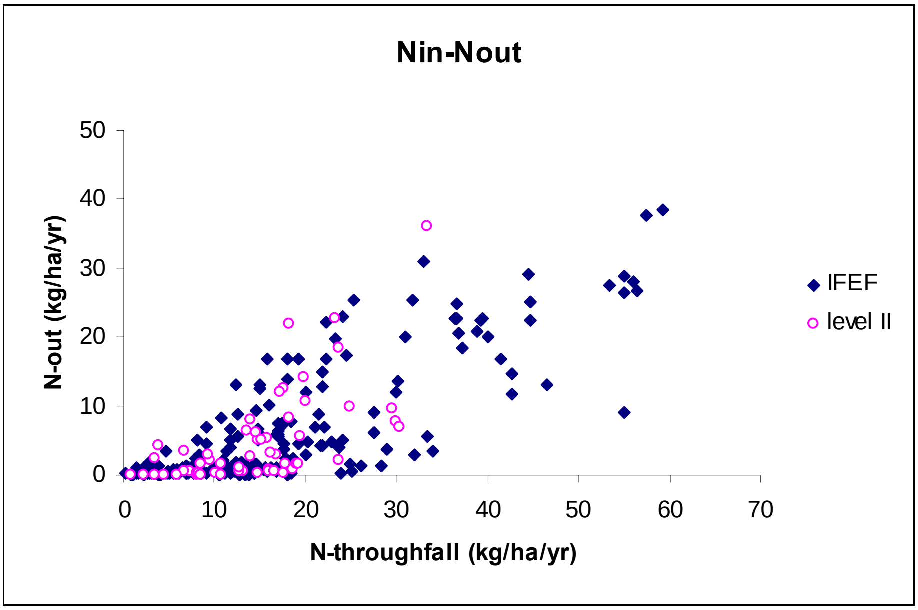


Figure 3.4.3-1: N leaching fluxes (kg N ha^{-1} y^{-1}) against N input in throughfall, IFEF and Level II sites.

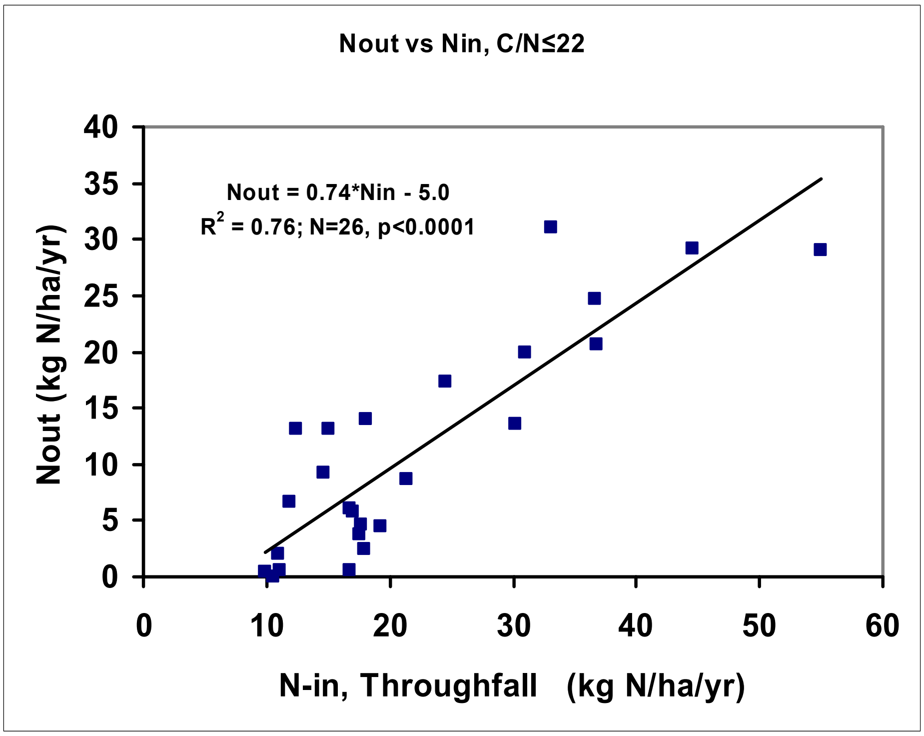


Figure 3.4.3-2: N leaching fluxes (kg N ha^{-1} y^{-1}) against N input in throughfall for IFEF forests with C:N ≤ 22

A plot of N_{in}, N_{out}, and MAT shows that the relationship with temperature for the low-N status sites is actually curvilinear and peaks at MAT 7.5C (Fig. 3.4.3-3). This additional relationship with temperature explains to a large degree the variability in nitrogen leaching from low N-status forests receiving Nin between 10 and 25 kg N ha^{-1} yr^{-1}. As the MAT of forests increases from -2C to 7.5C (4C to 7.5C shown in Fig. 3.4.3-3), nitrogen leaching generally increases and, within this intermediate range of N deposition, reaches levels as high as 75% of N-input. One hypothesis is that nitrogen turnover in relatively cold sites is microbially-dominated, with vegetation uptake limited for significant parts of the year. Higher leaching of N as mean annual temperature (MAT) increases then reflects enhanced microbial decomposition, including N mineralization, discoupled from uptake. (Similar 'pulses' of NO_3^- and/or NH_4^+ in leachate are sometimes observed in the autumn in temperate forests.) As MAT further increases, N leaching at any given level of N-input and C:N decreases, perhaps due to warmer temperatures greatly enhancing the productivity and uptake of trees and ground vegetation.

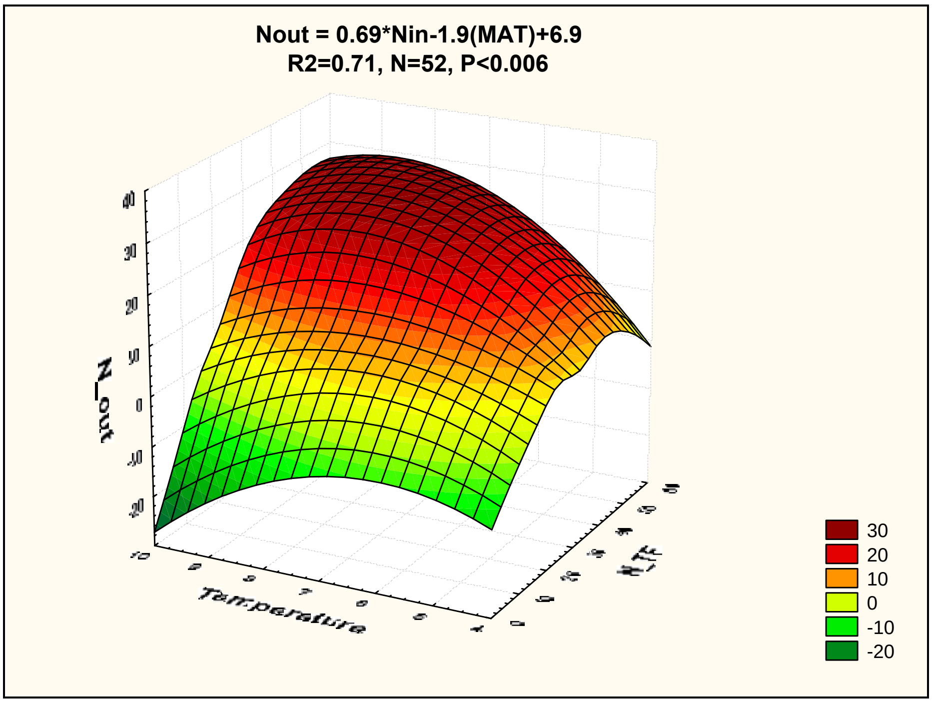


Figure 3.4.3-3: N leaching fluxes (kg N ha^{-1} y^{-1}) against N input in throughfall and mean annual temperature for IFEF forests with C:N > 22.

Analyses on the separate IFEF and Level II database yielded quite similar relationships between N leaching and N deposition. To gain insight into the strength and weakness of the developed relationships, and to identify sites and regions at risk from enhanced N leaching (defined here as ≥5 kg N ha^{-1} y^{-1}), the Level II relationships were validated on the IFEF database. From this validation and the previous analyses we can conclude the following:

- Low nitrogen leaching fluxes are generally overestimated and high ones slightly underestimated. This behaviour was also found when comparing the measured and predicted fluxes for the dataset upon which the models were developed.

- Sites receiving low N input (≤ 8 kg N ha^{-1} y^{-1}) are generally well predicted to leach low levels of N (most ≤ 3 kg N ha^{-1} y^{-1}). These sites are strongly N-limited and retain essentially all input-N. For some of these sites, negative leaching fluxes are predicted. This is simply a consequence of using a linear relationship that is not truncated at an output N flux of zero, and will be remedied in future analyses.

- Sites with a low organic horizon C:N ratio (≤ 22) are generally well predicted to leach N as a direct proportion of about 0.75 of N input (Fig. 3.4.3-2). These sites are strongly N-saturated.
- N leaching from forests with a relatively high organic horizon C:N ratio (>22) and receiving intermediate or high N deposition (>8 kg N ha^{-1} y^{-1}) is generally poorly predicted. These sites, about 40% of the IFEF forests, are transitional between N-limited and N-saturated. Adding mean annual temperature leads to higher correlation coefficients on the calibrations sets, but so far does not lead to better results when applying the model to the validation set. Other temperature relationships will be investigated in the future. This problem is most dramatic for mid-latitude and Mediterranean sites that receive a moderate amount of N input, have an above-average temperature, and relatively high C:N ratio. At these sites leaching fluxes may be strongly overestimated.

Attention should be focused in the future on understanding the nitrogen dynamics of forests that are not nitrogen saturated and receive moderate to high levels of N deposition. Further improvements in the databases, potentially leading to better predictions and more insights into processes, can be made by collecting more information on forest floor and soil carbon and nitrogen stocks, dissolved organic carbon and dissolved organic nitrogen (DOC/DON) leaching, local climate, and vegetation.

3.5 OZONE EXPOSURE AND OZONE INDUCED SYMPTOMS AT INTENSIVE MONITORING PLOTS - RESULTS FROM THE TEST PHASE

3.5.1 Introduction

Background

Ozone measurements suggest that surface ozone concentrations at mid- to high latitudes have more than doubled during the past century (MARENCO et al, 1994; SANDRONI et al. 1994). Elevated levels are found in urban areas, but also in rural and remote mountainous regions due to the transport of ozone and its precursors. During the spring and summer, in nearly all regions of Europe ozone concentrations are high enough to be of potential risk to sensitive plants. The value that is recognized as an accepted standard for the protection of forest trees from adverse ozone effects (Directive 2002/3/EC) is frequently and repeatedly exceeded in many areas of Europe, especially in the Mediterranean (SANZ et al. 1999).

Surveys in southern Switzerland have recorded ozone-like symptoms on numerous native tree, shrub, and forb species (INNES et al., 1996; SKELLY et al., 1998; INNES et al., 2001; VAN DER HEYDEN et al., 2001; NOVAK et al., 2003; 2005). However, little information is available on the effects of ozone on the multitude of native plant species throughout Europe (ASHMORE & DAVISON, 1996) but there is sufficient evidence strongly suggesting that ozone occurs at concentrations causing visible foliar injury to sensitive plants (see also UNECE-CLRTAP, 1999).

The lack of ozone data was a serious limitation for the EU Intensive Monitoring (Level II) database, since much of the ozone data at European level comes from monitoring devices located in urban/sub-urban areas e.g. DE LEEUW et al., 2001). Therefore, a comprehensive dataset from forest sites will provide a considerable input for a better understanding of ozone levels in remote areas. Besides the obvious connections with the potential effects on forests, especially ozone data are also relevant in relation to other issues which were subjected to important political agreement such as the changes of tropospheric chemistry and regional ozone formation (see e.g. the CLRTAP multi-pollutant, multi-effect directive; the UN Biodiversity Convention; the EU Habitat Directive; the EU acidification strategy, the UN/ECE CLRTAP, the EU Air Quality directive; DE VRIES, 2000).

Therefore, the 15th Task Force Meeting of ICP-Forests in Vilnius, Lithuania 1999 gave the mandate to the Extra Panel of Deposition to establish the Working Group of Ambient Air Quality in order to elucidate possibilities of monitoring air pollution concentrations at Level II sites by passive sampling, thus filling a gap of urgently needed information on air concentration of ozone and other major pollutants such as sulfur dioxide and nitrogen compounds at remote forest sites. Secondly, the mandate included the elaboration of a manual on the assessment of ozone induced injury on main tree species as well as other vegetation species at Level II plots rendering information on the occurrence of ozone injury and identifying ozone sensitive species functioning as indicators. At the 16th Task Force Meeting in Gent, Belgium 2000 the Submanuals on ozone injury assessment and air quality measurements by passive sampling were adopted and the 17th Task Force Meeting in Ennis, Ireland 2001 agreed on a test phase of ozone injury assessment for 1 year. Results from this test phase were reported in the Technical Report 2003 and the 19th Task Force Meeting 2003 in Zagreb, Croatia agreed to extend the test phase until 2005. Experiences made during that year with the assessment of ozone injury on Main Tree Species (MTS) and

Ground Vegetation (GV) became the basis of a revision of the Submanual of ozone injury assessment, which was adopted at the 20th Task Force Meeting 2004 in Växjö, Sweden.

Aims of the WG on Ambient Air Quality

The WG on Air Quality within the Expert Panel of Deposition aims to improve the knowledge of air concentration of various pollutants and effects associated with such an impact across forested areas in Europe. This is done by using the tools of *passive sampling* and *visible injury assessment* on MTS and GV on Intensive Monitoring Plots (IMP) within the network of ICP-Forests, i.e. Level II plots. Ozone injury of GV is assessed at so called Light Exposed Sampling Sites (LESS), established in the vicinity of Level II plots.

In order to meet concerns with respect to the heterogeneity of European vegetation, the working group established from the beginning of 2000 three validation centres (CEAM, Valencia, Spain, for Southern Europe; WSL, Birmensdorf, Switzerland for Central Europe; Univ. Copenhagen/METLA, Denmark, Finland for Northern Europe) in order to support countries with special interest in ozone-induced injury identification. At CEAM, the WG established a helpdesk, i.e. a telephone service and a web page (www.gva.es/ceam/ICP-forests) where all relevant information, including an extensive photo documentation of validated ozone-induced symptoms is collected and documented. Under www.ozone.wsl.ch, the WSL developed an online data base for ozone-induced symptoms which can be searched by over 80 species, geographic locations, symptom and plant forms, etc. The WSL developed microscopical methods to discriminate between ozone induced injury symptoms and other causes (see www.gva.es/ceam/ICP-forests) and provided the Lattecaldo Open Top Chamber (OTC) research and training facility for several Intercalibration courses, in collaboration with the Italian colleagues (see http://www.wsl.ch/ozone/ICP-Forests.ehtml) (Bussotti et al., 2003; 2005). Key objective of the WG was, to build up the expertise in the respective countries to identify ozone symptoms in order to increase the amount of confirmed and validated data regarding the occurrence of species specific, ozone-induced injury. For this purpose the WG organized, together with the countries Spain, France, Italy and Switzerland, four intercalbration courses with various training and intercalibration exercises (see also www.gva.es/ceam/ICP-forests for further information) developing simple but effective tools also for the discrimination of other causes. The information from the LESS on plant species showing ozone injury is collected and documented in an ozone sensitivity list which is published on the web page of CEAM, Spain (www.gva.es/ceam/ICP-forests).

The following report will highlight the results from the test phase 2001-2004 and focus on future possibilities to produce reliable information on both, the air concentration at remote forest sites and visible ozone-induced injury on selected plant indicators (MTS and GV) using methods according to the Submanual.

3.5.2 Materials and Methods

Assessment of ambient air pollutant concentration by passive sampling

State of the art: Passive samplers are being used for ozone monitoring in all countries that participated in the pilot phase and its extension. Other pollutants were also monitored in countries such as Spain and Germany (Box 3.5.2.1) which demonstrated that passive sampling is a useful technique for pollutants such as NH_3 as well. For validation purposes, passive samplers were collocated at continuous monitoring stations in certain countries to elucidate how these data sets compare with data from continuous monitoring sites according to the EU Daughter Directive`s reference method (COM 1999, 125) and/or with an instrument run at an EMEP site in accordance with the EMEP Manual (EMEP/CCC/ Report 1/15, NILU, Norway). This information is particularly important for QA/QC as well as for extending the data base for the further modeling of ozone concentrations across Europe (e.g. EMEP). Ambient air quality monitoring by passive sampling was done in accordance with the Submanual which is based on the CEN document 264 (CEN, 2001; table 3.5.2-1). Few countries such as Denmark, reported only continuous monitoring data in combination with ozone-like symptoms.

Table 3.5.2-1: Framework of recommendations for passive samplers according to the Submanual. [Source: Sanz, Calatayud & Sanchez (2004) in: Ferretti, Sanz & Schaub (2004)].

Issue	Recommendations
Choice of method CEN/TC 264/WG11 Diffusive samplers 1999-07-02	• Passive sampling is recommended on sites that do not currently monitor ozone using active samplers. • Individual countries are free to select the type of passive sampling device they use. Recommended samplers be run at selected sites in parallel with the EU Daughter Directive (COM 1999, 125) reference method, UV-spectroscopy and/or with an instrument run at an EMEP site in accordance with the EMEP Manual (EMEP/CCC/ Report 1/15, NILU, Norway)
Period of sampling	• Preferably on a 2-week basis. At remote sites, extended to four weeks if necessary, and at highly polluted sites, shortened to one week. • Measurements of ozone will be limited to the leafed period for deciduous species, but may be continued for the rest of the year for other pollutants.
Siting on the plot	• Where the samplers for wet deposition and the meteorological equipment are installed in IMPs
Number of samplers	• Duplicate samplers for ambient air quality is recommended at each site.
Sampling height	• Placed at a height of between 2 and 4 m above ground.

Passive sampling periods varied among countries form 1 week (Italy) to 4 weeks (Germany). All countries measured ozone concentrations for the vegetation period from April to September and countries such as Spain for the complete year. Different sampler types and methods were used by different countries. The main characteristics are summarized in table 3.5.2-2.

Table 3.5.2-2.: Passive sampler types used during the test phase and their main characteristics.

Type of Passive sampler	User	Description
Gradko International Ltd.	UK	The nitrite is oxidized to nitrate and after the exposure the filters are analyzed for total nitrate concentration with a ionic chromatograph.
IVL (Institutet för Vatten- och Luftvådsforskning)	France, Germany; Greece	According to IVL
Ogawa and Co., Inc. passive O3	Spain	Chemisorption occurs at two nitrite-coated filters. In the presence of ozone, the nitrite is oxidized to nitrate and after the exposure the filters are analyzed for total nitrate concentration with a ionic chromatograph.
Passam ag	Switzerland, Italy	Chemisorption of O_3 by reaction with 1,2-di(4-pyridyl)-ethylene (DPE); the ozonide formed undergoes a cleavage and yields an aldehyde. The amount of aldehyde is finally determined spectrophotometrically by the MBTH method at 442 nm.

There was a rather good agreement between the data sets gained by continuous monitoring and by passive sampling (DE VRIES et al., 2003; FERRETTI et al., 2004) demonstrating the suitability of the passive sampling technique which has the further advantage of being rather price worthy in comparison to continuous monitoring stations. Measurements are also in accordance with the Directive 2002/3/EC where zones of similar pollutant levels have to be discriminated within countries considering passive sampling as an indicative measure to fulfill the data quality objectives of the directive and to complement the results of the air quality assessments (participating countries should compare maps showing concentration distributions in each discriminated zone). As pointed out in table 3.5.2-2, countries use different types of passive samplers. Therefore it is strongly recommended to make cross calibrations with data sets from continuous monitoring sites within and between countries for reasons of quality assurance.

Table 3.5.2-3: Number of plots per country with passive samplers considered in this report. Only plots with passive sampler measurements having more than a 50% time cover of the period April-September were considered.

Country	2002	2003
France	27	-
Germany	40	35
Greece	3	3
Italy	26	25
Luxembourg	2	-
Spain	12	13
Switzerland	16	16
UK	13	9
Total	**139**	**101**

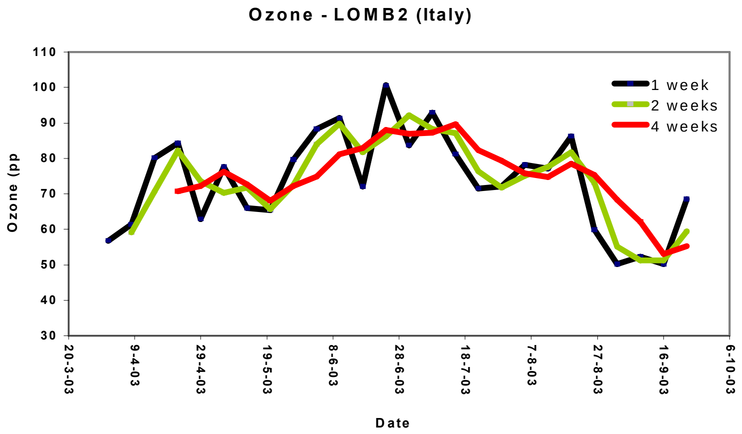


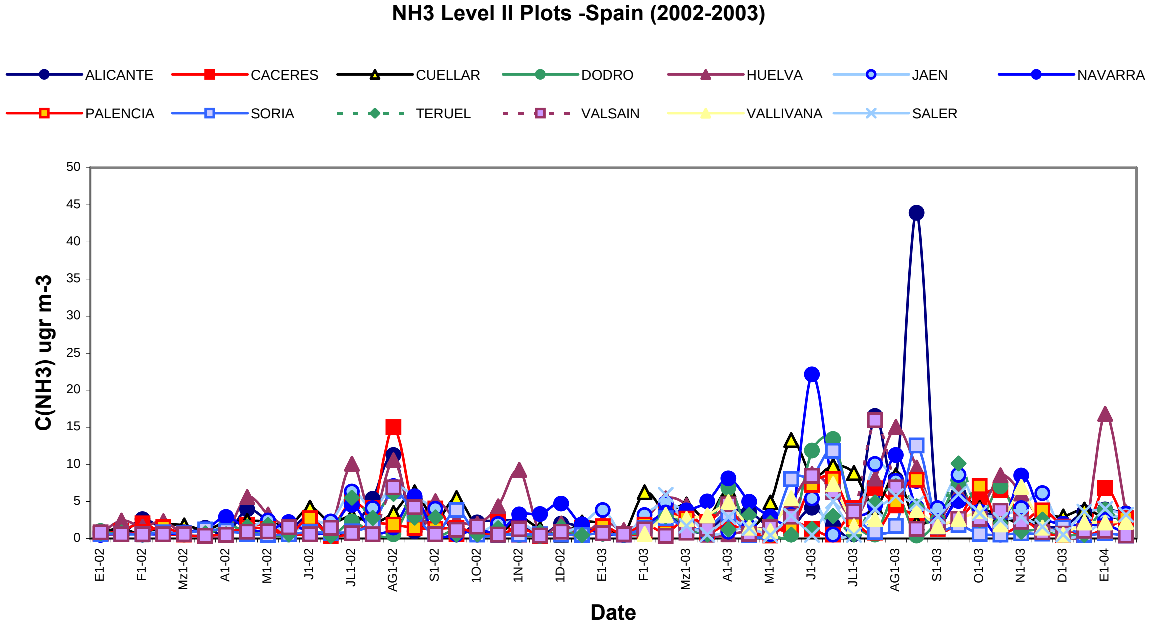
Figure 3.5.2-1: Ozone concentration expressed as one week, two weeks and 4 weeks average for one location in Italy (LOM1, Moggio). Sampling period for the site is 1 week by passive sampling. *Note*: Averages are assigned to the last day of the averaging period in the graph.

With respect to the sampling period 1 week intervals render the most information especially where frequent ozone episodes occur, and 1 week sampling should also be applied in areas with high ozone levels. Although 1 week periods are most suitable for deriving the AOT40 index as well as to further develop the hourly averages series for flux calculations, such exposure intervals are rather expensive to gain additional information. However, 4 week exposures such as applied in Germany, give only a very limited time resolution with respect to peek ozone episodes. Data from 14 day passive sampling periods as collected in Spain, Switzerland and France, however, are still short enough to show pronounced ozone episodes and to produce differences not exceeding differences of 15% between measured and estimated AOT40 values (GEROSA et al., 2004) and thus are still acceptable in most of the cases. In figure 1, data from one week with aggregated two and four week passive sampling periods are given for 2003 (01.04.-30.09.2003) for the Italian station LOM 1. It becomes apparent that aggregation smoothes the episodes with increasing exposure time to such an extent that major information on episodes and therefore also effects on humans, vegetation etc. becomes lost. Therefore, a two week sampling period can be recommended as European reference which still matches the demand for cost affectivity; however, countries should consider one week sampling periods for the future again which can be aggregated to the recommended reference period across Europe.

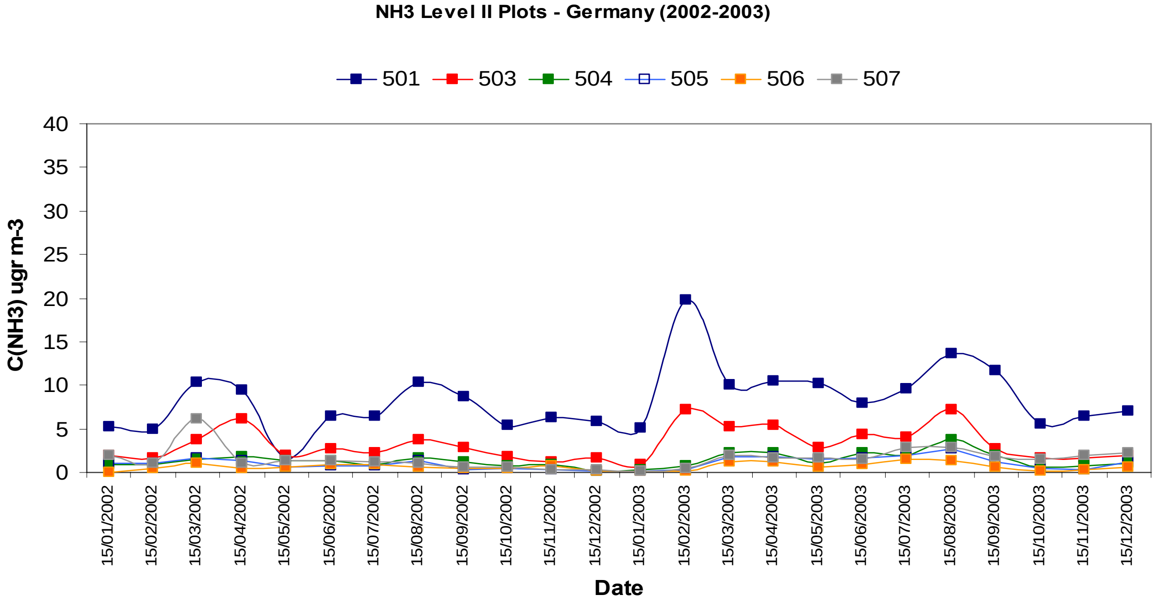
Box 3.5.2.1. Example: NH_3 14 days mean concentrations on Spanish Level II plots for 2002-03

Measurements were carried out for the complete year with 14 day exposure periods at the same Level II plots where ozone was measured in Spain and for 1 month exposure periods in Germany for 2002 and 2003. Data for 2002-2003 are shown. The lower ammonia concentrations appeared in winter, whereas maximum concentrations appear in spring and summer. Among years, in 2003 concentrations for most of the plots are higher than previous year due to the heat wave experienced in Europe during that year.

A - Spain



B - Germany



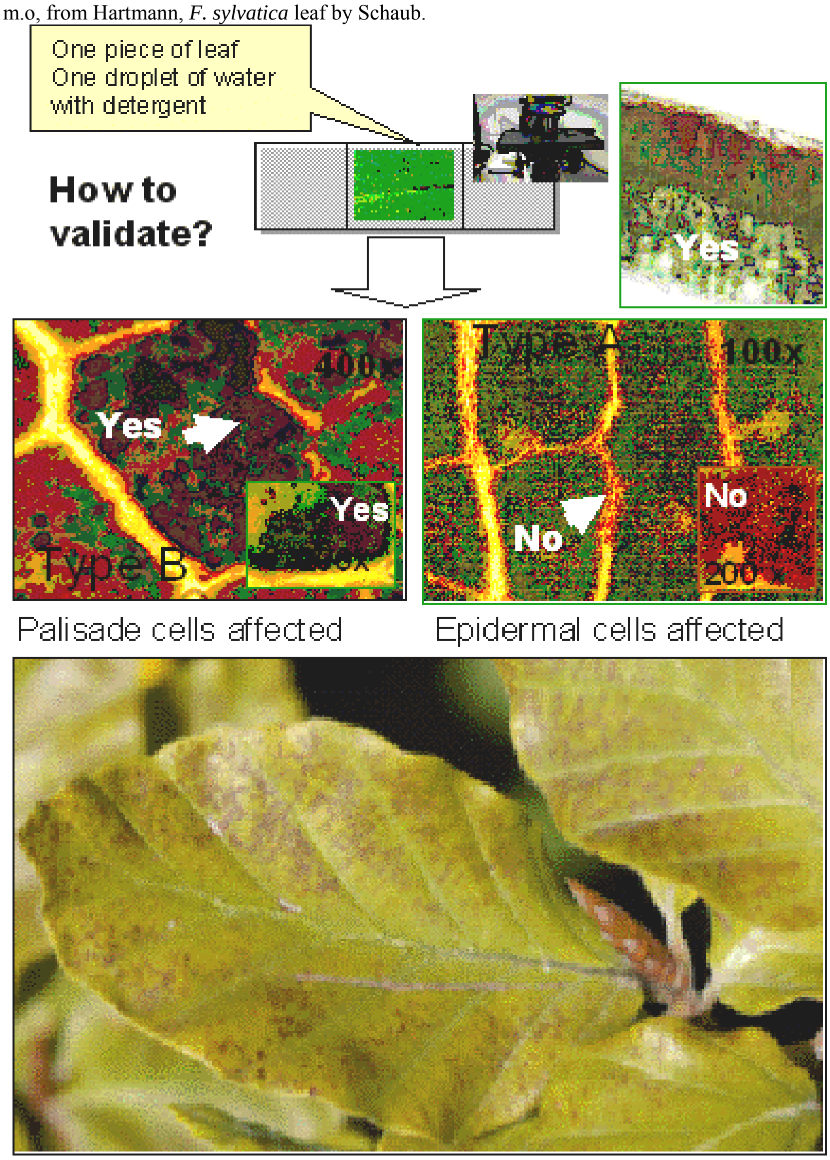
Ammonia 14 day means for 2002 and 2003 Level II plots in Spain (A) and 1 month means in one of the German Landers (B).

Assessment of visible injury

For the overall test phase of 2001-2003, six countries reported data on visible injury. Data were checked for consistency and dubious cases in discussion with the respective countries. Not all countries conducted the assessment over the 3 year test phase (Table 3.5.2-4). Furthermore, in cases when assessments were done for several consecutive years, different plots were assessed for different years. Thus, only 2, 9, and 15 plots were assessed in Italy, Spain, and Switzerland respectively for the entire three years.

Box 3.5.2.2. Validation of visible injury, some tools developed for countries to use. The *Fagus sylvatica* example.

Pictures from: m.o, from Hartmann, *F. sylvatica* leaf by Schaub.



Ozone visible injury in *Fagus sylvatica*

Determination of ozone injury on beech leaves. Ozone damage reveals itself as an upper surface leaf bronzing between the veins, in particular for sun exposed parts (see photo of *Fagus sylvatica*), which can be recognized in the field without using any sophisticated, technical equipment. When symptoms are not clear, they can be verified by the use of a simple microscopical method. In cases were only epidermal cells are affected, damage is not caused by ozone (type A, brown structures at the yellow lines). The brown and dark colored palisade cells however are symptoms of ozone damage (type B).
More detailed microscopical evaluations can be found at www.wsl.ch/forest/wus/bioindic/Valicewww-de/fValicewww.htm

In order to present longer data series some references and data for 2001 reported in DE VRIES et al. (2003) are included.

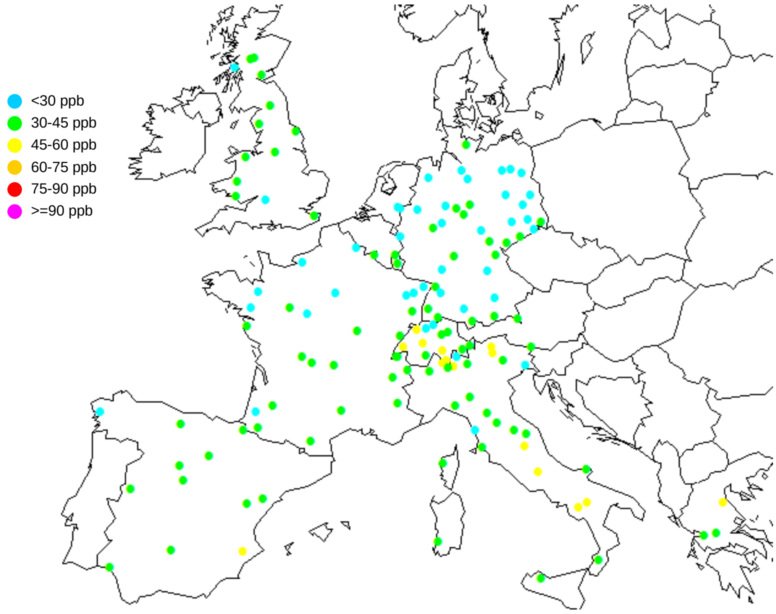
Table 3.5.2-4: Number of MTS and LESS assessed in 2001, 2002 and 2003 for all countries that submitted data.

	Plots assessed					
	2001		**2002**		**2003**	
Country	**MTS**	**LESS**	**MTS**	**LESS**	**MTS**	**LESS**
Austria	1	1	-	-	-	-
France	10	10	9	10	-	-
Germany	30	16	-	-	-	-
Greece	4	4	-	-	-	-
Hungary	-	-	-	9		9
Italy	8	8	-	7	2	5
Slovak Republic	3	3	-	-	-	
Spain	4	10	-	10	4	10
Switzerland	9	15	-	16	8	15
UK	3	0	-	-	10	10

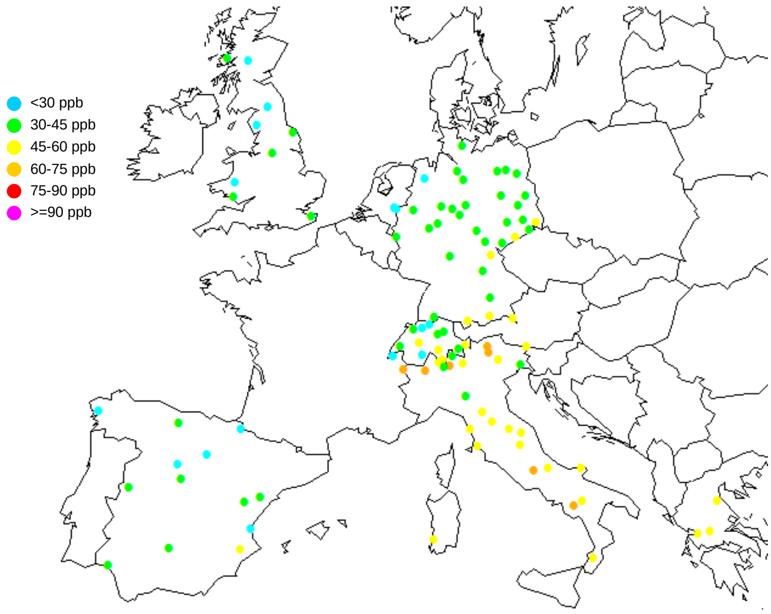
3.5.3 Results

Results from Passive Sampling

For a European overview, sampling periods per site and country were aggregated to 6 months means representing the vegetation period from April to September and are given in Figure 3.5.3-1 for the years of 2002 and 2003. Eight countries reported ozone concentrations for 2002 and only six repeated the exercise in 2003.



2002 **(a)**



2003 **(b)**

Figure 3.5.3-1: Mean ozone concentrations measured from April to September 2002 (a) and 2003 (b). Only plots with >50% of the days between April to September periods are represented.

While the concentrations at most of the stations in the UK ranged from 30 to 45 ppb, showing no distinct geographical distribution, concentrations in Germany increased from North to South and towards high elevation areas. France and Spain showed a similar distribution pattern in 2002 and time weighted seasonal average concentration rarely exceeded 45 ppb, except for one plot in Spain. However, in Switzerland and Italy about 30% of the plots ranged from 45 to 60 ppb in 2002 (Figure 3.5.3-1a). Figure 3.5.3-1b shows the seasonal time weighted average ozone concentrations at the Level II sites for 2003. In

2003, some countries could not join the program for various reasons. However, it became apparent that most stations except for the UK and Spain shifted up by one class where highest ozone concentrations were measured in northern Italy with time weighted average seasonal concentrations of 60-75 ppb.

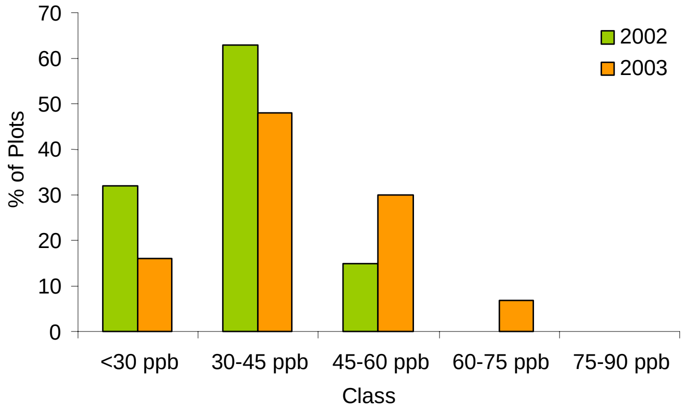


Figure 3.5.3-2: Frequencies of plots per class of 6 month mean ozone concentrations (April-September) for the years of 2002 and 2003. Only countries that performed the measurements during both years are included (Italy, Germany, Spain, Switzerland, UK, Greece).

The distinct shift to higher pollution classes between the years of 2002 and 2003 is given in Figure 3.5.3-2. Although the year 2003 was exceptional for central Europe concerning meteorology and ozone concentrations, 48 to 63% of all the Level II plots equipped with passive sampler devices showed concentrations ranging in the second class of 30 to 45 ppb during both years. Only some regions show a different distribution pattern, namely in Italy and southern Switzerland where shifts to higher classes were more pronounced.

Comparing the 14-day ozone concentrations of all Level II plots for the years of 2002 and 2003 by regression analysis, 2003 values are 13% higher than in 2002 (Figure 3.5.3-3).

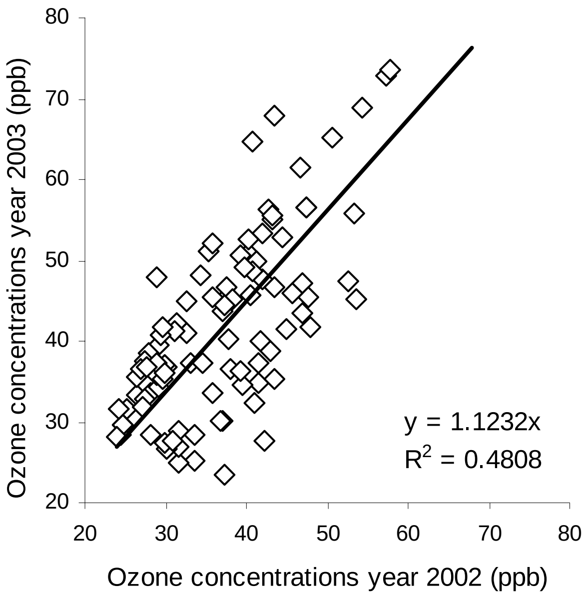
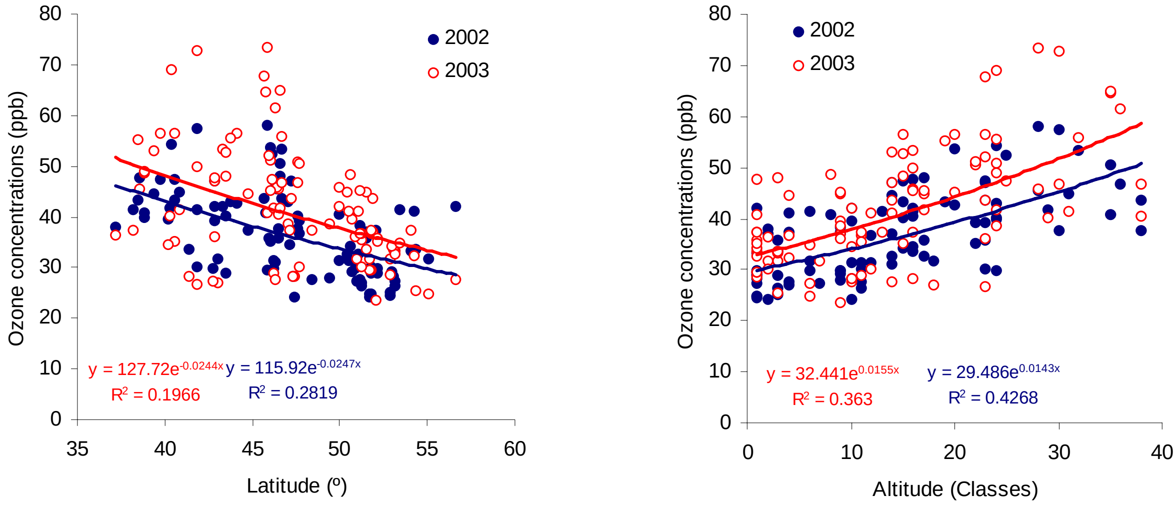


Figure 3.5.3-3: Linear regression of ozone concentration means for years 2002 and 2003 for all common plots (ppb) (April-September).

Figures 3.5.3-4a and 3.5.3-4b show the regression analyses for ozone concentrations (ppb) of Level II plots versus latitude and altitude respectively for the years 2002 and 2003. As also shown in FERRETTI, SANZ & SCHAUB (2004) for France, Italy and Spain ozone concentrations decreased with ascending latitude and increased with increasing altitude gradients which is still apparent when central and northern countries are included (UK, Germany). The years of 2002 and 2003 showed very similar overall patterns with higher concentrations in 2003. Some discrepancy can be observed between 45° and 50° of latitude in Figure 3.5.3-4b for the year 2002 and become even more pronounced in 2003. These values correspond to the regions of the Italian Po Valley and the Swiss Canton Ticino and may represent favorable conditions for ozone formation driven by topography and regional climate. Figure 5 also shows that gradients in latitude and altitude may vary from year to year. In this example, the correlation coefficient was lower in 2003. A possible explanation can be seen in the increase of ozone concentrations due to the hot climatic conditions, also leading to a higher variability of the ozone concentrations measured.



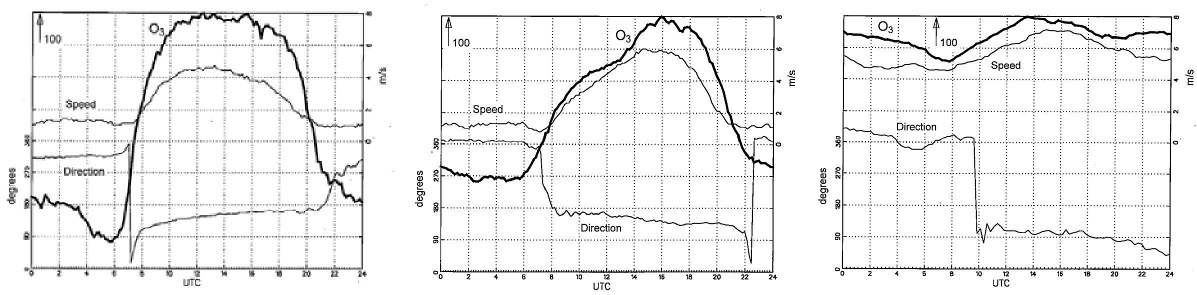
a) **b)**

Figure 3.5.3-4: Regression analysis for ozone concentrations (ppb) of Level II plots versus latitude (a) and (b) altitude respectively for the years 2002 and 2003.

In Box 3.5.3.1., the expected daily ozone cycles for different locations across the transport path of an aged air mass towards high mountain ranges or valleys are presented. This type of cycles that are described for the east coast of Spain (MILLAN et al., 2000) can be expected in most of the areas with such a complex topography in Europe, whereas the region of the northern Po Valley and the southern slopes of the Alps can be considered as an extreme example.

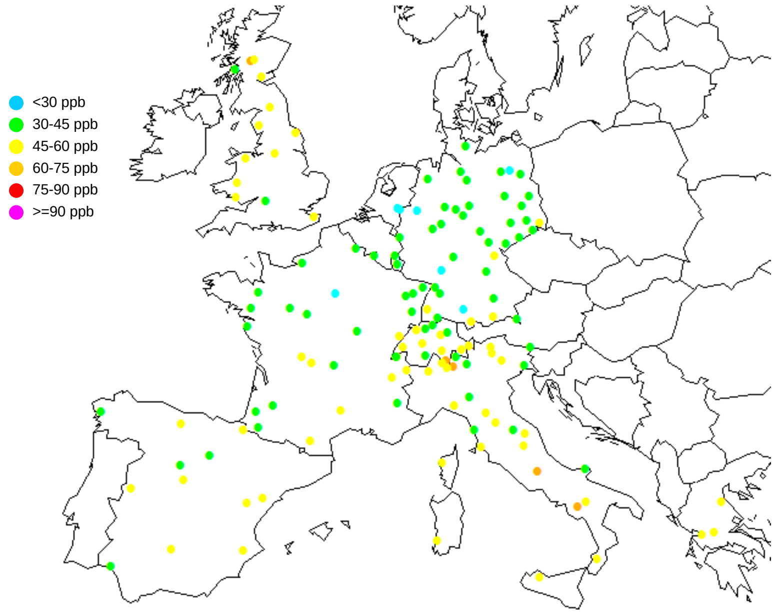
Box 3.5.3.1: Daily Ozone cycles

If aged polluted air masses are transported at high altitudes, ozone concentrations show no diurnal patterns during the summer measurement period (Figure 3.5.3.1c); in urban areas or flat rural areas (Figure 3.5.3.1a) however, a distinct diurnal pattern is found and hence the dose (time x concentration) is generally much higher in the mountainous areas than in regions with an urban climate. Along the transport path intermediate cycles can be found as well (Figure 3.5.3.1b).

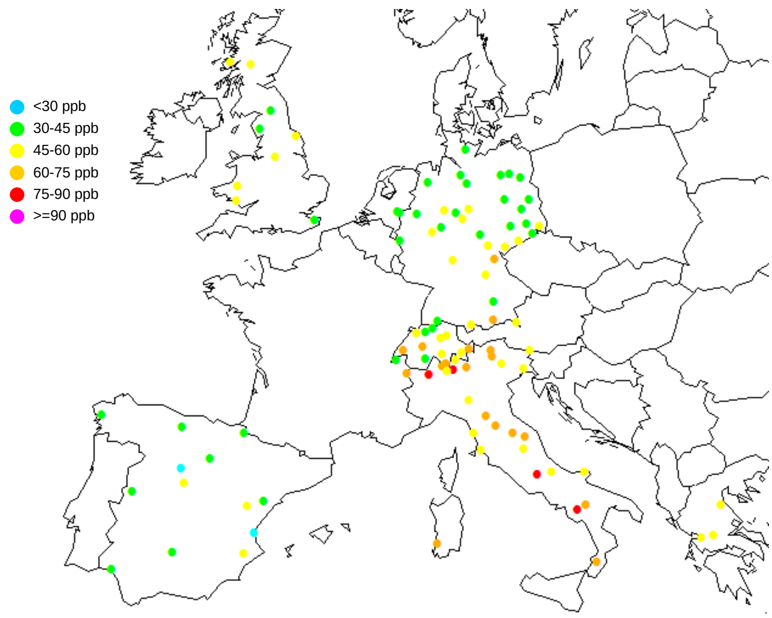


(a) **(b)** **(c)**

Figure 3.5.3.1: Diurnal normalized patterns of hourly ozone concentrations [ppb] for mountain stations (a), rural mid altitude (b), and suburban low altitude (c). [Source: Millán et al., 2000].



2002 (a)



2003 (b)

Figure 3.5.3-5: Values of maximum 4-week ozone concentrations measured from (a) April to September 2002 and (b) April to September 2003. Only plots with >50% time cover of the period April-September are considered.

The maps in figure 3.5.3-5 represent the maximum ozone concentrations measured during successive 4-week exposure periods (April to September). While the length of exposure period of the passive sampling devices should in principle not affect the average values for a 6 month measurement period, the time of exposure will have an effect on the maximum values measured during this very period as short high-ozone episodes (peaks) – which are important with respect to possible effects and hence risk - will not be reflected adequately during a 4-week exposure period (see also Figure 3.5.2-1). To produce a plot comparable picture in figure 6, successive four 1-week measurements have been aggregated to a monthly mean. For countries with 2-week exposure periods, 2 periods have been aggregated to a 4-weeks periods.

A quite different situation can be observed between the years of 2002 and 2003 as shown by the 6-month average concentrations. In 2003, four plots reached class 5 (75-90 ppb) in Italy and 11 plots reached class 4 (60-75 ppb), while in 2002, the number for plots belonging to those classes was 0 and 3 respectively. In Germany, the number of plots with an appropriate cover (>50%) of the period April-September varied in the two years considered, but two common plots during these years reached class 4 in 2003 and 12 plots belonged to class 3 (46-60 ppb) in contrast with only 5 plots in 2002. The observed shift to higher classes mostly occurred in the south of Germany.

In the present report, there is no attempt to calculate the AOT40 from passive sampling data but GEROSA et al (2004) calculated it for the years 2000, 2001 and 2002 for France, Italy, Spain and Switzerland. In general, the validation of the model estimates against the co-located samplers with continuous monitors showed a good agreement.

Results from the assessment of ozone-visible injury

MTS 2002 and 2003:
In 2002, only France carried out surveys of ozone injury for the dominant species (MTS) and symptoms were observed in *Pinus pinaster* and *P. sylvestris*. Whereas in 2003, Italy, Spain, Switzerland and the UK conducted surveys in MTS plots and *Fagus sylvatica* was symptomatic in 5 out of 6 plots in Switzerland, in one plot in Spain and in one of the samples examined from one Italian plot. *Pinus halepensis* showed a few symptoms also in Spain.

LESS 2002 and 2003:
Across Europe, 108 different plant species have been reported as being symptomatic by the different countries for 2001, 2002 and 2003. Only samples validated have been considered in the list, except for the samples originating from Hungary, where part of the species could not be validated; some of these species may require further investigations and therefore at present should be regarded as symptomatic with certain reservations. Also, *Salix caprea* assessed in the UK merits further analysis while the samples of *Viburnum lantana* were confirmed by microscopical analysis and OTC studies in Lattecaldo, already in VAN DER HEYDEN 2001. Annual herbs have been excluded since they have not been reported systematically by all the participating countries and a few subspecies have been considered separately since ozone sensitivity among the different subspecies may differ. From these 108 plants, 35 were trees, 27 shrubs and 46 were perennial herbs (Table 3.5.3-1).

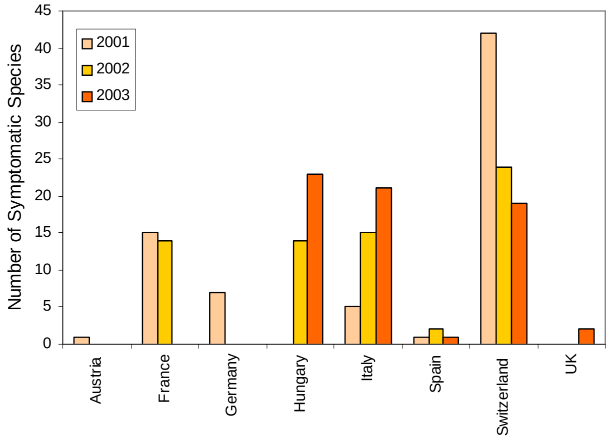


Figure 3.5.3-6: Overall number of symptomatic species per country and year for 2001, 2002 and 2003. All plots are included. Absent data indicate that no survey was conducted at a LESS for the respective year.

Across countries (Figure 3.5.3-6), Switzerland was the country where more symptomatic species were found with a declining trend from 2001 to 2003. Followed by Hungary and Italy, both countries showed an increasing trend. The UK reported injured species only in 2003. For Spain, although the number of injured species was generally low, symptoms were more apparent in 2002, probably due to the fact that the climatic conditions were more humid, combined with similar ozone concentration patterns as for 2003. The given numbers have to be considered with caution as number and location of the plots were not the same across years for Italy.

When individual species are considered, *Fagus sylvatica* was reported symptomatic for most plots (13 in 2001, 8 in 2002, and 6 in 2003)). Another widely reported symptomatic species is *Fraxinus excelsior* (8 plots in 2001, 8 in 2002, and 5 in 2003) in which ozone symptoms are very conspicuous and the species is recognized to be very sensitive to ozone.

Ozone-like injury has been observed on several plots for *Rubus* species. Since *Rubus* spp. is a widespread genus and common in Europe, these species are frequently included in the LESS surveys. However, ozone symptoms on *Rubus* have to be interpreted with great caution as the reddening of the leaves also occurs naturally in the field and it was decided to exclude *Rubus spp* from the sepecies list. Similar caution has to be paid with species of the genus *Cornus*. *Acer pseudoplatanus*, *Viburnum lantana*, *Carpinus betulus* and *Corylus avellana* should be mentioned as species showing typical ozone-induced injury across Europe. *Picea abies, Pinus halepensis* and *P. sylvestris* also showed chlorotic mottling in the needles for some years.

For the three years considered, a similar total number of symptomatic species was detected (55 to 57). However, due to the different number of countries conducting injury surveys and the different number of plots from year to year make any meaningful comparisons difficult. Switzerland is the country showing the highest number of symptomatic plants: 42 in 2001, 24 in 2002 and 19 in 2003. While in 2001, most of these species were trees (24 species), in 2002 the number of symptomatic trees decreased to 8 in 2002 and to 10 in 2003. Shrubs were the second most abundant group of symptomatic plants and a lower number of symptomatic perennial herbs have been recorded. Observation of symptoms in herbs is more problematic than in trees or shrubs since phenological processes become more relevant for establishing the most appropriate moment of injury observation. Italy and

France as well as Hungary also showed in 2003 a considerable number of symptomatic species. In the case of Italy, one of the plots is characterized by a rather high number of 11 symptomatic species in 2002 and 12 in 2003. In France and Hungary, symptomatic species are more spread among the different plots. In the other countries, ozone injury is restricted to a few plots and species as it is also the case for the UK with two symptomatic species or Spain, with 3. In Spain, it is important to notice that the IMP is too far from ideal LESS plots.

Table 3.5.3-1: List of symptomatic species observed in the LESS, in years 2001, 2002, 2003. Numbers indicate the number of plots in which a given species has been reported *symptomatic* for the different years and countries.

TREES

Scientific name	2001	2002	2003
Acer campestre	1		
Acer pseudoplatanus	2	3	3
Ailanthus altissima		2	2
Alnus glutinosa	3		
Alnus incana	2	1	1
Alnus viridis	1		
Betula pendula	1		
Carpinus betulus	4	3	1
Castanea sativa			1
Corylus avellana	3	4	4
Fagus sylvatica	13	8	12
Frangula alnus	1	1	1
Fraxinus excelsior	8	8	5
Fraxinus pennsylvanica			1
Picea abies	4	1	
Pinus halepensis	1	1	1
Pinus sylvestris	1		
Populus alba		1	1
Populus tremula	2		
Prunus avium	1		1
Prunus mahaleb			1
Prunus spinosa	3	1	1
Pyrus pyraster			1
Quercus ilex		1	
Quercus robur		1	1
Robinia pseudoacacia	1	2	1
Salix alba	1		1
Salix aurita		1	
Salix caprea	2		4
Salix spp.	1		
Salix viminalis		1	
Sorbus aria	2		
Sorbus aucuparia	2	1	
Sorbus mougeotti	1		
Ulmus procera			1
Total no. of trees	**24**	**18**	**21**

SHRUBS

Scientific name	2001	2002	2003
Bignonia sp.		1	
Cornus sanguinea	3	3	2
Crataegus laevigata	1		1
Crataegus monogyna	4	1	2
Crataegus oxycantha	1	1	
Euonymus europaeus	1	1	
Laburnum alpinum		1	1
Ligustrum vulgare		1	1
Lonicera nigra	1		
Lonicera periclymenum		1	
Lonicera xylosteum	4	3	
Rhamnus catharticus		1	
Ribes uva-crispa		2	
Rosa canina	3	1	
Rosa sp.	1		
Rubus fruticosus	6		
Rubus fruticosus hirtus		3	4
Rubus idaeus	5	2	2
Rubus spp.	1	2	3
Sambucus ebulus		1	1
Sambucus nigra	1		1
Sambucus racemosa	1		
Sorbus chamaemespilus	1		
Vaccinium myrtillus	1		1
Viburnum lantana	2	2	5
Viburnum opulus	2	1	1
Vitis vinifera		1	1
Total no. of shrubs	**18**	**19**	**14**

PERENNIAL HERBS

Scientific name	2001	2002	2003
Ajuga reptans			1
Aquilegia vulgaris	2		
Artemisia campestris	1		
Asclepias syriaca			1
Astrantia major	1	1	1
Carlina acaulis			1
Centaurea jacea		1	1
Centaurea montana		1	
Centaurea nigra	1	1	
Circaea lutetiana		1	
Cirsium helenoides	1		
Clematis vitalba			1
Cotoneaster tomentosa		1	
Cyclamen purpurascens			1
Epilobium hirsutum			1
Euphorbia dulcis			1
Filipendula ulmaria		1	
Gentiana asclepiadea			1
Geranium nodosum		1	
Geranium sylvaticum			1
Globularia nudicaulis			1
Helleborus niger	1		
Heracleum sphondylium		1	
Heracleum sphondylium juranum	1		
Impatiens parviflora	1		
Lamium album		1	
Lamium spp.	1		
Lathyrus vernus		1	
Limonium gmelini		1	1
Mycelis muralis		1	
Oenothera biennis	1		
Petasites alba			1
Plantago lanceolata	2		
Plantago major	1	1	
Rubia peregrina			1
Rumex acetosella			1
Saponaria officinalis			1
Senecio nemorensis	1		
Senecio ovatus	1		
Solidago canadensis		1	1
Solidago gigantea			1
Spiraea ulmaria	1		
Stachys recta			1
Symphoricarpos sp.		1	
Trifolium pratense		1	
Veronica urticifolia		1	
Total no. of perennial herbs	**15**	**18**	**20**

	2001	2002	2003
Total no. of trees	24	18	21
Total no. of shrubs	18	19	14
Total no. of perennial herbs	15	18	20
Total no. of species	57	55	55

The number of symptomatic species per biotype are compared for the years 2002 and 2003 (Figure 3.5.3-7). Focus is given to the years 2002 and 2003 since data from 2001 were analyzed in De Vries et al. (2003). If we restrict the analysis to countries that did the survey for both years (Italy, Spain and Switzerland) and reported also ozone concentrations, it can be observed that, although the year 2003 had much higher ozone concentrations specially in Italy and Switzerland, the number of symptomatic species did not increase except in Italy, where the perennial herbs are more affected. However, the results have to be taken with caution since in Italy plots for 2002 and 2003 do not fully coincide, whereas in Spain and Switzerland they are the same. For future surveys, it is highly recommended to re-assess at least the same plots as in previous years.

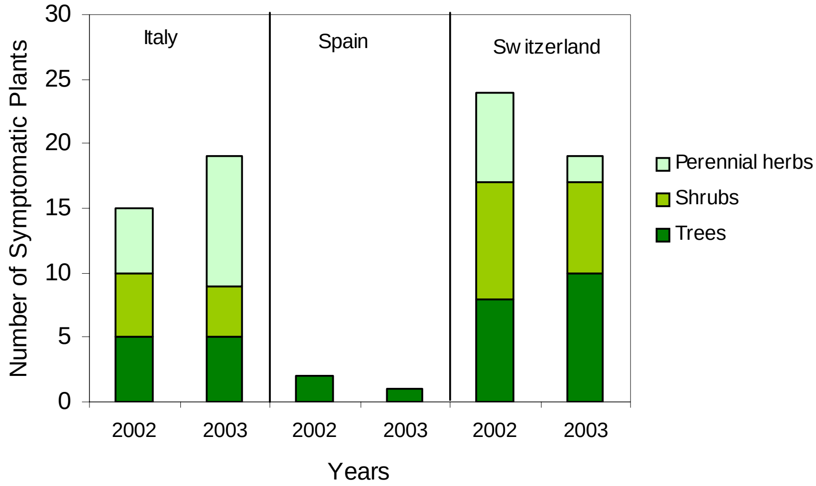


Figure 3.5.3-7: Number of symptomatic species per biotype (perennial herbs, shrubs and trees) for the 3 countries that completed the survey for the years 2002 and 2003 and which provided ozone concentration measurements.

Average number of symptomatic species per plot in the 26 common plots to 2002 and 2003 were ozone measurements were carried out (3 plots from Italy, 9 from Spain and 14 Switzerland) is represented in Figure 3.5.3-8,. both considering the average values from April to September in 2002 and 2003, and the maximum 2-week values reached for the same period. It can be seen that with increasing classes of ozone (classes 1-2: <45 ppb; classes 3-4: ≥60 and <75, classes 5-6: ≥ 75), the average number of symptomatic species increased for both years.

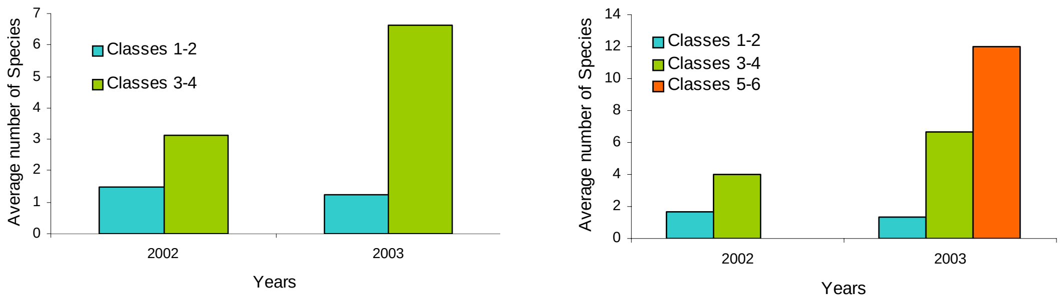
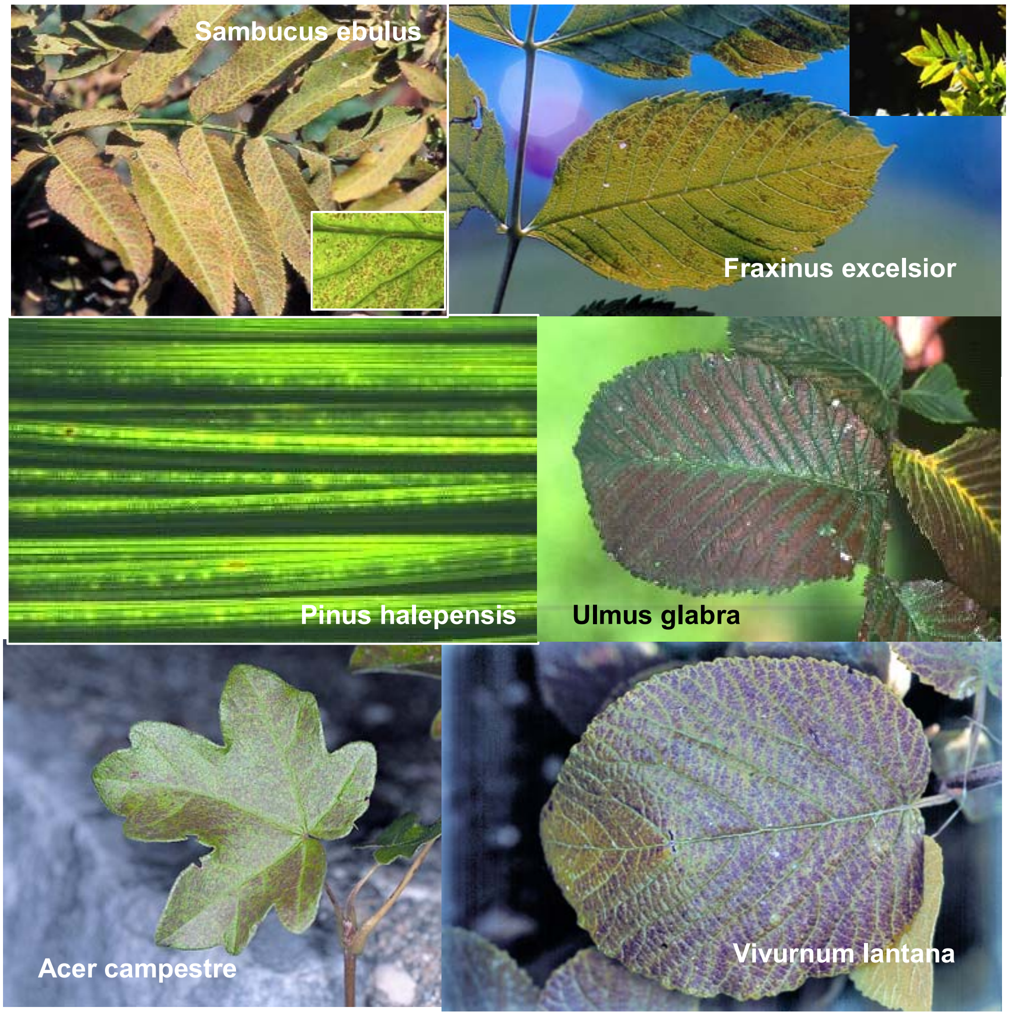


Figure 3.5.3-8: Average number of symptomatic species per plot in common plots to 2002 and 2003 where ozone measurements were carried out (countries: Italy, Spain, and Switzerland). The left graph is based in the average April-September classes reached in these plots, whereas the in the right graph calculations are based in the maximum 2-week values measured in this period.

It may be concluded that temperate plots located in humid areas such as the Italian Po Plane and the Swiss Canton Ticino showed the highest number of symptomatic species. Ozone symptom expression, however, is not very pronounced probably due to local climatic conditions adaptations of the existing plant communities in countries like Spain or Greece, although ozone concentrations are high in some Level II plots, (Figure 3.5.3-8).

Box 3.5.3.2: Visible injury: Illustrative examples



Pictures from: Sanz & Calatayud.

More samples of typical ozone-induced symptoms can be found at: www.gva.es/ceam/ICP-forests and www.ozone.wsl.ch

Possibilities of risk assessment

The assessment of ozone concentrations at remote forest sites in combination with the assessment of ozone-induced symptoms should result in an estimate of ozone risk for European forest ecosystems within the framework of the ICP-Forests Task Force Mapping and Modeling. However, it is recognized that ozone injury expression on leaves/needles has to be considered only as an indicator for a possible risk since injury is not only driven by the ozone concentration alone, but very much influenced by various internal and external growth factors influencing stomatal uptake and possible defense and detoxification mechanisms. As indicated by the fact that significantly higher ozone concentrations in 2003 did not necessarily result in more frequently occurring ozone-induced visible symptoms. To better explain this phenomenon, the WG proposes the assessment of both parameters in parallel at as many Level II sites over Europe as possible for a time period of 3 to 5 years and analyze these data together with other data from Level II sites by factor analysis for an overall dose response relationship allowing a calibrated risk assessment.

However, at the moment, the data set of the test phase is still not robust enough to derive a transparent and biologically relevant dose-response relationship. Therefore, at the moment, risk evaluations can only be conducted with the available models such as the purely ozone concentration based AOT40 statistics, as indicated in the Mapping Manual 2004 (www.icpmapping.org). However, the Mapping Manual 2004 indicates altogether three possible approaches for risk assessment: AOT40, Flux and MPOC of which the flux approach is anticipated to be the future method for the mapping of ozone Critical Levels.

The examples given are therefore restricted to the AOT40 approach, the modified AOT40 left ajar to several discussions at UNECE Workshops on ozone critical levels and the MPOC approach (VDI Guideline 2310, part 6, 2002). Ozone concentration data from 2 sites were analyzed for the years 2002 and 2003 correspondingly. The requirements for the selection of the 2 sites were availability of hourly ozone concentrations (complete data set April – September) as well as high ozone concentrations. Therefore data were selected from the stations BOL 1, in Italy and Lattecaldo in Switzerland. The flux approach discussed in Gothenburg 2003 (KARLSSON et al., 2003) as a new mapping procedure is, however at this point, not considered since the required data for the indicated model calculations were neither available for the two sites nor for most of the Level II sites, although some attempts were being undertaken for few plots (e.g. SCHAUB et al., 2004).

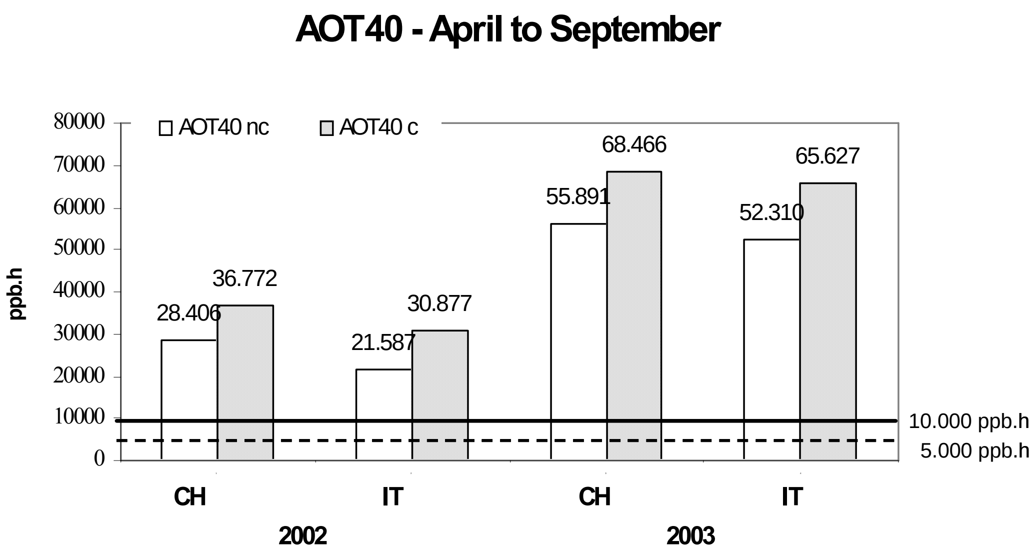
Figure 3.5.3-9 A shows the AOT 40 calculations. The 2 years differ significantly and AOT40 values in 2002 are roughly half of those in 2003. The critical levels for forest species of 10 ppm.h (FÜHRER and ACHERMANN, 1999) calculated for daylight hours during a 6 month period commencing 1 April is exceeded 2 to 3 times in 2002 and about 5 times in the year 2003 at both locations. The modified AOT40 values (grey bars) are about 13% higher compared to the corresponding AOT40. The modified AOT40 value allows for the fact that the ambient ozone concentrations generally increase with elevation above sea level and height above the ground. Since ozone measurements are generally executed in 2-3 m above ground, higher concentrations within or above the canopy at a height of 20 to 40 m above ground are usually underestimated. If these values are considered, the exceedances are up to 7 times for both stations in 2003. In 2003, the Workshop Ozone Critical Levels II (KARLSSON et al., 2003, see also UNECE Mapping Manual chapter 3.5.6) discussed to lower the AOT40 value to 5 ppm.h under certain conditions applying namely for the Nordic countries. However, if such a CL would be considered, the exceedances were doubled. Similar results are given by GEROSA et al. (2004); they calculated the AOT40 average for 2000-2002 values for 58 European ICP-Forests Level II stations on the basis of passive sampling results. They found that 69% and 95.8% of the stations exceeded the 10 ppm.h AOT40 CL and the 5 ppm.h AOT40 CL respectively.

In line with the EU-Directive 2002/3/EG dated 12.02.2002, negative effects on the vegetation, ecosystems and the environment should be avoided as far as possible; the AOT40 threshold as defined for the protection of forests (i.e. 10 ppm.h, daylight hours, April-September) on the other hand indicates a certain risk for European Forests, especially if the CL´s are exceeded by a factor of 6 (10 ppm.h) or 12 (5 ppm.h).

A risk evaluation in line with the MPOC (Maximum Permissible Ozone Concentrations) (VDI, 2002) is given in Figure 3.5.3-9 B. The MPOC approach allows not only deriving an index for a vegetation period of 6 months but also for different time periods allowing short term episodes to be evaluated for their potential ecological risk. Figure 10b gives the mean ozone concentration for the time intervals of 8 hrs and 1, 7, 30 and 90 days respectively as well as the 6 month for the 2 stations (BOL1 and Lattecaldo) and the years 2002 and 2003. The calculation of these indices is based on the hourly ozone concentrations measured at the continuous monitoring stations and multiplied with a default factor of 1.1 accounting for the concentration difference between measuring and canopy height. The values of the calculated indices are compared with an exposure-response curve based on current knowledge of ozone induced effects on trees. The 10% confidence intervals of the curve contain the area (yellow) where compliance ensures substantial protection with respect to growth, productivity, biodiversity and recreation (this does not exclude the development of ozone injury symptoms) while the area above and below signal either maximum protection (green area) or permanent damage (red area) (GRÜNHAGE et al., 2001; KRAUSE et al., 2003).

Even though 2003 was an exceptional ozone year for most European countries, calculated ozone concentrations for each index are in the yellow area indicating no substantial risk for permanent damage. The Lattecaldo site shows for both years markedly higher ozone concentrations and it becomes evident that mean concentrations for short time intervals (i.e. 1, 7, and 30 days) are much higher in comparison to the values from BOL1 in Italy. However, it can be seen that the 30 and 90 day mean concentration for Lattecaldo in 2003 reaches nearly the red area, indicating a critical situation for forests in this region. However, it has to be highlight that MPOC is conservative in its risk evaluation and intended to give a worst case scenario.

A



B

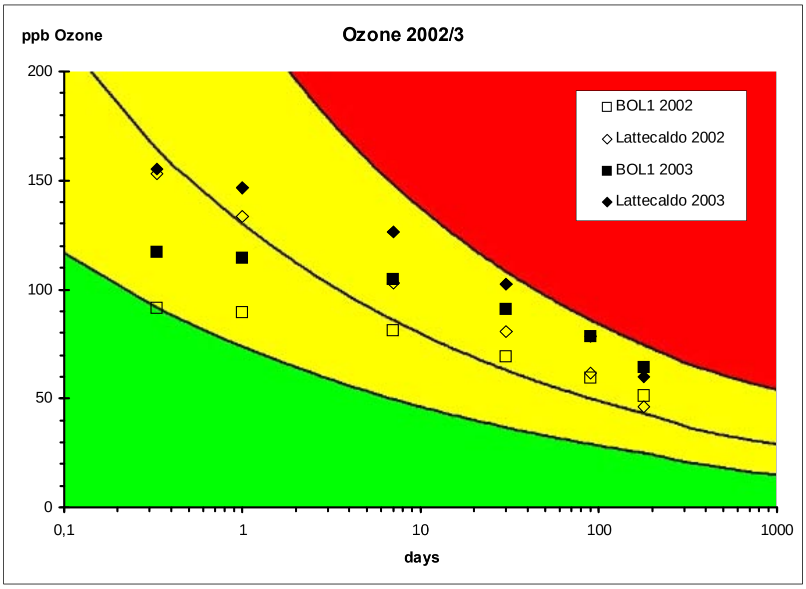


Figure 3.5.3-9: (A) AOT40 (ppb.h) for years 2002 and 2003 at Lattecaldo (CH) and BOL1 (IT). White columns represent the AOT40 measured at 2 m and the grey columns represent the value corrected for canopy height assumed to be 1.1 as default value. The dotted horizontal lines represent the critical levels for 6 months. (B) Maximum permissible ozone concentrations (MPOC) for the same stations and years, calculated for the time intervals of 8 hrs and 1, 7, 30 and 90 days as well as a season mean (April-September).

In Figure 3.5.3-10 A the hourly mean ozone concentrations are aggregated to 14 day means for the vegetation period (April-September) for the years 2002 and 2003 to simulate measurements with Passive Samplers over the recommended 14 day exposure period. This procedure generates twelve 14-day mean values. From these numbers mean ozone concentrations were calculated for 4, 8, 16 weeks as well as 6 months used as indices for risk evaluation according to the MPOC approach (VDI 2002, KRAUSE et al., 2003). A similar calculation was done for an exposure period of 28 days. The results show that data from passive sampling can be used for risk calculations rather well. However, shorter exposure indices in Figure 3.5.3-9 B tent to be higher than in Figure 3.5.3-10, indicating a greater risk for vegetation although all values are in the yellow area. This is in line with the former statement that high hourly values are stratified by the passive sampling data simulation and thus slightly underestimate the risk for vegetation by ozone.

Although the MPOC concept has not been used so far in the mapping program and it has also certain limitations as the other approaches, it seems worthwhile to have all three mapping approaches followed up in future mapping exercises in order to find out which approach is reflecting best the main aims of the UNECE LRTAP Convention, based on the available information in national air quality networks, e.g. the ones developed within the framework of the EU-directive 2002/3/EG. This would also include information made available by the measurements of ambient air quality on Level II sites as followed up by ICP-Forests.

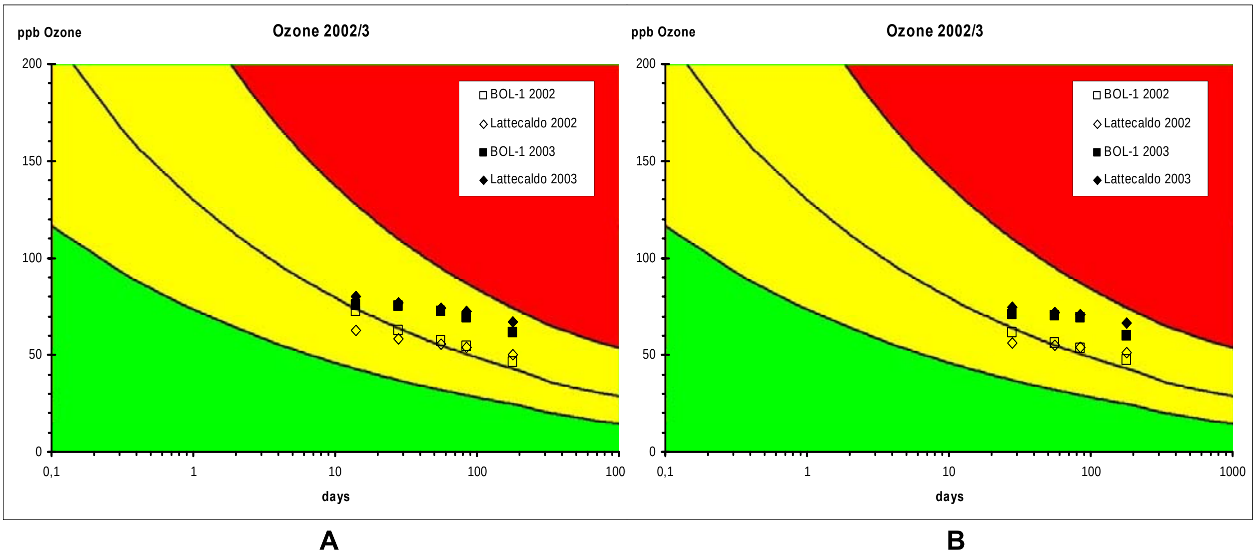


Figure 3.5.3-10: Hourly mean ozone concentration aggregated to 14 and 28 day means for the vegetation period of the years 2002 and 2003 (April-September) for the 2 stations Lattecaldo (CH) and Bol1 (Italy) to simulate measurements with passive samplers over the recommended 14-day exposure period (A) and 28-day period (B).

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3.5.4 Conclusions and recommendations

Conclusions on the test phase

The data presented here for ozone concentration measurements by passive sampling as well as the ozone injury assessment on MTS and ground vegetation from the selected LESS-sites relate to a 2-year test phase. The method outlined in the Submanual on Ambient Air Quality Measurements by means of passive sampling can be considered as established since results show that the concentrations derived are very well comparable to those measured by active monitoring. In order to have a time resolution also representing ozone episodes and exposure periods of 14 days for passive sampling are recommend as the future European reference exposure period.

The assessment of ozone injury on main tree species as well as ground vegetation at the LESS-sites has to be considered as the first and unique effects monitoring system on a European scale based on real field observations. However, this ambitious goal turned out as a very complex task and demanded knowledge which could only be gained by empirical work during training courses and in the countries themselves, leading to a time-consuming iterative process. So far, the data base collected is still rather limited, partly due to the fact that a second test face started after the Task Force meeting in 2003 and the WG felt the necessity to revise the Submanual during the 4th training course in September 2003 in Lattecaldo, Switzerland before continuing the national field campaigns. Hence, only very limited information on ozone injury is available for the year 2003. However, despite all these aggravations, the revised Submanual on ozone injury assessment, adopted by the Task Force in 2004, serves as a sound basis for forthcoming monitoring activities. The program is intended to serve as an independent information system together with the emission inventory data and the ambient air quality monitoring. While data derived from the latter can only give information on a potential ecological risk, the effects monitoring reveals information on effects truly manifested in form of visible symptom development, hence allowing the development of future and more realistic ecological risk scenarios possibly by the use of the flux approach combining both, air quality and plant response data.

Baring in mind the information of the evaluation of the available data, it is suggested that countries should assure their activities in this field at least to a selected number of Level II plots. For the very program, Level II plots should be chosen where sensitive MTS as well as GV with sensitive species are prevalent and the site coincides with comparatively high ozone concentrations. For Germany, these sites would preferably be situated in a mountainous area with beech forests preferably on a North to South transect. Six to eight Level II plots per country are considered sufficient, but assessments are recommended to be carried out twice during the growing season. Validation centres will help the countries to select the sites and periods based on their experience.

Outlook and recommendations

The Working Group follows its perspective given in the Technical Report 2003 as to link the information of the two information systems *ambient air quality* and *ozone effects assessment* in a spatial analysis of ozone concentrations and relating the effects on vegetation to these data in a geographic information system (GIS). The data of the two systems are placed as individual layers over a given geographic area and analysis looks for systematic coincidences like hot spots, etc. Such an approach seems to be appropriate in a system where many of the variables follow stochastic processes. Similar approaches have been used successfully in epidemiology. However, the methodology might need further development. In assessing relationships between ozone exposure indices and ozone injury, it is relevant for example to account for modifying factors such as geographical and meteorological influence factors. It is anticipated that a five-year measuring period will enable the necessary information basis.

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